Workshop Practices

(According to the Syllabus Prescribed by Director General of Civil Aviation, Govt. of India)

FIRST EDITION

WORKSHOP PRACTICES

Prepared by

L.N.V.M. Society Group of Institutes
* School of Aeronautics
(Approved by Director General of Civil Aviation, Govt. of India)

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Compiled by

Rajesh Saluja

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Dedicated To

Shri. Laxmi Narain Verma

[Who Lived An Honest Life]

Preface

Material” is the word which is associated with every object existing in the universe. The knowledge of material enhances our understanding of physical world.

The aircraft design is based on the suitability of material considering the various factors such as weight, strength, cost, reliability and easy availability. The knowledge of aircraft material is essential for aspirant of Aircraft maintenance engineering to get through their DGCA Licence papers and translate this knowledge on their day to day work in aviation field.

This book is prepared by L.N.V.M. Society Group of Institute, with the dedicated efforts by it’s experienced faculty and staff with the view to sumup the vast material details under single cover to impart the essential knowledge to AME trainees to succeed in their aspired carrier.

My thanks are due to those who helped me to bring out this valuable edition.

I would very much appreciate criticism, suggestions and detection of errors from the readers which will be grate fully acknowledged.

Arjun Singh

Senior Instructor

L.N.V.M. Society Group of Institutes Dated : March. 2008

CONTENTS

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UNIT : I

(A) KNOWLEDGE OF MATERIAL, PARTS AND USE OF HAND TOOLS, SIMPLE MACHINE TOOLS AND PRECISION MEASURING INSTRUMENTS.

(B) KNOWLEDGE OF VARIOUS WELDING AND ALLIED PROCESSES.

CHAPTER : 1
GENERAL SHOP SAFETY

1.1 GENERAL

An accident in a machine shop can be a messy and painful experience. Most accidents in a machine shop are the result of carelessness. The victim knows at the time that he should not do what he is about to do; he takes a chance. Sometimes he is lucky and gets away with it. Accident statistics prove that he who takes a chance most often loses. The result: pain; loss of time and money; broken tools and equipment; spoiled work. To these could be added the possibility of permanent disfigurement and disablement.

It takes time and experience to develop a skilled machinist. A skilled machinist is seldom involved in accidents. He knows that he cannot take chances with the certainty of the machine's timing, nor with the power of its movement. There are basic rules for the development of safe working habits. The rules must first be understood, then practiced until they become a habit. Each machine has individual hazards to the safety of a careless and thoughtless operator. The careful operator, however, quickly observes each potential danger and sets up a pattern of work habits that will keep him clear of involvement with any dangerous practice.

1.2 RULES FOR WORKSHOP SAFETY

The skilled machinist dresses safely. He wears nothing that could get caught on the moving job or machine. He is aware of the danger of flying chips and minute particles from abrasive wheels and of the horrible damage that flying particles from drills and cutting tools can do to the human eye. He wears his safety glasses from the time he enters the shop until he leaves it. The skilled machinist handles sharp cutting tools with care. He keeps the floor around his workplace free of oil and short pieces of stock. He stacks the rough castings and the finished workpieces separately and neatly. The stacked material is not permitted to interfere with his movements around the machine, and because of this it is not a hazard to his safety.

When a workpiece or a machine attachment is too cumbersome or too heavy for one man to handle comfortably, the careful worker asks for assistance.

The wise student or apprentice is one who observes and profits from the skilled machinist's example. Each workman or student in a machine shop is aware of the dangers that surround him; he has been warned of these dangers and has been instructed in the safety rules that apply to his shop activity. This is not sufficient to make a safe worker. Each worker in a machine shop, whether he be a machinist, student, or helper, must develop his own awareness of the importance of avoiding accidents, and his own awareness of the possible hazards to safety that his job involves. He also must develop safe working techniques. He must be alert to possible dangers, and he must be energetic in correcting conditions and habits that could lead to accidents and injury.

He should remove his necktie, wristwatch, and jewellery such as identification bracelet and rings. Sleeves are out of danger when they are rolled up. The machinist should wear an apron, shop coat, or coveralls. Apron strings should be tied at the back, and bulging pieces of cotton waste should not be carried in the pocket.

The strands of the wool that go into the making of a sweater are long unbroken. One strand caught on a revolving dog or job can bring the machine operator much closer to danger. Machine tool spindles, whether on a lathe or a drill press, turn many revolutions in a second, and much damage can be done before the machine is brought to a stop.

The soft material from which the upper part of the canvas shoe is made offers no resistance to a hard object, whether it is falling or stumbled against. The rubber soles are easily penetrable by steel chips and sharp-edged machined surfaces. Strongly made safety shoes having steel toe caps offer goods insurance against injuries.

Gloves should be worn when the worker is moving sheet metal or large pieces of stock, especially when stock edges are sharp or ragged. Gloves should also be worn when the worker is pouring liquids that are injurious to human skin and whenever it is necessary for him to handle metal chips of any size or shape.

Injury to the eye can be caused by flying particles of metal that result when the workpiece resists the cutting tool. These flying pieces of metal do not single out the man behind the cutting tool. Chips can fly in any direction to hit anybody in the shop. Everybody in the shop needs the protection of safety glasses.

A tucked-in tie can slip out of a buttoned shirt. A loose tie can very quickly become caught in a moving machine part; the results are painful.

When the ends of long or short apron tie-strings become loose, they can be easily caught on the moving parts of any machine.

Rolled-up sleeves present far less a hazard to safety than buttoned sleeves. A button can unfasten because of a worn buttonhole, or a button may be lost. The sleeve can then easily become caught in a moving job, with serious consequences to the machine operator.

Don't attempt to lift a job or machine attachment by yourself if it is too heavy or too awkward for one person to handle. Before lifting, be sure that you have a firm footing; keep your feet about 8 to 12 inches apart, and get a good balance. Keep your feet close to the job being lifted. Bend the knees; squat down but keep your back straight. When you are ready to lift, push your body up with the strength in your legs. Keep the job close to your body until you have it in the normal and convenient carrying position. Walk with firm steps; don't twist your body to change your direction, but change the position of you feet. Breathe normally; don't hold your breath. When lifting with another person's help, talk it over first, then move and lift together.

Although it is often easier to carry long pieces of stock on the shoulder it is not a safe way. We tend to watch where we are going and forget what happens to the part we are not watching. Stock should be carried vertically so that all of it can be watched at the same time.

Men do not walk through a machine shop with their eyes looking at the floor; therefore a workman is apt to step on a small piece of stock left on the floor. A fall can cause serious injury. A fall that carries the victim into a moving machine can be fatal.

Greese can be hazardous when it drips or is dropped on the shop floor. An oil slick under a quick-moving foot may result in a serious accident. Wipe up grease and oil that is dropped on the floor. Clean off the excess grease that is left near bearings and grease cups.

The things that contribute to a safe shop are floors, passageways - aisles and space around machines - kept clean and clear of small pieces of metal and machine attachments and accessories. There should be plenty of disposal can in designated places to receive waste, scrap materials, and floor and machine sweepings. The aisles of passage between machines should be clearly outlined.

There should be a place for each tool and each must be replaced after it has been used.

Because metal chips have sharp edges, which cut and penetrate skin, chips should never be handled. Machines can be kept clear of chips by periodically sweeping (or brushing) them away.

Remove the fuse controls the flow of electrical power to the motor of the machine. This should be done before the guards are removed or any part of the mechanism is touched. Many men who have neglected this safety practice have lost fingers because somebody pressed the starting button.

Guards removed to repair a machine, or to enable the machinist to make operative changes, should be replaced before the power is turned on. Operating unguarded machines is hazardous not only to the operators, but also to other workers who may come in contact with moving gears and other machine parts. Do not operate a machine until all guards have been replaced.

The term good house keeping indicates cleanliness and neatness, a place for everything with everything in its place. The result is a good housekeeping : a safe shop.

GENERAL SAFETY PRECAUTIONS WHILE WORKING WITH

Electricity

Electricity is a good servant but a bad master. Even non-fatal shocks can cause severe and permanent injury. Shocks from faulty equipment may lead to falls from ladders, scaffolds or other work platforms. Those using electricity may not be the only ones at risk; poor electrical installations and faulty electrical appliances can lead to fires which may also cause death or injury to others. Most of these accidents can be avoided by careful planning and straightforward precautions.

This topic outlines basic measures to help you control the risks from your use of electricity at work. More detailed guidance for particular industries or subjects is given further.

WHAT ARE THE HAZARDS?

The main hazards are:

1. Contact with live parts causing shock and burns (normal mains voltage, 220 volts AC, can kill);
2. Faults which could cause fires;
3. Fire or explosion where electricity could be the source of ignition in a potentially flammable or explosive atmosphere, e.g. in a spray paint booth.

ASSESSING THE RISK

Hazard means anything which can cause harm.

Risk is the chance, great or small, that someone will actually be harmed by the hazard.

The first stage in controlling risk is to carry out a risk assessment in order to identify what needs to be done.

REDUCING THE RISK (SAFETY MEASURES)

Once you have completed the risk assessment, you can use your findings to reduce unacceptable risks from the electrical equipment in your place of work. There are many things you can do achieve this; here are some.

Ensure that the electrical installation is safe

1. Install new electrical systems to a suitable standard, e.g. BS 7671 Requirements for electrical installations, and then maintain them in a safe condition;
2. Existing installations should also be properly maintained;
3. Provide enough socket-outlets-overloading socket-outlets by using adaptors can cause fires.

Provide safe and suitable equipment

1. Choose equipment that is suitable for its working environment;
2. Electrical risks can sometimes be eliminated by using air, hydraulic or handpowered tools. These are especially useful in harsh conditions;
3. Ensure that equipment is safe when supplied and then maintain it in a safe condition;
4. Provide an accessible and clearly identified switch near each fixed machine to cut off power in an emergency;
5. For portable equipment, use socket-outlets which are close by so that equipment can be easily disconnected in an emergency;
6. The ends of flexible cables should always have the outer sheath of the cable firmly clamped to stop the wires (particularly the earth) pulling out of the terminals;
7. Replace damaged sections of cable completely;
8. Use proper connectors or cable couplers to join lengths of cable. Do not use strip connector blocks covered in insulating tape;
9. Some types of equipment are double insulated. These are often marked with a 'double-square' symbol ⧈. The supply leads have only two wires - live (brown) and neutral (blue). Make sure they are properly connected if the plug is not a moulded-on type;
10. Protect lightbulbs and other equipment which could easily be damaged in use. There is a risk of electric shock if they are broken;
11. Electrical equipment used in flammable/explosive atmospheres should be designed to stop it from causing ignition. You may need specialist advice.

Reduce the voltage

One of the best ways of reducing the risk of injury when using electrical equipment is to limit the supply voltage to the lowest needed to get the job done, such as:

1. Temporary lighting can be run at lower voltages, e.g. 12, 25, 50 or 110 volts;
2. Where electrically powered tools are used, batter operated are safest;
3. Potable tools are readily available which are designed to be run from a 110 volts centre-tapped-to-earth supply.

Works Safely

Make sure that people who are working with electricity are competent to do the job. Even simple tasks such as wiring a plug can lead to danger - ensure that people know what they are doing before they start.

Check that :

1. Suspect or faulty equipment is taken out of use, labelled 'DO NOT USE' and kept secure until examined by a competent person;
2. Where possible, tools and power socket-outlets are switched off before plugging in or unplugging;
3. Equipment is switched off and/or unplugged before cleaning or making adjustments.

More complicated tasks, such as equipment repairs or alternations to an electrical installation, should only be tackled by people with a knowledge of the risks and the precautions needed.

You must not allow work on or near exposed live parts of equipment unless it is absolutely unavoidable and suitable precautions have been taken to prevent injury, both to the workers and to anyone else who may be in the area.

Underground power cables

Always assume cables will be present when digging in the street, pavement or near buildings. Use up-to-date service plans, cable avoidance tools and safe digging practice to avoid danger. Service plans should be available from regional electricity companies, local authorities, highways authorities, etc.

Overhead power lines

When working near overhead lies, it may be possible to have them switched off if the owners are given enough notice. If this cannot be done, consult the owners about the safe working distance from the cables. Remember that electricity can flash over from overhead lines even though plant and equipment do not touch them. Over half of the fatal electrical accidents are caused by contact with overhead lines. More detailed guidance on avoidance of danger from overhead electric lines is available from HSE.

Safety Precautions while working with gases like oxygen

Oil grease or similar substances must not be allowed to come into contact with compressed oxygen or liquid oxygen. Contact of this substance with oxygen may result in an explosion. Personnel working in an area of possible oxygen concentration, such as near an oxygen vent or a liquid oxygen spillage, or in a trench where oxygen seepage and concentration might occur, must ensure that their clothing is free from contaminations of oxygen before lighting a cigarette or approaching a naked flames. It is essential that the clothes be dries for at least 15 minutes before approaching a flame after any such contamination.

The following precautions must be strictly observed at all times :

1. Thoroughly wash all oxygen fittings, valves and parts with clean Tricolor Ethylene (TCE) / Carbon Tetra Chloride (CTC) before installation. Never use petrol, kerosene or other hydrocarbon solvents for this purpose. All tubing, lines valves etc. to be used in oxygen service, must be of an approved type and must be thoroughly degreased and blown out with clean oil-free compressed air or Nitrogen before being placed in service.
2. Do not permit the release of Acetylene or other flammable gases in the vicinity of the plant air intake. A concentration of Acetylene exceeding 5 parts per million in liquid oxygen may explode with extreme violence. Strict supervision is essential to minimize the possibility of contamination.
3. The plant and plant vicinity must be kept clean and free from abstractions at all times. Any oil leak within the plant surrounding must be rectified without delay. Oil spillage must be cleaned up immediately using rag and Carbon Tetra Chloride.
4. Do not lubricate oxygen valves, regulators, gauges or fitting with oil or any other substance.
5. Ensure that insulation removed from the Air Separator jacket is not contaminated with oil or other inflammable materials. Personnel carrying out maintenance on the Air Separation Plant equipment must wear clean overalls and their hands and tools must be free of oil. This ensures that the insulation and equipment within the jacket is not contaminated with oil. Should contamination take place the affected materials must be discarded and replaced by clean new material?
6. Do not fasten electric conduits to the plant or its pipelines.
7. Do not use oxygen as a substitute for compressed air, spark present in an atmosphere of oxygen will immediately burst into flame.
8. Do not fill any container or pipe line with oxygen unless it has been thoroughly degreased with clean CTC or TCE.
9. When discharging liquid oxygen or rich liquid from drains, valves or pipe lines, open valves slowly to avoid the possibility of being splashed. In particular ensure that liquid does not run into shoes or gloves. Contact with liquid oxygen rich liquid will cause frostbite evidenced by whiteness and numbness of the skin. The affected parts must be batched at once in cold (not box) water and seek medical attention immediately.
10. Do not breathe cold oxygen vapour. The temperature of the vapour rising from liquid oxygen is approximately 181°C. A deep breath of vapour at this temperature can result in frost-bitten lungs with resultant serious illness and permanent disability or death.
11. Do not experiment with liquid oxygen by putting solids or liquids into it for the purpose of watching the effect of the cold liquid. The object placed in the oxygen may catch fire or explode.
12. Do not pour liquid oxygen on the floor of the shop or around any object that can catch fire. As the liquid oxygen vaporizes, the cold vapours may be swept along ground into contact with combustible material. The whole floor of an office is known to have caught fire when oxygen vapours contacted a lighted cigarette butt. Spillage of liquid oxygen must be avoided especially in the vicinity of lubricated machinery, asphalt paving, concrete surface containing bitumen joints or where the liquid oxygen can flow into drains or sewers.

13. Do not use any pipe jointing on oxygen pipe threads except approved for oxygen service. Ordinary pipe jointing contains grease as a lubricant and will catch fire.
14. Compressor and expander lubricating oil consumption must be regularly checked any excessive consumption must be investigated immediately and the cause rectified.
15. The use a of a flame (e.g. for welding or cutting) in the immediate vicinity of the Air Separation plant or oxygen piping must be permitted only when the plant has been shut down and de frosted and when the oxygen content of the air within the equipment concerned does not exceed the atmospheric normal of 21%. Do not attempt repair until all pressure is released from the section to be dismantled.
16. Remember that pressure alone is not dangerous. A Boiler at 0.7 Kg/cm^{2}g may be more destructive in the event of an explosion than a small container at 220 kgs/cm^2 owing to the greater mass of metal involved. In general, fluid at high pressure and moving at a high velocity are the most dangerous. Use a face shield or chemical type safety goggles when using the oxygen or nitrogen test set to prevent possible injury to the operator in the event of a blow-back of the reagent.

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CHAPTER : 2
HAND TOOLS

2.1 HAND TOOLS

A machinist must be skilled in the use of the numerous hand tools, which have been designed to make his work easier. In addition to knowing how to use hand tools properly, the machinist must also know the various types of tools available to do a particular job, how to select the best type and size for a given job, and how to care for and store tools when not in use. A skilled craftsman takes great pride in his ability to use tools correctly. Because most of these tools are finely made and expensive the ownership of a good tool kit is a never-ending source of satisfaction and pleasure. This chapter describes and explains many common hand tools used by machinists and tool and diemakers.

2.2 CLASSIFICATION

There is a fairly large number of hand tools used in Workshop Practices. A broad classification of these tools, according to their use, is given below:

1. Marking and Measuring Tools.
2. Cutting Tools.
3. Striking, Benchwork & Fitting Tools
4. Precision Measurment Tools & Gauges.
5. Work Holding Tools
6. Thread Cutting Tools
7. Miscellaneous Tools.

2.2.1 MARKING AND MEASURING TOOLS

The common operation performed by these tools include marking, measuring, setting out angle and parallel lines and testing. All tools do not perform every operations but all those tools which do one or more of these operations are grouped together in this category. The tools included in this group are described below.

I. Steel Rules (Fig. 2.1)

Steel scales or rulers are essential to have in both six inch and 12 inch lengths. This type of measuring device is typically used for sheet metal layout, and for taking measurements where extreme precision is not required. Scales are made of either a tempered carbon steel or a satin-finished stainless steel, and are available in both flexible and rigid form. The flexible scale typically has a thickness of about 0.015 inch, while a rigid scale is about 0.040 inch thick.

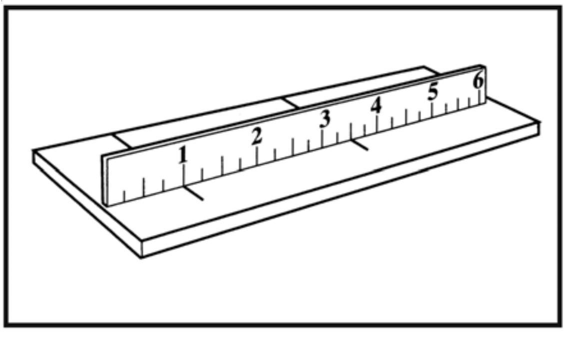


Fig. 2.1, The proper use of a steel scale requires that the end of the scale not be used to make a measurement. Instead, the one inch mark is used as the starting point. However, you must remember to subtract one inch from the final measurement.

Scales are graduated in exact portions of either a metric measurement, or a fractional measurement. Scales with fractional graduations are typically divided into increments of 1/32 inch on one side and 1/64 inch on the other side. A decimal scale is usually divided in tenths or fiftieths of an inch on one side while the other side is divided in increments of 1/100 inch. Metric graduations are measured in centimeters and millimeters, and are often included on the same scale. Since it is sometimes necessary to convert from metric to fractional or decimal form and vice versa it is a good idea to keep a conversion chart with your layout tools.

Because the end of a metal scale is not precisely cut, the cut, or factory end should not be used as a measuring guide. Instead, you should always begin measuring somewhere after the first few markings on a scale to ensure a correct measurement. The one inch mark is typically used as the starting point because it is easily subtracted from the final measurement.

II. Combination Set (Fig. 2.2)

It is a very useful instrument having a combination of five different instruments in one, thus facilitating a fairly wide range of uses, It consists of a steel scale graduated in inches and its parts or centimeters and millimeters. It is available in varying lengths from 20 cm to 60 cm. A groove, midway between its width, runs along its full length. At its one end is provided a flat square which enables its use as an engineer's try square in testing and setting right angles and also as a depth gauge. A bevel protractor provided at the middle carries a spirit level. The latter enables its use for testing trueness of flat surfaces and the former as a bevel protractor for setting, testing, marking, measuring and duplicating different angles. A centre-square provided at the other end is used for locating centres at the end faces of round bars, avoiding the use of V-block, etc. All these attachments can be used simultaneously or separately, or as a combination of two or more, depending upon the requirement. All the attachments are provided with nuts and screws to lock them in position. These nuts carry knurls at their outer surfaces, as shown in the diagram, to provide a firm grip during screwing and unscrewing. A combination set is shown in Fig. 2.2, and a few typical applications of it are shown.

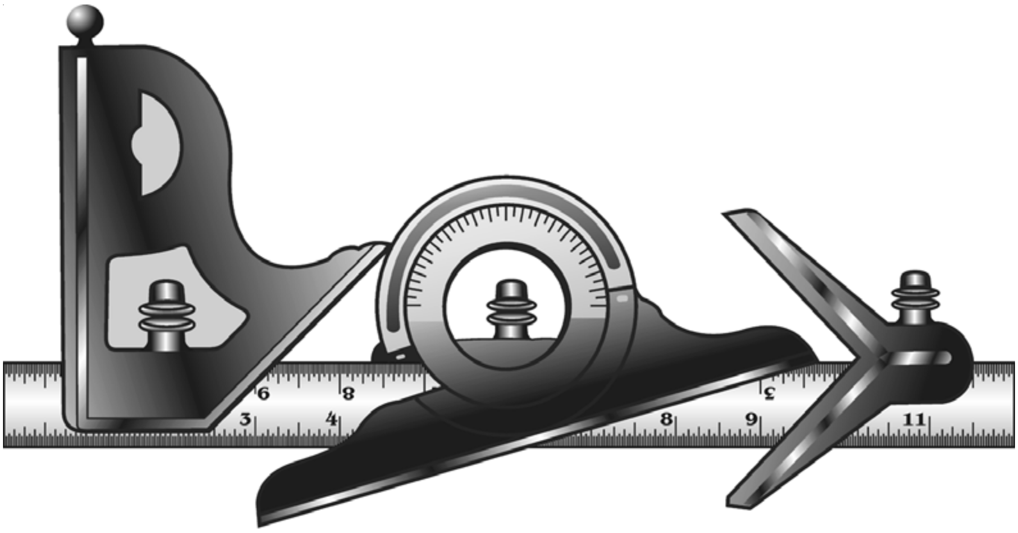


Fig. 2.2, Combination Set

III. Bevel Protractor (Fig. 2.3)

A bevel protractor (Fig. 2.3) is a tool for measuring angles within one degree. It consists of a steel rule, a blade, and a protractor head. The protractor head has a revolving turret graduated to read from 0° to 180° in opposite directions. The head may be a reversible type with shoulders on both sides of the blade or a nonreversible type with a single shoulder. Most bevel protractors contain a spirit level, which is useful when measuring angles in relation to a horizontal or vertical plane. A plain steel protractor may be more convenient to use for laying out and checking angles on some types of work.

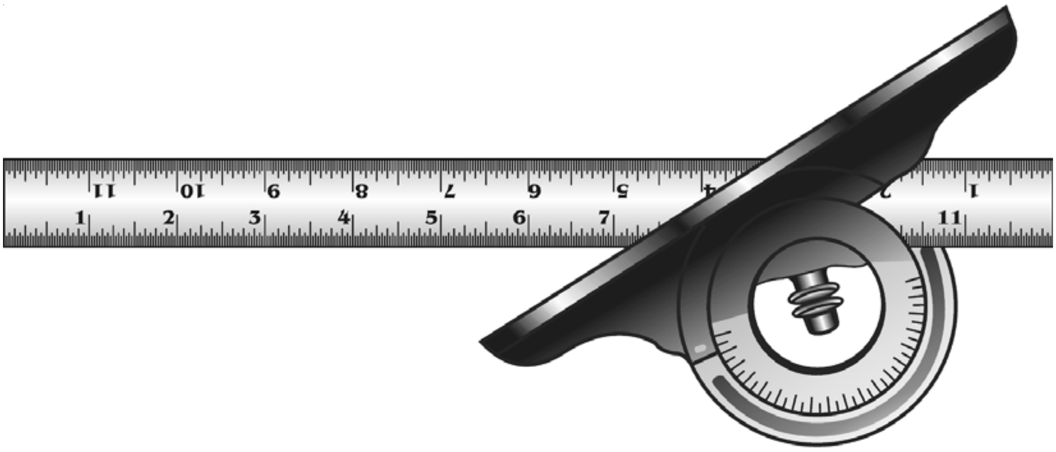


Fig. 2.3, Bevel Protractor

IV. Inside & Outside Calipers (Fig. 2.4)

Calipers are a type of measuring device typically used to measure diameters and distances or for comparing sizes. As an aviation maintenance technician you must be familiar with three types of calipers. They are the inside caliper, the outside caliper, and the hermaphrodite caliper.

Calipers are very similar to dividers in that they have two legs with some type of pivot. Inside calipers are used to measure the inside diameter of a hole, and have legs that point outward. Outside calipers, on the other hand, are used to measure the outside diameter of an object and have legs that point inward. When using either type of calipers you adjust the caliper until it fits snugly across the widest part of an object, and then measure the distance between the caliper leg points with a steel scale.

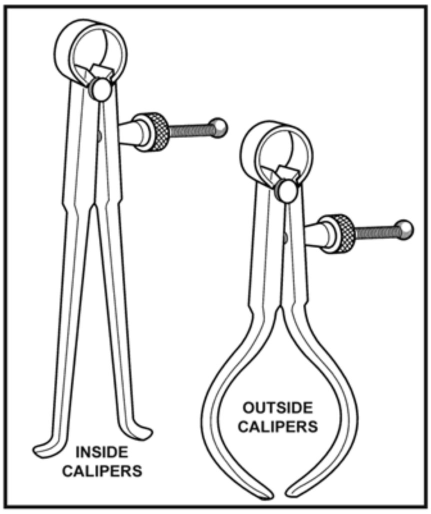


Fig. 2.4 (a), Inside calipers have legs with ends that curve to the outside, whereas outside calipers have legs with ends that curve to the inside.

V. Hermaphrodite Caliper

Hermaphrodite calipers are used to scribe marks that are a specific distance from a radius edge. These calipers have one sharp-pointed leg, and one leg that curves to the inside. To use hermaphrodite calipers, the material being worked on is first covered with layout dye, and the distance required is adjusted between the two caliper point is then moved along the radius edge as the sharp point is drawn across the surface.

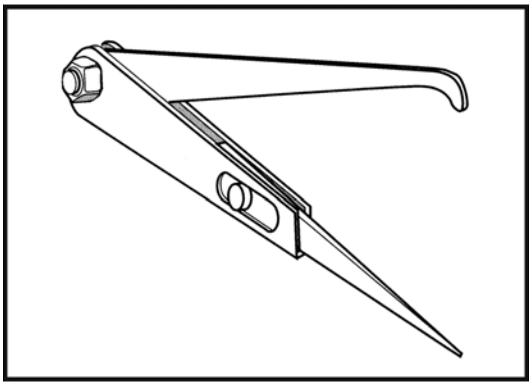


Fig. 2.4 (b), Hermaphrodite calipers are used to mark distances away from edges. These calipers have the straight leg of a divider and a leg that curves inward similar to an outside caliper.

VI. Angle Plates (Fig. 2.5)

Are precision tools made of cast iron, tool steel, or granite (Fig. 2.5). They are widely used as fixture for holding work to be laid out, machined, or inspected. The faces are at right angles and may have threaded holes, slots, and fitted clamps for holding workpieces. Tool-makers's clamps and C clamps are also used to hold the work. Angle plates are generally used on surface plates and machine tool tables. Cast iron plates are surface ground and hand scraped to a high degree of accuracy. Hardened tool-steel angle plates are surface-ground very accurately and may be lapped for accuracy and finish.

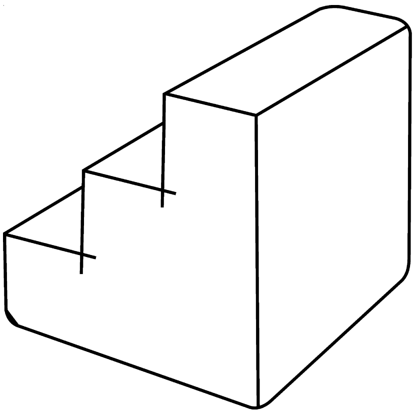


Fig. 2.5, Angle Plates.

VII. Surface Plate (Fig. 2.6)

It is a cast iron plate having a square or rectangular top perfectly planned true and square with adjacent machined faces. This top is finished true by means of grinding and scraping (Fig. 2.6). This plate carries a cast iron base under it and the bottom surface of the base is also machined true to keep the top surface of the plate in a perfect horizontal plane. Its specific use is in testing the trueness of a finished surface , testing a try square, providing adequate bearing surface for V-block and angle plates, etc., in scribing work.

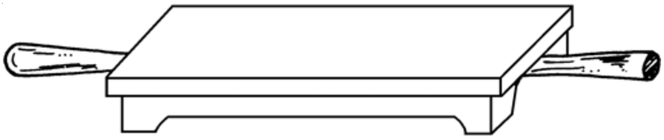


Fig. 2.6, Surface Plate

VIII. Try Square (Fig. 2.7)

It is better known as engineer's try square and is a very common tool used for scribing straight lines at right angles to a true surface or testing the trueness of mutually normal surfaces. They are made in different sizes out of steel pieces. In construction they are similar to a carpenter's try square but are comparatively more accurate. They can be made either in one piece or in two pieces. The most commonly used type is the one shown in Fig. 2.7. It consists of a steel blade fitted into a steel stock of rectangular cross-section.

They are well hardened and tempered to suit the need. Some more accurate types of try squares are made with their blades having bevelled edges properly ground and finished square. Both inner and outer surface of the blade are kept truly at right angles to the corresponding surfaces of the stock. In order to maintain this trueness this tool should be handled with sufficient care and should never be used as a striking or supporting tool. The accuracy of this tool should be frequently checked to ensure the trueness as it effects the accuracy of the finished job to a considerable extent.

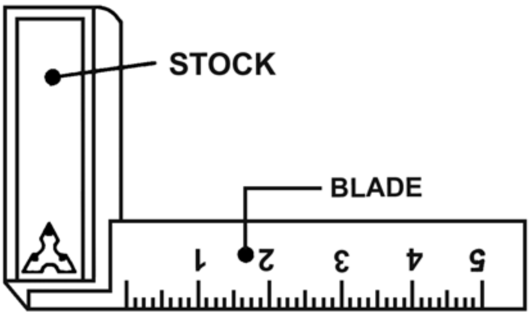


Fig. 2.7. Try square.

IX. Surface Gauge (Fig. 2.8)

It is a principal marking tool in a fitting shop and is made in various forms and sizes. It consists of a cast iron sliding base fitted with a vertical steel rod. The marker or scriber is fitted into an adjustable device carrying a knurled screw at one end, as shown in Fig. 2.8. By means of this screw the scriber can be loosened or tightened to set it at any desired inclination, moved to and fro inside the hole accommodating it or adjust its height along the vertical pillar. Normally it is used in conjunction with either a surface plate or marking table. Its specific use is in locating centres of round rods held in V. Block, scribing straight lines on work held firmly in its position by means of a suitable device like angle plate and also in drawing a number of lines parallel to a true surface. The instrument just described is a very simple form of surface gauge. It has now largely been replaced by a more accurate instrument called universal surface gauge.

Fig. 2.8, Surface Gauge

X. Universal surface gauge (Fig. 2.9)

It is an improved variety of the simple scribing block described above. (Fig. 2.9). It is so designed that appreciably finer adjustments can be made very quickly. It consists of a cast base, perfectly machined and planed at the top, bottom and all sides. This base usually carries a V-shaped slot at the bottom so as to render it suitable for use on round objects. Two guide pins are provided at the rear end of the base which can be pressed down to project below the base. The pins can be used against the edge of the surface plate of any other finished surface for guiding the instrument during scribing. A swivel bolt is provided at the top of the base in which the spindle is fitted. This spindle can be swung and locked in any desired position by means of the adjusting screw which is provided with a knurled nut at its end for this purpose. The scriber is fitted in a adjustable screw on the spindle and is capable of being adjusted at any inclination and height along the spindle. A rocker is provided at the top of the base and it carries an adjusting screw at its rear end.

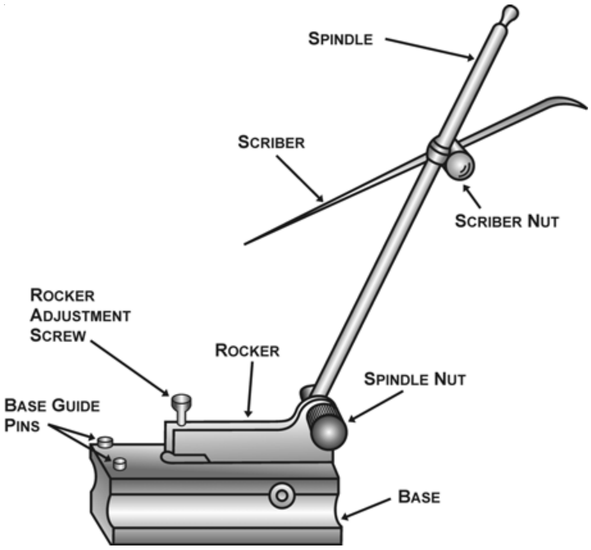


Fig. 2.9, Universal Surface Gauge

In operation the spindle is secured in the swivel bolt and is set at a desired inclination. The scriber is swivelled and set at approximately required height. Finer adjustments, to bring the point of the scriber at the exact correct height, are then made by means of the adjusting screw provided on the rocker. This instrument is used for scribing parallel lines at desired heights from a plane surface, comparing the trueness of two similar heights, setting out a desired height and similar other operations, and forms an indispensable instrument of bench work.

XI. Scribers (Fig. 2.10)

Dimension layout on metal parts, regardless of the accuracy, is typically accomplished by using layout dye and a marking tool called a scriber. Scriber have needle-sharp points and are usually made of hard steel or are carbide tipped. To use a scriber, a layout dye is typically applied to the metal first and the scriber is used to scratch through the dye. However, this procedure will causes stress concentrations on the surface of a bend and, therefore, it is not acceptable to use this method to indicate bend lines. Instead bend lines should be marked with a soft tipped marker.

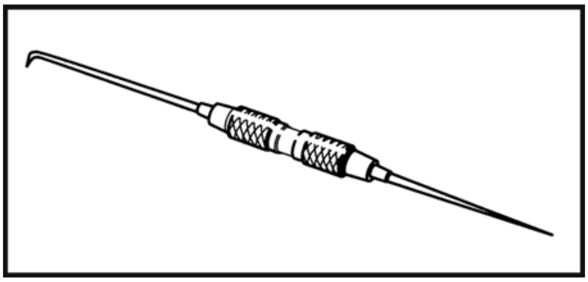


Fig. 2.10, A Scriber is typically used with layout dye to mark reference points on a material. However, scriber marks should never be used for bend lines as they cause stress concentrations that can lead to component failure.

XII. Dividers (Fig. 2.11)

Dividers are very useful instruments employed in marking work. They are similar in construction to the calipers but their legs are not bent. Also, the free ends of the two legs are sharp points. They may have either a friction-joint or a spring arrangement, as shown in Fig. 2.11. Their principal use is in measuring distance between two point or parallel lines on flat surface, dividing a given length in a definite ratio, drawing circles and arcs and transferring dimensions from scales to objects. The spring type dividers are more accurate and are widely used. Trammel is a useful alternative to dividers, particularly in large work. Essentially it consists of two adjustable vertical legs, mounted on a common rod called beam, which can be brought closer or opened out, as desired. These vertical legs are usually provided with a slot at the top so as to mount them on the beam, and at the bottom they are shaped to have a sharp point.

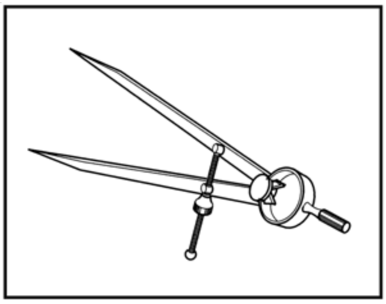
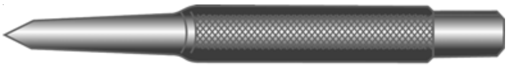


Fig. 2.11, Spring dividers

XIII. Punches

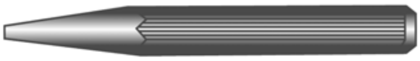
Punches are used to start holes for drilling; to punch holes in sheet metal; to remove damaged rivets, pins, or bolt; and to align two or more parts for bolting together. A punch with a mushroomed head should never be used. Flying pieces might cause an injury. Typical punches used by the aircraft mechanic are shown in Fig. 2.12.

Prick punches are used to place reference marks on metal. This punch is often used to transfer dimensions from a paper pattern directly on the metal. To do this, first place the paper pattern directly on the metal. Then go over the outline of the pattern with the prick punch, tapping it lightly with a small hammer and making slight indentations on the metal at the major points on the drawing. These indentations can then be used as reference marks for cutting the metal. A prick punch should never be struck a heavy blow with a hammer because it may bend the punch or cause excessive damage to the material being worked.



CENTER PUNCH

PRICK PUNCH



STARTING PUNCH

PIN PUNCH

ALIGNING PUNCH

HOLLOW SHANK GASKET PUNCH

Fig. 2.12, Typical punches

Large indentations in metal, that are necessary to start a twist drill, are made with a center punch. It should never be struck with enough force to dimple the material around the indentation or to cause the metal to protrude through the other side of the sheet. A center punch has a heavier body than a prick punch and is ground to a point with an angle of about 60°.

The drive punch, which is often called a tapered punch, is used for driving out damaged rivets, pins, and bolts which sometimes bind in holes. The drive punch is therefore made with a flat face instead of a point. The size of the punch is determined by the width of the face, which is usually 1/8 inch to ¼ inch.

Pin punches, often called drift punches, are similar to drive punches and are used for the same purposes. The difference in the two is that the sides of a drive punch taper all the way to the face while the pin punch has a straight shank. Pin punches are sized by the diameter of the face, in thirty-seconds of an inch, and range from 1/16 to 3/8 inch in diameter.

In general practice, a pin or bolt which is to be driven out is usually started and driven with a drive punch until the sides of the punch touch the side of the hole. A pin punch is then used to drive the pin or bolt the rest of the way out of the hole. Stubborn pins may be started by placing a thing piece of scrap copper, brass, or aluminum directly against the pin and then striking it with a hammer until the pin begins to move.

Never use a prick punch or center punch to remove objects from holes, because the point of the punch will spread the objects and cause it to bind even more.

The transfer punch is usually about 4 inches long. It has a point that tapers, then turns straight for a short distance in order to fit a drill-locating hole in a template. The tip has a point similar to that of a prick punch. As its name implies, the transfer punch is used to transfer the location of holes through the template or pattern to the material.

2.2.2 CUTTING TOOLS

The various cutting tools in the various shops in workshop practices are discussed below :-

I. Hack Saw

The hacksaw is the chief tool used by the fitter for cutting rods, bars and pipes into desired lengths. It consists of a metal frame, which may be solid, as shown in Fig. 2.13 (a), or adjustable, as shown in Fig. 2.14 (b). The blade fits over two pegs which project from the pins sliding in the ends of the frame. The wing nut at the front end to the frame is for tensioning the blade. The blades are made of carbon or high-speed steel and may be finished with the cutting edge only hardened or they may be hard all over. The soft-backed blades are tougher and less liable to break then the all-hard blades. The blades are specified by its length and the point or pitch. The length of the blade is the distance between the outside edges of the holes which fit over the pins. The most usual balde for hand work is 250 mm long and 12.5 mm wide. The point or pitch is measured by the number of teeth per 25 mm length.

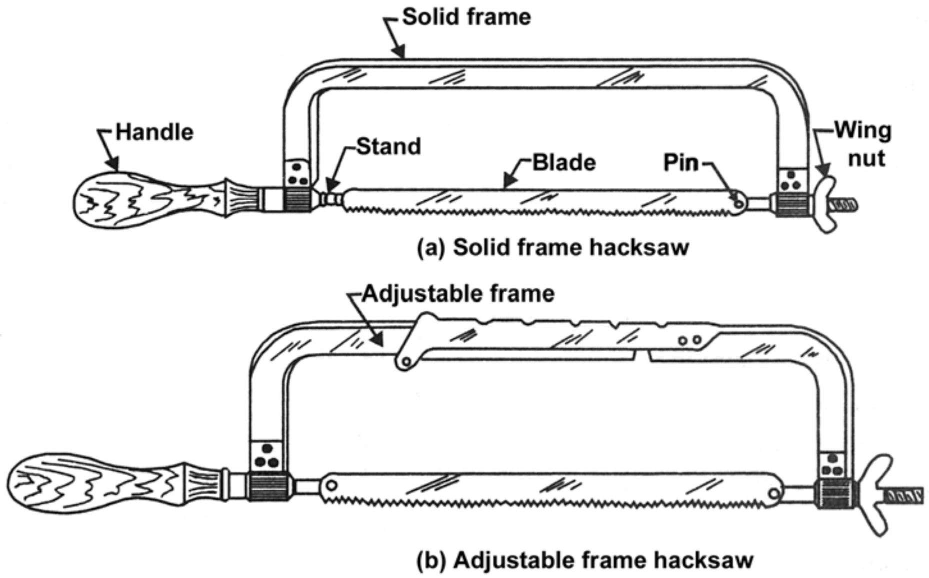


Fig. 2.13, Types of hacksaws.

The points of the teeth are bent, as shown in Fig. 2.14 (a), to cut a wide groove and prevents the body of the blade from rubbing or jamming in the saw cut. This bending of the teeth to the sides is called the setting of the teeth as shown in Fig. 2.14 (b). Usually alternate teeth are set to right and left, every third of fifth tooth left straight to break up the chips and help the teeth to clear themselves. The fine-toothed blades for cutting thin metal are sometimes made with a wavy set to minimize stripping of the teeth from the blade.

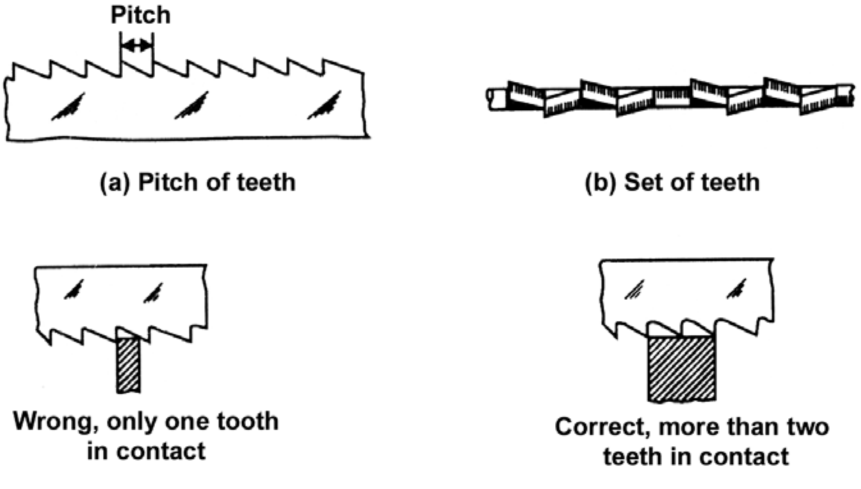


Fig. 2.14, Position of teeth.

The choice of the blade for any particular class of work depends upon the pitch of the teeth and at least two or three teeth should be in contact with the surface being sawn, as shown in Fig. 2.14 (c). If this is not attained, the teeth will be stripped from the blade and sawing too sharply over a corner will also result in teeth being torn off.

The best all-round blade for hand use is one with 16 to 18 teeth per 25 mm. For other special classes of sawing, the following blades should be used :

a. 14 teeth per 25 mm, for solid brass, copper and cast iron.
b. 24 teeth per 25 mm, for silver, steel and thin cast steel rods.
c. 32 teeth per 25 mm, for sheet metal and tubing e.g., steel, copper and conduit tubing.

The following should be kept in mind while using a hacksaw :

i. The blade must be strained tightly in the frame and steady strokes (about 50 per minute)should be used.
ii. The breakage of blades may be due to the following reasons :
a. rapid and rratic strokes,
b. too much pressure,
c. blade held too loosely in the frame, and
d. work not held firmly in the vice.
iii. Solid metals should be cut with a good pressure and thin sheets and tubes with light pressure.

II. Chisels

There is a fairly good variety of chisels used for chipping work by a fitter. Some very commonly used forms are Flat, Cross-cut or cape, Round nose and Diamond point chisels (Fig. 2.15). All the chisels are forged from bar stock of carbon steel, usually of octagonal or hexagonal cross-section to the desired shape and the cutting edge ground to the correct angle. The forgoing operation is followed by annealing, hardening and tempering to make chisel body tough and obtain a sharp cutting edge. Full length of the chisel is never hardened, only a small length above the cutting edge (say about 20 to 30 cm) is subjected to this treatment so that the remaining length if left tough and comparatively softer. The included angle at the cutting edge varies between 40 degree and 70 degree depending upon the material on which it is to be used. Approximate cutting angles for common materials are as follows:

Brass and copper : 40^{o}
Wrought iron : 50^{o}
Cast iron and general cutting work : 60^{o}
Steel (cast) : 70^{o}

a. Flat Chisel

It is a general purpose chisel which is most widely used in cutting work, chipping large surfaces, cutting metal sheets, rods, bar stocks and similar other purposes. Since it cuts the metal in cold state it is also frequently known as cold chisel. In grinding, its cutting edge is given a slight rounding so as to prevent the corners from digging into the metal.

b. Cross Cut Chisel or Cape Chisel

It is a comparatively narrow chisel having its cutting edge slightly broader than the blade. It is done to keep the blade free when the chisel is used to cut deep into the metal. Normal widths of the cutting edge vary from 3 mm to 122 mm. This chisel is used to cut parallel grooves on large surfaces before chipping by means of a flat chisel cutting key ways etc.

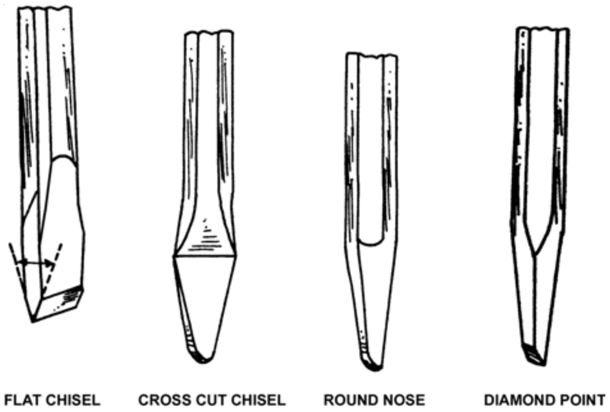


Fig. 2.15, Types of Chisels

c. Round Nose Chisel

It is used for drawing the eccentric hole back to correct centre which has run-off centre during drilling operation. Another specific use of this type of chisel is in cutting oil grooves and channels in bearing and pulley bushes and cleaning small round corners.

d. Diamond Point Chisel

It is a special purpose chisel used for chipping rough plates and cutting cast iron pipes, cutting 'V' grooves, chipping sharp corners, to square up corners of previously cut slots and cleaning angles.

Other chisels can be made in desired shapes to suit the work. A particular form known as side chisel, is very useful in cleaning and finishing up slots which have been previously drilled such as cotter ways etc. Chisels which are used in electric or pneumatic hammers have similar cutting edges but their heads are made to have a parallel shank so as to suit the socket of the hammer.

III. Files

Files of different types are the principal hand tools used by a fitter. All the files, irrespective of their shape, size and grade essentially consist of two main parts, viz., a toothed blade and a pointed tang which is fitted in a wooden handle. Details of parts of a file are shown in Fig. 2.16. Files are generally forged out of high carbon steel or Tungsten steel followed by cutting of teeth hardening and tempering etc. These files are manufactured in different varieties and their classification is governed by the following factors:

a. Effective length - i.e. excluding the length of tang.,
b. Shape or form of the cross-section.,
c. Depth, spacing and cut of teeth.

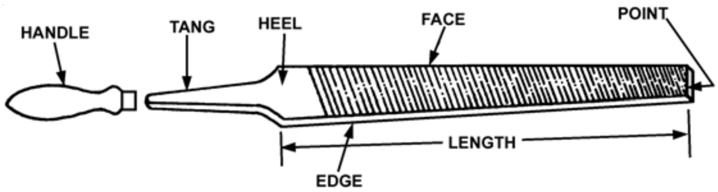


Fig. 2.16, Different parts of File

Length of the files

It varies according to the need but the most commonly used lengths range usually from 10 cm to 40 cm and they cover almost all sorts of filing work done by hand. Lengths between 10 cm and 15 cm are generally used for fine work, between 15 cm and 25 cm for medium sized work and above 25 cm for all general and large sized jobs.

Cross-Section

Files are manufactured having different shapes of their cross-sections to suit the variety of shapes which they have to work on. The most commonly used shapes of the cross-sections are shown in fig. 2.17. At no. 1 is shown the section of a square file which carries double cut teeth in all the four faces and is normally made tapered for about one-third of its length near the end opposite to the tang, although square files without this tapered length are also available At no 2 is shown a three square or triangular file which normally carries single cut teeth on all the faces and is made tapered towards the end for about two third of its length near the tip. The cross-section is an equilateral triangle.

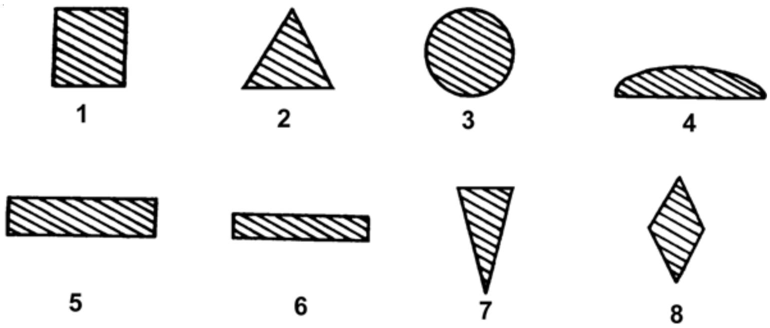


Fig. 2.17, Cross-sections of files.
1. Square 2. Triangular or three square 3. Round 4. Half round
5. Rectangular-1 6. Rectangular-2 7. Knife edge 8. Diamond file.

A round file has a circular cross-section as shown in Fig 2.17 at no. 3 and carries single cut teeth all around its surface. It is normally made tapered towards the tip and is frequently known as Rat-tail file. Parallel round files having same diameter throughout the length are also available. At No. 4 is shown the cross-section of a half-round file. It normally has single cut teeth on the curved surface and double cut teeth on the flat surface.

Cross -Sections of Flat and Hand Files are shown respectively at No. 5 and 6. Both these files have a rectangular cross-section and the difference between them lies in the way they are tapered. A flat file is tapered towards the tip both in its length as well as thickness whereas a hand file is tapered in thickness only. The former carries double cut teeth on both the flat faces and single cut teeth on the edges. In a hand file the flat faces carry double cut teeth and one of the edges single cut. One edge, known as safe edge, does not have normally any teeth and hence this file is also known as safe edge file. It is very useful in filing a surface which is at right angles to an already finished surface. The face edge is kept facing the finished surface during the operation so that it is not spoiled. *Pillar files* are also of rectangular cross-section but are narrower in width and carry double cut teeth on all the surfaces. They can be tapered as well as parallel.

At No. 7 is shown the cross-sections of a *knife edge file* which carries double cut teeth on the two broad faces and single cut teeth on the edge. It is specifically used in filing narrow and intricate sharp corners having an included angle of less than 90 degree. Cross-section of a diamond shaped file, used for special purpose work is shown at No.8.

There are a number of other types of files is use which are all special purpose files and are not in general use. A *ward file* is a thin flat file having fine cut teeth, about 10 cm long, used for fine work. *Needle files* are thin small files having a parallel tang and a thin, narrow and pointed blade made in different shapes of its cross-section to suit the particular needs of the work. They are used for filing very thin and delicate work. *Rifflers* are spoon shaped double ended files having double cut teeth on the curved faces and are used for filing curved surface in the interior. Flat files are sometimes bent, by heating to a dull red heat then hammering by a soft material such as lead or wood etc., followed by re hardening to give them desired shapes and are then used for filing deep surfaces. They are then known as set files.

Teeth

Type of teeth and spacing between teeth, known as pitch, play an important role in the selection of files for a particular work. According to the type of teeth the files are classified as i) single cut and ii) Double cut. In a single cut files the teeth are cut in parallel rows running across the faces and are normally inclined at an angle of 60^o with the centre line of the face. Float is the term frequently used for these files and they are particularly used for hard metals. They give a better finish as compared to the double cut files but at the same time remove the material at a comparatively slower rate.

In a double cut file there are two sets of teeth; one similar to those of a single cut file and the other running diagonally across the first set and inclined at an angle of about 10 degrees, to the centre line of the face on which the teeth are cut. All the teeth are having a negative rake i.e., slopping backwards and thus cut only in the forward stroke. The angles given above are suitable for general work in steel and for softer materials, these angles are changed, e.g., 30 degree and 60^o for wrought iron. The second or up cut angle is increased sometimes upto 90 degree even, for non-ferrous metals like brass and bronze etc.

Depending upon the pitch of the teeth the files are classified as:

1. Rough	having 8 teeth per cm.
2. Middle or coarse	having 10 teeth per cm.
3. Bastard	having 12 teeth per cm.
4. Second cut	having 16 teeth per cm.
5. Smooth	having 20 to 24 teeth per cm.
6. Dead smooth	having 40 or more teeth per cm.

The above grade of files are respectively used for filing after chipping a casting effecting heavy reduction of stock, filing huge bulk of work, making the surfaces smooth after the application of any of the above files and finishing purposes. All the above grades of files may have either single cut or double cut teeth. Pitch of the teeth varies directly as the size of the files. Smaller the file finer the pitch and larger the file coarser will be the pitch.

Filing

Filing is the most important operation that a metal worker has to learn. Filing is usually an after-treatment and usually done after chipping. It serves to remove the burr from cuts and clean the face of the cuts, and to finish the final shape of a workpiece. In general no more than 0.6 mm tooling allowance should be left for filing. Filing allows work to be made accurate to 0.05 mm, in some cases to 0.02 mm, and even to 0.01 mm.

Working with the file requires some skill. Normally the work is held in a vice and should be level with the operator’s elbow. He should place his left foot in the direction of the file stroke, and his right foot should be placed at an angle of 90^o in relation to his left foot.

The proper handling of the file is also an important condition for satisfactory filing work. In principle, the worker should grip the file handle with his right hand, which is to guide the file. When working with large files, the ball of the left thumb should be placed on the end of the file blade which is clasped by the fingers. The left hand exerts an increasing pressure on the file in the forward motion.

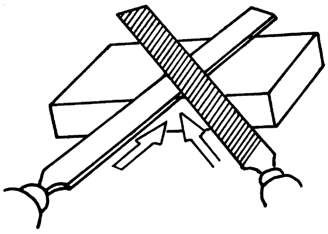


Fig. 2.18, Cross filing

The right hand is to guide the stroke also when working with medium-size files, while thumb and forefinger of the left hand exert the necessary pressure. For very light work with small files it is better to point the first finger along the top of the handle to give more sensitive control and file is pressed against the workpiece with several fingers of the left hand.

It should be noted that the file cuts only on the forwards stroke, hence if required the file can be lifted off the work for the return on the work during the return stroke, but the pressure from the left hand is released. Filing should always be carried out with the file making the longest possible strokes so that all the teeth of the file receive even wear. The file should also be moved across the work with slow steady strokes (50 to 60 per minute), taking care to keep it horizontal, and covering the whole of the filing area at each stroke.

Methods of Filing

Generally speaking, there are three main methods of using a hand-flat file

In cross- filing the file strokes run alternately from the right and from the right to the left as shown in Fig. 2.18. This is the common most form of filing and the one used for general shaping. In this method the possibility of rounding is minimized, and the score marks made in the work by the file teeth are crisscrossed so that maximum amount of metal is removed. The aim in cross-filing is always to move the whole of the file surface across the whole of the work surface in one stroke.

In straight-filing the file is pressed forward approximately at right angles to the length of the work. On the back stroke, the file should be lifted clear of the work in order not to blunt the teeth. Straight-filling is specially useful on long and narrow pieces of work whose width is less than that of the file.

In draw-filing the handle of the file is not held. Instead, both hands are placed to close together on the blade. The file is placed at right angles across the work while the hands, and especially the thumbs, grip the file and move it up and down the length of the metal. It does not move much material, but a smoother cutting action is achieved than with cross or straight-filing.

Care of Files

Files are very brittle and should be placed thoughtfully in the bench well in such a way that they do not rub or knock against other tools, especially those of cast steel. Similarly, the file should never be used on hardened steel, or hard surface scale such as cast iron skin, or allowed to strike against the hardened vice jaws. When not in use, the files are protected from rust by coating them lightly with machine oil. Before using the file, the oil should be removed with carbon tetrachloride or caustic soda. Make sure that the handle is firmly fixed to the file . New files are generally first used on copper, brass, and later on wrought iron and mild steel. Filing, especially the filing of soft metals, causes the file teeth to become clogged with particles of metal. This is known as pinning and, unless the obstructions are removed they will make deep scores across the work and also the file will be unserviceable. Vigorous rubbing with a file brush or file card down the lines of the teeth will clean the file. After brushing the file, chalk may be rubbed into the teeth. Rubbing the file teeth with chalk will help to prevent pinning.

Worn files may be reused to a certain extent by dipping in hydrochloric acid but of course there is a limit to the number of times this etching process can be carried out. Worn files are useful for making scraper, punches, chisels, etc. They are also useful on the soldering bench when re-tinning soldering irons.

IV. Scrapers

Scraping means shaving or paring off thin slices or flakes of metal to make a fine, smooth surface. This is done with tools called scrapers which have very hard cutting edges. The material is a good quality forged steel and the cutting edge is usually left very hard. Old files make excellent scrapers. The teeth of the file must first be ground off on all sides. They are then heated and bent to the desired shape and ground to have the cutting edge, followed by hardening and tempering. Scrapers are fitted with short, round handles that fit the hand snugly.

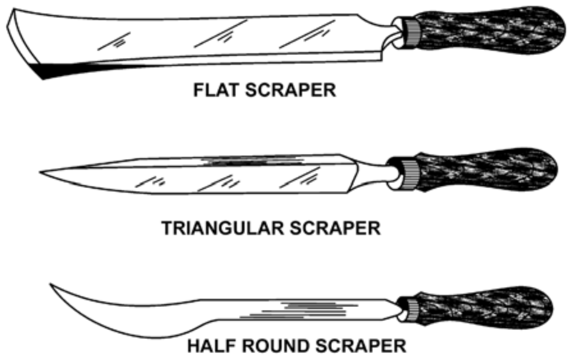


Fig. 2.19, Type of Scrapers

Since a scraper removes very thin chips, the scraping allowance should be small. These allowances depends on the width and length of the surface to be scraped or on the diameter and length of the hole to be scraped. Table gives the allowances for scraping the plane surfaces and holes.

Surface Wt. (mm)	Scraping allowance (mm) for the surface lengths (mm)				
	100 - 500	500 - 1,000	1,000 - 2,000	2,000 - 4,000	4,000 - 6,000
Upto 100	0.10	0.15	0.15	0.25	0.30
100 - 500	0.15	0.20	0.25	0.30	0.40

Scrapers are made in a variety of lengths from 100 mm upwards and in many shapes, as shown in Fig. 2.19, depending on the work to be done. These are : triangular, and half-round.

a. Flat Scraper

The flat scraper is the most common and also the most easily made. The cutting edge is at the end. It should be curved a little, looking at the broad side. This is done to keep from taking too broad a cut and to pre broad a cut and to prevent the corners of the scraper from coming in contact with the surface being scraped and making deep scratches. A flat scraper is used for producing a perfectly flat surface. Flat single-ended scrapers vary in length from 100 to 250 mm, double ended scrapers having no handles can be 350 to 400 mm long. Scraper for rough work are 20 to 30 mm wide, and for extra-accurate work they are made 16 to 20 mm wide, and for extra accurate work 5 to 10 mm wide. The thickness at the cutting end varies from 1 to 3.5 mm. The lip angle of scrapers for rough scraping is 60 to 75 degrees, for finish scraping 90 degrees.

b. Triangular Scraper

The triangular scrapper has three cutting edges and is made from a triangular file. It is used to scrape round or curved surfaces and to remove sharp corners and burrs. The blade is usually 150 mm long.

c. Half Round Scraper

A half- round scraper is, in shape, like a half-round file. In fact, they are often made from old half-round files. They are used to scrape round or curved surface. The length of the blade from the handle should be at least 150 mm.

Care of Scraper

Scrapers have very sharp cutting edges. When, not in use, therefore, these scrapers should be stored so that the blades are protected from damage. Either it should be kept in a special case or wrapped in a piece of cloth. If the edges of scraper require sharpening, the blade must be ground on the grinding wheel and then finished on the oilstone.

Scraping

Scraping is used for obtaining a truer flat surface than can be produced by machining or filing. So scraping often follows filing. Having got the surface of the block reasonably flat with the file, the block should first be tested on the surface plate, which is of cast iron and has a perfectly flat upper surface.

The top of the surface plate is covered with a very thin film of Prussian blue. Red lead may be used instead of Persian blue. The surface to be scraped is then laid on the surface plate and moved back and forth. Thus the high spots on the work will be marked with Prussian blue. If a thick coat is put on the surface plate, the low spots on the work will be marked as well as the high ones. The high spots are scrapped down, the scraper being worked with a small circular motion . The work is wiped clear of scraping before each testing. The process is repeated until the colour is spread evenly over the surface.

During scraping the handle of the scraper is held in the right hand with the first finger extended. The left hand is placed on the lower end of the scraper and controls the cutting action.

For scraping cylinder surface of a bearing either the curved or triangular scraper is used, with the handle in the right hand and the left controlling the cutting edge.

V. Snipes

Hand snips serve various purposes, straight, curved, hawksbill, and aviation snips are commonly used (Fig. 2.20). Straight snips are used to cut straight lines when the distance is not great enough to use a squaring shear, and to cut the outside of a curve the other types are used to cut the inside of curves or radii. Snips should never be used to cut heavy sheet metal.

Fig. 2.20, Various types of snips.

Aviation snips are designed especially to cut heat-treated aluminum ally and stainless steel. They are also adaptable for enlarging small holes. The blades have small teeth on the cutting edges and are shaped to cut very small circles and irregular outlines. The handles are the compound-leverage type, making it possible to cut material as thick as 0.051". Aviation snips are available in two types, those that cut from right to left and those that cut fro, left to right.

Unlike the hacksaw, snips do not remove any material when the cut is made , but minute fractures often occur along the cut. Therefore, cuts should be made about 1/32" from the layout line and finished by hand-filing down to the line.

2.2.3. STRIKING, BENCHWORK & FITTING TOOLS

I. Hammers

Hammers were one of man's earliest tools. The types of hammers used by machinists are limited, but they are available in many sizes. Machinist's hammers are classified as *hard or soft hammers.*

a. Hard hammer

It is one that is made of carbon steel and forged to shape and size. It is heat-treated to make the striking face hard. A soft hammer [Fig 2.21(a)]. may have the entire head made of a soft metal such as lead, babbitt, copper, or brass. Soft-faced hammers have only their striking surfaces made of plastic, rubber, or rawhide. The faces are either clamped or press fitted on the metal hammerhead [Fig 2.21 (b)]. A hard hammer is used for striking punches, cold chisels, steel letters, and figures. It is also used for forging hot metal, riveting, bending, straightening, peening, stretching, and swaging.

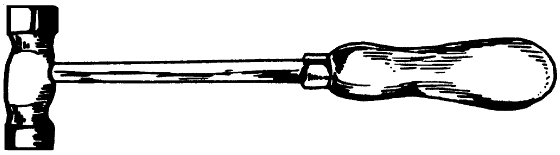


Fig. 2.21 (a), Soft hammers with brass head.

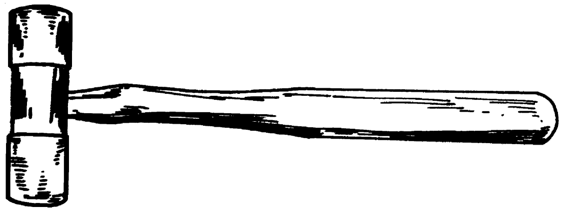


Fig. 2.21 (b), Plastic faced soft hammer.

b. Soft hammers

The are used when striking finished or semifinished workpieces to prevent marring the finished surfaces. For example, soft hammers are commonly used for seating a workpiece in machine vise or tapping finished work being set up for a machining or layout operation.

Various types of hard hammers most commonly used by machinists and identification of their parts

The hammers most commonly used by machinists are the ball-peen (Fig . 2.23). the straight-peen (Fig 2.24). and the cross-peen (Fig 2.22). The flat face of the ball-peen is used for general work such as striking punches; the rounded (ball) end is used for riveting and peening. The straight-peen, which has peen-end parallel to the axis of the handle, is used for stretching and drawing out metal when forging. The cross-peen, which has a peen-end at right angles to the hammer handle, is used for riveting, stretching and drawing metal.

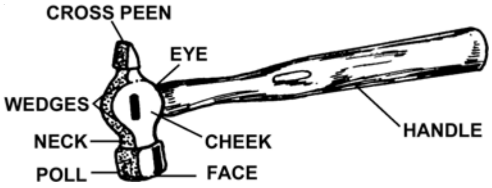


Fig. 2.22, Cross peen hammer

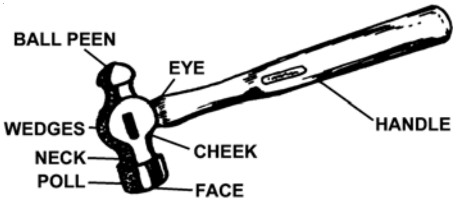


Fig. 2.23, Ball-peen hammer

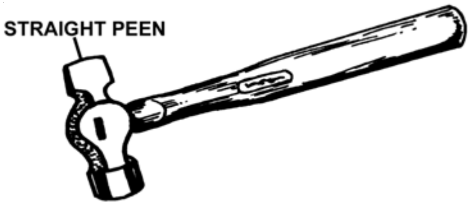


Fig. 2.24, Straight peen hammer

a. Sledge hammer

Sledge hammers are comparatively 3 to 4 times heavier than the hand hammers. They are available in varying sizes and weights from 3 kg to 8 kg. They are employed when heavy blows are needed in forging and other operations done on heavy jobs. Sledge hammers can be of straight peen, cross peen or double faced typed as shown in figs. 2.25, 2.26 and 2.27 respectively. The straight peen hammer is one which carries the peen formed parallel to the axis of the eye at one end and a flat face at the other end. Cross peen hammer is similar in construction to the former except that the peen runs at right angles to the axis of the eye. If the hammer has no peen formation and instead carries flat faces at both ends, it is known as a Double Ended or Double faced hammer.

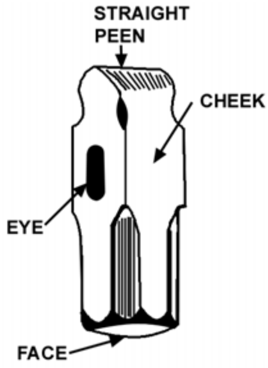


Fig. 2.25, Straight peen sledge hammer.

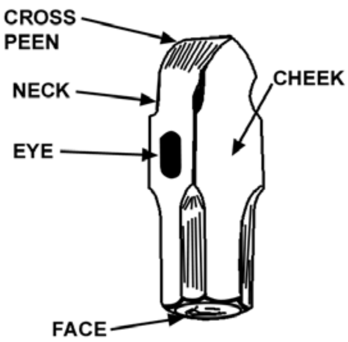


Fig. 2.26, Cross peen sledge hammer.

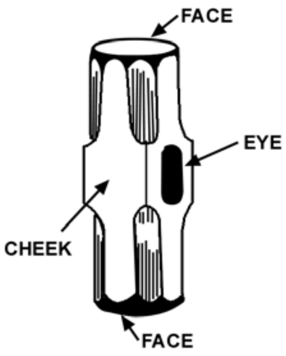


Fig. 2.27, Double faced sledge hammer.

b. Claw hammer

[Fig. 2.28] It is made of cast steel and carries the striking face at one end and the claw at the other. The face is used to drive the nails into the wood and other striking purposes and claw for extracting nails out of the wood. Its size is designated by its weight and it varies form 0.25 kg. to 0.75 kg.

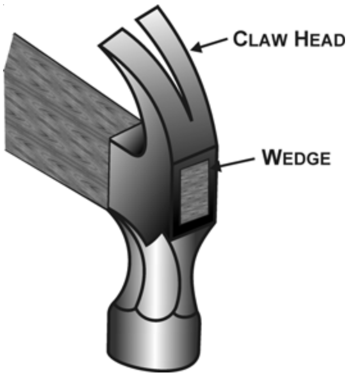


Fig. 2.28, A claw hammer

c. Mallet

It is made of hard wood and is rectangular or round in shape, provided with a wooden handle. It is used for striking the cutting tools, which have a wooden handle. A typical form is shown in Fig. 2.29.

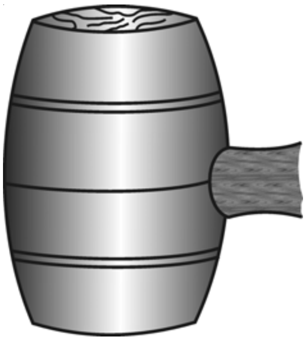


Fig. 2.29, A Mallet.

d. Peening, or Swaging

Peening, or swaging, is stretching or spreading of metal by hammering. Examples of peening include flattening the end of a rivet, spreading babbitt metal to fit tightly in a bearing, and straightening a bar by stretching its short side.

A hammer handle should be gripped near the end so the full leverage may be obtained when swinging the hammer. A solid blow is difficult to deliver when the handle is gripped too close to the head of the hammer. The amount of force with which the hammer strikes depends, in part, on the length of the handle and the weight of the head. To get the most advantage of the handle's length it should be held as far from the head as possible.

Size of hammers

The size of a hard hammer is specified by the weight of the head without the handle. Ball-peen hammer size ranges from 2 oz. to 3 lb. Size of soft-faced hammers are specified by the diameter of the face and the length of the head and range from 5/8- in. diameter to 3-in. Faces are specified in degrees of hardness from supersoft to extra hard.

II. Screw Drivers

The screwdriver is a tool for driving or removing screws. Frequently used screwdrivers include the common, crosspoint, and offset. Also in use are various screwdriver bits that are designed to fit screws with special heads. The shank of screwdriver is made of steel set into a wooden or plastic handle. The blade is shaped or flattened to fit recesses in the heads of screws or bolts. Screwdrivers are made in many sizes.

A common screwdriver must fill at least 75 percent of the screw slot (Fig. 2.30). If the screwdriver is the wrong size, it will cut and burr the screw slot, making it worthless. A screwdriver with a wrong size of blade might slip and damage adjacent parts of the structures. The common screwdriver is used only where slotted head screws or fasteners are used on aircraft.

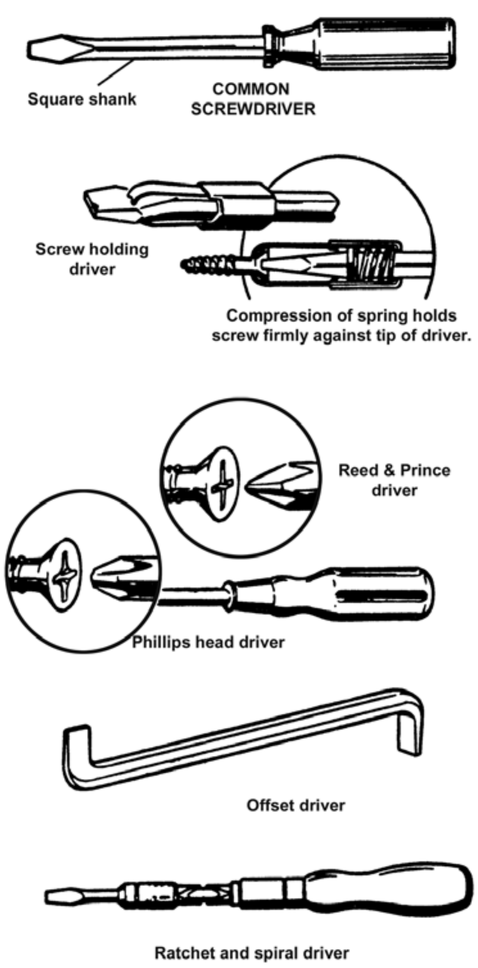
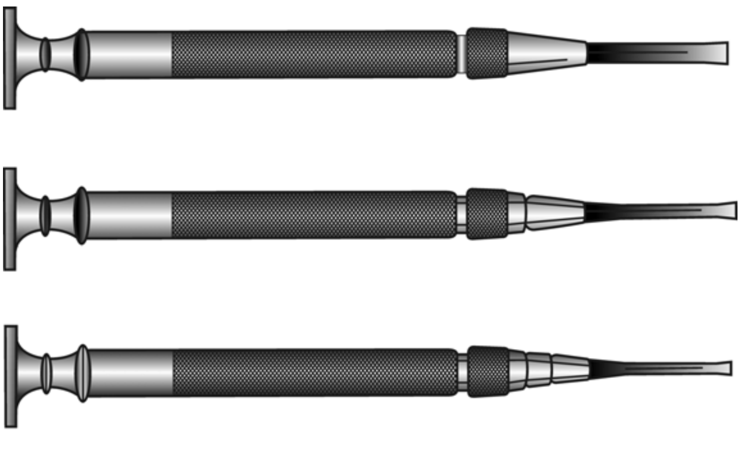


Fig. 2.30, Screwdrivers and their uses.

The two common recessed head screws are **the Phillips** and **the Reed and Prince**. As shown in Fig. 2.30, the Reed and Prince recessed head forms a perfect cross, the Phillips screwdriver is blunt on the end. The Phillips screwdriver is not interchangeable with the Reed and Prince. The use of the wrong type of screwdriver results in mutilation of the screwdriver and the screwdriver results in mutilation of the screwdriver and the screwhead. A screwdriver should not be used for chiselling or praying.

Figure 2.31 shows a set of jewelers' screwdrivers. Fig. 2.32 shows the correct way to hold this screwdriver. A stubby screwdriver (Fig. 2.33) helps to start screws where space is limited.



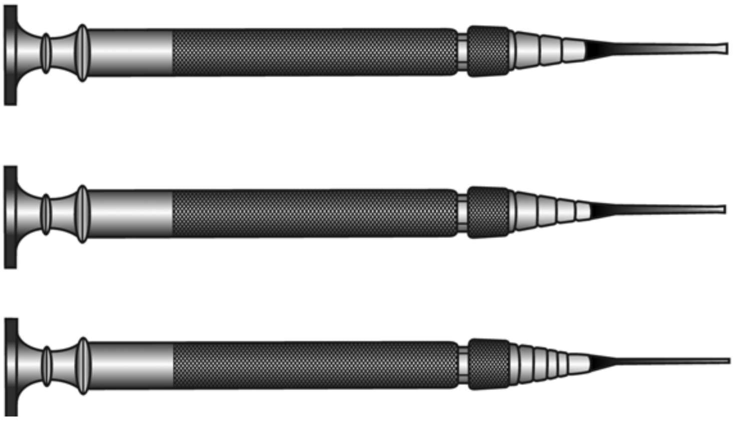


Fig. 2.31, A set of Jewelers' screwdrivers.

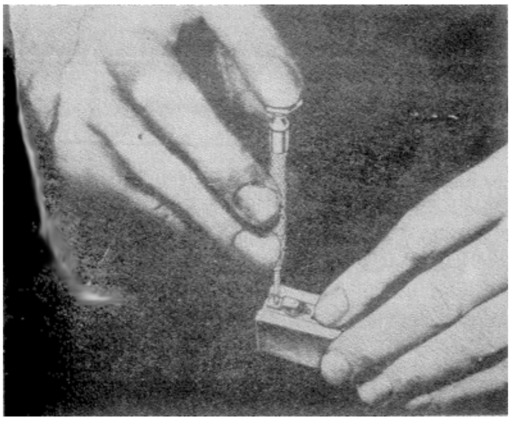


Fig. 2.32, Correct way to use a jewelers' screwdriver.

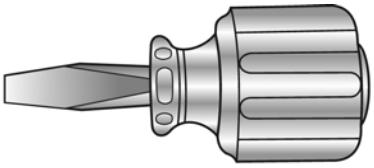


Fig. 2.33, A stubby screwdriver.

A ***heavy-duty screwdriver*** (Fig. 2.34) is of average length but is made with a heavy blade and a square shank. The shape of the shank permits the use of a wrench to assist in tightening a screw. Heavy (thick) material is used so that the blade and shank will resist being twisted when a wrench is used.

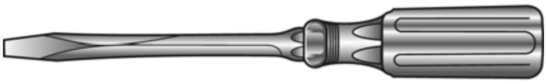


Fig. 2.34, Heavy-duty square-shank screwdriver.

A ***Phillips screwdriver*** (Fig. 2.35) is specially designed to fit the heads of Phillips screws. It differs from other screwdrivers in that the end of the blade is fluted instead of flattened. It is made in several sizes. Each size is numbered and relates the diameter of the blade with the point number. For example, a No. 2 point has a ¼-in-diameter shank.

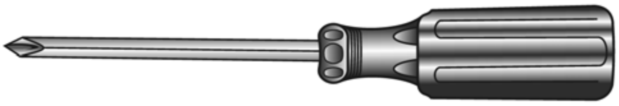


Fig. 2.35, Phillips screwdriver with No. 2.

A ***double-ended offset screwdriver*** (Fig. 2.36) is used for turning screws in awkward places where there is not enough room to use a regular screwdriver.

Fig. 2.36, Double-ended offset screwdriver.

A screwdriver blade should be ground so that the faces will be almost parallel with the sides of the screw slot. The end of the blade should be made as thick as the slot in the screw will permit. A lade ground to a chisel point has a tendency to slip out of the screw slot and, also, to leave a ragged edge on the slot.

Excessive heat at the time of grinding, indicated by a blue color appearing on the blade, will draw the temper of the steel and cause the blade to become soft. This will result in the end of the blade being bent out of shape when a heavy pressure is applied to tighten a screw.

When reconditioning a screwdriver blade, grind the end of the tip first to square it with the shank. Next, grind the blade to the thickness required by holding it on the grinding wheel. Usually, the radius of the grinding wheel will produce a satisfactory end on the blade.

III. Spanners & Wrenches

A wrench or a spanner is a tool for turning nuts or bolts. It is usually made of steel. There are many kinds of wrenches. They may consist of a slot, socket, pins or movable jaws for grasping the nut, with the rest of the tool serving as a handle for applying pressure.

Various types of wrenches

a. Single-ended wrench

(Fig. 2.37,a) A single-ended wrench is one that is made to fit one size of nut or bolt. This is the most inexpensive type of wrench and is quite efficient in ordinary situations.

b. Double-ended wrench

(Fig. 2.37, b) It has two openings, one at each end of the handle to fit two different sizes of nuts or bolt heads.

c. Closed-end wrench

(Fig. 2.37,c) It is similar to a single-ended wrench, but, because it entirely encloses a nut, there is little danger of the wrench slipping off the nut or of the jaws spreading apart. For these reasons, it is preferred for some jobs. It is also known as a box wrench.

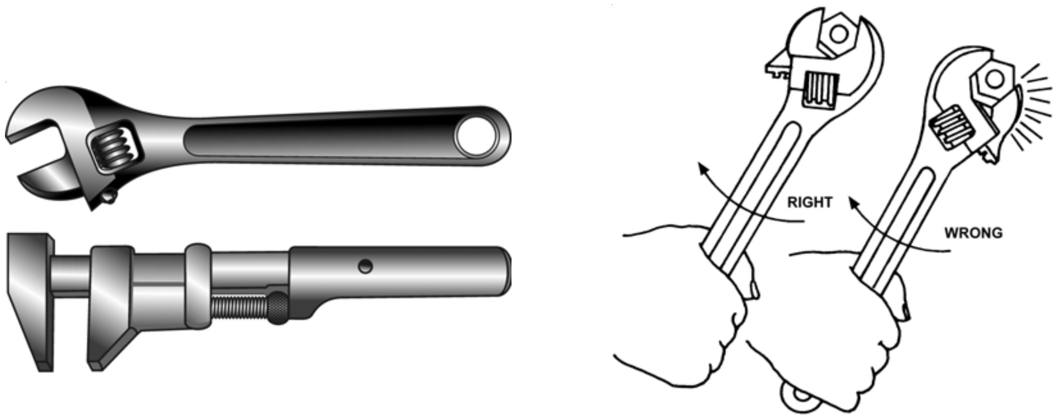
d. Adjustable wrench

(Fig.2.37,d) It has a movable jaw, which makes it adjustable to various sizes of nuts. A heavy type of adjustable wrench is the monkey wrench. When using this type of tool, point the jaws in the direction of the force applied. This will prevent the jaws from springing apart, and the wrench will be less likely to slip off a nut. The movable jaw should be adjusted so that it is tight against a flat surface of the part to be turned. It is not good practice to use a wrench as a hammer.

(a) Single-ended wrench

(b)

(c)



(d) Adjustable Wrench

Fig. 2.37, Types of wrenches.

e. Lever-jaw wrench

[Fig 2.38 (e)]. It is a combination gripping tool with adjustable jaws, which may be locked in place. It may be used as a wrench, clamp, pliers, or vise.

f. Combination wrench

[Fig 2.38 (f)] It has two types of openings of the same size. One end has a box type opening with the opposite end designed as an open end. It is a very practical wrench because it can be used in places where the space for movement is limited; if one end will not work conveniently, the other end will.

g. Check-nut wrench

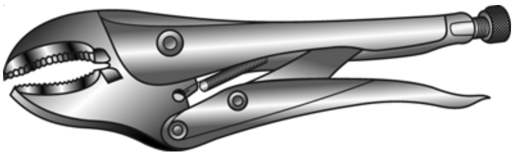
[Fig. 2.38 (g)]. It is a thin, single - ended or double-ended wrench used for turning check or jam nuts. The thinness of these nuts, often used in narrow spaces, requires the use of a thin wrench. These wrenches are not intended for hard use. The openings are offset at an angle of 15^o.

h. Tool-post wrench

[Fig.2.38 (h)]. It is a combination box and open-end wrench. The open end is straight rather than offset. The square box end is designed to fit tool-post screws and setscrews on lathes and other machine tools. It is ruggedly designed to withstand wear and hard use.

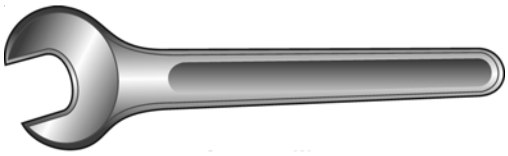
i. Square box wrench

[Fig. 2.38 (i)]. It is a single-head closed-end wrench having a rather short handle. It is widely used for square-head setscrews on tool-holders for the lathe and other machine tools. The square opening is made at an angle of 22.5^o for convenience.

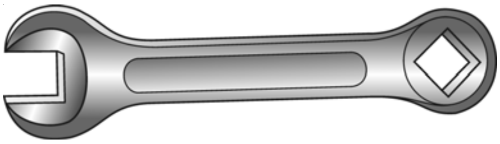


e. Lever Jaw Wrench

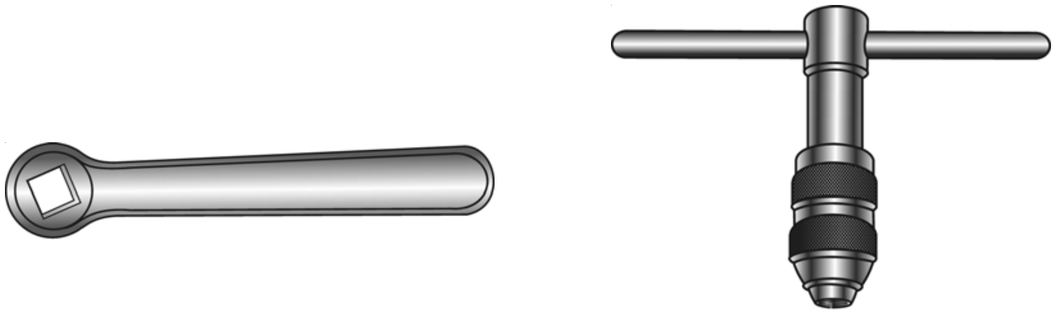
f. Combination Wrench



g. Check nut Wrench



h. Tool post wrench



i. Square Box Wrench **j. T-handle Tap Wrench**

Fig. 2.38, Types of Wrenches

j. T-handle tap wrench (sometimes called a T-tap wrench)

It is used to hold and turn small taps up to about ½- in. [Fig. 2.38(j)] It usually has two inserted jaws, which can be adjusted to fit the square end of the tap. The chuck when tightened holds in tap securely. This type of wrench is made in several size, each size having a capacity for several sizes of taps. This wrench may also be made with a long shank for tapping holes that are difficult to reach. It is also useful for turning small hand reamers.

k. 12- point box wrench

[Fig. 2.39(k)] It is designed with 12 notches, or points, inside a closed end. The points of a nut may be gripped by any one of the notches of the wrench, which permits the turning of a nut where only a short pull of the wrench is possible.

l. Adjustable tap wrench

[Fig.2.39 (l)] It is a straight type of wrench having a solid V-shaped opening in the centre. A sliding member, or adjustable jaw, operated by one of the handles makes it possible to hold taps of various sizes. This type of wrench is made in many sizes to turn tap and reamers of all sizes.

m. T-socket wrench

It is made in the form of a T, as shown in [Fig. 2.39(m)] The hole, or socket, in the end is made in a variety of shapes such as square, hexagonal, or octagonal. It is generally used on jobs where there is insufficient space to permit the use of an ordinary wrench. The handle may be removed from the hexagon-shaped head of the wrench to permit the use of another wrench to turn it when more pressure is required than can be applied with the handle.

n. Offset socket wrench

[Fig. 2.39(n)]. It is made with the same variety of sockets as a T-socket wrench. It is designed to be used on nuts requiring great leverage or in places where a T-socket wrench cannot be used.

o. Pinhook spanner wrench

It is designed, as shown in Fig. [2.39(o)] to fit around the edge of large round nuts, which have holes in them to fit the pins of the wrench.

p. Adjustable-hook spanner wrench

[Fig. 2.39(p)] It is used on round nuts having notches or slots cut on their periphery to receive the hook at the end of the wrench. Being adjustable, it will fit many sizes of nuts.

q. Adjustable pin-face wrench

[Fig. 2.39(q)] It is designed, with two arms, each having a pin in one end. This tool is used to adjust nuts that are enclosed so that an ordinary wrench cannot be placed around them. A nut in this situation is made with holes around the face to accommodate the pins in the ends of the adjustable legs of the wrench.

r. Strap wrench

[Fig.2.39(r)]. It is used for turning cylindrical parts or pipes, removing bezels, or holding or revolving any job on which the surface finish must be preserved.

s. Stillson- type pipe wrench

[Fig.2.39 (s)]. It is designed with adjustable jaws that are serrated, making it possible to grip round pipe and other cylindrical parts. The serrated edges tend to cut into the metal being gripped, so care should be used to protect plated or finished surfaces being turned with this kind of wrench.

t. Hexkey wrench

It is sometimes called an Allen wrench and is made of hexagon-shaped stock to fit the holes in the head of setscrews or socket-head screws. They are available in many sizes. [Fig. 2.39(t)]

u. Socket wrenches

They are round box type wrenches having two openings. One opening is a square hole into which the various driving attachments used for turning the socket wrench are plugged.[Fig. 2.39(u)]

The socket end has an opening with angular notches to fit bolt heads and nuts. This notched opening is made with either 4, 6, 8, or 12 points. The 6 and 12-point sockets are used for hexagon-headbolts and nuts, while the 4- and 8- point sockets are used for square-head bolt and nuts.

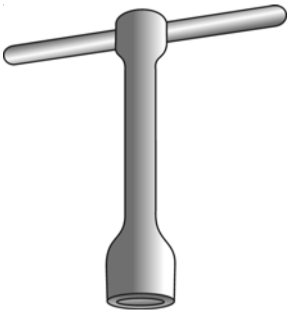
v. Ratchet wrench

[Fig. 2.39(v)] may be either of the socket type or the open-end type. The handle turns the interchangeable sockets through a ratchet mechanism. This mechanism may be adjusted to operate in the clockwise or the counter clockwise direction so that the ratchet wrench may be used to tighten or loosen nuts or bolts . The sockets may be standard or extra deep sockets. For hard-to-reach nuts or bolts, extension bar sockets can be used .

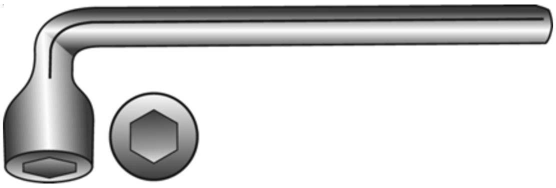
Socket have a lock-on feature in the form of a small hole on the side of the square hole into which a small spring-loaded ball in the driving attachment fits. When the socket is pushed on the drive attachment and the hole and ball are aligned, the ball is forced into the hole, thus preventing the socket from dropping off.

k. 12 point box wrench

l. Adjustable tab wrench

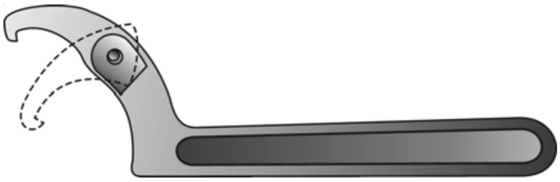


m. T-socket wrench



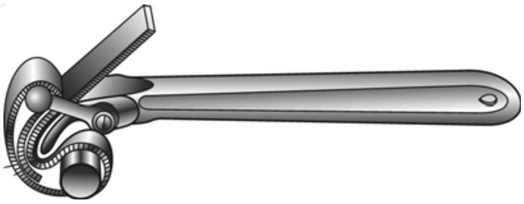
n. Offset socket wrench.

o. Pin hook spanner wrench



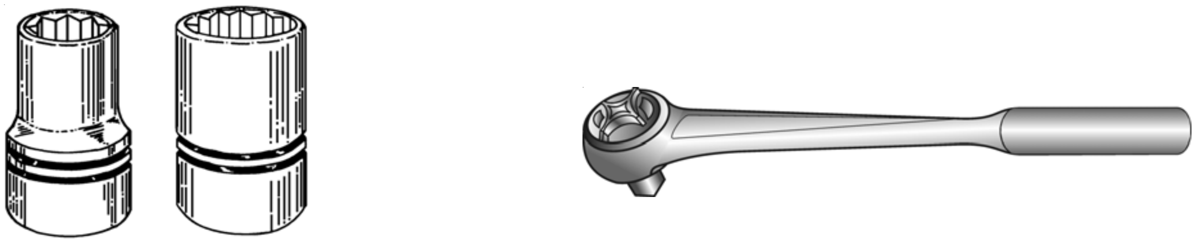
p. Adjustable hook spanner wrench

q. Adjustable pin-face wrench



r. Strap wrench

s. Stillson type pipe wrench **t. Hexkey wrench**



u. Socket wrench **v. Ratchet wrench.**

Fig. 2.39, Types of wrenches

x. Torque wrenches

They are used when it is necessary to know the amount of turning or twisting force being applied to a nut. The amount of force is usually indicated on a dial or scale, which is mounted on the wrench handle [Fig. 2.41(b)] On some models the amount of torque required can be preset on the dial, and an indicator will signal when that amount of force is reached.

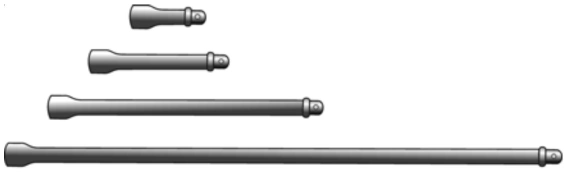
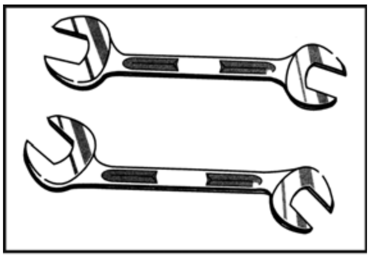


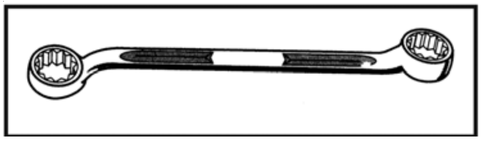
Fig. 2.40 (a) Extension bars

Fig. 2.40 (b) Torque wrench.

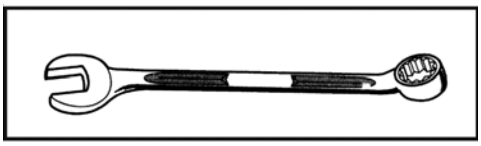
The three most commonly used torque wrenches are the flexible beam, rigid, and ratchet types (Fig. 2.41). When using the flexible-beam and rigid-frame torque wrenches, the torque value is read visually on a dial or scale mounted on the handle of the wrench. To ensure that the amount of torque on the fasteners is correct, all torque wrenches must be tested at least once per month (or more often, if necessary).



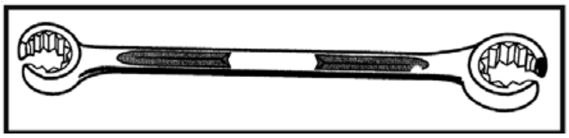
OPEN END WRENCH



BOX-END WRENCH



COMBINATION WRENCH



FLARE NUT WRENCH

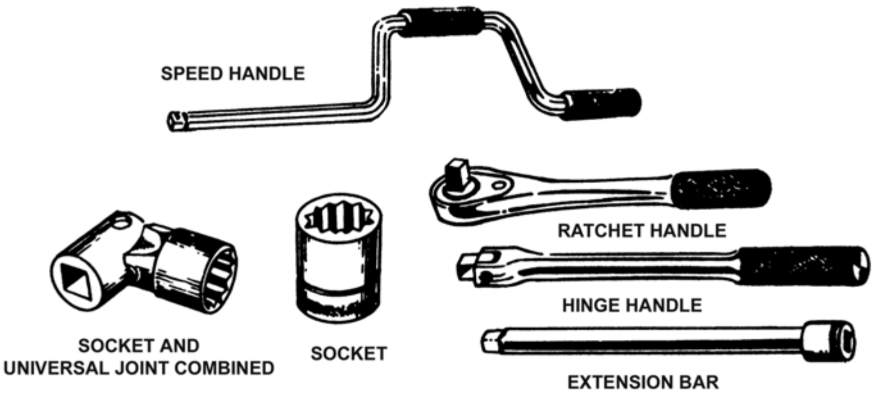


Fig. 2.41, Wrenches and Sockets

IV. Pliers

The most frequently used pliers in aircraft repair work include the slip-joint, longnose, diagonal-cutting, water-pump, and vise-grip types as shown in Fig. 2.42 and Fig. 2.43. The size of pliers indicates their overall length, usually ranging from 5 to 12 inches. In repair work, 6-inch, slip-joint pliers are the preferred size.

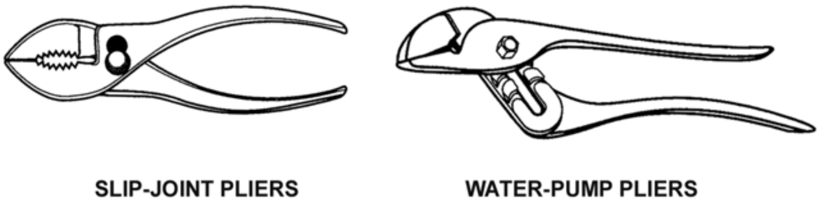


Fig. 2.42, Types of pliers

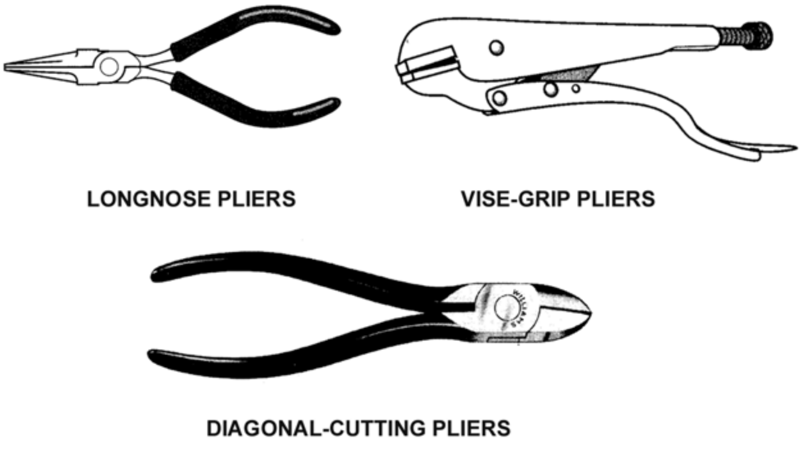


Fig. 2.43, Types of pliers

Slip-joint pliers are used to grip flat or round stock and to bend small pieces of metal to desired shapes. ***Long-nose*** pliers are used to reach where the fingers alone cannot and to bend small pieces of metal to desired shapes. Long-nose pliers are used to reach where the fingers alone cannot and to bend small pieces of metal. ***Diagonal-cutting*** pliers or ***diagonals or dikes*** are used to perform such work as cutting safety wore and removing cotter pins. ***Water-pump*** pliers, which have extra-long handles, are used to obtain a very powerful grip. ***Vise-grip*** pliers (sometimes referred to as a vise-grip wrench) have many uses. Examples are to hold small work as portable vise, to remove broken studs, and to pull cotter pins.

The ***flat nose* plier**, as shown in Fig. 2.44 (a) has flat jaws with small grooves. It is used for forming and holding work.

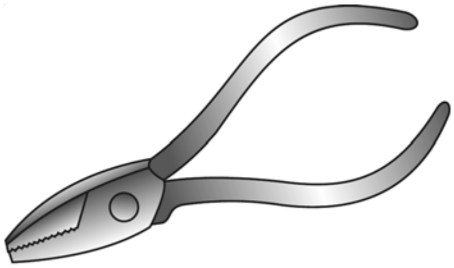


Fig. 2.44 (a) Flat Nose Plier

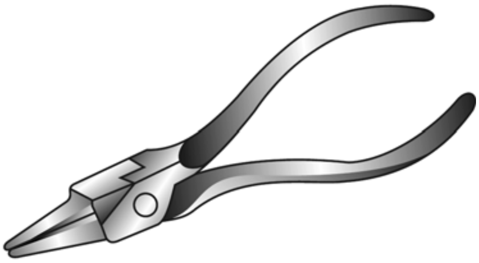


Fig. 2.44 (b) Round Nose Plier

The ***round nose* plier**, as shown in Fig. 2.48 (b), has long jaws rounded on the outside. It is used for holding and forming the various shapes and patterns.

Pliers are not an all-purpose tool. They are not to be used as a wrench for tightening a nut, for example. Tightening a nut with pliers causes damage to both the nut and the plier jaw serrations. Also, pliers should not be used as a prybar or as a hammer.

V. Crimping Tool

The precise form of the crimp is determined by such factors as the size and construction of the conductor, the materials, and the dimensions of the termination. It is, therefore, most important that only the correct type of die and crimping tool should be used, and that the necessary calibration checks have been made to the tool.

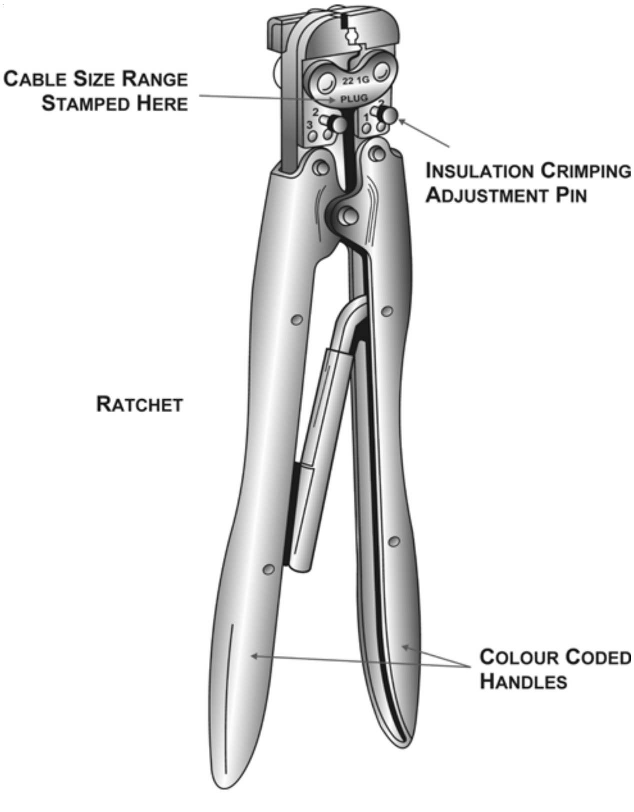


Fig. 2.45, Example of a hand operated crimp tool.

Hand crimping tools (see Figure 2.45) normally have a self-locking ratchet which prevents opening of the tool until the crimping action is complete. Some tools are equipped with a nest of various size dies to allow for a range of different sizes and types of terminations, while others are suitable for one size and type only. In addition, many of the tools and /or dies are colour coded to correspond with the colour marking used on some terminations. It is essential that the recommendations and instructions of the relevant aircraft or equipment manufacturer should be strictly complied with when undertaking work of this nature.

2.2.4. PRECISION MEASUREMENT TOOLS & GAUGES

The precision instruments are those which have ability to measure parts with an accuracy of 0.001 mm or better.

I. Micrometers (Inside & Outside)

Figure 2.46 illustrates the typical standard type of micrometer for the measurement of external dimension. The main components of the instrument are the frame, anvil, barrel, sleeve (or thimble) and the spindle. The jaws of the frame are suitable machined to receive the anvil (which is usually a press fit), and the barrel, which is frequently fitted into the frame with a fit which permits rotational adjustment by spanner or special key. The barrel is engraved with a graduated scale equal in length to the measuring range of the instrument (usually 1 in. or 25 mm.), and is bored and internally screwed with a fine and accurate right-hand thread. This thread accommodates the spindle which is machined with a matching male thread. An integral sleeve on the spindle surrounds the barrel when the spindle is inserted and screwed into the assembly, and this is usually knurled at the outer end to facilitate easy finger operation. The inner end of the sleeve is bevelled to prevent barrel scale shadows, and the bevelled portion is graduated into equal divisions around its periphery.

Some micrometers may have a fixed barrel and a removable or adjustment anvil which might be located by a grub screw or a pin. Others may be equipped with a spindle locking device (as illustrated) which, when used, ensures that the instrument remains set any specific dimension or reading . The spindle attachment containing a spring loaded ratchet (also illustrated) is a common fitment, and this produces preset “feel” to the operation of the instrument. Many micrometers are provided with tungsten or carbide tipped anvils and spindles to reduce wear on the measuring faces.

Note

British Standard 870 prescribes that when a friction or ratchet attachment is fitted to the spindle, the force it exerts between the measuring faces shall be between 1½ to 2¼ lb.

The details of micrometers for the measurement of British dimensions are given in paragraph below, whilst those for measurement of Metric dimensions are covered in paragraph under topic Metric system.

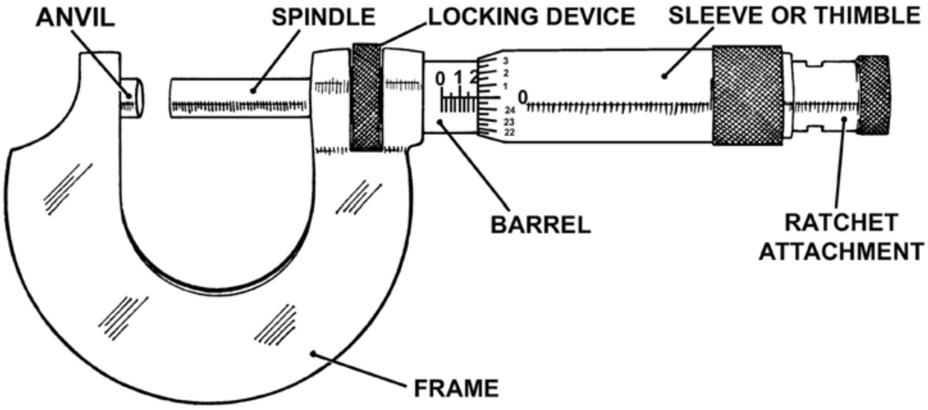


Fig.2.46, Typical Standard External Micrometer.

Note

Some instruments not to British Standard, although quite accurate, may not be provided with the general means of adjustment. Due allowance for “zero” error must therefore be made, and the error must be added to all measurements made.

Note

The British Standard prescribes that micrometer frames upto 4 in. shall be of a suitable quality of steel, those above 4 in. and up to 12 in. may be of a suitable quality of steel or malleable cast iron, and those above 12 in. may be of suitable steel, malleable cast iron or light alloy. The Standard recommends that suitable heat-insulating grips should be attached to the frame in convenient positions, and that frames should be heat-treated to avoid secular changes that might take place in the material.

a. Inside Micrometer

An inside micrometer (Fig. 2.47) is designed with the same graduations as an outside micrometer and is adjusted by revolving the thimble in the same way. It is used for taking internal measurements where greater accuracy is required than can be obtained with inside calipers of telescoping gages. It is available in many sizes.

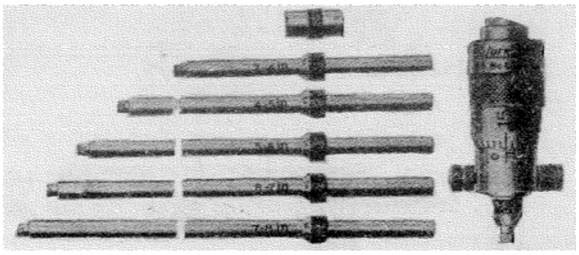


Fig. 2.47, Inside Micrometer.

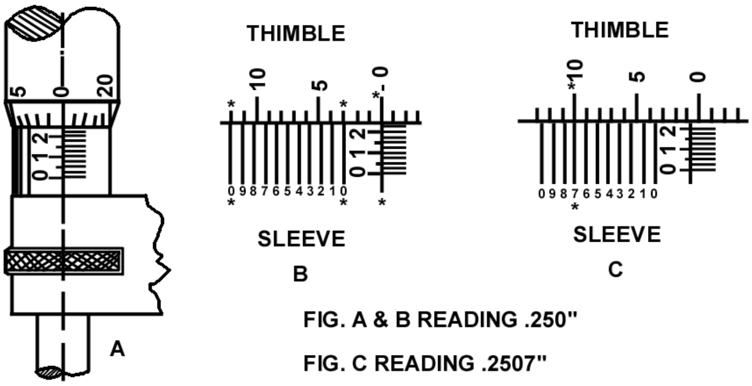


Fig. 2.48, Reading the vernier scale of a micrometer.

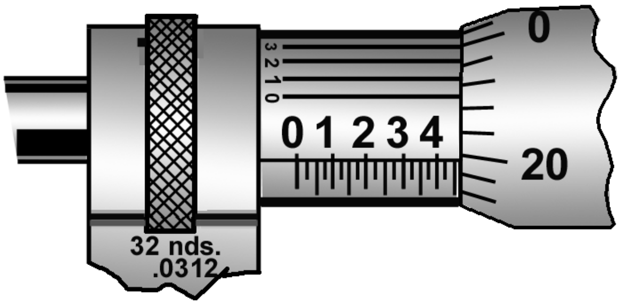


Fig. 2.49, Vernier scale on the sleeve of a micrometer.

b. Screw Thread Micrometer

The thread micrometer (Fig. 2.50) is used to measure the pitch diameter of threads. The spindle has a 60° conical point, and the anvil has a matching groove.

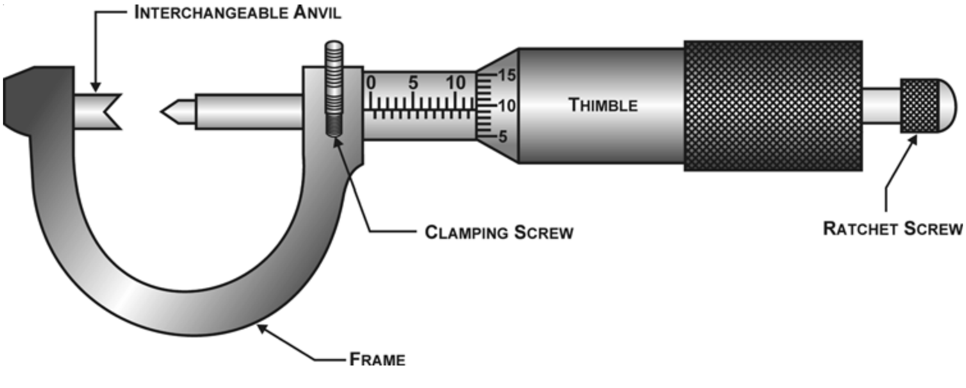


Fig. 2.50, Thread Micrometer.

c. Depth Micrometer

These instruments (Figure 2.51) have a similar application to the vernier depth gauge . They consist of the standard type barrel, sleeve and spindle, and the barrel is attached to, or is integral with a base plate having hardened contact faces, which are ground and lapped square to the spindle axis. Some of these instruments are available in combination sets with detachable spindles, to cover various ranges of measurement and to widen the application and others may be provided with detachable base plates of various dimensions and shapes.

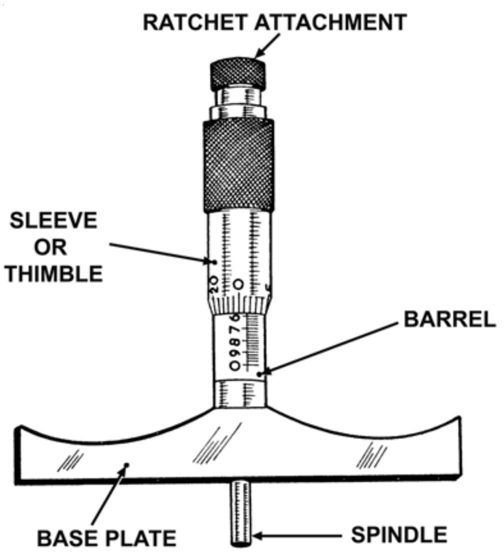


Fig. 2.51, Typical Depth Micrometer.

d. Tube Micrometers

These micrometers are similar to the standard type except for the frame and the anvil. The frame is usually of single jaw semi-horseshoe" shape, and the anvil is a vertical shouldered and ground spindle-post, fitting into the frame at 90° to the spindle axis. Generally, these instruments are supplied with several anvils which differ in the diameter of the measuring tip, and this feature gives the instrument a wider range of tube thickness measurement.

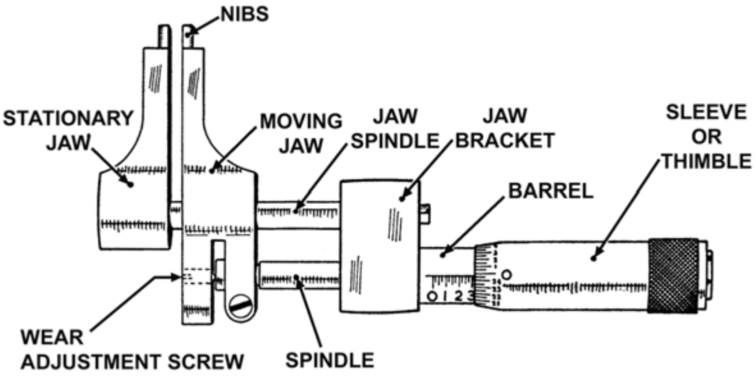


Fig. 2.52, Typical Calliper Micrometer.

e. Calliper Micrometers

This type of micrometer (Fig. 2.52) is particularly suited to the measurement of small internal diameters. It consist of the standard barrel and spindle assembly, with an offset pair of jaws located by a bracket attached to the inner end of the barrel. The stationary jaw is located on the outer end of a ground spindle, and this is recessed into the barrel bracket at its inner end. The moving jaw slides on the outer jaw spindle with a precision fit, and a split lug on the jaw clamps a split bush bearing in a recess machined in the end of the micrometer spindle. Some of these instrument are available with sets of removable jaws with differing nib widths, which stage and widen the measuring range of the calliper instrument

Note

It should be borne in mind when taking internal measurements, that with instrument which give a zero reading with the jaws closed, the dimension over the nib must be added to the micrometer readings.

f. Vee-block Micrometers

Drills, taps, reamers and certain cylindrical lapping tools, are manufactured with three, five or seven flutes, and these micrometers are necessary for the accurate measurement of the cutting or lapping dimensions of these tools. The micrometers are similar to the standard type, except that the anvil is integral with the frame, and, adjustment to the spindle, the anvil is vee-shaped to the appropriate angle to facilitate measurement of three, five or seven-fluted tools.

II. Vernier Based Instruments

Vernier System

A brief description of the vernier system as a means of defining linear dimensions is as follows.

Assuming two lines of equal length, each divided separately so that the total number of divisions in one is greater by one division than the number of divisions in the other, the displacement or reading is equal to the linear difference between any two divisions. For example, one of the most commonly used scales is where the main scale is divided into 20ths (0.050) of an inch and the vernier scale comprises 50 divisions over a distance of 2.45 in., each division equalling 0.049 in. Thus the difference between any division on the main scale and any division on the vernier scale is 0.001 in. This principle is illustrated in Figure 2.53.

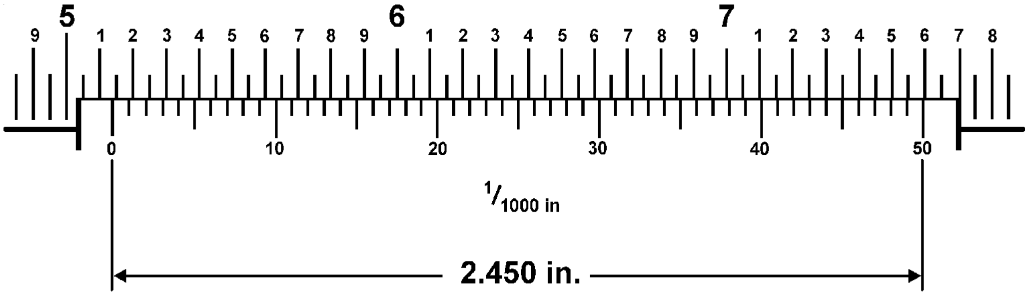


Fig. 2.53, The Vernier Scale.

One other widely used scale is where the main scale is divided into 40ths (0.025) of an inch and the vernier scale is divided into 25 equal divisions over a distance of 1.225 in., each division equalling 0.049 in. The same principle as described in the previous paragraph applies but, with this type, the vernier scale is read on alternative lines of the main scale, the two divisions together equalling 0.050 in.

There are two other types of scales in use but these have largely been superseded due to the necessity of having to use some form of magnification to obtain a true reading. In one, the main scale is divided into 40ths (0.025) of an inch and the vernier scale is divided into 25 divisions over a distance of 0.60 in., each division equalling 0.024 in. In the other the main scale is divided into 50ths (0.020) of an inch and the vernier scale has 20 divisions over a distance of 0.380 in., each division equalling 0.019 in.

In addition to the decimal inch scaled instruments described above, vernier instruments graduated to the metric system are obtainable. Some of these are composite types with inch and metric scales on opposite sides, whilst others read inches or metric dimensions only.

Reading the Inch-Unit Vernier

To read measurement registered by this vernier, the number of inches and subdivisions of an inch that the zero line of the vernier scale has moved over the main scale should be noted, and to this reading should be added the thousandths of an inch, which is indicated where a line of the vernier scale is coincident with a line on the main scale. For example, in Figure 2.53, the scale registers the following settings. Main scale : inches = 5, tenths = 1 and the 43rd line of the vernier scale is coincident with a line on the main scale. The reading thus obtained is 5.000+0.100+0.043=5.143 in.

Reading the Metric-Unit Vernier

This instrument reads in a similar manner to the inch-unit vernier, has main scale graduation of centimetres, millimetres and half millimetres. The vernier scale (equal to 24 half millimetres) is divided into 25 equal divisions, producing a difference between main scale and vernier scale graduations of $0.5 \times 1/25=1/50$ mm. (0.02mm.).

In some instances difficulty may be experienced in deciding which two lines are in fact coincident. In such cases a decision may be helped by the fact that the lines on either side of the most nearly coinciding lines appear to be equally stepped (see Fig. 2.53). It should be borne in mind that it is a fundamental of the vernier system that not more than one line of the vernier scale can be truly coincident with a line on the main scale.

Measuring Capacity

The measuring capacity of a vernier instrument is its graduated length minus the length of the vernier scale. Thus an instrument having a scale such as that described in paragraph 2.1 may have, for example, a graduated scale of 14.450 in. minimum but would be supplied as having a measuring capacity of 12 in.

a. Vernier Callipers

This instrument consists of a beam, on which is marked the main scale, and two jaws between which the item to be measured is placed. One jaw is integral with the beam whilst the other, upon which is mounted the vernier scale, slides along the beam (Figure 2.54). The measuring faces of the jaws are accurately machined to be straight and parallel.

With precision calliper gauges the movable jaw is connected to a clamping device (termed the “fine adjustment clipper”) by means of the fine adjustment screw assembly. The clipper can be locked on to the beam at any position by means of a locking screws, the accurate setting of the measurement being achieved by rotating the knurled wheel of the fine adjustment screw assembly in the required direction.

A Vernier calliper is used where insufficient accuracy would be obtained with ordinary callipers. However, some degree of skill is necessary (unless the instrument is provided with a friction lock) to obtain the correct “feel”, otherwise inaccurate readings will be obtained and, if over tightened, the instrument may be permanently damaged. Thus, the jaws should always be closed gently on to the work piece, no attempt being made to alter the measurement by force.

When setting the callipers to a given measurement, the caliper should be securely locked at the approximate measurement and the final adjustment made by means of the fine adjustment screw. After setting the instrument, the jaw locking-screw should also be tightened before the calliper is used.

The parts to be measured should be perfectly clean, since foreign matter will not only affect the reading obtained but may damage the accurately finished faces of the jaws.

For the measurement of internal dimensions, some instruments are provided with a pair of “knife-edge” jaws mounted immediately above those used for external measurement. Other instruments have the outside lower portion of the external measuring jaws rounded (the “nibs” shown in Figure 2.54), the overall dimension of the nibs with the calliper closed usually being some convenient figure (e.g. 0.3 in). Which must be added to the indicated reading. The allowance to be made for the width of the nibs is usually indicated on the fixed jaw (see Figure 2.54). No attempt must be made to force a locked calliper between two surfaces, otherwise wear or out-of-parallelism may result.

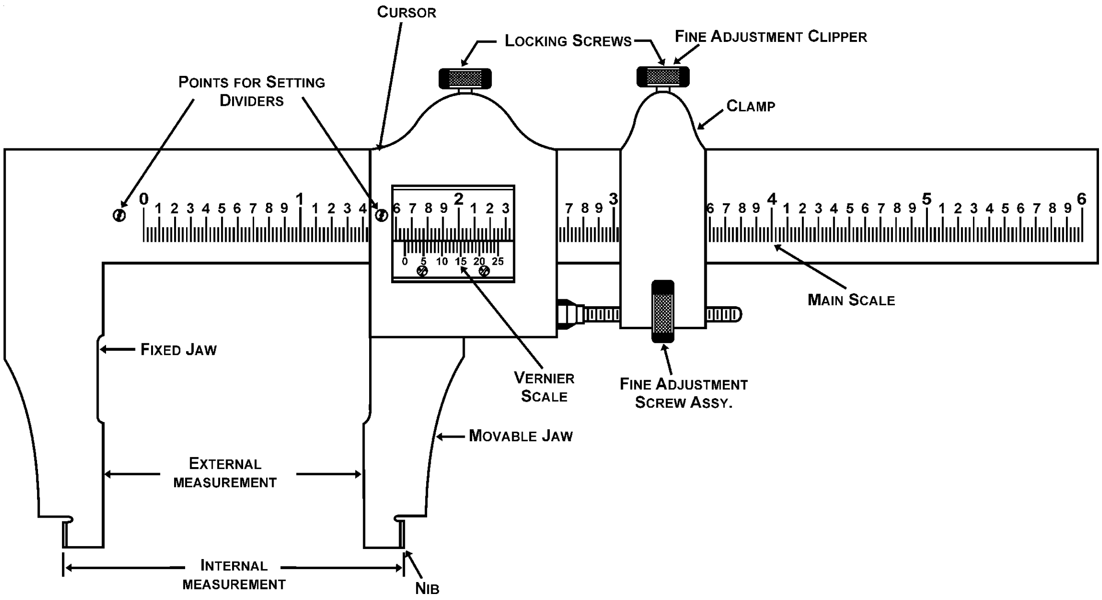


Fig. 2.54, Vernier Calliper.

Some makes of callipers are marked with two spots, or “targets”, one on the fixed jaw and one on the movable jaw, from which dividers or trammels may be set after the calliper has been set.

Before use (in particular, before using a particular instrument for the first time) the calliper should be checked by closing the jaws and holding the instrument up to the light, checking for full contact of the measuring surfaces. Without disturbing the jaws, the reading of the calliper should then be checked to ensure that the zero lines of the main scale and the vernier scale are concident.

b. Vernier Height Gauge

In principle the vernier height gauge is an adaptation of the vernier calliper gauge but instead of the measurement being based on the distance between fixed and movable jaws, it is calculated on the distance between a movable jaw and the surface on which the instrument stands (usually a surface table). See Figure 2.55.

The instruments is provided with a relatively heavy base having a lapped underface; the upper surface of the movable jaw (termed the measuring jaw) is the surface of the base. The measuring jaw is provided with a detachable scriber to permit the accurate marking out of work pieces. The scriber itself is produced within fine tolerances, it being a requirement of B.S. 1643 that the measuring faces must be flat and parallel to within 0.0002 in.

The main scale of the instrument does not commence at zero, since as the measurement is taken from a surface table, this surface, is, in fact the zero (see Figure 2.55).

Since it is the top of the measuring jaw from which measurements are taken, it is necessary to fit the scriber for external measurements, but for internal measurements the scriber may be removed. However, in some instances the measuring jaw may not project sufficiently to permit an internal measurement to be taken, in which case the scriber may be fitted to the measuring jaw as shown in Figure 2.56. When so used the thickness of the measuring jaw (usually marked on it) must be subtracted from the indicated reading. If the scriber is fitted to the top of the measuring jaw for internal measurement (again in an upside down position), the thickness of the scriber (usually marked on it) must be added to the indicated reading.

When assessing external measurements it is advisable not to preset the height gauge, otherwise the scriber may ride over the work piece, giving an incorrect reading. The scriber should be lowered gently on the surface to be measured, care being taken to hold the base firmly on the surface table, and the setting locked. Conversely, when making internal measurements, the measuring jaw should be raised gently to the surface to be measured to avoid lifting the work piece.

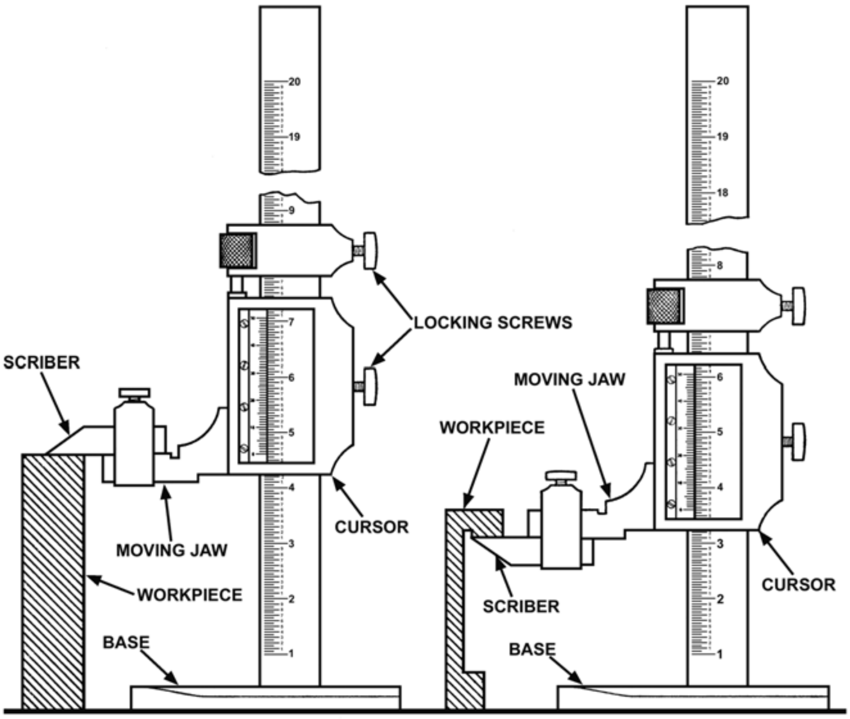


Fig. 2.55 & 2.56, Vernier Height Gauge.

Note

It is particularly important to hold the base down firmly when using the fine adjustment screw.

When setting the instrument to an external flat surface the use of the lighting method described in this paragraph may be found useful in checking the final setting.

It is essential that at all times the base of the instrument, the surface table, any ancillary measuring equipment used and the work piece itself should be kept perfectly clean to ensure accuracy of measurement. It a height gauge is left on a surface table but is not in immediate use, steps should be ensure that it is not knocked over and damaged.

c. Vernier Depth Gauge

This instrument is again based on the vernier calliper principle, except that in this case the beam carrying the main scale passes at right-angles through a jaw on which is mounted the vernier scale. The jaw is placed over the depth to be measured (e.g. a blind hole) and the beam is lowered into the hole until contact is made with the bottom or some other predetermined point of contact, when the indicated measurement is read in the manner described for the vernier calliper.

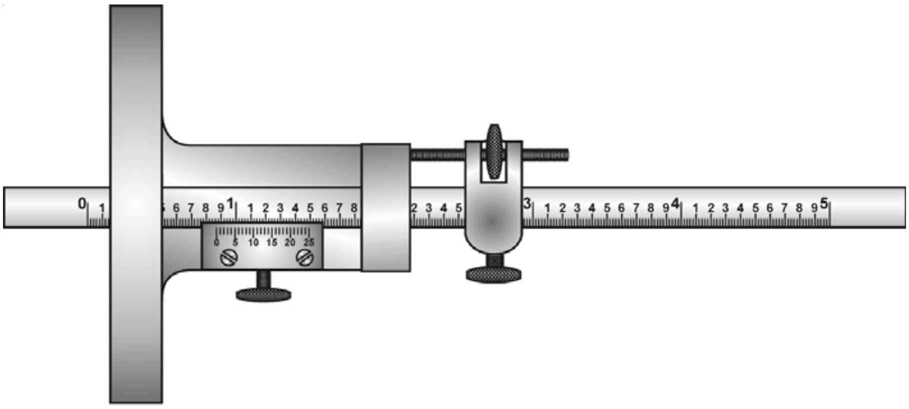


Fig. 2.57, Depth Gauges.

d. Vernier Bevel Protractors

A typical bevel protractor consists of a solid base or “stock”, one face of which is machined flat so that it can be laid accurately on a flat surface, e.g. a surface table. An adjustable straight edge attached to the instrument can be set to any angle relative to the base.

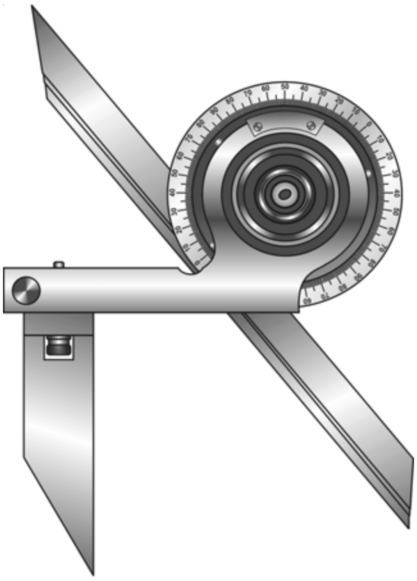


Fig. 2.58, Vernier Bevel Protractor

Angular movement of the straight edge rotates a die on which is mounted a circular protractor scale (graduated in degrees) which, in conjunction with the vernier scale, permits the units (minutes) to be read in a similar manner to the vernier calliper. Thus, the number of whole degrees which have been passed by the vernier zero mark should be noted and then, continuing to read in the same direction (this is important as the scales are identical to the right and left of the zero lines), add the number of minutes indicated by the coincidence of a line on the vernier scale with a line on the main scale, in the example shown in Figure 2.59, the reading is 14° 20'.

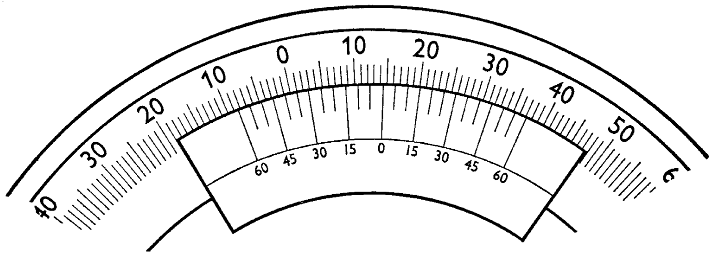


Fig. 2.59, Vernier Protractor Scale.

In the scale shown in Figure 2.59, a length of 23^o of the main scale is divided into twelve equal parts to form the vernier scale. Thus one division of the vernier scale equals $23^o/12$, or 1^o 55', the difference between one division of the vernier scale and two divisions of the main scale being 5'. The instrument can, therefore, be read to an accuracy of 5', but if greater accuracy is required, the angle should be measured by the sine bar method.

In order to facilitate the reading of the protractor, some manufacturers provide a magnifying glass or eyepiece which can be mounted on the instrument.

III. Ring Gauge

The ring gauges are used to check the diameter of shafts or studs. These are cylindrical in shape and has a hole of the exact size specified for the part to be checked. In using a ring gauge, it should fit over the part being checked without the use of force and without any noticeable side movement. A standard ring gauge commonly used is shown in Fig. 2.60. The limit ring gauges with 'Go' and 'Not go' ends are also available. The 'Go' and 'Not go' ended are identified by an annular groove on the periphery of the gauge.

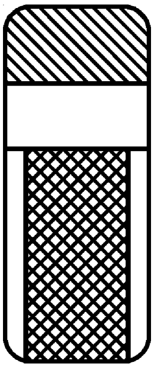


Fig. 2.60, Ring Gauge.

IV. Plug Gauge

A plug gage (Fig. 2.61) is used to test the accuracy of holes. It should engage the hole to be checked without using pressure and should be able to stand up in the hole without falling through, just bale to slowly slide through. The shape of the plug (Fig. 2.62) may be conical, as gage A and C; square, as gage D; hexagon, as gage H; or one of the several others shown.

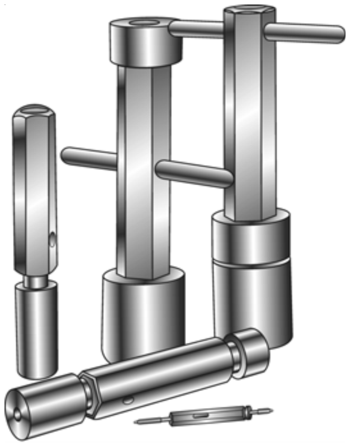


Fig.2.61, Plug Gages

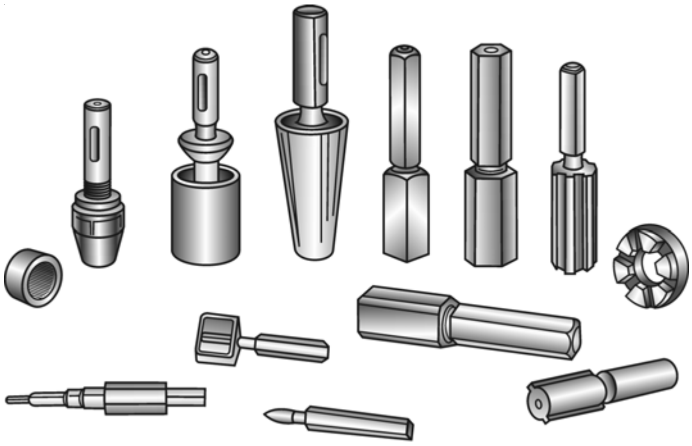


Fig. 2.62, Various shapes of plug gages.

V. Filler Gauge

The filler gauge, as shown in Fig.2.63, is used to check the clearances between two mating surfaces. It consists of a series of thin steel strips (known as leaves) hardened and ground to various thicknesses. Each leaf is marked with its thickness which varies from 0.05 mm to 1 mm. The leaves are pivoted in holder of knife shape.

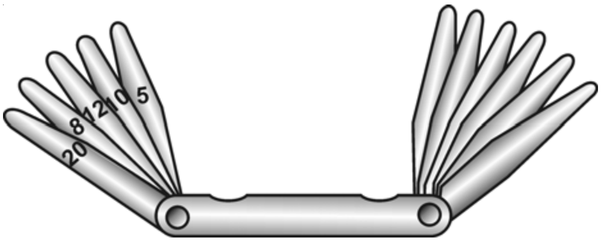


Fig. 2.63, Filler Gauge.

VI. Snap Gauge

A snap gage (Fig. 2.64) is made with openings to fit over a part to be checked. The part may be cylindrical or flat. Snap gages are made double-ended for measuring two dimensions, and also singled-ended. An adjustable type of snap gage is shown in Fig. 2.64. They are made in many sizes, with openings ranging from 1/4 to 12 in. The lower anvils of the gage may be adjusted as much as 1/4 in. to a required dimension. Gages with two anvils are sometimes referred to as go and not-go gages. When this is the case, the inner anvil is raised slightly higher than the front one. For example, to measure a shaft with a dimension of 1.500 and a 0.003 limit more or less would call for the inside opening to be 1.498 and the outside opening to be 1.503. In order to pass inspection, the shaft should go through the outer setting of the gage, but should not go through the inner setting.

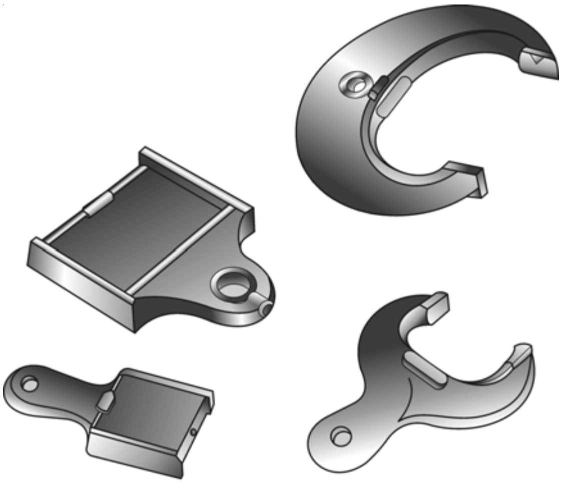


Fig. 2.64, Snap Gauge

VII. Radius Gauge

The radius or fillet gauge, as shown in Fig. 2.65, is used to check the radii of curvature of concave or convex surfaces. It consists of a number of steel blades having standard radii ground and lapped on the ends and sides. The size of the radius of the curve is stamped on the blade for ready reference. The blades on one end of the gauge are used to check the concave surfaces and those on the other end are used for the convex surfaces.

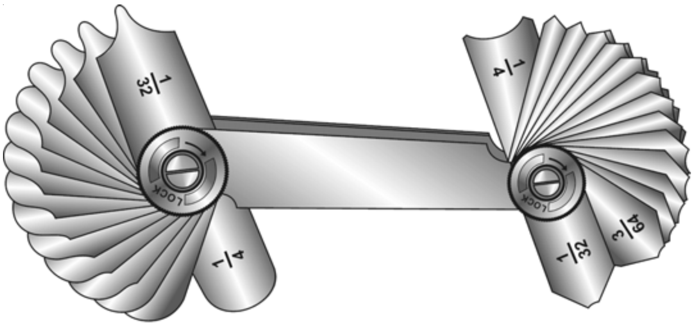


Fig. 2.65, Radius or fillet gauge

VIII. Wire Gauge

A wire gauge is a flat, circular steel piece having slots all along its periphery. These slots have different standard sizes which are engraved near their bottom. The size of each slot represents the correct diameter of the wire of which it represents the gauge. The gauge number varies inversely as the size of the wire. That is, the higher the gauge number the thinner the wire and vice versa.

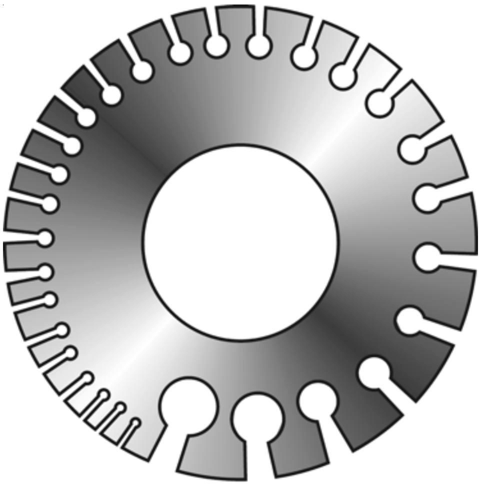


Fig. 2.66, A Wire Gauge

IX. Dial Test Indicator

An indicating gage exhibits visually the variations in the uniformity of dimensions or contour; the amount of variation is indicated by a lever on a graduated dial. There are many types of indicating gages, and new uses for them are constantly being devised.

The most common type of indicator is shown in Fig. 2.67 (A). While it is generally referred to in the shop as a dial indicator, it is more properly called a ***test set***. It consists of a sturdy steel base with T-slots on its top and bottom surfaces, a steel column, which may be securely fastened to the base, an adjustable clamp, which fits on the column, an indicator-holding rod, and a dial indicator. This is a general-purpose gage used in all departments of a toolroom. One of the most common uses for it is in setting a piece of work in a four-jaw lathe chuck accurately.

Dial indicators are made in five standard sizes, ranging from 1¼ to 3% in. in diameter. The size of the graduations on the face of the dial may vary from 0.00005 to 0.001 in. Some dials are of the balanced type, as in Fig. 2.68. In this case, the graduations are numbered consecutively on both sides of zero. Continuous dials have the graduations numbered continuously around the dial, as in Fig. 2.69. Indicators usually have a range of 2½ revolutions of the indicator hand. Some indicators have a revolution counter built in, which indicates how many revolution the indicator hand has made (from one to ten) on the face of the continuous dial. Another desirable feature is a double dial, which permits setting zero at any required position around the edge of the dial, independent of the revolution center.

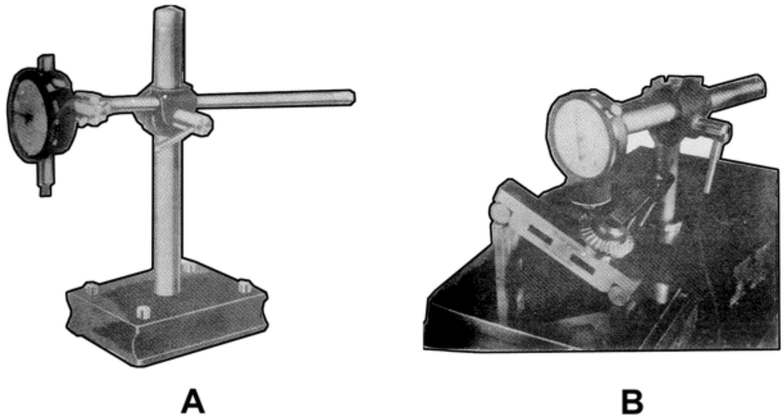


Fig. 2.67, (A) Dial indicator test set. (B) Application of test set.

Fig. 2.68, Dial indicator test set.

Fig. 2.69, Continuous dial with revolution counter and double dial.

X. Gauge Blocks

Johansson-type gage blocks are the standard of precision measurement for the world. They measure accurately in millionths of an inch, an accomplishment considered impossible before their introduction.

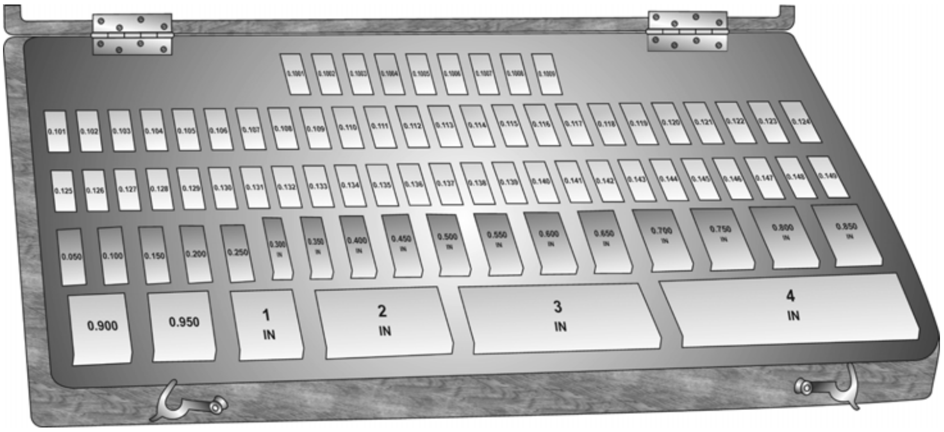


Fig. 2.70, Gauge Block

Precision gage blocks of the Johansson type are rectangular pieces of tool steel, approximately $\frac{3}{8}$ in. by $1\frac{3}{8}$ in. The blocks are hardened, ground, stabilized, ad finished to an accuracy within a few-millionths part of an inch from the specified size. Gage blocks are sized according to their thickness.

Precision gage blocks embody in their commercial manufacture the solution of four universally recognized metallurgical and mechanical problems-flat surfaces in steel, parallel surfaces in steel, accuracy as to dimension in steel, and effective heat treatment and seasoning of steel.

Making a flat surface in steel is one of the most remarkable achievements in mechanics. A flat surface with an extremely high finish, having the appearance of burnished silver, is produced by the Johansson method; it approaches nearer the perfect plane than any other surface produced by the hand of man. These flat-lapped surfaces, when thoroughly cleaned and slid one on the other with a slight in-ward pressure, will take hold as though magnetized. They have been known to sustain a weight of 200 lb on a direct pull, although the contacting surfaces are less than ½ sq. in. Scientists have offered atmospheric pressure, molecular attraction, and a minute film of oil on the lapped surfaces as explanations of this phenomenon.

The degree of parallelism attained in the manufacture of the Johansson gage blocks is demonstrated by the fact that any block in a given combination may be turned end for end, at will, without affecting the parallelism of the two extreme surfaces of the combination.

The making of one steel surface parallel with another is good, but to make one surface a predetermines parallel distance from another surface with an accuracy in millionths of an inch is a more remarkable achievement. This accomplishment is proven by the way in which an equivalent combination of precision gage blocks checks against one solid block.

An important operation in making gage blocks is the seasoning of the metal. This must be done so that the internal stresses and strains within the metal are relieved. The molecules of the steel may be said to be at rest, and because of this, the usual warping or growing is checked.

A full set of gage blocks consists of 81 blocks that have surfaces flat and parallel within 0.000008 in. In addition to the regular blocks, many accessories have been designed to be used with them. A group of accessories including a foot block, straightedge, scriber, trammel points, adjustable holder, and jaws of various sizes.

Another style of precision gage block is the Hoke type; a complete set is in the first three rows. These blocks are approximately 0.950 in. square and vary in thickness. The hole through the center of each block permits the use of internal tie rods, by means of which rapid, compact assembling of various attachments is possible without the use of clamps. Many of these attachments are in the back of the box of gage blocks.

Some types of gage blocks have holes near the ends; they may be joined together by an eccentric clamp after the ends have been wrung together.

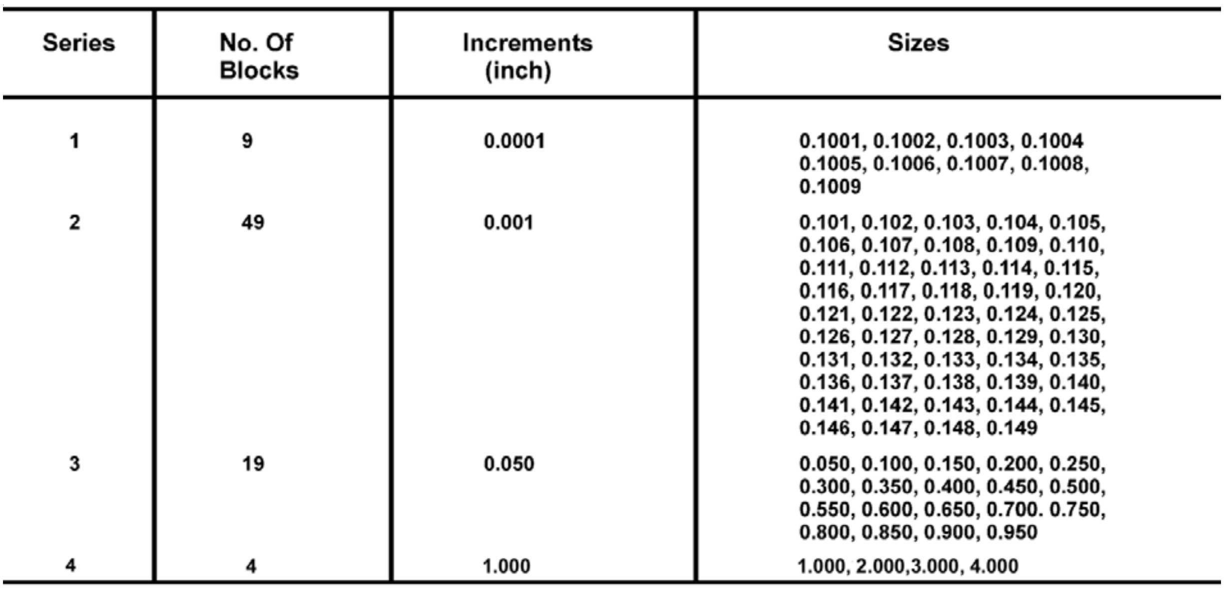
Precision gage blocks and an Electro limit height gage are being used to check the location of a hole in a master railroad gage.

The first series consists of nine blocks, ranging in size from 0.1001 to 0.1009 in. by steps of 0.0001 in.

The second series consists of 49 blocks, ranging in size from 0.101 to 0.149 in. by steps of 0.001 in.

The third series consists of 19 blocks, ranging in size from 0.050 to 0.950 in. by steps of 0.050 in.

The fourth series (Fig. 2.71) consists of four blocks measuring 1,2,3 and 4 in.



Series	No. Of Blocks	Increments (inch)	Sizes
1	9	0.0001	0.1001, 0.1002, 0.1003, 0.1004 0.1005, 0.1006, 0.1007, 0.1008, 0.1009
2	49	0.001	0.101, 0.102, 0.103, 0.104, 0.105, 0.106, 0.107, 0.108, 0.109, 0.110, 0.111, 0.112, 0.113, 0.114, 0.115, 0.116, 0.117, 0.118, 0.119, 0.120, 0.121, 0.122, 0.123, 0.124, 0.125, 0.126, 0.127, 0.128, 0.129, 0.130, 0.131, 0.132, 0.133, 0.134, 0.135, 0.136, 0.137, 0.138, 0.139, 0.140, 0.141, 0.142, 0.143, 0.144, 0.145, 0.146, 0.147, 0.148, 0.149
3	19	0.050	0.050, 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, 0.550, 0.600, 0.650, 0.700. 0.750, 0.800, 0.850, 0.900, 0.950
4	4	1.000	1.000, 2.000,3.000, 4.000

Fig. 2.71, Precision gage-block series.

XI. Sine Bar

A sine bar (Fig. 2.72) consists of a hardened and ground steel bar in which two hardened and ground-plugs of the same diameter are set. For ease in making calculations, the center distance between the plugs is 5, 10, or 20 in. The edges of the bar must be parallel with the center line of the two plugs. A sine bar is always used in conjunction with a true surface such as a surface plate (Fig. 2.73), from which measurements are taken. The sine bar receives its name from the fact that, in setting a sine bar to a required angle, as in Fig. 2.80, dimension AB is calculated by multiplying the sine of the required angle by the length of the sine bar.

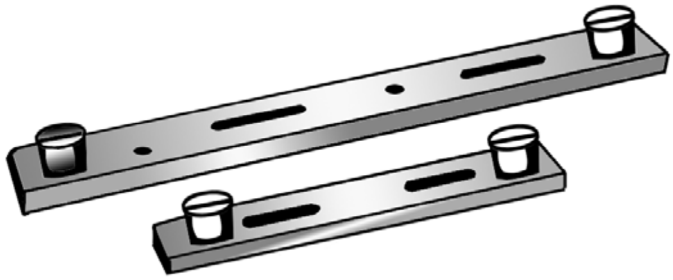


Fig. 2.72, Sine bars.

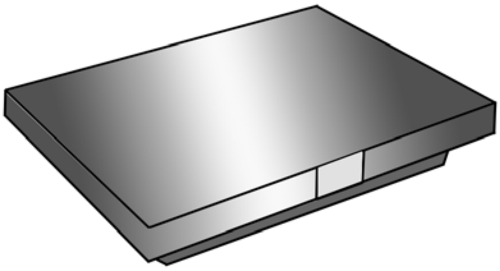


Fig. 2.73, A granite surface plate.

The sine bar may be used to set a piece of work to a required angle. In Fig. 2.73, the plug at one end of the sine bar is elevated above the other plug a distance equal to the sine of the required angle, multiplied by the length of the sine bar. For example, if the angle is 32°29' and the sine bar is 5 in. long, the distance of one plug of the sine bar above the other plug equals the sine of 32°29', which is 0.53705, multiplied by 5, which equals 2.68525 in A sine bar may be set in position by the use of gage blocks or with the aid of a vernier height gage. Figure 2.75 shows four gage blocks being used to set a sine bar.

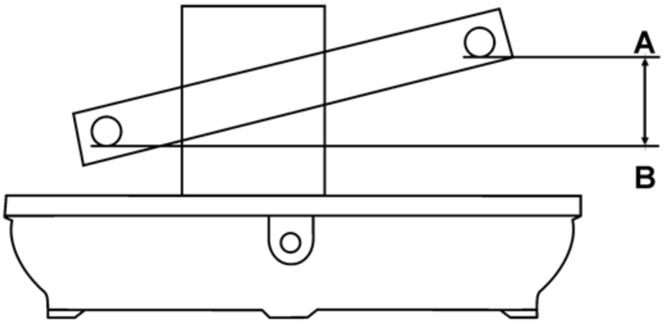


Fig. 2.74, The distance AB is equal to the sine of the angle multiplied by the length of the sine bar.

The sine bar may also be used to determine the size of an angle. The vertical distance between the plugs of the 5-in., sine bar in Fig. 2.76 is found to be 3.3131 in. By dividing the distance by 5, it is found that the sine of the required angle is 0.66262, which is shown in a table of sines to represent an angle of 41°30'.

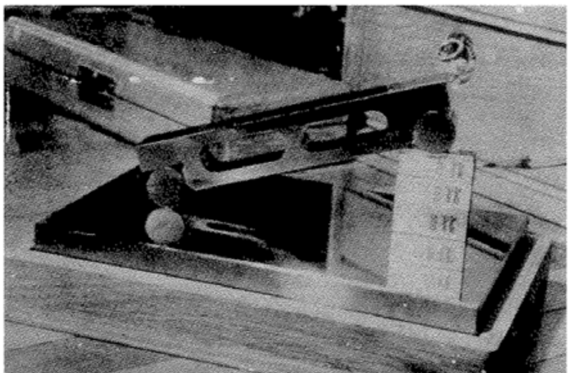


Fig. 2.75, A sine bar may be set to an angle using precision gage blocks.

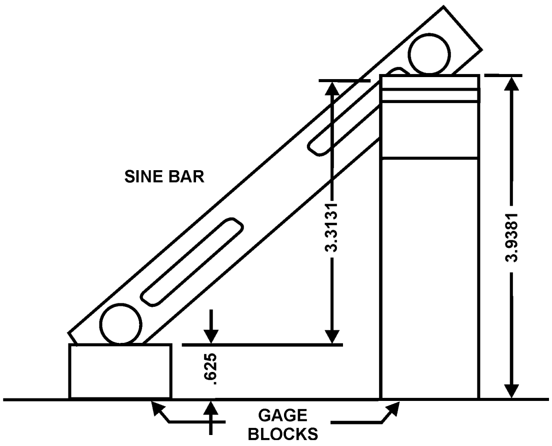


Fig. 2.76, The angle at which a sine bar is set may be determined by the vertical distance between the two plugs of the sine bar.

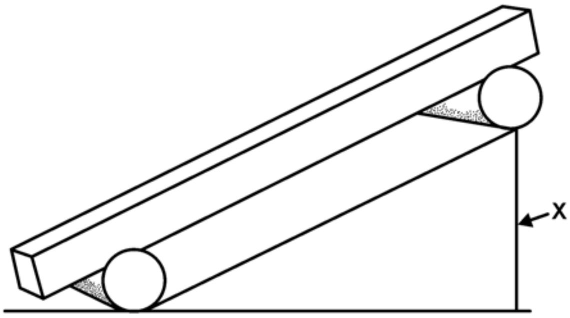


Fig. 2.77, Diagram for sine bar problem.

A precision angle has always been difficult to set because of the trigonometric calculations used with the sine bar. The chief difficulty lies in the dimension X of Fig. 2.77, which often results in a figure with many decimal places. Gauge blocks can only approximate this value. For example, to measure 44°30' by the sine-bar method, the following steps are required when using a 5-in. sine bar.

Find the sine of 44°30' from the trigonometric tables.

0.7009093

Multiply by 5 to find dimension X.

3.5045465

Determine the combination of gage blocks necessary to make this dimension.

$$\begin{array}{r} 0.1005 \\ 0.104 \\ 0.300 \\ \underline{3.000} \\ \hline 3.5045 \\ \hline \end{array}$$

Residual error (the difference between the calculated and actual values).

$$\begin{array}{r} 3.5045465 \\ -3.5045000 \\ \hline 0.0000465 \\ \hline \end{array}$$

This error cannot be eliminated in sine-bar procedure. However, it can be eliminated with the use of angle gage blocks. With angle gage blocks, a 45° block is wrung on a 30' block so that the plus end of the 45° block contacts the minus end of the 30' block which forms an angle of 44°30'. This is a simple procedure, and more important, it is absolutely accurate.

A complete set of 16 angle blocks yields 356,400 angles in steps of one second, with an accuracy measured in millionth parts of a circle. At first glance, the ability of a few blocks to measure hundreds of thousands of angles seems impossible. However, angles can be measured by subtraction as well as by addition, which allows a few blocks to perform this surprising job.

XII. Screw Pitch Gauge

It is a very effective, fool-proof and fairly accurate instrument used to check the pitch of the threads cut on different items. It consists of a metal case carrying a number of blades which have teeth of different pitches, cut on their edges and markings corresponding to these pitches on their surfaces. In operation, different blades are tried on the threads one after the other and when any one of them is found meshing with the cut teeth, the relevant reading is read directly from the marking on the matching blade surface. A typical form of this gauge is shown in Fig. 2.78. It can be used to measure and check the pitches of both external and internal threads. It is for the same reason that the free ends of the blades are made narrow to enable them to enter the hollow parts easily while checking the internal threads. In some instruments the blades are made to have markings both for the pitches as well as a value equal to double the depth of the threads. The latter quantity helps in readily determining the drill size to be used before tapping.

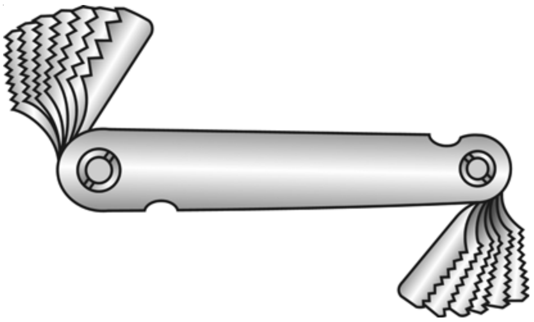


Fig. 2.78, Screw-pitch gauge.

2.2.5. WORK HOLDING TOOLS

I. Clamping and Holding Devices

Many devices have been designed to hold work securely while it is being measured or machined. Some of them are for one specific piece of work; others are of more general nature. These include many types of clamps and vises.

a. C-Clamp

A C-clamp (Fig. 2.79) is an all-purpose clamp, made in the shape of the letter C. In general use for all kinds of work, it is made in many sizes.

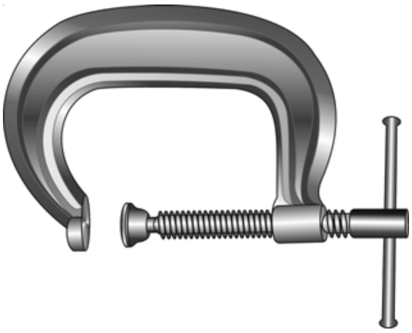


Fig. 2.79, C-clamp.

b. Parallel Clamps

A toolmakers' clamp (Fig. 2.80) consists of two flat steel jaws, which may be adjusted to fit a piece of work by mans of a screw passing through the center of each jaw. Another screw in the end of one jaw is used to exert pressure on the other jaw. This pressure tightens the opposite ends of the jaws. It is used by toolmakers for holding small parts both at the bench and at machines. This tool is also known as a Parallel Clamp. Care must be taken to keep the jaws in a parallel position. Otherwise the clamp screws may seem to be tight but will not be holding the work tightly because they are just being tightened one against the other (Fig. 2.81).

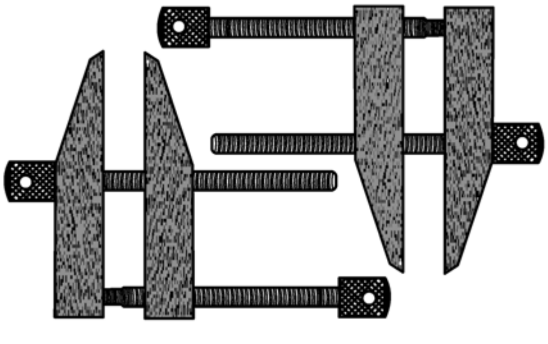


Fig. 2.80, Toolmakers' parallel clamps.

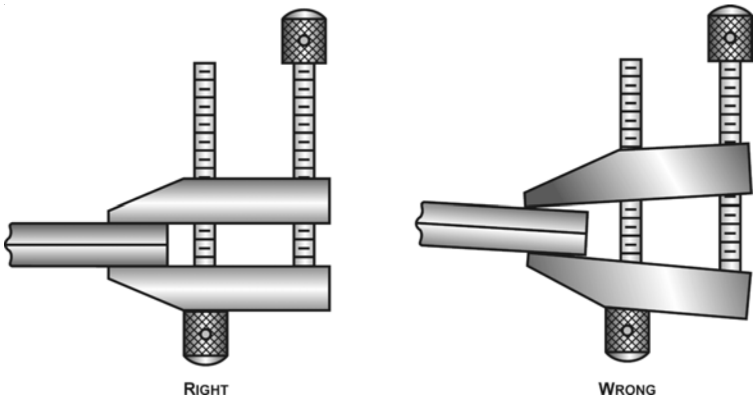


Fig. 2.81, Right and wrong way to use toolmakers' parallel clamps.

II. Vices & V-Block

Vices are the most suitable and widely used tools for gripping different jobs in position during the various operations carried out in a fitting shop. There is a fairly good number of different types of vices which are in engineering use such as parallel jaw vice, swivel vice, machine vice, hand vice, pipe vice and tool maker's vice.

a. Pin Vice

A *pin vice* is used for holding very small pieces like wire nails and pins etc. It is nothing but a small form of collect chuck. It consists of a handle and a tapered nose carrying a small collet chuck at its end. The collet carries three hardened steel jaws which are operated by rotating the handle. The piece to be held is inserted between the jaws, the handle rotated and thus it is gripped in the collet. Now the operation can be done by the other hand as shown in Fig. 2.82.

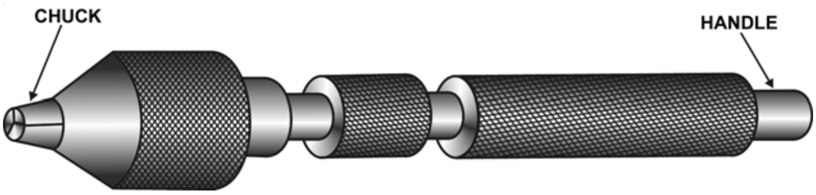


Fig. 2.82, Pin Vice.

b. Hand Vice

For gripping very small object a *hand vice* Fig. 2.83. is usually employed. These vices are made in various shapes and sizes and a commonly used type is shown in Fig. This vice in appearance is similar to a leg vice. It consist of two steel legs hinged together at the bottom and carrying the hardened steel jaws at the other end (top). A spring attachment is provided between the two legs which always tends to keep the jaws separate. A screw is fastened to one leg and passes through the other. At the free end of the screw a wing nut is provided. The piece to be held is gripped between the serrated jaws by tightening the wing nut. The vice as whole, together with the gripped piece, is held in one hand and the required operation performed by the other hand. Evidently, therefore, the manipulation of the work is more or less similar to that when it is directly held in the hand.

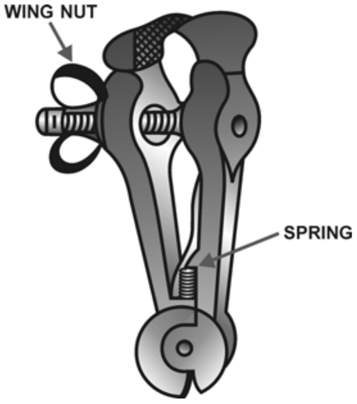


Fig. 2.83, Hand Vice.

c. Bench Vice

The parallel jaw vice is most commonly used in general fitting work. It is shown in full section in Fig. 2.84 and swivel type bench vice in 2.85. These vices are available in different trade sizes and the selection of a suitable size will depend upon the maximum size of the work it is expected to grip. The width of the jaws determines the size of the vice.

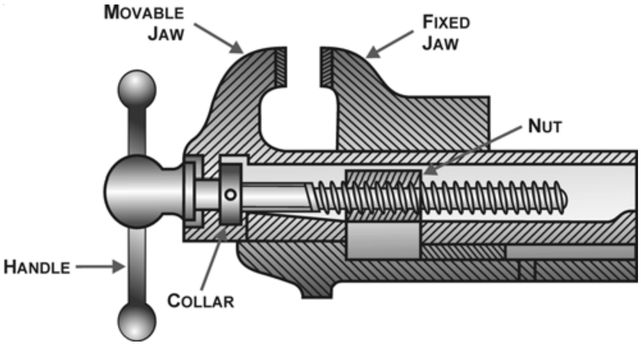


Fig. 2.84, Paralled jaw bench vice.

In fixing it on the fitter's bench it is held with the help of bolts passing through the planks of the bench and the holes provided in the base of it. These bolts are tightened by means of nuts and thus the vice is held firmly on the bench. The jaws of the vice are usually kept overhanging the edge of the bench.

It essentially consists of a cast steel body carrying a fixed jaw, a movable steel jaw, square threaded screw and a fixed nut under the movable jaw piece. The threaded screw which is made to pass through the movable jaw at the outer end carries a handle at its outer end a collar inside so as to prevent it from coming out of the jaw when revolved. It runs through the fixed nut longitudinally under the movable jaw. Separate cast steel plates, known as the jaw plates, are fixed to the jaws by means of set screws which are made flush with the working faces of these plates. The holding faces of these plates are provided with serrations to increase the gripping power of the jaws. Finished surfaces should be protected when placed in the vice by using brass or copper jaw caps as in Fig. 2.86.

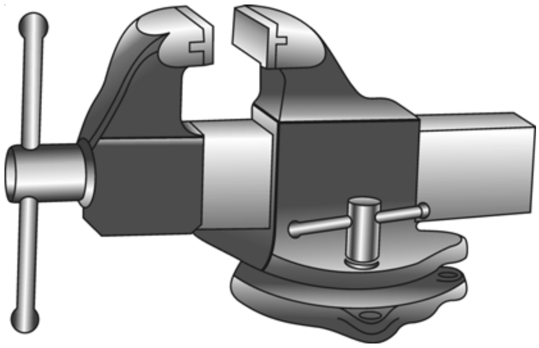


Fig. 2.85, Swivel-type bench vise.

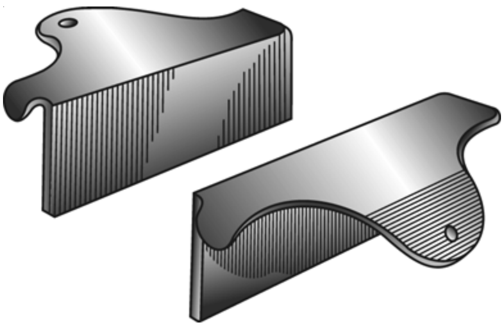


Fig. 2.86, Protective jaw caps for vise.

For gripping the work in the vice the jaws are opened out by withdrawing the movable jaw by rotating the screw, the work is held between the jaws by one hand and the screw tightened by rotating the handle by other hand. This brings the two jaws closer and pressure on the work is attained by tightening or loosening screw depending upon the need. The work to be held in this vice may be of any regular or irregular shape and a desired amount of grip can be applied. The parallel jaws of the vice enable the work to be held square so that the filing, scrapping and chipping operations can be performed accurately. On account of the serrations on the gripping faces of the jaw plates there is always a likelihood of the work surface getting damaged when gripped tightly between these jaws. To avoid this, soft plate liners, such as those of copper or tin, are interposed between the work and the jaws. This prevent the work surface from coming in direct contact with the indented jaws.

d. Machine Vice or Toolmaker's Vice

For holding very small tools and other work a very simple type of hand operated vice is used by the tool makers, known as *tool maker's vice*. It consists of a U-shaped body carrying a screw in one limb. A metal block is placed between the end face of the screw and the other limb of the body. The piece is gripped between the surface of this block and the free limb of the body, by the tool makers, for small machining operations like drilling or tapping etc. It is shown in Fig. 2.87.

Similarly for holding pipes and tubes etc., a special type of vice known as *pipe vice*, is used.

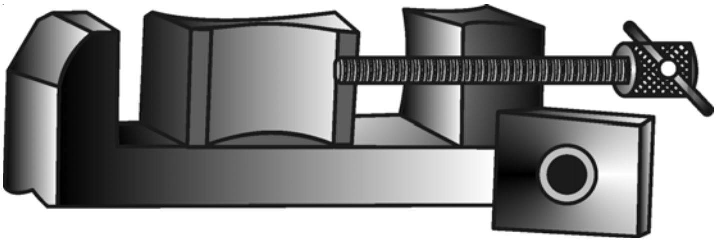


Fig. 2.87, Toolmaker's vise.

e. V-Block

A 'V' block, serves as a very useful support to the work in marking and drilling etc. It usually works in conjunction with a U- clamps as shown in the Fig. 2.88 . Round bar can be very successfully held in it. The bar length is placed longitudinally in block and the screw in the clamp tightened. This grips the rod firmly with the latter's axis parallel to the V-groove. Its specific use is in holding the round bars, during marking and centre drilling their end faces, which are to be held between centres on the lathe. Also it is very suitable for holding round bars in drilling operation when the axis of the drill is to be kept normal to the axis of the bar.

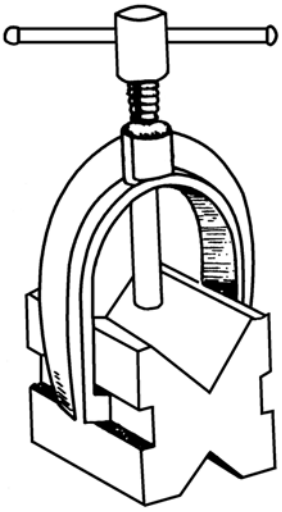


Fig. 2.88. V-Block

■■■

CHAPTER : 3
TAPS, DIES, DRILLS AND REAMERS

INTRODUCTION

This chapter deals with the various thread cutting tools and various types of drills and reamers that are used for making and finishing holes. This chapter will also give a brief introduction of boring operation and at the end we will find out the difference between drilling, reaming and boring.

3.1 THREAD CUTTING TOOLS

Thread cutting tools are used to cut internal as well as external screw threads. Threads can be cut of any form or type depending upon the usages. They may be V-threads or square threads, of British Standard or American Standards, all the threads can be cut either using hand tools or machine tools. Various threads forms are discussed in the later chapters. In this chapter we will just discuss the thread cutting tools.

I. Dies

A tool used for cutting external threads on bars or tubes is called a die. It consists of a nut having portions of its thread circumference cut away and shaped to provide cutting edges to the remaining portions of the threads. After hardening and sharpening of the cutting edges, this is screwed on to the bar upon which the thread is to be cut. In order to hold and manipulate the die it is carried in the centre of a pair of operating handles called stocks.

a. Solid die

A solid die is one which has fixed dimension and cannot be adjusted for larger or smaller diameter (Fig. 3.1).

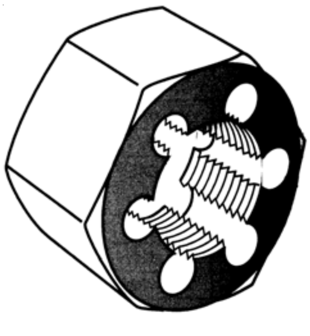


Fig. 3.1, Solid Die

b. Split die

The split dies, as shown in Fig. 3.2 (a), consist of a pair of dies or jaws which fit into the stocks, as shown in Fig. 3.2 (b), and are clamped by a screwed ring. These dies slide and may be adjusted by screws which bear against their outer faces. This permits the dies to be set a small amount open while the first cut is taken down a bar and closed into the correct size for the final finishing cut.

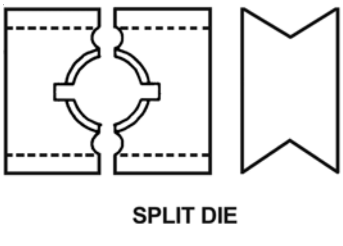


Fig.3.2, (a) Split die

Fig.3.2 (b) Stock for split die.

c. Adjustable die

Adjustable means that it can be set to cut larger or smaller diameter. A circular adjustable split die as shown in fig is very common. The die is split through one side and a slight adjustment is made by means of the setscrew shown. If this screw is tightened up the die is opened up slightly, whilst unscrewing will cause the die to spring in. Another common type is the two-piece rectangular die. In this type the dies are fitted into a special stock and they are closed by means of the adjusting screw (Fig. 3.3).

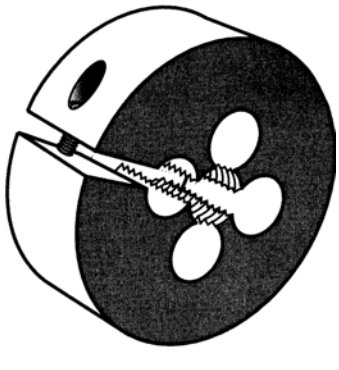


Fig. 3.3 Adjustable die.

The size of a die is specified by the outside diameter of the thread to be cut and pitch of the thread.

II. Taps

The hand operated taps used in fitting shop are employed for cutting internal threads in cylindrical holes or for cleaning damaged threads in similar parts. A tap consists of a toothed body having flutes (usually 4) cut on its surface, a round shank and a square formation at the end of the shank. The flutes are provided for the same purpose as in case of a twist drill and square formation at the top enables a firm grip by tapping handle or wrench. All the hand taps of different sizes are available in a set of three taps of each size known as Taper, Second and Plug or bottoming taps respectively as shown in fig. 3.4. In the threading operation they are used in the same order as taper, second and plug.

In a taper tap last five or six threads are ground out to produce a tapered surface such that diameter at the end of this tap becomes slightly less than or equal to the diameter of the hole to be tapped. This enables the tap to enter the holes without any difficulty and as the tap advances into the hole each successive tooth of the body increases the depth of threads until the entire tapered portion has entered the hole. After this, with the further advancement of the tap in the hole, the remaining teeth on the body of the tap gradually increase the depth of the threads to the required value. It is evidently the first tap to be employed during the operation.

After full length of the toothed body of the tap has been screwed down in the hole, this tap is withdrawn and then follows the second or intermediate tap. Second tap is entered into the hole and screwed down its full length in the same fashion as taper tap and thus the threads are cut and finished to the required size. If, however, the threads are to be cut in a blind hole where it is not possible to pass the second tap through the hole, a plug or bottoming tap is used after the second tap to finish the threads right upto the bottom of the hole as the cutting teeth in the plug tap extend right upto its bottom end.

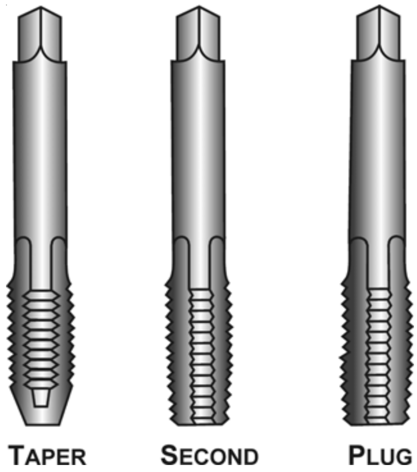
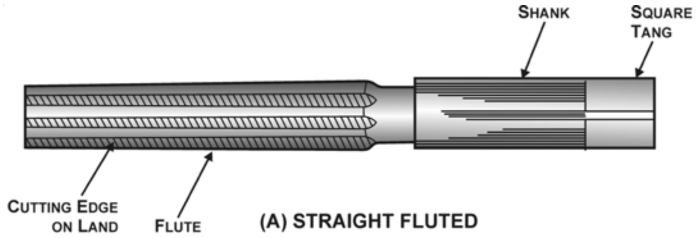


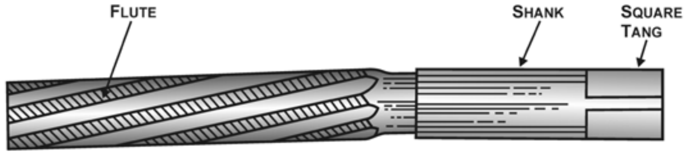
Fig. 3.4, Taps.

3.2 REAMERS

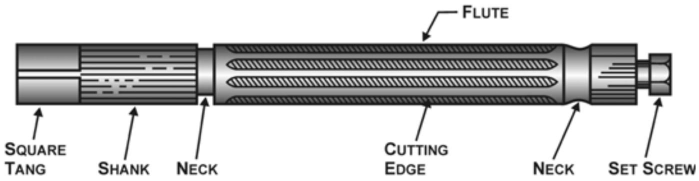
When an accurate hole with a smoother finish is required a reamer is used to remove a little metal from the hole and to bring it to the correct size. The reamers are supposed to remove minimum amount of metal from 0.1 to 0.15 mm for rough reaming and 0.05 to 0.02 mm for finish reaming. Holes with a diameter less than 25 mm should be first rough reamed and then finished reamed. Holes over 25 mm in diameter are first enlarged with a counterbore. They are then rough reamed and finally brought to size with a finishing reamer.



(A) STRAIGHT FLUTED



(B) HELICAL FLUTED



(C) EXPANSION

Fig. 3.5, Type of reamers.

There are two kinds of reamers namely, those which are turned by hand, called hand reamers, and those which are used on the machine, called machine reamers. There are also reamers which can be expanded which means that they can be made larger to cut a little oversize. These are called expanding reamers. An expanding reamer is specially made so that its size can be changed by 1.6 mm.

They are obtainable in cast steel or in high speed steel, with parallel or tapered cutters, with straight or spiral flutes. The standard tapered reamers are 1 in 50 and then there is a range of reamers for morse tapers.

The hand reamer in Fig. 3.5 has a square shank for holding in a tap wrench or similar tool. This is a parallel reamer, and it has a series of straight flutes cut along its length. The number of cutting edges varies according to the make and size of the reamer. The cutting edges of reamers have a small amount of land along their top edges. When the reamer is sharpened it is ground in the flute, and top of the land must not be touched. Some hand reamers are slightly tapered at the end so that a gradual ‘ lead in’ to the hole may be obtained. The taper extends for approximately a quarter of the total length. This type of reamer is useful for starting the reaming operation. Hand reamers are also obtainable with spiral flutes. The spiral is left- handed. If the reamer had a right-hand spiral it would tend to screw itself into the hole too quickly as the reamer was turned and produce an irregular hole.

TYPES OF REAMERS

The reamers are of the following types :

I. Hand Reamers

Hand reamers are usually provided with a parallel shank and square tang, as shown in Fig. 3.5. The tang is made so in order to hold it in a handle. The flutes may be straight or spiral. In both cases the reamer carries a taper towards the end of its flutes, for a length about equal to its diameter, in order to have an unrestricted entry into the previously drilled hole. It should be noted that these reamers are not to be used for machine reaming in any case. Before starting the operation, the reamer should be held true and straight and in operation it should always be rotated in one direction only. In case of hand reaming the material to be removed should not be more than 0.127 mm.

II. Chucking or machine reamers

This category includes two types of power driven reamers, namely fluted reamers and rose reamers. The latter class may have straight or taper shank. The teeth are bevelled at the end and cutting takes place only there. No relief is provided on the lands, which are almost as wide as the grooves. The fluted part of this reamer is slightly tapered towards the shank. This is not a finishing tool and is usually followed by hand reamer. As such, its size is normally kept from 0.076 mm to 0.127 mm below the nominal size.

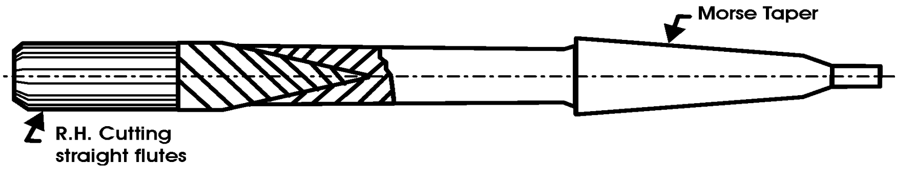


Fig. 3.6, A rose reamer.

The fluted reamer differs from the rose reamer in that, for the same diameter, it carries more number of teeth than the rose reamer. Another difference is that its lands are narrower than the grooves (flutes) and are relieved for the entire length. The shank may be tapered or straight. Due to inconvenience in holding, it is advisable that reamers below 12 mm diameter should not have taper shank and those above 25 mm diameter the straight shank. Two typical forms of rose and fluted machine reamers are shown in Figs. 3.6 and 3.7 respectively.

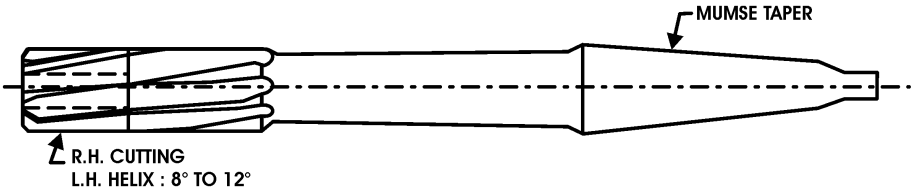


Fig. 3.7, Fluted machine reamer.

III. Adjustable reamers

These reamers are available in both straight shank as well as taper shank. The main body is made to have parallel grooves in which are fitted adjustable blades. These blades can be made to project outward or drawn in so that the same reamer can easily be adjusted to suit different sizes of holes within a fairly wide range over or under the nominal size. This is a specific advantage of this type of reamer over other types. Another valuable feature is that its blades can be easily sharpened and adjusted and, therefore, have longer life. All the above factors compensate the extra cost of this kind of reamer as compared to the solid type. These reamers are available in different sizes and in both types i.e., hand and machine. The body may be in one piece with shank or shell type (Fig. 3.8).

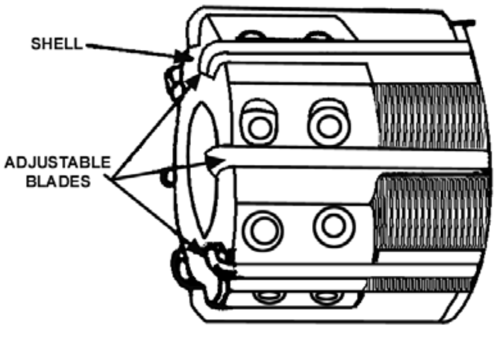


Fig. 3.8, Shell type adjustable reamer.

IV. Expansion reamers

The whole body of an expansion reamer consists of mainly two parts. The main body, which carries the cutting teeth, carries a slightly tapered hole inside and is slitted longitudinally to allow expansion. A tapered plug is fitted at the end which, when screwed on, creates the desired expansion. The flutes may be straight or spiral. The former type is shown in Fig. 3.9. It should, however, be carefully noted that this tool should not be confused with the adjustable reamer as it is not meant for reaming oversize or undersize holes. The provision for slight expansion is simply to make the life of the tool longer for reaming the standard size holes.

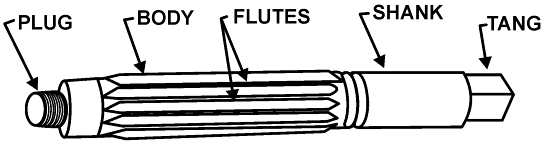


Fig. 3.9, Straight flute expansion reamer.

V. Taper reamers

Taper reamers are made in sets of two, one for roughing and the other for finishing. They are available in all the different standard sizes. Hand taper reamers are provided with a square formation at the end of the shank so that they can be held in wrench. Their shank is parallel. The machine taper reamers may have a straight or taper shank and the tang is bevelled as usual. The notches provided on the lands of roughing reamers help in breaking the chips. The flutes are straight or spiral. The latter form is very common in machine reamers. A pair of hand taper reamers is shown in Fig. 3.10.

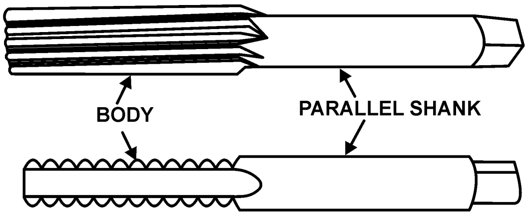


Fig. 3.10, Hand taper reamers.

VI. Taper pin reamers

This is a standard form of taper reamers which carries a standard taper of about 20 mm per metre along its body. These reamers are used for finishing taper pin holes of standard sizes. They may have helical or straight flutes. A straight flute taper pin reamer is shown in Fig. 3.11.

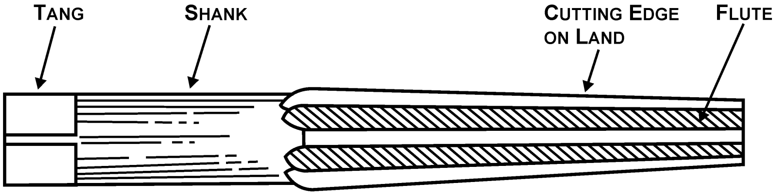


Fig. 3.11, Straight flute taper pin reamer.

VII. Shell reamers

These reamers are manufactured both in rose type as well as fluted type. They are mounted on an arbor. The same arbor can be used for different reamers. This effects a considerable saving in material, particularly in case of large size reamers. That is why these reamers are generally available in comparatively larger sizes only. The arbor may have a straight or taper shank. Two standard types of arbors and a straight fluted shell reamer are shown in Fig. 3.12.

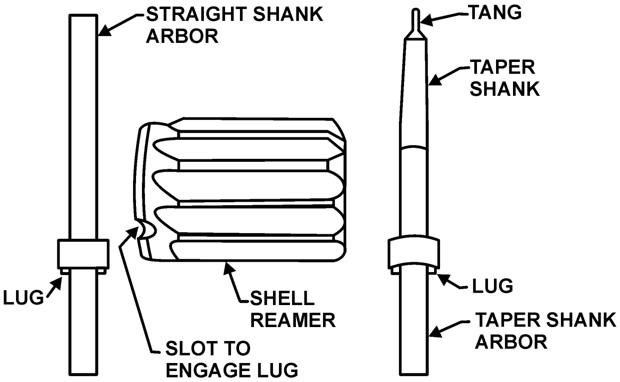


Fig. 3.12, Shell reamer with arbors.

VIII. Carbide tipped reamers

In mass production work, where reaming is a regular operation, ordinary high speed steel reamers will not prove economical. In such cases a preferable practice will be to use carbide tipped reamers which will withstand heavy loads, retain cutting edges under high temperatures, have more resistance to abrasion and employ higher cutting speeds. All these factors will jointly contribute towards a cheaper and at the same time a high quality production. Particularly in castings and other hard metals, their use will give very good results. In these reamers small bits or tips, made of cemented carbides, are inserted in the lands. In order to have full advantage of these reamers, it is necessary that sufficient stock of material should be left to be removed by reaming. Some representative forms of carbide tipped reamers are shown in Figs. 3.13, 3.14 and 3.15.

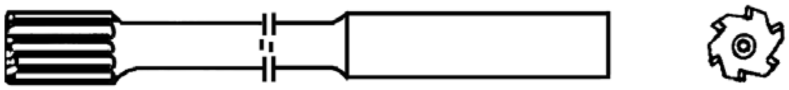


Fig. 3.13, A parallel shank carbide tipped reamer.

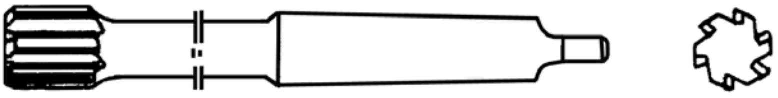


Fig. 3.14, A taper shank carbide tipped reamer.

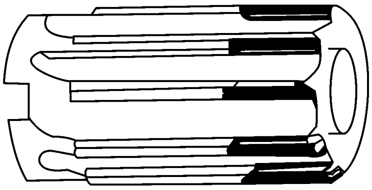


Fig. 3.15, A carbide tipped shell reamer.

IX. Jobber's reamer

A Jobber's Reamer (Fig. 3.16) is a taper-shank machine reamer having flutes about the same length as a hand reamer; it is used as precision finishing reamer.

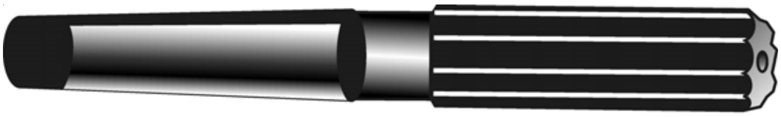


Fig. 3.16, Jobber's reamer

SOME OTHER IMPORTANT FORMS OF REAMERS

I. Socket reamer for Morse Taper

A large number of standard parts carry Morse Tapers and also the shanks of a number of tools like drills, reamers, etc., carry this taper. The socket M.T. reamers are made and used for finishing the tapered holes to one of the six standard morse tapers, numbering from 1 to 6, as required. They may carry parallel shanks or taper shanks and can be hand type or machine type. The cutting edges on the body of such a reamer are tapered to conform to the required morse taper. The flutes may be parallel or helical. A parallel shank socket reamer for Morse Taper, carrying parallel flutes is shown in Fig. 3.17.

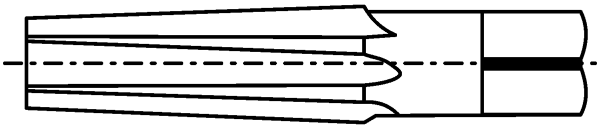


Fig. 3.17, A parallel shank socket reamer for Morse Taper.

II. Machine Bridge Reamers

These reamers are also known a structural reamers because they are mainly used in structural work, such as ship building, bridge making, etc. In such fabrications, a large number of steel plates, stays and similar other parts carry punched or drilled holes, which require sizing and finishing at site in order to obtain proper alignment while assembling and to facilitate the use of standard size bolts and rivets in the assembly. Since the operation is carried out at site, usually portable electric drills or pneumatic tools are used to hold and rotate these reamers. These reamers carry mores taper shanks and are available in a fairly wide range of diameters. Two common varieties of these reamers, namely a straight fluted and a helical fluted machine bridge reamers are shown in Fig. 3.18 and 3.19 respectively.

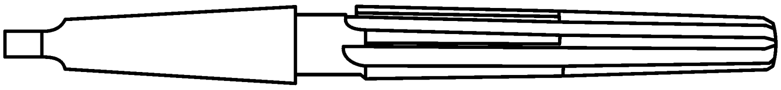


Fig. 3.18, A straight fluted machine bridge reamer.

Fig. 3.19, A helical fluted machine bridge reamer with square tang.

III. A stub screw machine reamer

This reamer carries spiral flutes and right hand cut. It is provided with a parallel shank which carries a hole. This hole enables its fitting into a floating holder. Such a reamer is shown in Fig. 3.20.

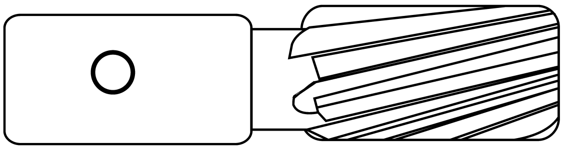


Fig. 3.20, A spiral fluted R.H. cut stub screw machine reamer.

IV. Die maker's reamers

These are fluted chucking reamers carrying three flutes with a large helix angle. This helps in quicker cutting required in die making. That is why they are largely used in die making work. Such a reamer is shown in Fig. 3.21.

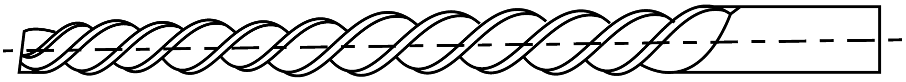


Fig. 3.21, A die maker's reamer.

V. Burring reamers

These are hand reamers, which may have straight or spiral flutes. Their principle applications are in removing burrs from cut pipe pieces or conduits, but in thin jobs they can be used for enlarging holes also. A straight fluted burring reamer is shown in Fig. 3.22.

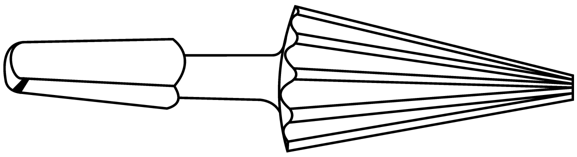


Fig. 3.22, A straight fluted Burring Reamer.

Machine reamers are made parallel along their length with a slight taper in the same way as hand reamers, but they are mostly made with a taper shank. These, too, have left-handed spiral flutes.

3.3 DRILLS

Drilling is an important operation carried out in a fitting shop for producing different types and sizes of holes in different materials. There are many forms of drills used for this purpose. The simplest form is a *Flat Drill* which has a flat section at the cutting edge and can have a parallel tapered or square shank according to the requirement. It is very easy to be manufactured and is the cheapest of all forms. It has many disadvantages too, such as:

1. Deep holes cannot be drilled by means of it as it does not have any suitable means of excavating the cut material out of the hole during the operation.
2. Due to the presence of the metal chips inside the drilled holes its cutting edges are spoiled very soon, necessitating very frequent grinding of these edges.
3. It is unsuitable for being used at the high speeds as its cutting edges are spoiled owing to the heat generated due to friction at these speeds.
4. Speaking in the strict sense of accuracy it is not very accurate and dependable.

The other important and most widely used form of drills is a *fluted twist drill.* It has a cylindrical body carrying the spiral flutes cut on its surface. Twist drills are usually made of highspeed steel, of course some cheaper varieties are made of high carbon steel also. They are made in different forms to suit the work but the *most commonly used types* are

i. Those having parallel shank and
ii. Those having tapered shank as shown in fig. 3.23.

Parallel shank is provided on small sized drills (say upto 12.7 mm) only and those above this size are usually provided with a tapered shank which normally carries the Morse taper. Other types of shanks used on twist drills are the bit shank and ratchet shank, but they are not so commonly used as the above. It is important to note the different terms applied to twist drills as shown in fig. 3.23.

The twist drill essentially consists of two main parts, a shank which is gripped in the chuck of the drilling machine and the body which forms the main cutting unit. Tapered shank drills are provided with a tang at the end of the shank to ensure a positive grip, as this tang fits a slot provided in the socket and enables an easy removal from the socket when required. Main advantages of using twist drills are:

1. The chips and the cutting of the metal are automatically driven out of the hole through the spiral flutes.
2. Cutting edges are retained in good condition for a fairly long period, thus avoiding the frequent regrinding.
3. Heavier feeds and speeds can be quite safely employed.
4. For the same size and depth of hole they need less power as compared to other forms of drills.

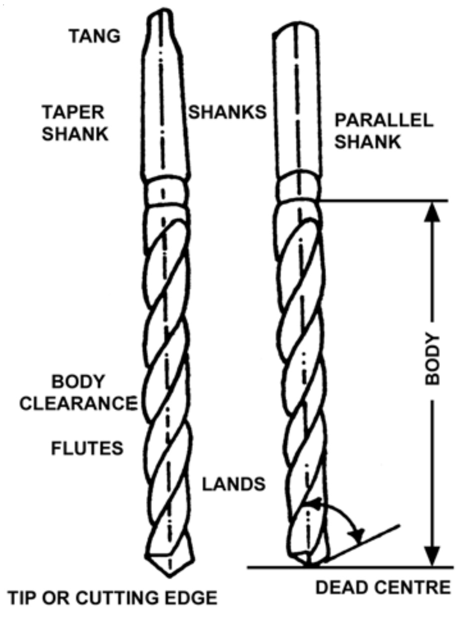
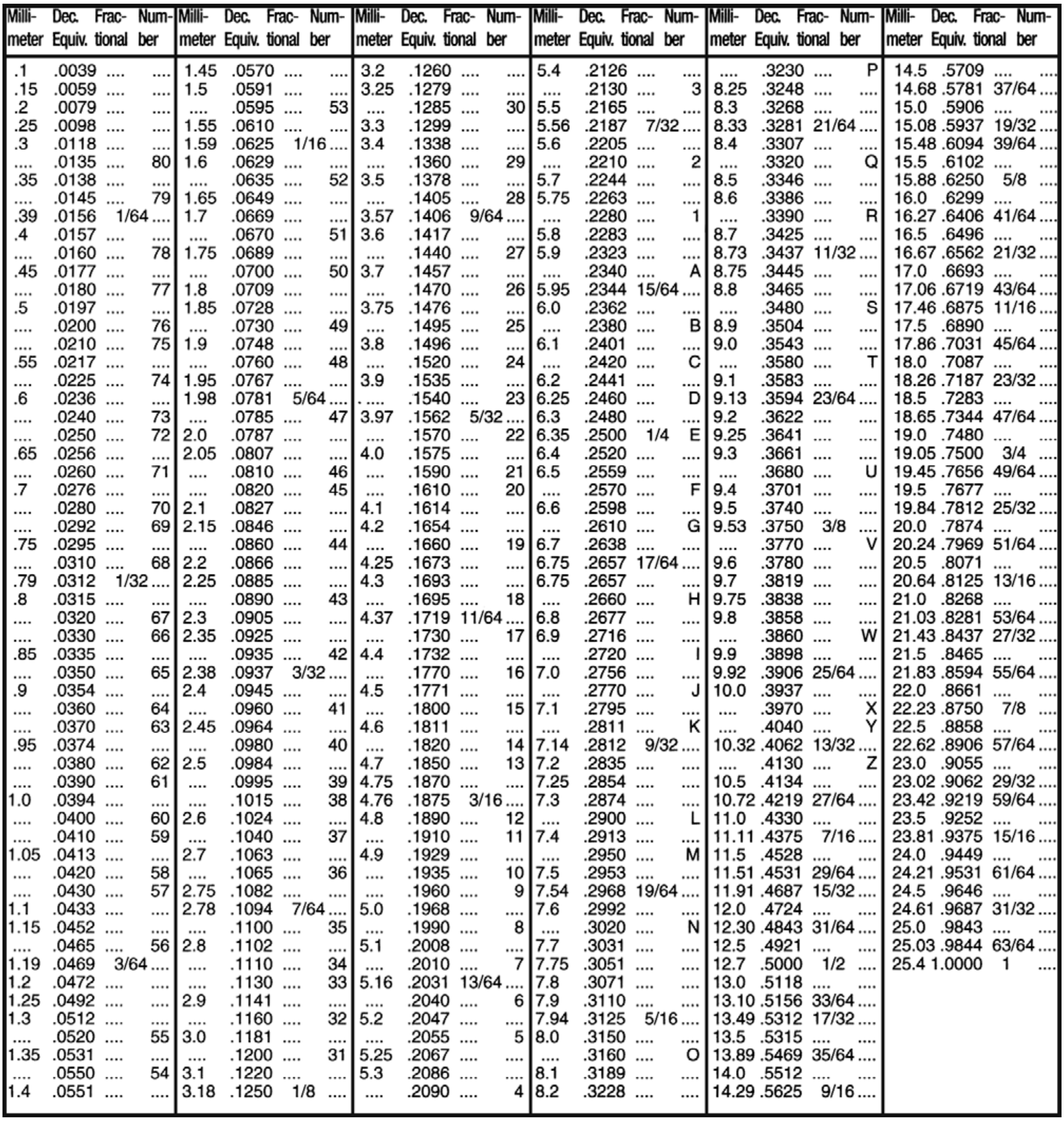


Fig. 3.23, Twist drill

Drill sizes

There are three methods used to indicate drill sizes : the number, fractional, and letter. Number drills range in size from 0.0135 inch for the number 80 to 0.2280 inch for the number 1 drill. Fractional drill are available in sets from 1/64 inch (0.0156) to 1/2 inch (0.500). Drill sizes larger than 1/2 inch are typically available individually and are not normally available in sets. Letter drill sizes are all larger than number sizes and range from A (0.2340) to the Z (0.4130). The only drill size available in two sets is the 0.2500 inch drill which is the letter E drill and the 1/4 inch drill. (Fig. 3.24).



Millimeter	Dec. Equiv.	Fractional	Number
.1	.0039	....	....
.15	.0059	....	....
.2	.0079	....	....
.25	.0098	....	....
.3	.0118	....	....
....	.0135	....	80
.35	.0138	....	....
....	.0145	....	79
.39	.0156	1/64	....
.4	.0157	....	....
....	.0160	....	78
.45	.0177	....	....
....	.0180	....	77
.5	.0197	....	....
....	.0200	....	76
....	.0210	....	75
.55	.0217	....	....
....	.0225	....	74
.6	.0236	....	....
....	.0240	....	73
....	.0250	....	72
.65	.0256	....	....
....	.0260	....	71
.7	.0276	....	....
....	.0280	....	70
....	.0292	....	69
.75	.0295	....	....
....	.0310	....	68
.79	.0312	1/32	....
.8	.0315	....	....
....	.0320	....	67
....	.0330	....	66
.85	.0335	....	....
....	.0350	....	65
.9	.0354	....	....
....	.0360	....	64
....	.0370	....	63
.95	.0374	....	....
....	.0380	....	62
....	.0390	....	61
1.0	.0394	....	....
....	.0400	....	60
....	.0410	....	59
1.05	.0413	....	....
....	.0420	....	58
....	.0430	....	57
1.1	.0433	....	....
1.15	.0452	....	....
....	.0465	....	56
1.19	.0469	3/64	....
1.2	.0472	....	....
1.25	.0492	....	....
1.3	.0512	....	....
....	.0520	....	55
1.35	.0531	....	....
....	.0550	....	54
1.4	.0551	....	....
1.45	.0570	....	....
1.5	.0591	....	....
....	.0595	....	53
1.55	.0610	....	....
1.59	.0625	1/16	....
1.6	.0629	....	....
....	.0635	....	52
1.65	.0649	....	....
1.7	.0669	....	....
....	.0670	....	51
1.75	.0689	....	....
....	.0700	....	50
1.8	.0709	....	....
1.85	.0728	....	....
....	.0730	....	49
1.9	.0748	....	....
....	.0760	....	48
1.95	.0767	....	....
1.98	.0781	5/64	....
....	.0785	....	47
2.0	.0787	....	....
2.05	.0807	....	....
....	.0810	....	46
....	.0820	....	45
2.1	.0827	....	....
2.15	.0846	....	....
....	.0860	....	44
2.2	.0866	....	....
2.25	.0885	....	....
....	.0890	....	43
2.3	.0905	....	....
2.35	.0925	....	....
....	.0935	....	42
2.38	.0937	3/32	....
2.4	.0945	....	....
....	.0960	....	41
2.45	.0964	....	....
....	.0980	....	40
2.5	.0984	....	....
....	.0995	....	39
....	.1015	....	38
2.6	.1024	....	....
....	.1040	....	37
2.7	.1063	....	....
....	.1065	....	36
2.75	.1082	....	....
2.78	.1094	7/64	....
....	.1100	....	35
2.8	.1102	....	....
....	.1110	....	34
....	.1130	....	33
2.9	.1141	....	....
....	.1160	....	32
3.0	.1181	....	....
....	.1200	....	31
3.1	.1220	....	....
3.18	.1250	1/8	....
3.2	.1260	....	....
3.25	.1279	....	....
....	.1285	....	30
3.3	.1299	....	....
3.4	.1338	....	....
....	.1360	....	29
3.5	.1378	....	....
....	.1405	....	28
3.57	.1406	9/64	....
3.6	.1417	....	....
....	.1440	....	27
3.7	.1457	....	....
....	.1470	....	26
3.75	.1476	....	....
....	.1495	....	25
3.8	.1496	....	....
....	.1520	....	24
3.9	.1535	....	....
....	.1540	....	23
3.97	.1562	5/32	....
....	.1570	....	22
4.0	.1575	....	....
....	.1590	....	21
....	.1610	....	20
4.1	.1614	....	....
4.2	.1654	....	....
....	.1660	....	19
4.25	.1673	....	....
4.3	.1693	....	....
....	.1695	....	18
4.37	.1719	11/64	....
....	.1730	....	17
4.4	.1732	....	....
....	.1770	....	16
4.5	.1771	....	....
....	.1800	....	15
4.6	.1811	....	....
....	.1820	....	14
4.7	.1850	....	13
4.75	.1870	....	....
4.76	.1875	3/16	....
4.8	.1890	....	12
....	.1910	....	11
4.9	.1929	....	....
....	.1935	....	10
....	.1960	....	9
5.0	.1968	....	....
....	.1990	....	8
5.1	.2008	....	....
....	.2010	....	7
5.16	.2031	13/64	....
....	.2040	....	6
5.2	.2047	....	....
....	.2055	....	5
5.25	.2067	....	....
5.3	.2086	....	....
....	.2090	....	4
5.4	.2126	....	....
....	.2130	....	3
5.5	.2165	....	....
5.56	.2187	7/32	....
5.6	.2205	....	....
....	.2210	....	2
5.7	.2244	....	....
5.75	.2263	....	....
....	.2280	....	1
5.8	.2283	....	....
5.9	.2323	....	....
....	.2340	....	A
5.95	.2344	15/64	....
6.0	.2362	....	....
....	.2380	....	B
6.1	.2401	....	....
....	.2420	....	C
6.2	.2441	....	....
6.25	.2460	....	D
6.3	.2480	....	....
6.35	.2500	1/4	E
6.4	.2520	....	....
6.5	.2559	....	....
....	.2570	....	F
6.6	.2598	....	....
....	.2610	....	G
6.7	.2638	....	....
6.75	.2657	17/64	....
6.75	.2657	....	....
....	.2660	....	H
6.8	.2677	....	....
6.9	.2716	....	....
....	.2720	....	I
7.0	.2756	....	....
....	.2770	....	J
7.1	.2795	....	....
....	.2811	....	K
7.14	.2812	9/32	....
7.2	.2835	....	....
7.25	.2854	....	....
7.3	.2874	....	....
....	.2900	....	L
7.4	.2913	....	....
....	.2950	....	M
7.5	.2953	....	....
7.54	.2968	19/64	....
7.6	.2992	....	....
....	.3020	....	N
7.7	.3031	....	....
7.75	.3051	....	....
7.8	.3071	....	....
7.9	.3110	....	....
7.94	.3125	5/16	....
8.0	.3150	....	....
....	.3160	....	O
8.1	.3189	....	....
8.2	.3228	....	....
....	.3230	....	P
8.25	.3248	....	....
8.3	.3268	....	....
8.33	.3281	21/64	....
8.4	.3307	....	....
....	.3320	....	Q
8.5	.3346	....	....
8.6	.3386	....	....
....	.3390	....	R
8.7	.3425	....	....
8.73	.3437	11/32	....
8.75	.3445	....	....
8.8	.3465	....	....
....	.3480	....	S
8.9	.3504	....	....
9.0	.3543	....	....
....	.3580	....	T
9.1	.3583	....	....
9.13	.3594	23/64	....
9.2	.3622	....	....
9.25	.3641	....	....
9.3	.3661	....	....
....	.3680	....	U
9.4	.3701	....	....
9.5	.3740	....	....
9.53	.3750	3/8	....
....	.3770	....	V
9.6	.3780	....	....
9.7	.3819	....	....
9.75	.3838	....	....
9.8	.3858	....	....
....	.3860	....	W
9.9	.3898	....	....
9.92	.3906	25/64	....
10.0	.3937	....	....
....	.3970	....	X
....	.4040	....	Y
10.32	.4062	13/32	....
....	.4130	....	Z
10.5	.4134	....	....
10.72	.4219	27/64	....
11.0	.4330	....	....
11.11	.4375	7/16	....
11.5	.4528	....	....
11.51	.4531	29/64	....
11.91	.4687	15/32	....
12.0	.4724	....	....
12.30	.4843	31/64	....
12.5	.4921	....	....
12.7	.5000	1/2	....
13.0	.5118	....	....
13.10	.5156	33/64	....
13.49	.5312	17/32	....
13.5	.5315	....	....
13.89	.5469	35/64	....
14.0	.5512	....	....
14.29	.5625	9/16	....
14.5	.5709	....	....
14.68	.5781	37/64	....
15.0	.5906	....	....
15.08	.5937	19/32	....
15.48	.6094	39/64	....
15.5	.6102	....	....
15.88	.6250	5/8	....
16.0	.6299	....	....
16.27	.6406	41/64	....
16.5	.6496	....	....
16.67	.6562	21/32	....
17.0	.6693	....	....
17.06	.6719	43/64	....
17.46	.6875	11/16	....
17.5	.6890	....	....
17.86	.7031	45/64	....
18.0	.7087	....	....
18.26	.7187	23/32	....
18.5	.7283	....	....
18.65	.7344	47/64	....
19.0	.7480	....	....
19.05	.7500	3/4	....
19.45	.7656	49/64	....
19.5	.7677	....	....
19.84	.7812	25/32	....
20.0	.7874	....	....
20.24	.7969	51/64	....
20.5	.8071	....	....
20.64	.8125	13/16	....
21.0	.8268	....	....
21.03	.8281	53/64	....
21.43	.8437	27/32	....
21.5	.8465	....	....
21.83	.8594	55/64	....
22.0	.8661	....	....
22.23	.8750	7/8	....
22.5	.8858	....	....
22.62	.8906	57/64	....
23.0	.9055	....	....
23.02	.9062	29/32	....
23.42	.9219	59/64	....
23.5	.9252	....	....
23.81	.9375	15/16	....
24.0	.9449	....	....
24.21	.9531	61/64	....
24.5	.9646	....	....
24.61	.9687	31/32	....
25.0	.9843	....	....
25.03	.9844	63/64	....
25.4	1.0000	1	....

Fig. 3.24, Drill siz es are given in number, fractional, and letter form. Notice that the 0.2500 decimal equivalent is the only size that has both a letter and a fractional form.

Since it is often difficult to tell the exact size of a given drill there are several commercially produced gauges available that simplify this task. (Figure 3.25)

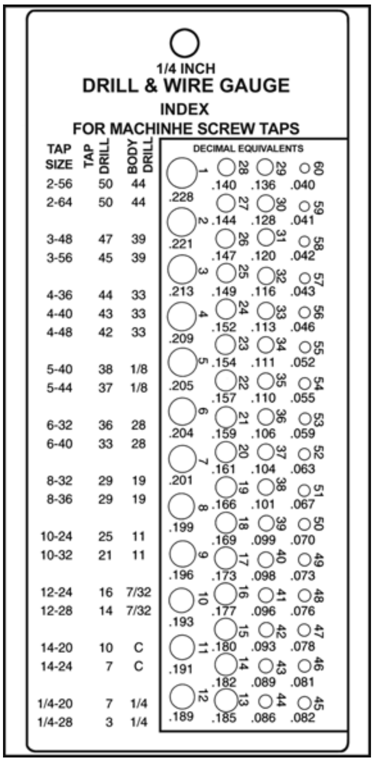


Fig. 3.25, Most drill gauges have holes in which you insert a drill in the appropriate hole. The gauge illustrated above also indicates tap sizes so you can drill the proper size hole for a tap.

Combined Drill & Counter Sunk

A combined drill and countersink (Fig. 3.26), more commonly referred to in the shop as a center drill, is used to produce both a short drilled hole and a countersunk hole in one operation. The angel on these drills is always a 60° included angle. It is used largely for drilling center holes in work to be turned between centers in the lathe and for starting holes in the correct location on a drilling machine.

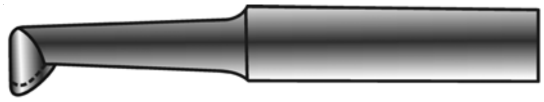
Fig. 3.26, Countersink and countersunk hole.

Fig. 3.27, Combined drill and countersink.

3.4 BORING

Boring illustrated in Fig. 3.28 is performed to enlarge a hole by means of an adjustable cutting tool with only one cutting edge. This is necessary where suitable sized drill is not available or where hole diameter is so large that it cannot be ordinarily drilled. The other reasons for performing the boring operations are :-

1. To finish a hole accurately and to bring it to the required size.
2. To machine the internal surface of a hole already produced in casting.
3. To correct out of roundness of the hole.
4. To correct the location of the hole as the boring tool follows an independent path with respect to the hole.



ROUGH BORING TOOL

FINISH BORING TOOL

SINGLE POINT SOLID BORING TOOLS

Fig. 3.28, Boring

3.4.1 Difference between Drilling, Reaming and Boaring

Drilling is the operation of producing a cylindrical hole by removing metal by the rotating edge of a cutting tool called the drill whereas Reaming is an accurate way of sizing and finishing a hole which has been previously drilled and Boring is the operation performed to enlarge a hole by means of an adjustable cutting tool with only one cutting edge.

■■■

CHAPTER : 4

METAL CUTTING AND CUTTING TOOLS

INTRODUCTION

In the metal-working industry workpieces of most different shapes and dimensions and of different materials are worked. The various working processes fall into two groups, the group of non-cutting shaping, e.g. forging, pressing, drawing, etc. These two groups may be sub-divided as shown in Fig. 4.1.

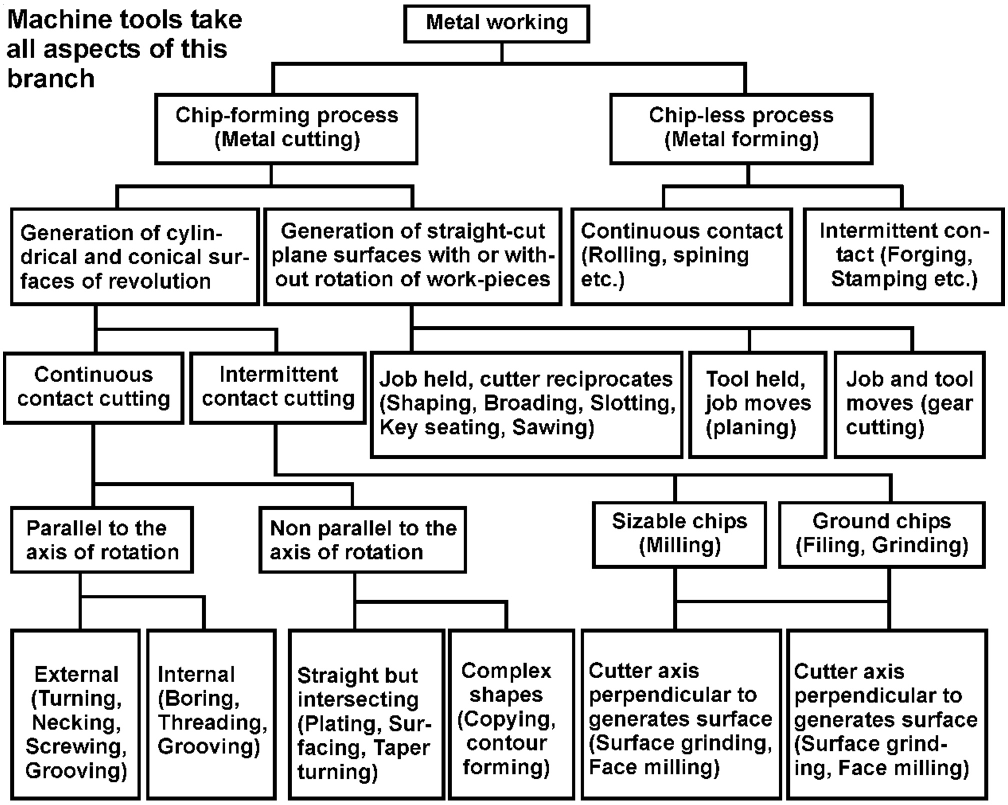


Fig. 4.1, Metal working process.

The process of metal cutting in which chip is formed is affected by a relative motion between the workpiece and the hard edge of a cutting tool held against the workpiece. Such relative motion is produced by a combination of rotary and translating movements either of the workpiece or of the cutting tool or of both. Depending on the nature of this relative motion, metal cutting processes are called by names example : turning, planing, boring etc. Nature of relative motion for various continuous cutting operation is listed in Table 4.1.

Table 4.1, Nature of Relative motion for Various Cutting operations

Operation	*Motion of job*	*Motion of cutting tool*
Turning	Rotar	Forward translation
Boaring	Forward translation	Rotation
Drilling	Fixed	Rotation as well as translatory feed
Planing	Translatory	Intermittent translation
Milling	Translatory	Rotation

4.1. TYPES OF CUTTING TOOLS

A cutting tool may be used either for cutting apart, as with a knife, or for removing chips. Parts are produced by removing metal mostly in the form of small chips.

Chip removal in the metal-cutting process may be performed either by cutting tools having distinct cutting edges or by abrasives used in grinding wheels, abrasive sticks, abrasive cloth, etc. These abrasives have a very large number of hard grains with sharp edges which remove metal from the workpiece surface in such operations as grinding.

All cutting tools can be divided into two groups. These are :

1. Single-point tools
2. Multi-point tools

Single-point cutting tools having a wedge-like action find, a wide application on lathes, and slotting machines. Multi-point cutting tools are merely two or more single-point tools arranged together as a unit. The milling cutter and broaching tool are good examples of this type.

The simplest form of cutting tool is the single-point tool. The cutting process as performed by multi-point tools closely resembles machining as performed by single-point tools. In this text the cutting action of a single-point tool is dealt with elaborately.

4.2. ORTHOGONAL AND OBLIQUE CUTTING

The two basic methods of metal cutting using a single-point tool are the orthogonal or two-dimensional, and the oblique or three-dimensional. Orthogonal cutting takes place when the cutting face of the tool is 90° to the line of action or path of the tool. If, however, the cutting face is inclined at an angle less than 90° to the path of the tool, the cutting action is known as oblique. Orthogonal and oblique cutting action are illustrated in Fig. 4.2, which shows two bars receiving identical cuts. The depth of cut is the same in both cases, and so is the feed, but the force which cuts or shears the metal acts on a larger area in the case of the oblique tool. The oblique tool will, thus, have a longer life as the heat developed per unit area sue to friction along the tool-workpiece interface is considerably small. Alternatively, the oblique tool will remove more metal in the same life as an orthogonal tool.

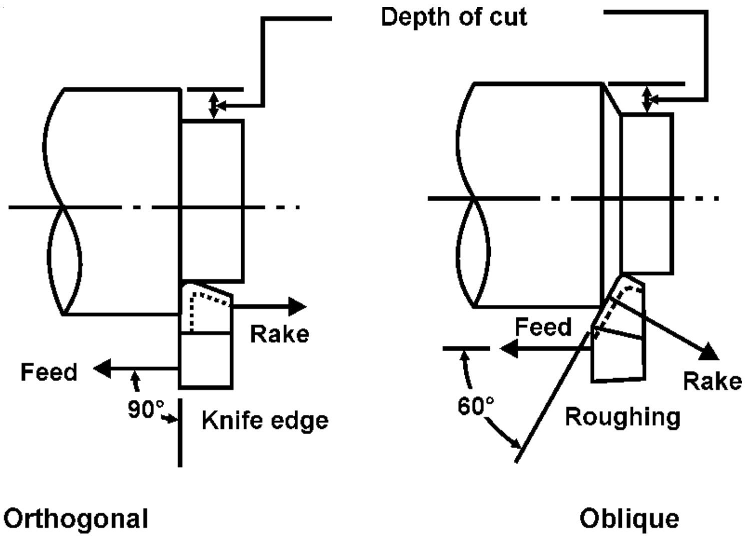


Fig. 4.2, Orthogonal and oblique cutting

Fig. 4.3. shows the chip flow in orthogonal and oblique cutting. In orthogonal cutting shown at (a) where the cutting edge of the tool OC is at right angles to the direction of the relative velocity V of the work, the chip coils in a tight, flat spiral. In oblique cutting as shown at (b) and at (c) where the cutting edge of the tool is inclined at the angle i , the chip flows sideways in a long curl. The inclination angle i is defined as the angle between the cutting edge and the normal to the direction of the velocity V of the work. An angle of interest in oblique cutting is the chip flow angle n_c , which is defined as the angle measured in the plane of the cutting face between the chip flow direction and the normal to the cutting edge. In orthogonal cutting, $i = 0$, $n_c = 0$.

Orthogonal cutting in the machine shop is confined mainly to such operations as knife turning, broaching and slotting, the bulk of machining being done by oblique cutting. But orthogonal cutting is the simplest type and is considered in the major part of this Chapter. The principles developed for orthogonal cutting apply generally to oblique cutting.

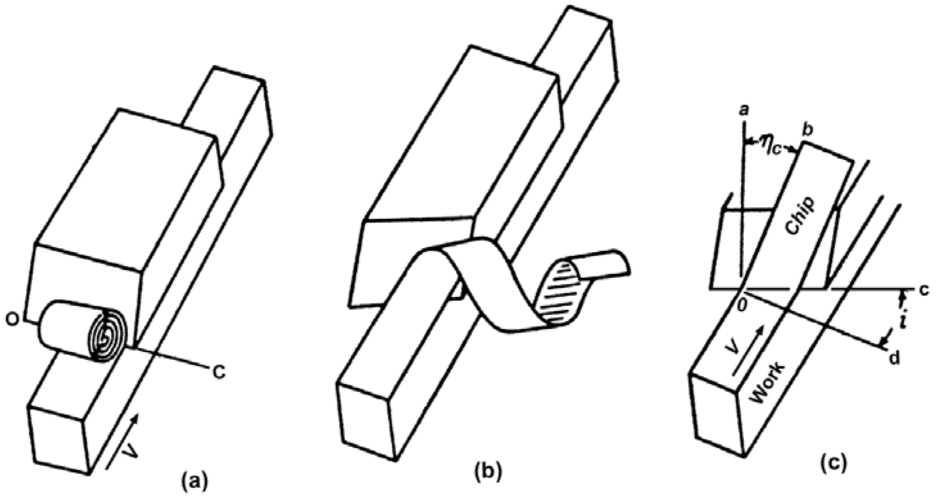


Fig. 4.3, Direction of chip flow in orthogonal and oblique cutting.

4.3 MECHANICS OF CUTTING AND CHIP FORMATION

In Fig. 4.4 the tool is considered stationary, and the workpiece moves to the right. The metal is severely compressed in the area in front of the cutting tool. This causes high temperature shear, and plastic flow if the metal is ductile. When the stress in the workpiece just ahead of the cutting tool reaches a value exceeding the ultimate strength of the metal, particles will shear to form a chip element which moves up along the face of the work. The outward or shearing movement of each successive element is arrested by work hardening and the movement transferred to the next element. The process is repetitive and a continuous chip is formed having a highly compressed and burnished underside, and a minutely serrated top side caused by the shearing action. The place along which the element shears is called the shear plane. Thus the chip is formed by plastic deformation of the grain structure of the metal along the shear plane as shown in Fig. 4.4.

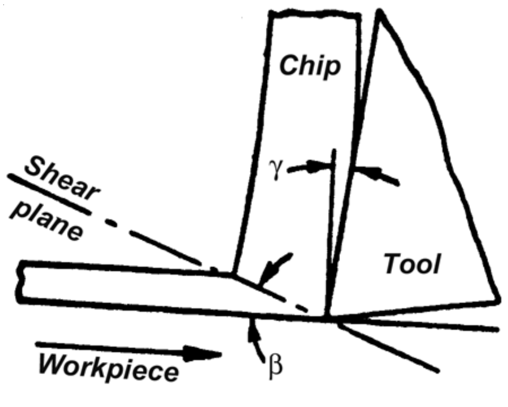


Fig. 4.4, Shear plane in metal cutting.

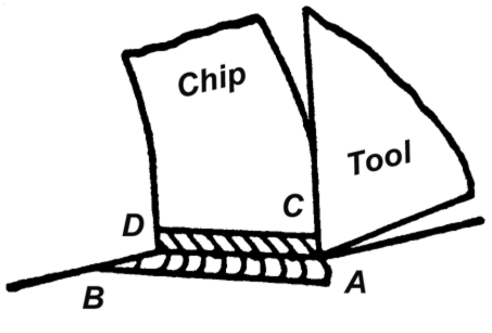


Fig. 4.5, Shear zone during metal cutting.

Actually, the deformation does not occur sharply across the shear plane, but rather it occurs along a narrow band. The structure begins elongating along the line AB below the shear plane and continue to do so until it is completely deformed along the line CD above the shear plane in Fig. 4.5. The region between the lower surface AB, where elongation of the grain structure begins, and the upper surface CD, where it is completed and the chip is born, is called the shear zone or primary deformation zone.

In Fig. 4.5 the shear zone is included between two parallel lines AB and CD. Actually, however, these two lines may not be parallel but may produce a wedge-shaped zone which is thicker near the tool face at the right than at the left. This is one of the causes of curling of chips in metal cutting. In addition, owing to the non-uniform distribution of forces at the chip-tool interface and on the shear plane the shear plane must be slightly curved concave downward. This also causes the chip to curl away from the cutting face of the tool.

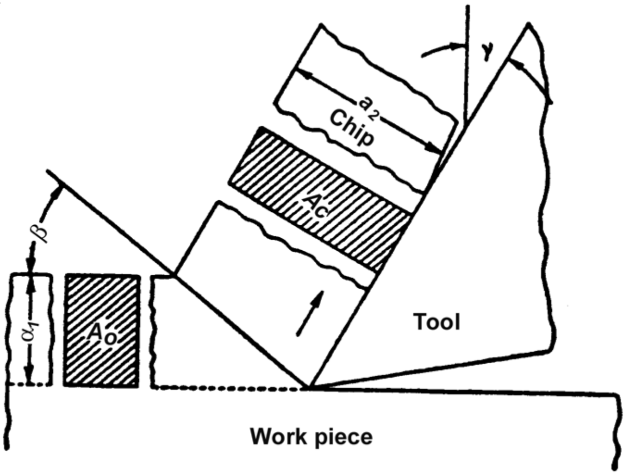


Fig. 4.6, Geometry of chip formation in orthogonal cutting.

4.4. TYPES OF CHIP

The form and dimension of a chip in metal machining indicate the nature and quality of a particular machining process, but the type of chip formed is greatly influenced by the properties of the material cut and various cutting conditions.

In engineering manufacture particularly in metal machining processes hard brittle metals have a very limited use, and ductile metals are mostly used. Chips of ductile metals are removed by varying proportions of tear, shear, and flow. This results in three general types or shapes (Fig. 4.7):

1. The discontinuous or segmental form
2. The continuous or ribbon type.
3. The continuous with built-up edge.

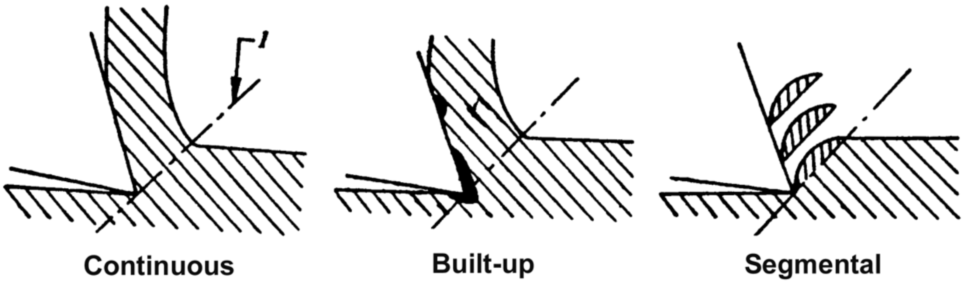


Fig. 4.7, Basic chip forms

Discontinuous or segmental chips consist of elements fractured into fairly small pieces ahead of the cutting tool. This type of chip is obtained in machining most brittle materials, such as cast iron and bronze. These materials rupture during plastic deformation, and form chips as separate small pieces. As these chips are produced, the cutting edge smoothes over the irregularities, and a fairly good finish is obtained. Tool life is also reasonably good, and the power consumptions low. Discontinuous chips can also be formed on some ductile metals only under certain conditions particularly at very low speeds and if the coefficient of friction is low. With ductile metals, however, the surface finish is bad and the tool life is short.

Conditions tending to promote its formation include : brittle metal, greater depth of cut, low cutting speed and small rake angle.

Continuous chips consist of elements bonded firmly together without being fractured. Under the best conditions the metal flows by means of plastic deformation, and gives a continuous ribbon of metal which, under the microscope, shows no signs of tears or discontinuities. The upper side of a continuous chip has small notches while the lower side, which slides over the tool face, is smooth and shiny. The continuous form is considered most desirable for low friction at the tool-chip interface, lower power consumption, long tool life and good surface finish.

Factor favourable to its formation are : ductile metal, such as mild steel, copper, etc., fine feed, high cutting speed, large rake angle, keen cutting edge, smooth tool face and an efficient lubrication system.

The term built-up edge implies the building up of a ridge of metal on the top surface of the tool and above the cutting edge. It appears that, when the cut is started in ductile metals, a pile of compressed and highly stressed metal forms at the extreme edge of the tool. Owing to the high het and pressure generated there, this piled up metal is welded to the cutting tip and forms a "false" cutting edge to the tool. This is usually referred to as the "built up edge". This weld metal is extremely strain hardened and brittle. So the weaker chip metal tears away from the weld as the chip moves along the tool face. The built-up becoming unstable, breaks down and some fragments leave with the chip as it passes off and the rest adheres to the work surface producing the characteristic rough surface. The built-up edge appears to be a rather permanent structure as long as the cut is continuous at relatively high speeds and has the effect of slightly altering the rake angle. At very high speeds, usually associated with sintered-carbide tools, the built-up edge is very small or nonexistent, and a smooth machined surface results.

Conditions tending to promote the formation of built-up edges include : low cutting speed, low rake angle, high feed, lack of cutting fluid and large depth of cut.

4.5 CHIP BREAKERS

A continuous-type chip from a long cut is usually quite troublesome. Such chips foul the tools, clutter up the machine and workplace, besides being extremely difficult to remove from the swarf tray. They should be broken into comparatively small pieces for ease of handling and to prevent it from becoming a work hazard., Hence chip breakers are used to reduce the swarf into small pieces as they are formed. The fact that the metal is already work-hardened helps the chip breaker to perform effectively. Various types of chip breakers are made, but all of them consist mainly of a step or groove ground into the leading edge of the tool or a piece of cutting-tool material clamped on top of the cutting-tool (see Fig. 4.8)

Fig. 4.8, Chip breakers

In normal shop practice common methods of breaking the chips are summarized as follows :
1. By clamping a piece of sheet metal in the path of the coil.
2. ***By a stepped type breaker*** in which a step is ground on the face of the tool along the cutting edge.
3. ***By a groove type breaker*** in which a small groove is ground behind the cutting edge.
4. ***By a clamp type breaker*** in which a thin-carbide plate or camp is brazed or screwed on the face of the tool.

Effective control of the chip, as it moves across the face of the tool, may also be achieved by proper selection of tool angle, feed, depth of cut and cutting fluids used. A large positive front rake gives rise to a looser chip formation, which flows down the face of the tool, and away from the workpiece, leaving the newly cut surface unscratched. A small positive or negative side rake has the effect of decreasing the radius at which the chip coils. Hence the tendency to produce short, easily managed chip. Slightly increased feed gives a thicker chip which breaks more quickly. A small depth of cut with a fine feed allows the chip to form into comparatively small pieces or direct it into the swarf tray. The use of a good stream of coolant that acts as a quenching medium causes the hot chip to become harder and break into small pieces.

4.6 CUTTING-TOOL NOMENCLATURE

Cutting-tool nomenclature means systematic naming of the various parts and angles of a cutting-tool. The surfaces on the point of a tool bear definite relationship to each other that are defined by angles. The principles underlying cutting-tool angles are the same whether the tool is a single-point tool, a multipoint tool, or a grinding wheel. Since a single-point tool is the easiest to understand, it will be discussed in greater detail. The basic angles needed on a single-point tool may be best understood by removing the unwanted surface form an oblong tool blank of square section. However, the complete nomenclature of the various parts of a single-point tool is shown in Fig. 4.9. These are : shank, face, flank, heel, nose, base, back rake, side rake, side clearance, end cutting edge, wide cutting edge, and lip angle. These elements define the shape of a tool.

The Shank is that portion of the tool bit which is not ground to form cutting edges and is rectangular in cross-section.

The face of the cutting-tool is that surface against which the chip slides upward.

The flank of a cutting-tool is that surface which face the workpiece.

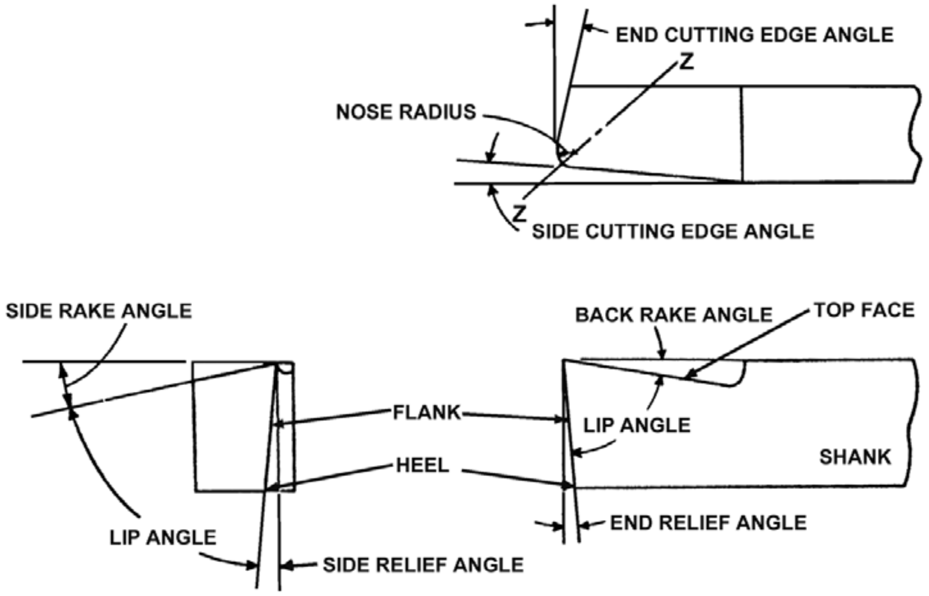


Fig. 4.9, Tool nomenclature and tool angles.

The heel of a single point tool is the lowest portion of the side-cutting edges.

The nose of a tool is the conjunction of the side- and end-cutting edges. A nose radius increases the tool life and improves surface finish.

The base of a tool is the under-side of the shank.

The rake is the slope of the top away from the cutting edge. The larger the rake angle, the larger the shear angle and subsequently the cutting force and power reduce. A large rake angle is conducive to good surface finish. Each tool has a side and back rake. Back rake indicates that the plane which forms the face or top of a tool has been ground back at an angle sloping from the nose. Side rake indicates that the plane that form the face or top of a tool has been ground back at an angle sloping from the side cutting edge. Side rake is more important than back rake for turning operations.

The side clearance or side relief indicates that the plane that forms the flank or side of a tool has been ground back at an angle sloping down form the side cutting edge. Likewise, the end clearance or end relief indicates that the nose or end of a tool has been ground back at an angle sloping down from the end cutting edge.

The end cutting edge angle indicates that the plane which forms the end of a tool has been ground back at an angle sloping form the nose to the side of the shank, whereas the side cutting edge angle indicates that the plane which forms the flank or side for a tool has been ground back at an angle to the side of the shank. In the main, chips are removed by this cutting edge.

The lip or cutting angle is the included angle when the tool has been ground wedged-shaped.

Multipoint Tools

Cutters like twist drills, reamers, taps, milling cutters have two or more tool points each. They differ in overall appearance and purposes, but each cutting blade acts as and has the basic features of a single-point tool. The milling cutter, and drill like a single point tool, have various angles of importance. A milling cutter has clearance ; it often has both a secondary and a primary clearance. A land also exists on a milling cutter and a drill. This is the narrow surface resulting from providing a primary clearance. A land also exists on a milling cutter and a drill. This is the narrow surface resulting from providing a primary clearance. They may have different rakes depending on the intended use. These kinds of tools have been described in more detail in connection with these machines in later chapters.

4.7. CUTTING SPEEDS AND FEEDS

The cutting speed of a cutting tool may be defined as the speed at which the cutting edge passes over the material. Cutting speed is ordinarily expressed in metre per minute, often referred to a surface speed in meter per minute.

The feed of a cutting tool is the distance the tool advances into or along the workpiece each time the tool point passes a certain position in its travel over the surface. In the case of turning on a lathe, the feed is the distance that the tool advances in one revolution of the workpiece. On a shaper, the feed is the distance the work is moved relative to the tool for each cutting stroke. For single-points tools, feed is specified in millimeters per revolution, millimeters per stroke, etc. it also may be expressed as millimeters per tooth for milling cutters and broaches.

Since so many factors are required to be considered, it is difficult to state definitely what the speed and feeds for a given material should be. In general, the speed and feed are determined by the following factors :

1. Kind of a material being cut : The harder the material, the more force required to remove the chip and the more rapid the wear on the tool. For this reason, hard materials are to be machined at lower cutting speeds and smaller feeds than soft materials.

2. Kind of material and life of the tool : An increase in cutting speed will result in more intensive heat generation, consequently, more heat resistant tool materials should be used when machining at high cutting speeds. Carbon steel tools can take about one half the cutting speed of a high-speed steel tool. Stellite and carbide and carbide tools will stand still greater speeds. These heat resistant ools ma be used under heavier feeds than other tool materials.

3. Shape (angles) and dimension of the cutting elements : A change in the chief angles of the tool will correspondingly change the forces due to the cutting action, as well as the conditions for heat transmission through the cutting elements of the tool. The heavier the cutting elements, the easier the heat will flow to the body of the tool. Therefore, tool wear will vary for various shapes and dimensions of the cutting elements and even of the body of the tool. Forming tools, taps, and other tools that are expensive and difficult to sharpen should be operated at speeds and feeds that insure long life.

4. Size of Chip Cross-section : The size of chip cross-section affects the forces due to cutting and, consequently the amount of heat generated. Tool wear is more rapid with an increase in cutting speed than with an increase in chip cross-section. For this reason, an increase in production capacity at a given tool life can be provided by increasing the cross-section of the chip removed and not the cutting speed. In such cases, the cross-section of the chip should be increased by increasing the depth of cut and not the feed.

5. Types of finish desired : In general, high cutting speeds and fine feeds give the best finish.

6. Rigidity of the machine : No work should be done at speeds and feeds that cause vibration in the machine.

7. Types of coolant used : Cooling with cutting fluids is not only for carrying away the heat generated, but also because of the lubricating affect of the fluid on the working surface of the tool. When a cutting fluid is used in machining tough material, the productivity may be increased from 15 to 30 % and more in comparison with dry operation. So higher cutting speeds and larger feeds may be given using a suitable cutting fluid.

4.8. TOOL LIFE AND WEAR

The tool life is an important factor in a cutting tool performance since considerable time is lost whenever tool is ground and re-set.

A tool cannot cut for an unlimited period of time. It has its definite life. If a cutting tool is to have a long life it is essential that the face of the tool be as smooth as possible. Tool life is the time a tool will operate satisfactorily until it is dulled. A blunt tool causes chatter in machining, poor surface finish, increase in cutting forces and power consumption, overheating of the tool.

Tool Failure

The failure of cutting tools may be the result of :

1. Wear on the flank of the tool (Fig. 4.10) : Flank Wear is a flat portion worn behind the cutting edge which eliminates some clearance or relief. Flank wear takes place when machining brittle materials like C.I. or when feed is less than 0.15 mm/rev. The worn region at the flank is called the wear land. The wear land width is measured accurately with a Brinel microscope. Increased wear land means that frictional heat will cause excessive temperature of the tool at its cutting point; it will rapidly loose its hardness, and catastrophic failure of the tool will be imminent. In the meantime, the burnishing action of the tool at its wear land will mean poor surface finish on the workpiece.

A quantitative term setting the limit of the permissible value of wear is known as "criterion of wear". The criterion of wear for different tool materials is given below in Table 4.2.

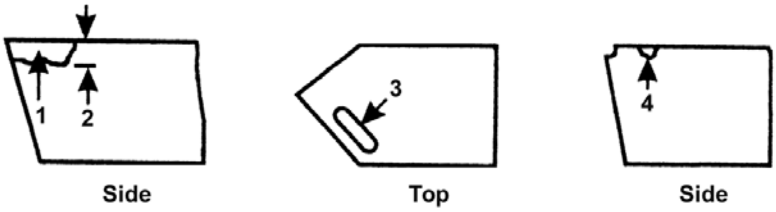


Fig. 4.10, Common types of tool failure.

2. Wear at the tool-chip interface occurs in the form of a depression or crater (Fig. 4.10). This is caused by the pressure of the chip as it slides up the face of the cutting tool. Both flank and crater wear take place when feed is greater than 0.15 mm/rev at low or moderate speeds. Actually a limited amount of cratering or depression improve the cutting action. But as the crater is further enlarged, some material which supports the cutting edge is removed. This eventually will cause the cutting edge to be weakened so that it will break. This type of failure occurs when high speed steel, stellite, or sintered-carbide tools turn ductile metals.

Table 4.2, Criterion of Wear in Cutting Tools

Tool Material	*Job Material*	*Cutting Condition*	*Predominant Wear*	*Criterion of wear*
h.s.s.	C.I.	Semi-rough	flank	1.5 to 2 mm
h.s.s.	Steel	Semi-rough	flank	0.6 to 1.0 mm
Cemented carbide	Steel	S > 0.3 mm	flank	1.4 to 1.7 mm
Cemented carbide	C.I.	S < 0.3 mm	flank	0.8 mm to 1.0 mm
Ceramic tool	C.I., Steel	_	flank	0.6 mm

3. A combination of flank wear and cratering.

4. The spalling or crumbling of the cutting edge (Fig. 4.10) as when cutting extremely hard material. A cutting tool that has improperly ground relief angles will either rub on the material or be weak because of excessive clearance angles. If the cutting edges are not well supported, they will be subject to cracking and spalling. The proper setting of the tool is, therefore, an important consideration.

Other factors that cause the tool to chip or spall are excessive chip loads, intermittent heating and cooling, and interrupted cutting. Excessive chip loads are cased by too fast a feed or too deep a cut. Intermittent heating and cooling result because the cutting fluid is not able to cover the cutting point constantly, and because the tool keeps entering and leaving the material. Interrupted cutting is caused by a tool entering and leaving the work as in milling or planing. Hard grades of carbide are likely to chip under these conditions.

5. The loss of hardness because of excessive heat but under cutting conditions when the temperature and stresses are high, plastic deformation may cause loss of "form stability", i.e. cutting ability of the tool. Various tool materials can withstand various heating temperatures (critical temperatures) before they lose the required hardness - 200° to 250°C for carbon tool steels, 560°C for high-speed steels and 800° to 1,000°C for cemented carbides.

6. Fracture by a process of mechanical breakage when the cutting force is very large or by developing fatigue cracks under chatter conditions.

Frequently in the formation of chips, high-frequency vibration occurs when the tool or work is not supported rigidly, because of the sliding of the chip elements into sections, because of the flank wear, or because of the periodic sloughing off of the built-up edge. These work, or even the whole machine, which is tun may cause a disagreeable noise called chatter.

Factors affecting tool life

The life of a tool is affected by many factors such as : cutting speed, feed, depth of cut, chip thickness tool geometry, material of the cutting fluid and rigidity of the machine. Physical and chemical properties of work materials influence tool life by affecting form stability and rate of wear of tools. The nose radius also tends to affect tool life. Researchers have identified a number of factors which are established by experimental verification. Some of them are briefly described in the subsequent paragraphs.

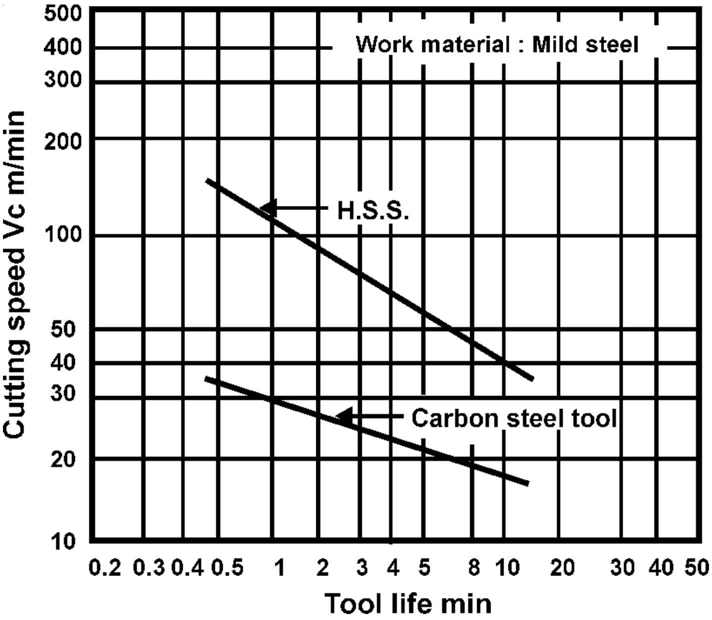


Fig. 4.11, Tool life vs cutting speed.

Cutting speed

Cutting speed has the greatest influence on tool life. As the cutting speed increases the temperature also rises. The heat is more concentrated on the tool than on the work and the hardness of the tool matrix changes so the relative increase in the hardness of the work accelerates the abrasive action. The criterion of wear is dependent on cutting speed because the predominant wear may be wear for flank or crater if cutting speed is increased. It has been found that at cutting speeds greater than 100 m per min in carbide turning of steel, crater wear may become predominant.

The relation of the cutting speed to the tool life is expressed by the formula :

$$VT^n = C$$

where, V = Cutting speed in m per min
T = tool life in minutes
n = exponent which depends on the tool and the workpiece. The value of exponent n is about 0.1 for high-speed steel tool, 0.20 to 0.25 for carbide tools, and 0.4 to 0.55 fro ceramic tools.
C = constant which is numerically equal to cutting speed that gives a tool life of one minute.

A typical V vs. T relationship is shown in fig. 4.11 which indicates that as cutting speed increases, tool life decreases. Obviously, if a very low cutting speed is used, the tool will last a long life. In case of carbide tools very low cutting speed, usually below 30 m per min, may reduce tool life. However, an intricate cutting tool that is difficult to sharpen should be run at a low speed so that it does not have to be sharpened again.

Feed and depth of cut

The tool life is influenced by the feed rate also. With a fine feed the area of chip passing over the tool face is greater than that of a coarse feed for a given volume of swarf removal, but to offset this chip will be greater. Hence the resultant pressure will nullify the advantage; it is, however, possible to balance the two opposing influences to obtain an optimum feed rate.

The effect of feed and depth of cut on tool life is given by :

$$V = \frac{257}{T^{0.19} \times s^{0.36} \times t^{0.08}} \, m \ per \ min$$

where, s = feed in mm per min,
and t = depth of cut in mm

Another relation between cutting speed for a given tool life, depth of cut and feed is given by :

$$V_t = \frac{C_v}{t^x . s^y} \text{ m per min.}$$

where, V_t = cutting speed for a given tool life in m per min,

C_v= a coefficient depending upon machine and workpieces variables,

x, y = exponents which depend on the mechanical properties of the material being machined.

The above relation shows that for a constant tool life cutting speed decreases with the increase of feed and depth of cut.

Tool Geometry

The tool life is also affected by tool geometry. A tool with large rake angle becomes weak as a large rake reduces the tool cross-section and the amount of metal to absorb the heat. It is -5° and +10° for turning austenitic steel by a carbide tool. The nose radius tends to improve tool life and is evident from the relation :

$$VT^{0.0927} = 331\,R^{0.244}$$

where R = nose radius of h.s.s. tool. But the size of the radius is limited by vibration. The effect of clearance is to improve tool life at first and then tool life decreases because of decreased strength. The optimum clearance is between 10° to 15°. Side cutting edge angle (ϕ_s) may improve tool life under non-chatter conditions :

$$VT^{0.11} = 78\left(\phi_s + 15°\right)^{0.264}$$

where ϕ_s = side cutting edge angle of h.s.s. tool cutting steel. With cemented carbide, side cutting edge angle varies between 3° to 25°. The effect of end cutting edge angle is to improve surface finish, rigidity and equivalent speed. The optimum end cutting edge angle is 4° to 10°. Similarly, the clearance is seen to be optimum for 12° to 15°.

Tool material

The effect of tool material on tool life is shown in Fig. 4.12 which indicates that higher cutting speed is not the only criteria considered for removing large volume of metal. What is most desirable is the high rate at which the stock will be removed per cutting edge or tool-life. An ideal tool would remove the same amount of metal per cutting edge at any speed.

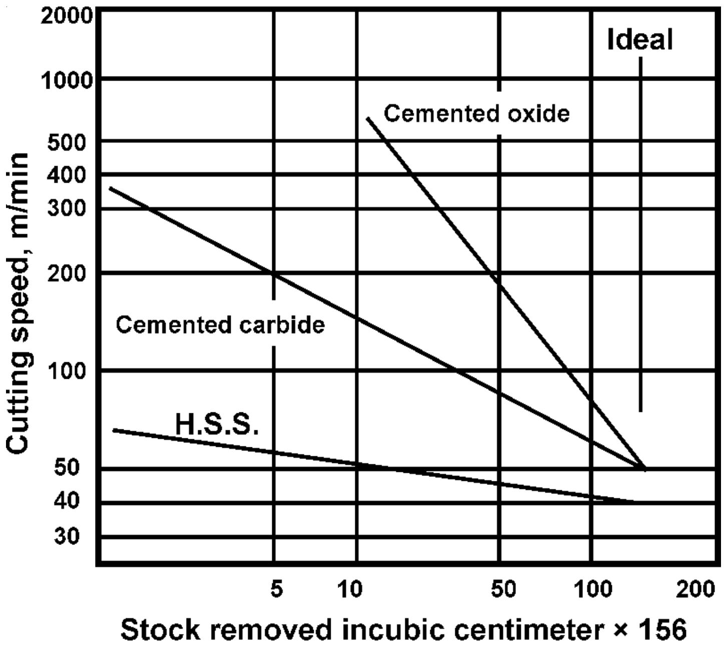


Fig. 4.12, Stock removed vs cutting speed.

Physical and chemical properties of work materials influence tool-life by affecting form stability and rate of wear of tool.

Cutting fluid

Cutting fluids affect tool-life to a great extent. A cutting fluid does not only carry away the heat generated and keep the tool, chip and workpiece cool, but reduces the coefficient of friction at the chip-tool interface and increases tool-life.

Measuring tool-life

Tool-life is the time elapsed between two successive grinding of a cutting tool. Tool-life may be measured in the following ways :

1. Number of pieces machined between tool sharpenings.
2. Time of actual operation viz., the time the tool is in contact with the job.
3. Total time of operation.
4. Equivalent cutting speed.
5. Volume of material removed between tool sharpenings.

In practice it is more profitable to assess the tool-life in terms of the volume of metal removed because the wear is related to the area of the chip passing over the tool surface. The volume of metal removed from the workpiece between tool sharpenings for a definite depth of cut, feed, and cutting speed can be determined as follows :

Notation :

t = depth of cut in mm
S = feed in mm per rev
d = diameter of the workpiece in mm
V = cutting speed in m per min
T = time to tool failure in min
n = revolution per min of the workpiece
L = tool-life in terms of metal removed until tool fails in mm^3.

Cross sectional area of chip = ts mm^2
Length of chip in one revolution = πd mm
$\therefore$ Volume of metal removed / rev = π dts mm^3
Volume of metal removed / min = π dtsn mm^3/min
Volume of metal removed until tool fails = π dtsn T mm^3

$$\therefore \quad L = \pi\, dtsn\, T$$

$$V = \frac{\pi dn}{1{,}000} \text{ m/min}$$

$$\therefore \quad \text{Too-life, L} = 1{,}000 \text{ ts VT mm}^3 / \text{min}$$

4.9. CUTTING TOOL-MATERIALS

Characteristic :

The characteristics of the ideal material are :

1. ***Hot hardness :*** The material must remain harder than the work material at elevated operating temperatures.
2. ***Wear resistance :*** The material must withstand excessive wear even though the relative hardness of the tool-work materials changes.
3. ***Toughness :*** The term 'toughness' actually implies a combination of strength and ductility. The material must have sufficient toughness to withstand shocks and vibrations and to prevent breakage.
4. ***Cost and easiness in fabrication :*** the cost and easiness of fabrication should have within reasonable limits.

Type of Tool Materials

The selection of proper tool material depends on the type of service to which the tool will be subjected. No material is superior in all respects, but rather each has certain characteristics which limits its field of application.

The principal cutting materials are :

1. Carbon steels
2. Medium alloy steels
3. High-speed steels
4. Stellites
5. Cemented Carbides
6. Ceramics
7. Diamonds
8. Abrasives

1. Carbon Steels

Carbon steels contain carbon in amounts ranging from 0.08 to 1.5 per cent. A disadvantage of carbon tool steels is their comparatively low-heat and wear-resistance. They lose their required hardness at temperatures from 200° to 250°C. Therefore, they may only be used in the manufacture of tools operating at low cutting speeds (about 12 m/min) and of hand operated tools. But they are comparatively cheap, easy to forge, and simple to harden.

2. Medium alloy steels

The high carbon medium alloy steels have a carbon content akin to plain carbon steels, but in addition there is, say, up to 5 per cent alloy content consisting of tungsten, molybdenum, chromium and vanadium. Small additions of one or more of these elements improve the performance of the carbon steels in respect of hot hardness, wear resistance, shock and impact resistance and resistance to distortion during heat treatment. The alloy carbon steels, therefore, broadly occupy a midway performance position between plain carbon and high speed steels. They lose their required hardness at temperatures from 250° to 350°C.

These tool steels are of two types ;

1. Type - O tool steels,
2. Type - A tool steels.

Type - O tool steels are oil quenched for hardening. It has C - 0.90%, Mn- 1.00%, W - 0.5% and Cr - 0.5%. Punching dies are generally manufactured from this steel.

Type - A tool steels are hardened by slow cooling in a current of air after heating it to a high temperature (1100°C to 1300°C). The composition of this type of steel is C - 1.0%, Cr - 5%,. It is mainly used to manufacture thread rolling dies, coining dies and gauges.

3. High-speed steels

High-speed steel (h.s.s.) is the general purpose metal for low and medium cutting speeds owing to its superior hot hardness and resistance to wear. High-speed steels operate at cutting speeds 2 to 3 times higher than for carbon steels and retain their hardness up to about 900°C. It is used as a popular operations of drilling, tapping, hobbing, milling, turning etc. There are three general types of high-speed steels; high tungsten, high molybdenum, and high cobalt. Tungsten in h.s.s. provides hot hardness and form stability, molybdenum or vanadium maintains keenness of the cutting edge, while addition of cobalt improves hot hardness and makes the cutting tool more wear resistant. Three general types of high-speed steels are as follows :

a. 18-4-1 high speed steels (T-series) : This steel containing 18 per cent tungsten, 4 per cent chromium and 1 per cent vanadium, is considered to be one of the best of all purpose tool steels. In some steels of similar composition the percentage of vanadium is slightly increased to obtain better results in heavy-duty work.

b. Molybdenum high -speed-steel (M-series) : This steel containing 6 per cent molybdenum, 6 per cent tungsten, 4 per cent chromium and 2 per cent vanadium have excellent toughness and cutting ability.

   There are other molybdenum high speed steels now marketed, having various tungsten-molybdenum ratios, with or without cobalt, or with variations in percentages of the minor alloys chromium and vanadium.

c. Cobalt high-speed steels : This is sometimes called super high-speed steel. Cobalt is added from 2 to 15 per cent to increase hot hardness and wear resistance. One analysis of this steel contains 20 per cent tungsten, 4 per cent chromium, 2 per cent vanadium and 12 per cent cobalt.

Table 4.3 shows the compositions of selected types of h.s.s.

Table 4.3, Compositions of H.S.S.

Designation	*Percentages of contributions*					
	C	*W*	*Mo*	*Cr*	*V*	*Co*
T - 1	**0.75**	**18.00**	**–**	**4.00**	**1.00**	**–**
T - 2	**0.85**	**18.00**	**–**	**4.00**	**2.00**	**–**
T - 5	**0.80**	**18.00**	**–**	**4.25**	**2.00**	**8.00**
T - 15	**1.50**	**12.00**	**–**	**4.50**	**5.00**	**5.00**
M - 1	**0.80**	**1.75**	**8.50**	**3.75**	**1.20**	**–**
M - 2	**0.85**	**6.00**	**5.00**	**4.00**	**2.00**	**–**
M - 10	**0.90**	**–**	**8.00**	**4.00**	**2.00**	**–**
M - 45	**1.25**	**8.25**	**5.00**	**4.25**	**1.60**	**5.50**

4. Stellites

Stellite is the trade name of a nonferrous cast alloy composed of cobalt, chromium and tungsten. The range of elements in these alloys in 40 to 48 per cent cobalt, 30 to 35 per cent chromium, and 12 to 19 per cent tungsten. In addition to one or more carbide forming elements, carbon is added in amounts of 1.8 to 2.5 per cent. They can not be forged to shape, but may be deposited directly on the tool shank in an oxy-acetylene flame, alternately, small tips of cast stellite can be brazed into place. Stellites preserve hardness up to 1000°C and can be operated on steel at cutting speeds 2 times higher than for high-speed steel. These materials are not widely used for metal cutting since they are very brittle, however, they are used extensively in some non-metal cutting application, such as in rubbers, plastics, where the loads are gradually applies and the support is firm and where wear and abrasion are problems.

5. Cemented carbides

Cemented carbides are so named because they are composed principally of carbon mixed with other elements. The basic ingredient of most cemented carbides is tungsten carbide which is extremely hard. Pure tungsten powder is mixed under high heat, at about 1500°C, with pure carbon (lamp black) in the ratio of 94 per cent and 6 per cent by weight. The new compound, tungsten carbide, is then mixed with cobalt until the mass is entirely homogeneous. This homogenous mass is pressed, at pressures from 1,000 to 4,200 kg/cm^2, into suitable blocks and the heated in hydrogen. Boron, titanium and tantalum are also used to form carbides. The amount of cobalt used will regulate the toughness of the tool. A typical analysis of a carbide suitable for steel machining is 82 per cent tungsten carbide, 10 per cent titanium carbide and 8 per cent cobalt.

Carbide tools are made by brazing or silver-soldering the formed inserts on the ends of commercial steel holders. The most important properties of cemented carbides are their very high heat and wear resistance. Cemented carbide tipped tools can machine metals even when their cutting elements are heated to a temperature of 1,000°C. They can withstand cutting speed 6 per cent or more than 6 times higher manufactured material and has extremely high compressive strength. However, it is very brittle, has low resistance to shock, and must be very rigidly supported to prevent cracking.

The two types of cemented carbides are the tungsten and titanium tungsten varieties. The tungsten-type cemented carbides are less brittle than the titanium-tungsten type ; they contain 92 to 98 per cent tungsten carbide and from 2 to 8 per cent cobalt. These cemented carbides are designed chiefly for machining brittle metals such as cast iron, bronze, but they may also be used for non-ferrous metals and alloys, steel, etc. The titanium-tungsten type are more wear-resistant. They contain 66 to 85 per cent tungsten carbide, 5 to 30 per cent titanium carbide and 4 to 10 per cent cobalt. These cemented carbides are designed for machining tougher materials chiefly for various steels.

6. Ceramics

The latest development in the metal-cutting tools uses aluminium oxide generally referred to as ceramics. Ceramics tools are made by composing aluminium oxide powder in a mould at about 280 kg/cm^2 or more. The part is then sintered at 2200°C. This is known as cold pressing. Hot pressed ceramics are more expensive owing to higher mould costs. Ceramic tool materials are made in the form of tips that are to be clamped on metal shanks. Other materials used to produce ceramic tools include sillicon carbide, born carbide, titanium carbide and titanium boride.

These tool have very low heat conductivity and extremely high compressive strength. But they are quite brittle and have a low bending strength. For this reason, these materials can not be used for tools operating in interrupted cuts, with vibrations as well as for removing a heavy chip. But they can withstand temperatures up to 1200°C and can be used at cutting speeds 4 times that of cemented carbides, and up to about 40 times that of high-speed cutting tools. They are chiefly used for single-point tools in semi-finish and finish turning of cast iron, plastics, and other work, but only when they are not subject to impact loads. To give them increased strength often ceramic with a metal bond, known as "cermets" is used. Because of the high compressive strength and brittleness the tips are given a 5 to 8° negative rake for carbon steel and zero rake for cast iron and for non-metallic materials to strengthen their cutting edge and are well supported by the tool holder. Heat conductivity of ceramics being very low the tools are generally used without a coolant.

7. Diamond

The diamonds used for cutting tools are industrial diamonds, which are naturally occurring diamonds containing flaws and therefore of no value as gemstones. Alternatively they can be also artificial. The diamond is the hardest known material and can be run at cutting speeds about 50 times greater than that for h.s.s. tool, and at temperatures up to 1650°C. In addition to its hardness the diamond is incompressible, is of a large grain structure, readily conducts heat, and has a low coefficient of friction. Diamonds are suitable for cutting very hard materials such as glass, plastics, ceramics and other abrasive materials and for producing fine finishes. The maximum depth of cut recommended is 0.125 mm with feeds of say, 0.05 mm.

8. Abrasive

Abrasive grains in various forms-loose, bonded into wheels and stone, and embedded in papers and clothes-find wide application in industry. They are mainly used for grinding harder materials and where a superior finish is desired on hardened or unhardened materials.

For most grinding operations there are two kinds of abrasives in general use, namely aluminium oxide (carborundum) and silicon carbide. The aluminium oxide abrasives are used for grinding all high tensile materials, whereas silicon carbide abrasives are more suitable for low tensile materials and non-ferrous metals.

9. Cubic boron nitride (CBN)

This material, consisting atoms of boron and nitrogen, is considered as the hardest tool material available next to diamond. It is having high hardness, high thermal conductivity and tensile strength. In certain application a thin layer (0.5 mm) of CBN is applied on cemented carbide tools to obtain better machining performance. It can also be made in terms of indexable inserts in standard from and size. This material is traded in the name of 'BOROZON'.

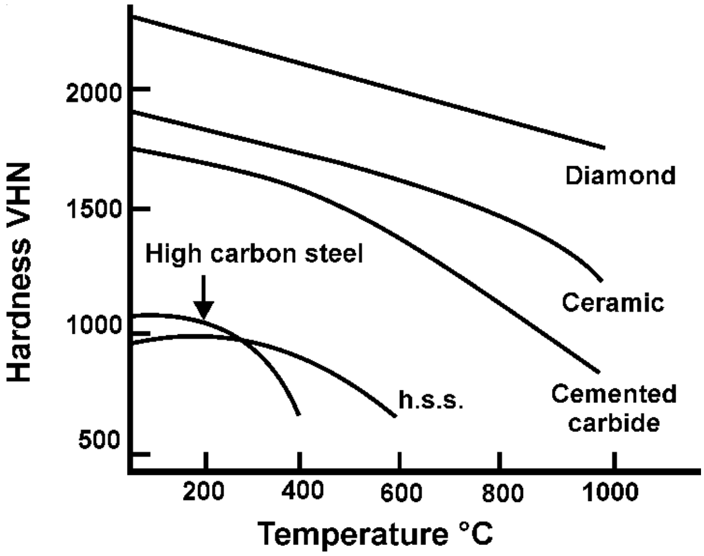


Fig. 4.13, Hardness profiles of cutting tool materials

The variations of hardness of a few of the tool materials with the temperatures are shown in fig. 4.13.

4.11. CUTTING FLUIDS

Cutting fluids, sometimes referred to as lubricants or coolants are liquids and gases applied to the tool and workpiece to assist in the cutting operations.

Purpose of Cutting Fluids

Cutting fluids are used for the following purposes :

1. ***To cool the tool :*** Cooling the tool is necessary to prevent metallurgical damage and to assist in decreasing friction at the tool-chip interface and at the tool-workpiece interface. Decreasing friction means less power required to machine, and more important, increased tool life and good surface finish. The cooling action of the fluid is by direct carrying away of the heat developed by the plastic deformation of the shear plane and that due to friction. Hence, a high specific heat and high heat-conductivity together with a high film-coefficient for heat transfer is necessary for a good coolant. For cooling ability, water is very effective, but is objectionable for corrosiveness and lack of friction reducing wear.
2. ***To cool the workpiece :*** The role of the cutting fluid in cooling the workpiece is to prevent its excessive thermal distortion.
3. ***To lubricate and reduce friction :-***
   a. The energy or power consumption in removing metal is reduced
   b. Abrasion or wear on the cutting tool is reduced thereby increasing the life of the tool;
   c. By virtue of lubrication, less heat is generated and the tool, therefore, operates at lower temperatures with the tendency to extend tool life; and
   d. Chips are helped out of the flutes of drills, taps, dies, saws, broaches, etc.

   An incidental improvement in the cutting operation is that the built-up edge will be reduced, which, in turn, will decrease friction at the tool-workpiece area and contribute toward a cooler tool. It is, therefore, evident that the proper choice of lubricant is important to give the optimum cooling effect and lubrication condition in metal cutting.

4. ***To improve surface finish.***
5. ***To protect the finished surface from corrosion.*** To protect the finished surface from corrosion, especially in cutting fluids made up of a high percentage of water, corrosion inhibitors are effective in the form of sodium nitrate or triethanolamine.
6. ***To cause chips break up into small parts*** rather than remain as long ribbons which are hot and sharp and difficult to remove from the workpiece.
7. ***To wash the chips away from the tool :*** This is particularly desirable to prevent fouling of the cutting tool with the workpiece.

Properties of Cutting Fluids

A cutting fluid should have the following properties :

1. High heat absorption for readily absorbing heat developed.
2. Good lubricating qualities to produce low-coefficient of friction.
3. High flash point so as to eliminate the hazard of fire.
4. Stability so as not to oxide in the air.
5. Neutral so as not to react chemically.
6. Odourless so as not to produce any bad smell even when heated.
7. Harmless to the skin of the operators.
8. Harmless to the bearings.
9. Non-corrosive to the work or the machine.
10. Transparency so that the cutting action of the tool may be observed.
11. Low viscosity to permit free flow of the liquid.
12. Low priced to minimized production cost.

Choice of cutting fluids

The choice of cutting fluid depends upon the following factors.

1. Type of operation.
2. The rate of metal removal.
3. Material of the workpiece.
4. Material of the tool.
5. Surface finish requirement.
6. Cost of cutting fluid.

Type of Cutting Fluids

The type of cutting fluid to be used depends upon the work material and the characteristic of the machining process. For some machining processes, a cutting fluid which is predominantly a lubricant is desirable. With other machining processes, a cutting fluid which is predominantly a coolant should be used. Cutting fluids are classified in seven main groups. These include water, soluble oils, straight oils, mixed oils, chemical additive oils (sulphurized and chlorinated), chemical compounds and solid lubricants.

1. Water

Water, wither plain or containing an alkali, salt or water-soluble additive but little or no oil or soap are sometimes used only as a coolant. But water alone is, in most cases, objectionable for its corrosiveness.

2. Soluble oils

Soluble oils are emulsions composed of around 80 per cent or move water, soap and mineral oil. The soap acts as an emulsifying agent which break the oil into minute particles to dispose them throughout water. The water increases the cooling effect, and the oil provides the best lubricating properties and ensures freedom from rust. By mixing various proportions of water with soluble oils and soaps, cutting fluids with a wide range of cooling and lubricating properties can be obtained.

3. Straight oils

The straight oils may be (a) straight mineral (petroleum) oils, kerosene, low-viscosity petroleum fractions, such as mineral seal, or higher-viscosity mineral oils, (b) straight fixed or fatty oils consisting animal, vegetable, or synthetic equivalent, lard oil, etc. They have both cooling and lubricating properties and are used in light machining operations.

4. Mixed oils

This is a combination of straight mineral and straight fatty oil. This blend makes an excellent lubricant and coolant for automatic-screw-machine work and other light machining operations where accuracy and good finish are of prime importance.

5. Chemical-additive oil

Straight oil or mixed oil when mixed up with sulphur or chlorine is known as chemical additive oil. Sulphur and chlorine are used to increase both the lubricating and cooling qualities of the various oils with which they are combined. Sulfurized mineral oils are commonly used for machining the tough, stringy, low-carbon steels. Chlorinated mineral oils are particularly effective in promoting anti-weld characteristics.

6. Chemical compounds

These compounds consist mainly of a rust inhibitor, such as sodium nitrate, mixed with a high percentage of water. Chemical compounds have grown in favour as coolants, particularly in grinding and on machined surface where formation of rust is to be avoided.

7. Solid lubricants

Stick waxes and bar soaps are sometimes used as a convenient means of applying lubrication to the cutting tool.

Table 4.3 shows different types of coolants and lubricants and lubricants used for different machining operations.

Theory of Cutting Fluid

The basic function of an effective cutting fluid is to reduce kinetic coefficient of friction, Dr. Merchant, one of the pioneers in the theory of metal cutting, has suggested a theory to explain the penetration of cutting fluid. It is assumed that minute capillaries exist at the tool-chip interface as shown in Fig. 4.14 on a submicroscopic scale. As the chip move up the tool face, it contacts mainly the tops of the asperities in the point contact zone creating capillaries between the chip and the tool. These capillaries draw in the cutting fluid which chemically reacts to produce a solid low-shear strength film. Under the condition of high pressure and temperature at the "nascent" chip surface the highly reactive chemical action produces relatively weak solid providing a "sandwich filling" to keep the chip and tool apart thereby reducing friction. It is well established that small change in tool temperature can produce considerable change in tool life. Cutting fluids directly control the amount of heat at the chip tool face and thereby increase tool life.

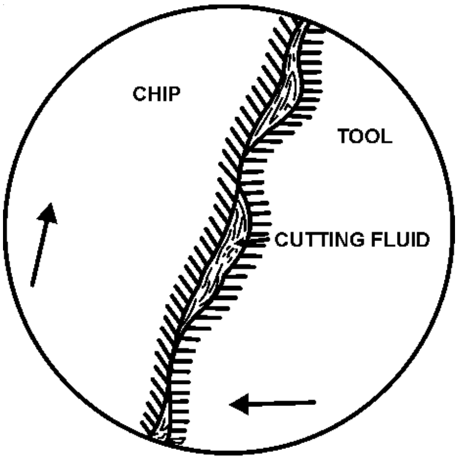


Fig. 4.14, Penetration of cutting fluid

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CHAPTER : 5
MACHINE SAWS

INTRODUCTION

Metal cutting by means of a hand hacksaw, though being a common and widely employed method, is not commercially sound as it involves a lot of labour and time. Also, its use is confined to small work only and that too where a small number of pieces are to be cut. The increasing demand of high production has led to the introduction of power driven metal cutting saws. It is more so for the reason that, except castings and forgings, which are very nearly finished to the required size and shape, most of the stock materials are received in standard sizes and shapes. It is obvious, therefore, that every stock materials is required to be cut to convenient length before being fed to the machine tool for further operation. No only in length, but quite often we may have to cut the bar stock in all directions to bring it roughly to the required shape. This will effect a lot of saving in further machining time. All these requirements and the economic considerations have made the power driven metal cutting saws almost indispensable in modern workshops. In this chapter we will discuss these machines in detail.

5.1. THE DIFFERENT TYPES OF METAL CUTTING SAWS ARE BROADLY CLASSIFIED AS :

1. Reciprocating saws (Power hacksaws)
2. Band-saws
3. Circular saws

1. Reciprocating Saw (Power Hacksaw)

This machine carries a reciprocating frame, in which is mounted the cutting blade. This blade is in the form of a steel strip, on one edge of which the teeth are cut. This blade moves forward and backwards with the frame. Cutting takes place in one direction only, the other stroke being idle.

2. Band-Saws

These machines carry an endless steel blade, having the teeth cut on its one edge. This blade passes over two large wheels, one at the top and the other at the bottom. As the wheels rotate, the blade also rotates along with them and, thus, provides a continuous cutting action. Also, it enables sawing along a premarked contour.

3. Circular Saw

This machine carries a disc type rotating blade which provides a continuous cutting action. These machines are of two types, one being the cold sawing machine and the other high speed abrasive disc machine.

5.2. THE POWER HACKSAW

The machine is designed and constructed to provide means for clamping the work and a reciprocating action to the saw blade by mechanical power. During the cutting stroke the blade bears down on the work, whereas in the idle stroke it is lifted up so as to be clear of the work. Since the cutting is not continuous, this machine cuts the metal at a comparatively slower rate than the other metal sawing machines. On the other hand, it carries an advantageous feature also in that several bars or flats, etc., of the stock material can be clamped at a time and cut simultaneously. Another advantage is that its operation does not need a continuous attention as the machine stops automatically as soon as the cut is over. With the result, a single operator can handle more than one machines at a time. Most of these machines are designed in draw-cut type, i.e., they cut during the backward stoke. Every machine carries a means to lift the blade during each idle stroke so that the blade is clear of the work and its teeth are prevented from being damaged due to dragging over the work. A hydraulic lifting mechanism is very common in all the modern power hacksaws.

5.3. DETAILS OF A POWER HACKSAW

The main parts and controls of 'COBRA' No. 9, power hacksaw machine, manufactured by M/s. The Mysore Kirloskar Ltd., Harihar (India), are shown in Fig. 5.1. In this machine, the cutting takes place during he backward stroke. It should, therefore, be ensured while fixing the blade that its teeth point in a backward direction. The forward stroke is an idle stroke and the frame is lifted up, to make the blade clear of the work, in this stroke by means of a hydraulic device. On the top of the frame is provided an adjustable weight, which can be adjusted to different positions to regulate the saw feed. When pipes or other thin sections are to be cut, the adjustable weight should be placed behind the moving centre of the frame to adjust the cutting force. It may, sometimes, be required to remove the weight totally from the machine frame when very light work is to be cut.

The machine carries a quick action vice. The movable jaw can be swivelled to 45° on either side to clamp material of different sizes and at desired inclination. Inside the main body of the machine is housed the coolant tank made in two parts. A sufficiently wide slot is made in the bed, through which the used coolant falls into the sump and the swarf is collected in a separated tray. A self-priming centrifugal type coolant pump is fitted to feed the coolant in sufficient quantity during the operation. Ample amount of coolant is always needed for efficient operation and longer life of the blade. Sometimes, however, when sawing is to be done dry or when hard metals are being sawn, which need the application of heavy cutting pressure, oil should be applied on the blade by means of an oil can.

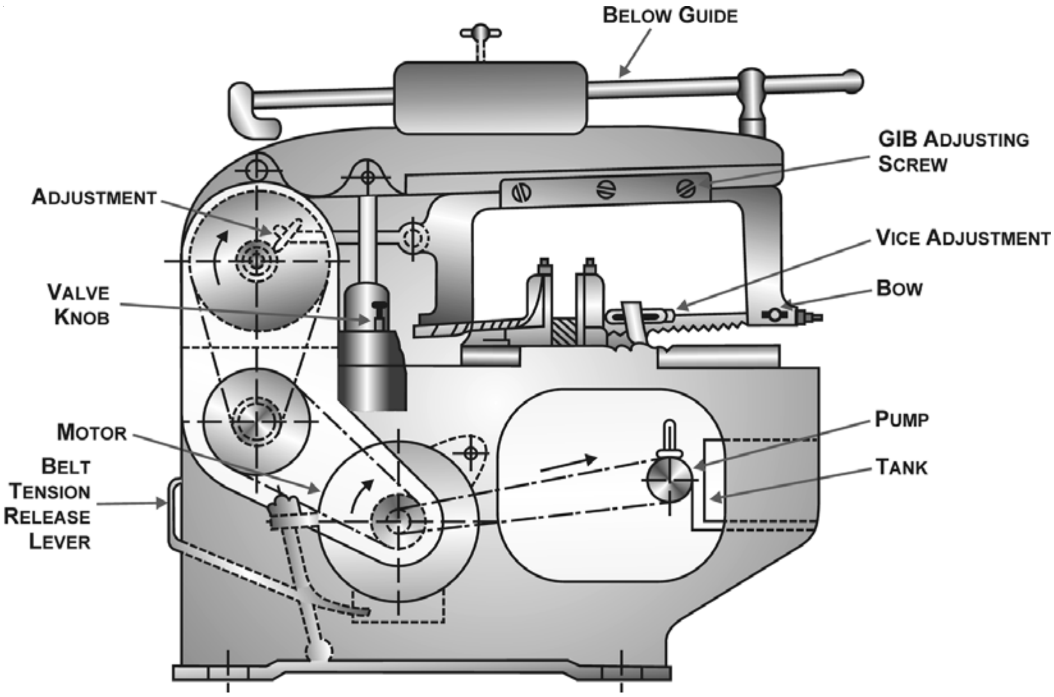


Fig. 5.1, A Power Hacksaw Machine.

The main driving motor is also housed in the body of the machine. It is suspended on a hinge by means of a spring to avoid noise and vibrations and maintain proper belt tension. The motor shaft carries a two step pulley, which is connected to the pulley on crankshaft by means of V-belts to transmit power to the latter. The pulley diameters enable two speeds of the saw frame, i.e., 75 and 110 strokes per minute. For automatic cut-off of the motor at the end of the cut a cam is fitted on the main shaft. This cam carries the cut-off switch which actuates a roller operated limit switch by pushing out the contactor. To restart the motor, use the push button which restores the whole circuit. Limit switch can also be used to adjust the depth of cut. Length of stroke can be adjusted by making necessary displacement of the crank pin centre towards or away from the centre of rotation of the crank.

5.4. HACKSAW BLADES

Hacksaw blades are made of thin strips of high carbon steel or high speed steel. They are made in two varieties, namely all hard and hard teeth with soft back. The latter class has a more flexible body than the former and the chances of breakage of the blade are less, whereas the former class cuts more speedily and has more life of teeth. The H.S.S. blades enable the application of higher cutting speeds and more depth of cut. The teeth of these blades are arranged for cutting in one direction only; usually in moving towards the machine, i.e., the pull stroke. Remember that the hand hacksaw blade cuts in the push stroke.

Setting of teeth

It is the term that denotes bending of alternate teeth of the saw blade in opposite directions. It is done to make the width at the cutting edges more than the actual thickness of the blade. The result is that the width of the slot produced is more than the blade thickness, so that the body of the blade is clear of the side walls of the slot as the cut proceeds and the teeth do not clog into the material. There are three common methods of setting :

1. Regular alternate

In this method, one tooth is bent to one side and the next one to the other side. This bending of teeth alternately in opposite directions continues for the whole length of the blade. This is a common method for most of the blades.

2. Double alternate

In this system, alternate pairs of teeth are bent in opposite directions instead of single alternate teeth. This method is commonly used in fine-teeth blades.

3. Alternate centre

In this style of setting, one tooth remains straight, the next bent to the right, the next bent to the left, followed by the next one as straight, and so on.

There is one more style of setting, known as wavy set. It is exclusively used in blades used for cutting very thin sheets and tubes. In this, the teeth are set exactly as regular alternate, but in addition to that the edge of the blade is also crimped right and left.

Number of teeth

The blades for power hacksaw machines are made in lengths from 30 cm to 60 cm and width from 25 mm to 32 mm. The thickness usually varies from 0.6 mm to 1.6 mm. The standard number of teeth per cm are approximately 1.5, 2.25, 3, 4, 5, 5.5 and 7.

Enough care should be taken in selecting adequate number of teeth for sawing a particular metal and to suit the section to be cut. Coarse teeth should be used for cutting mild steel, cast iron and bronze, medium teeth for annealed high carbon and high speed steel and fine teeth for solid brass, iron pipes and heavy tubes. Wavy set blades should be preferred for thin tubes and metal sheets.

There is no hard and fast rule or formula to decide the number of teeth in a blade suitable for sawing a particular section. As a general rule, for guidance, it is a common practice, while selecting blade, that the number of teeth selected should meet the following conditions :

1. Thin section - At least one tooth will always ride on the surface of the metal.
2. Thick section - Coarse pitch blade should be used in order to provide sufficient clearance for the chips.

The correct and wrong conditions of sawing and the results thereof are shown in Fig. 5.2, which should be carefully studied.

Blade length

The following table (No. 5.1) will serve a useful guide in selecting a proper blade length for a particular job.

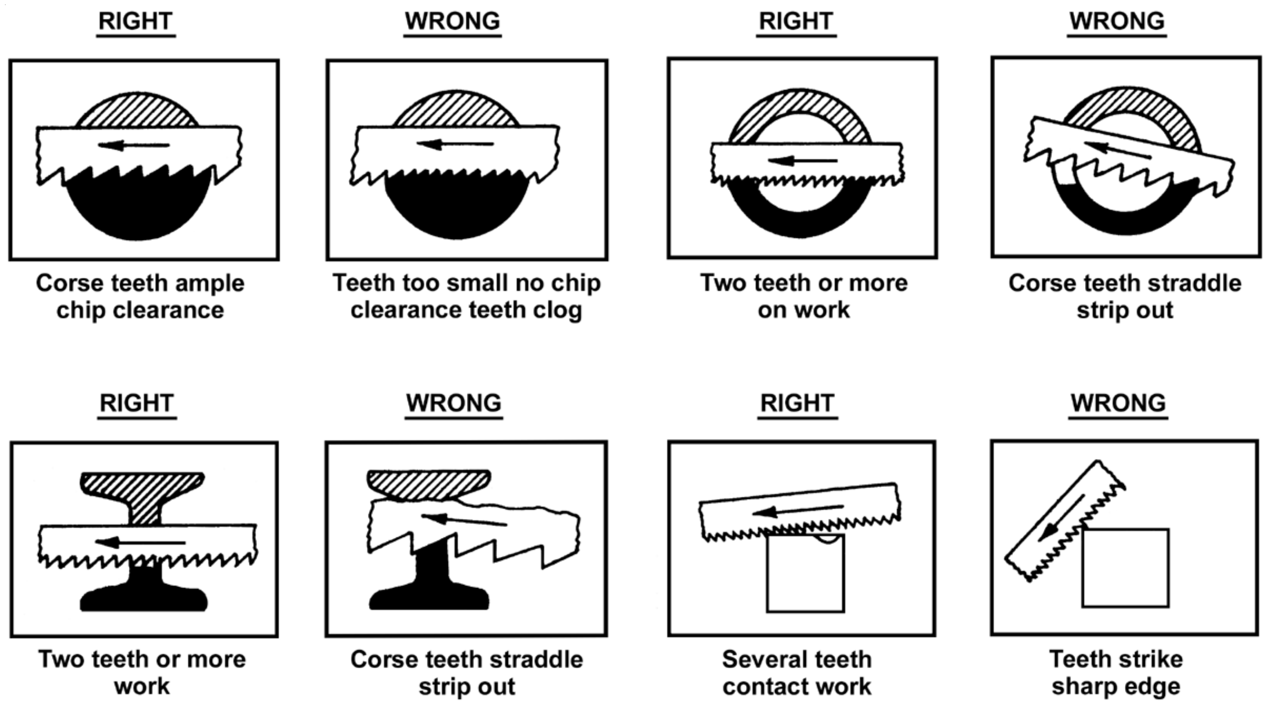


Fig. 5.2, Correct and wrong sawing conditions.

Table 5.1, Suitable blade lengths

Stock size	Suitable length of blade
up to 100 mm	300 mm
100 to 150 mm	350 mm
150 to 225 mm	425 mm
225 to 300 mm	525 mm
300 to 375 mm	600 mm

Blade specifications

To fully specify a power hacksaw blade the following details should be mentioned :

1. Length
2. Width
3. Thickness
4. Number of teeth per cm.

5.5. MACHINE SIZE AND SPECIFICATIONS

The size of a power hacksaw machine is usually designated by the maximum size of the bar stock (round or square or both) that it is capable to cut. Other details required to specify it fully are the following :

1. Maximum and minimum length of blade to be fixed
2. Maximum length of stroke of the blade
3. Number of strokes per minute, maximum and minimum
4. H.P. or kW of motor
5. Type of drive and lift.

5.6. BLADE FAILURES AND THEIR PREVENTION

The power hacksaw blade may be broken due to many reasons. The possible causes of blade failures and their remedies are given in Table 5.2. They need a careful study.

Table 5.2, Causes of blade failures and their remedies

	Causes	Remedies
1.	Blade teeth point in wrong direction	Put a new blade with its teeth pointing in correct direction, i.e., towards the crank
2.	Wrong blade chosen	Correct blade size and number of teeth should be selected to suit the type of material to be cut and the thikness of the section of the stock
3.	Work held loosely	The work should be properly clamped. Loose work will result in chatter and ultimately breakage of the blade.
4.	Improper tension in blade	The blade should neither be too tight nor too loose. Both will result in breakage of the blade
5.	Abrupt falling of blade on the job.	The frame should be lowered slowly and put gently over the job.
6.	Leaving the blade tight when the machine is not in operation	The blade tension should be released when the machine is to remain idle for a longer period.
7.	Using a new blade on an unfinished cut.	It is for the reason that a new blade is always thicker than the old one. So, in case of breakge in the middle of the cut another old blade should be used.
8.	Improper pressure on the job	Apply a medium pressure in the beginning, increase it to a maximum in the middle and reduce to a minimum in the end.
9.	Improper speed and feed used	Use a light feed and high speed for light sections and vice versa for thicker sections.
10.	Blade teeth worn out and setting becomes inadequate	Sharpen the worn out blade and set the teeth properly before further use.

5.7. HEAVY DUTY POWER HACKSAWS

They are also known as Production hacksaws. These are heavier in construction and are provided with some additional accessories. In production type heavy duty hacksaws, the work table is hydraulically operated. A number of rods, bars or other sections, which are to be cut, are grouped together and clamped. Then they are cut together to the required length in a single setting. An adjustable workstop is provided in the table and stock is fed each time to this top to set the desired length, avoiding the measurement and setting of this length every time. In these machines, most of the operations like moving the stacked stock to required length each time, clamping of stacked material, raising of saw frame after cutting is over, circulation of cutting fluid, etc., are hydraulically controlled.

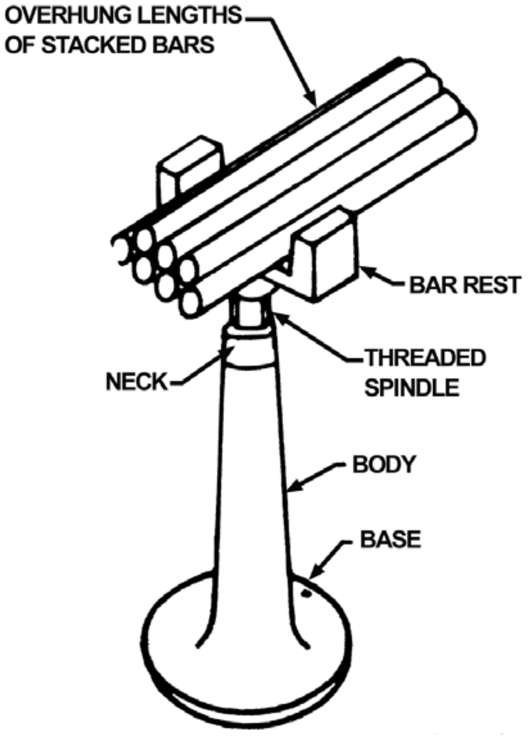


Fig. 5.3, A floor stand to support the overhanging bars.

The long and overhanging lengths of the stacked bars are supported in these machines over a floor stand of the type shown in Fig. 5.3. The stand consists of cast body, which carries internal threads inside its upper neck. This neck acts as a nut, inside which works a vertical screwed spindle. A bar rest is provided on the top of the screwed spindle. By rotating the screwed spindle, the height of the bar rest can be adjusted anywhere according to requirement. The stacked bar lengths are placed and supported over this bar rest.

5.8. THE VERTICAL BAND-SAW MACHINE

Band-saws are made in various different sizes. If proper tools are used, these saws, in addition to the metal cutting operation, can perform other operations also, viz., filing and polishing. The main parts, illustrated in Fig. 5.4, of a vertical band saw are the following :

1. Column

It is a heavy vertical cast iron structure, which is hollow from inside. Inside it is housed the coolant pump assembly and, sometimes, the electric motor. The motor may be fitted separately outside also. On the outside of it are fitted the starter and other controls. Its top part is made projecting outwards to accommodate the upper wheel. It is fitted with a cover on its one side, which is hinged to it to open or close according to the need. It is known as Head.

2. Bed

It is also a heavy cast iron structure and is generally cast integral with the column. It, in conjunction with the column, forms the main supporting member of the machine. It is also made hollow. Its one sidewall carries the bearing and the driving shaft, on which is mounted the lower wheel. The other sidewall carries a hinged cover, which can be opened and closed as and when desired. At its top, it carries the machine table.

3. Table

It is also made of cast iron and carries a long slot at its centre, through which passes the saw blade. The table may be of fixed type or tilting type, the latter being more useful. The tilting type of table is mounted on trunnions to enable its inclination to either side. It is this part of the machine on which the work is supported during the operation.

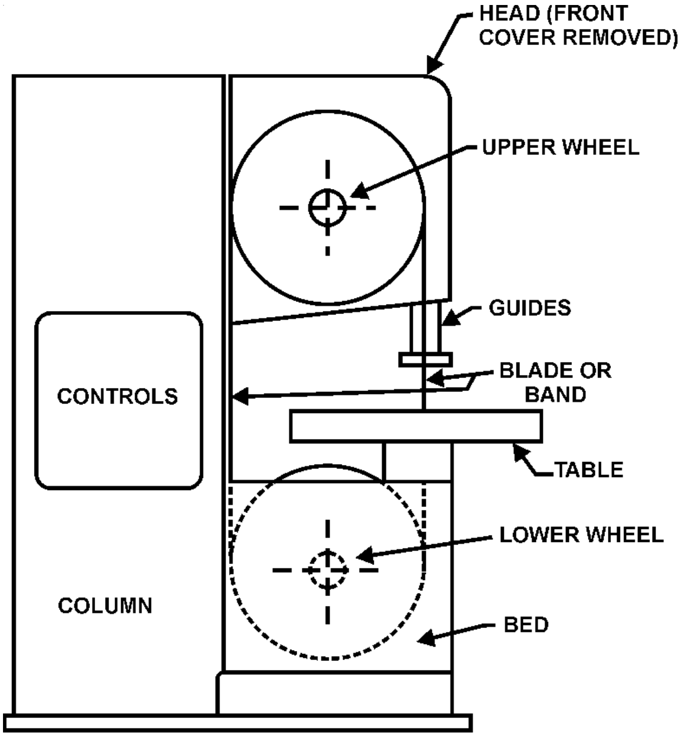


Fig. 5.4, A Vertical Metal band saw.

4. Wheels

Two wheels are provided, one at the top and the other below it. They are mounted on two different shafts and are connected by means of an endless saw blade called band. The centre distance between the two wheels can be varied a little, by raising or lowering the upper wheel, to adjust the tension in the band. The periphery of both the wheels is lined with vulcanised rubber or similar other material to provide enough friction between the saw band and the wheel, so that no slipping of the former takes place. Another, equally big, advantage of this lining is that there is no wear on the saw teeth and they last for a longer time.

5. Guides

These guides are provided to keep the band straight while it penetrates into the work. As such, they should be kept as near to the work as possible. In absence of these guides, due to the cutting pressure, the band may be twisted to the side which will result in the breakage of the band or a spoiled work or both. The guides used are of three types :

1. ***Roller guides :*** They are mainly used to reduce friction when very high cutting speed is to be employed.
2. ***Insert type guides :*** They are used in general work where and when slow speed is to be employed, as is needed in precision work.
3. ***File band type :*** They are used when a file band is employed.

6. Blade or Band

It is that part which does the cutting operation. The blades used are of three types :

a. Saw band - for metal cutting
b. File band - for filing
c. Polishing band - for polishing.

5.9. DETAILS OF BAND TOOLS

The main parts of a band tool are shown in Fig. 5.5. The face forms the main bearing surface against which the chip strikes. Gullet helps to remove the chips from the cut. The saw bands are made in two varieties, flexible and all hard. The former class carries hardened teeth with flexible back. The latter class is hardened all over. These bands are made endless by welding their two ends together.

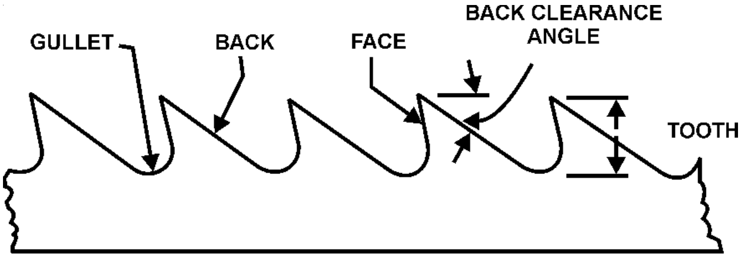


Fig. 5.5, Main parts of a band.

Teeth setting
The band teeth are also set in the same way and for the same purposes as those of the power hacksaw blade. Fig. 5.5 shows the following styles of teeth setting :

a. Alternate set or straight set
b. Alternate and centre set or Racker set
c. Wave-set

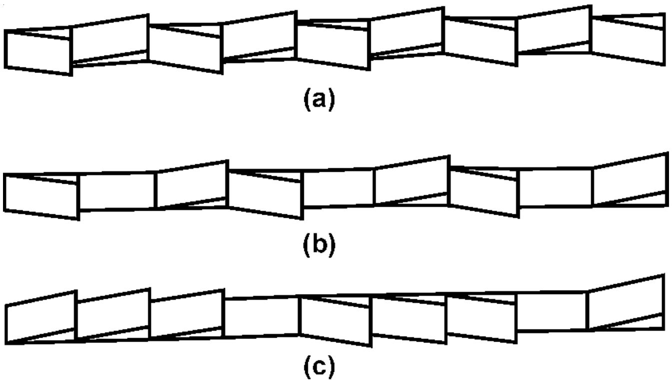


Fig. 5.6, Setting of band saw teeth

Types of Bands
The following types of saw bands are in common use :

1. Precision Band
It is a flexible-back type band and can be used both for ferrous and non-ferrous metals and alloys. Sometimes it is used for cutting wood and plastics also. It normally runs at slow speeds.

2. Friction Band
It is made of a special type of steel to withstand high temperature. It is specifically used for cutting very hard alloys and castings. What happens actually in cutting with this band is that, due to friction between the band and the metal, as it runs at a very high speed, a very high amount of heat is generated making the metal soft, which is removed by the advancing band. It is rather a latest technique of metal cutting.

3. Buttress Band
It has a coarse pitch and deep gullets and runs at slow speed. It is extensively used in sawing wood, plastics and non-ferrous metals. The blade is made in flexible back type.

4. Claw Teeth Band
Used commonly for light metals and alloys and wood, this band is comparatively less in width than others and its teeth carry a positive rake.

5. Scallop-Edge Band
Its teeth carry a souble bevelled cutting edge. This band is commonly used for cutting soft materials and gives a smooth finish.

6. Knife-Edge Band
It carries a straight cutting edge, instead of teeth, and is used for cutting soft materials. Its specific use is incutting soft fibrous materials like paper.

7. File Bands

A file band consists of a number of short file segments which are fastened to a flexible steel band, by means of clips, so that it can freely pass over the rotating wheels. Each of these segments carries a snug at one end and a hole at the other. Snug of one segment fits into the hole os the next one and thus a series is formed to give continuous filing action. The two ends of the flexible band are joined by means of a latch, so that they can be separated as and when needed. The file bands are quite frequently needed for filing dies and form tools and burrying, etc.

8. Spiral Blade

Because of their shapes, these blades are capable of cutting in any direction without disturbing the work. When these blades are used, special types of saw guides are to be employed to allow their free running. They are mainly used in sawing wood and plastics.

9. Diamond Tooth Blade

It consists of a series of cylindrical segments, carrying diamonds bonded in a sintered tungsten alloy. This blade is chiefly used to cut very hard materials like ceramics.

10. Grind Band

It is made almost in the same way as a file band with the difference that the file segments are replaced by abrasive segments. These segments are welded to a flexible steel band. A specific difference is that the cutting takes place on the edge instead of the flat surface of the band.

Cutting Speed

The cutting speed in a bandsaw largely depends upon the material to be cut. For common metals, the following average cutting speeds are recommended, when using a high speed steel band.

Table 5.3, Recommended cutting speeds for band sawing with HSS bands

Sl. No.	Material to sawn	Cutting speed m/min
1.	Cast iron	30
2.	Mild steel	45
3.	Bronze	75
4.	Brass	90
5.	Thin sections, pipes and tubes, etc.	90

5.10. HORIZONTAL BAND SAWS

This type of machine is also known as a cut-off band saw or cut-off band machine. In general appearance they look like a power hacksaw, but the cutting mechanism of these saws is quite different. The frame of these machines carries two wheels, with their axes horizontal, which are connected together by means of an endless saw band. A tension control mechanisms always maintains proper tension in the blade, so that it runs continuously when the wheels rotate. One of the wheels is the driving wheel, connected to the motor, while the other wheel (driven wheel) acts as an idler wheel. There are two guides provided on the path of the band. These guides turn the blade such that it runs vertical between the two guides to cut the workpiece vertically. The principle of sawing on this machine is schematically shown in Fig. 5.7, in which the vertical cutting of the workpiece due to turned band by guides is quite clearly visible. The frame of the machine is normally hinged so that it can be swung in a vertical plane to raise it after cutting or lower it before starting sawing. A hydraulic or pneumatic system controls the cutting fluid supply and many other mechanisms of the machine.

The adjustable supports and guides incorporated at the cutting area support the band to enable it to bear the applied cutting force and turn it to become vertical to saw the workpiece in a vertical plane, as shown in the diagram. Cutting takes place due to continuous feed in go the band into the work, since the saw band continues to run in the same direction always. These machines always operate at higher cutting speeds than those used for reciprocating power hacksaws. A few important points to be borne in mind while operating these machines are :

1. Band tension should be correctly adjusted
2. Wheel guards should be locked before starting sawing
3. Proper saw blade, speed and feed should be used
4. Proper coolant, if required, should be used and in abundance.
5. The band supports and guides should be adjusted as close to the workpiece as possible.
6. The workpiece(s) should be tightly clamped.

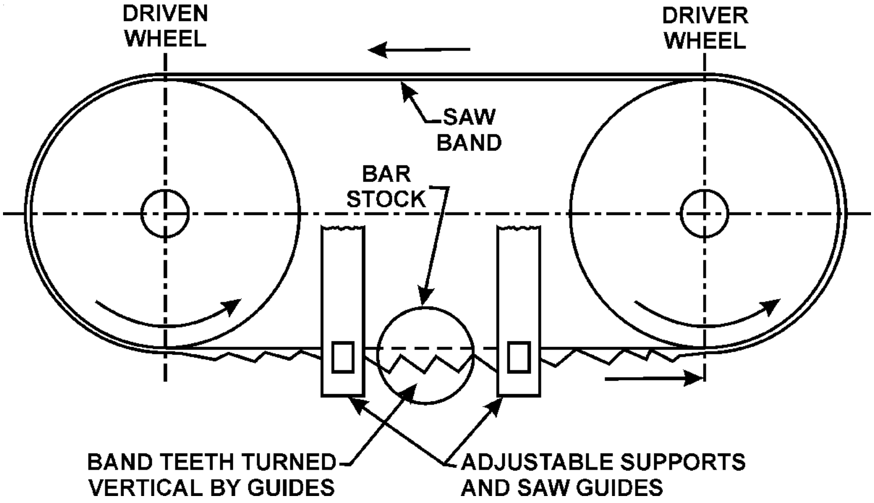


Fig. 5.7, Principle of operation of a horizontal bandsaw machine.

5.11. USE OF CUTTING FLUIDS

Irrespective of the type of machine used for metal sawing, a good cutting fluid is use in most cases due to the following reasons :

1. For minimising friction between the saw teeth and chips.
2. For washing away the cut material and, thus, preventing it from depositing at the cutting edges of saw teeth or around them.
3. For dissipating the heat generated over the saw teeth.
4. For preventing development of high temperature in the cutting area and, thus, preventing the cutting teeth from softening.
5. To increase the life of the saw teeth and, thus, increase productivity.

The common types of cutting fluids used include sulphurised oils, soluble oils and synthetic chemical fluids.

■■■

CHAPTER: 6

LATHE MACHINE

6.1 CONSTRUCTION, ACCESSORIES, WORKING & OPERATIONS PERFORMED ON THE FOLLOWING MACHINE TOOLS

6.1.1 Lathe machine

The lathe can be defined as a machine tool which holds the work between two rigid and strong supports called centres or in a chuck or face plate while the latter revolves. The chuck or the face plate is mounted on the projected end of the machine spindle. The cutting tool is rigidly held and supported in a tool post and is fed against the revolving work. While the work revolves about its own axis the tool is made to move either parallel to or at an in inclination with this axis to cut the desired material. In doing so it produces cylindrical surface, if it is fed parallel to the axis (Fig. 6.1) or will produce a tapered surface if it is fed at an inclination.

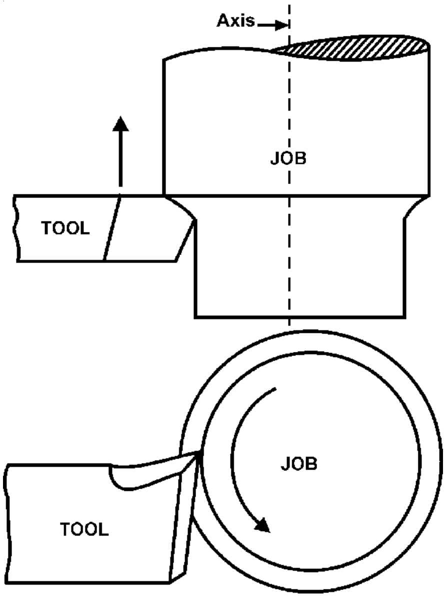


Fig. 6.1, Working principle

Types Of Lathe

Lathes of various designs and constructions have been developed to suit the various conditions of metal machining. But all of them employ the same fundamental principle of operation and perform the same function. The types generally used are as follows.

i. Speed Lathe

It is the simplest of all the lathe and consists basically of a bed, headstock, tailstock and tool post on an adjustable slides. The headstock is very simple in construction and the maximum number of spindle speeds is 2-3. The feed of cutting tool is done purely by hand controls and operate at high speed. The type of machine is used only for simple surface finishing operations and the percentage of accuracy is negligible.

ii. Engine Lathe

This is the most common type of lathe machine. The basic components are similar to the speed lathe. In this type the head stock is very large in size. The cutting tool is mounted on the tool post with an additional arrangement that is a lead screw and carriage. By this arrangement the cutting tool can be fed either by hand or automatically. The amount of metal cut or removed is considerably more than the speed lathe. Based on the power supply construction of head stock spindle, this lathe is again classified into three types: *(a) Belt driven lathe (b) Independent motor driven lathe (c) Gear head lathe.*

iii. Bench Lathe

This machine is smaller when compared to the engine lathe. The lathe is mounted on a bench. It is very small in construction. These are generally used for small precision works in small production workshops.

iv. Tool Room Lathe

Other than the attachment of the engine lathe the tool room lathe is provided with three more extra arrangements, thread gauge, chuck and taper arrangement pump for coolant etc. Tool room lathe is basically used for mass production and surface finishing process such as cutting tools, dies and gauges.

v. Capstan And Turret Lathe

This is wholly different from a standard lathe machine. In a standard lathe machine, the cutting tool is mounted on a carriage by means of a tool post. The cutting tool is fed into the work piece by operating the carriage. In a capstan and turret lathe, the carriage arrangement is dispensed with a turret attachment provided to the tail stock of the lathe machine. The turret, hexagonal in shape can be fitted with a number of tools which can be fed into the work in proper sequence. A numbers of operations can be set up of the workpiece and cutting tool.

vi. Special Purpose Lathe

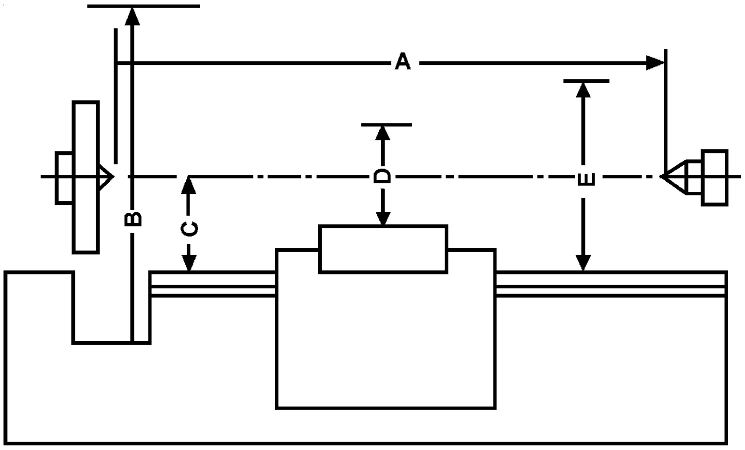
The scope of this types of lathes are very limited, it can be used continuously for single type of operation, once the required type of operation attachment is fitted when the operation is continuous. This is used in mass production shops where a single types of operation is done on a large number of workpiece.

vii. Automatic Lathe

As the name indicates, the machining processes are done automatically in the set up of workpieces, cutting tool, change of gears and cutting tools and similar operations are done in a minimum time. An operator needs only look to the general maintenance of the machine and to remove the finished products from time to time.

Lathe Specification and Sizes

The size of a lathe is designated in many different ways. The practice usually differs with different countries. For example a S.S.S.C. (Sliding, surfacing and screw cutting) lathe is specified in U.S.A. by its swing. The term swing denotes the maximum diameter of the work which can be accommodated on the lathe. This swing is specified at different positions on the lathe as shown in Fig. 6.2 It will be observed that the swing is specified in the gap (in case of gap bed lathe), over the carriage and over the bed. These measurements indicate the maximum diameter of the work which can be safely accommodated over these positions during the operation.



LATHE SIZE

A-Maximum length that can be accommodated between centres. B-Swing in gap. C-Height of centres. D- Swing overcarriage. E- Swing over bed.

Fig. 6.2, Lathe Size.

In England the practice of specifying the lathe is different. There the swing is not mentioned and instead of this they specify the lathe by the height of centres (or of the spindle axis) over the bed. The dimension is exactly half of the swing over bed as specified in U.S.A. It would be interesting, therefore, to observe here that the same lathe will be designated in two different ways depending upon in country of manufacture. For example, a 13" swing-over -bed lathe of U.S.A. will be designated as a 6½" lathe in England, the former indicating the maximum diameter and the latter the maximum radius of the job (or height of centres over the bed) that can be accommodated over the bed.

In U.S.S.R the term swing is not used though they designate the lathe by the same dimension, i.e., by giving the maximum diameter that can be turned above the bed. They also give the height of centres above the bed. Thus they have a sort of combination of both the above conventions. In our country also a combination of the above two methods is followed. Most of the manufacturers in our country specify the swing and the height of centres over the bed.

The important dimensions required to be mentioned for a S.S.S.C. lathe can be summarised as follows :

1. Height of centres over bed,
2. Maximum swing over bed,
3. Maximum swing over carriage,
4. Maximum swing in gap- in case of gap bed lathes only,
5. Maximum length of work that can be mounted and turned, or in other words the maximum distance between centres, and
6. Length of bed.

However it may be noted that by giving only the above dimensions the lathe cannot be fully specified. The complete specifications of a lathe will include various other data also. This, it is hoped, will be more clear through a concrete example. Given below, for this purpose, are the complete specifications of a Harihar D-1 lathe, manufactured by M/s. The Mysore Kirloskar Ltd., Mysore (India).

Height of centres over flat bed ways	165mm.
Maximum swing over carriage	210mm.
Maximum swing over bed	330mm.
Maximum distance between centres	600mm.
Width of bed	238mm.
Hole of through the spindle (Diameter)	35mm.
Morse taper of centre	No . 3.
Spindle Nose, Type and size- Threaded 2-3/8" dia × 8 TP 1.	
Face plate diameter	300mm.
Max. size of tool holder-Single tool post	15 mm × 32 mm.
Square tool post	12.5 mm.sq.
No. of spindle speeds	8
Range of spindle (Approx.)	22 to 750 r.p.m.
Metric Threads, Pitch range (33 pitches)	0.2 to 6.0 mm.
Inch Threads, T.P.1. range (23 pitches)	4 to 40
Lead screw diameter	25.4mm.
Lead screw threads	8 T.P.1.
Motor —I. H.P., 3-phase, 400 / 440 V.	50 cycles.

I. Parts of Lathe Machine

The lathe carries the following main parts as illustrated by a block diagram in Fig. 6.3 Detailed mechanical features of the lathe are shown in Fig. 6.5.

i. Bed

The bed of a lathe acts as the base on which he different fixed and operating parts of the lathe are mounted. This facilitates the correct relative location of the fixed parts and at the same time provides way for a well guided and controlled movement of the operating part (carriage). Also it has to withstand various forces exerted on the cutting tool during the operation. It must, therefore, be of a very rigid and robust construction. Lathe beds are usually made as single piece casting; the material 'Cast Iron' facilitating an easy sliding action . However, in case of extremely large machines the bed may be in two or more pieces, bolted together to form the desired length. Bed castings are usually made to have a box section incorporating cross webs as shown in Fig. 6.4.

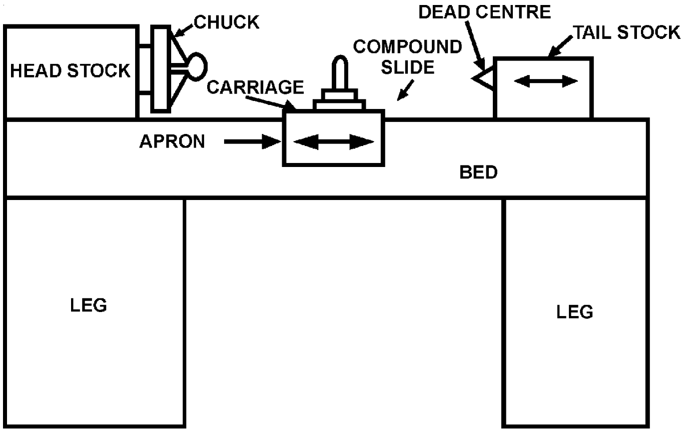


Fig. 6.3, Block Diagram of lathe.

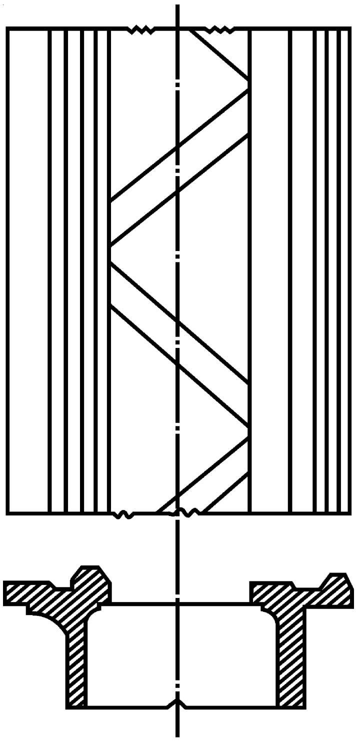


Fig. 6.4, Lathe Bed.

There is always a likelihood of distortion taking place due to cooling stresses set up during solidification of the casting. To avoid this a very common practice of natural seasoning, called ageing, is prevalent. For this the bed castings are rough machined and then left in open for considerable time, usually a couple of years or so, and then machined to the required size for final assembly. The ways which come in contact with the sliding parts are very accurately and finely finished.

All-flat ways are not very popular now, although it is easy to produce them. The prismatic, or inverted 'V' ways, are now preferred over the flat ways for the reason that their construction totally disallows the entry of chips and dirt, etc. between the saddle and the bed, thus preventing the contact surfaces from being spoiled due to scratching. Also they provide very efficient guiding surfaces and the wear of the bed, does not have any appreciable effect on the overall alignment of the lathe. Most of the countries adopt a combination of the flat and prismatic shapes .

In this the flat ways act as support, i.e., taking the maximum portion of the load and the stresses, whereas the prismatic shapes act as guide ways. Tail stock is usually guided along the bed by a combination of one prismatic and one flat way.

An important point to be borne in mind is that an accurate location and proper levelling of the bed, during installation and afterwards, plays an important role. Even very strong beds are observed to have been distorted if they are placed on unlevelled foundation. This twisting of beds affects the accuracy of the work very seriously. The bed should, therefore be tested for level both lengthwise as well as crosswise.

Gap Beds

Though it is not a very common practice, some beds are made to have a gap just adjacent to the front of the head stock. Such beds are known as Gap beds. They provide an advantage that the lathe having such a bed is capable of accommodating jobs which are larger in diameter than the provided swing over the bed. But, this is true for jobs of shorter length only.

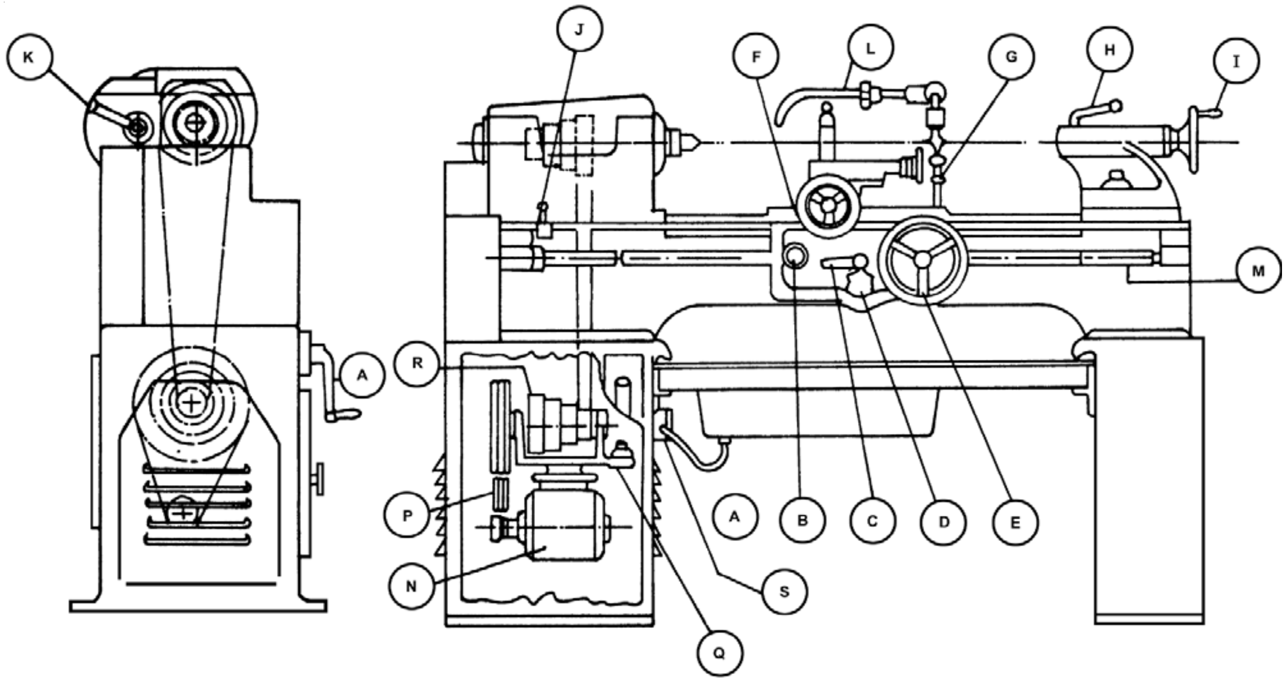
On the other hand, it offers an equally great disadvantage when short and precision work is to be done. For such work the saddle is required to be brought closer to the headstock and the gap of the bed makes the saddle to project over it unsupported. The gap bed is therefore never adopted for precision lathes.

ii. Head Stock

The headstock is that part of the lathe which serves as a housing for the driving pulleys and back gears, provides bearing for the machine spindle and keeps the latter in alignment with the bed. It consists of the following parts :

a. Cone pulley,
b. Back gears and back gear lever,

c. Main spindle, d. Live centre, and
e. Feed reverse lever.



A- Belt tension release lever, B- Half nut lever, C- Feed engaging lever, D- Star wheel, E- Hand feed wheel, F- Hand wheel for cross feed screw, G- Hand wheel for compound rest, H- Tailstock spindle locking lever, I- Tailstock handwheel, J- Reversing switch, K- Back gear engaging lever, L- Coolant delivery pipe, M- Lead screw, N- Electric motor, P- 'V' belts, Q- Countershaft bracket, R- Countershaft cone pulley.

Fig. 6.5, The Engine lathe.

The back-geared headstock consists of a casing accommodating the main spindle, the three or four step-cone-pulley and the back gears. The internal mechanism of this type of headstock is shown in Fig. 6.6. In this a step cone-pulley is mounted on the main spindle, which carries a spur gear G_1 at its one end and pinion P_1 at the other. Gear G_1 is firmly keyed to the spindle so that it can never revolve free of the same. The spindle carries a sleeve over it which is a loose fit. The cone pulley is firmly secured to this sleeve. Also the pinion P_1 is firmly keyed to this sleeve. This arrangement force the opinion P_1 to revolve with the cone pulley under all conditions. A spring knob K engages the gear G_1 with the cone pulley. The cone pulley is driven by means of a belt, through a countershaft, by an electric motor as shown in Fig. 6.6. This arrangement enables 4 different speeds of the spindle.

Use of back Gears

The back gears are used for effecting reduction in spindle speeds, thereby facilitating a wider range of speeds as shown in fig. 6.7. The back gears are mounted on an eccentric shaft which is operated by means of a hand lever known as back gear engaging lever. The back gears consists of a spur gear G_2 (opposite pinion P_1) and a pinion P_2 (opposite gear G_1). When speed reduction is desired the knob is pulled out to make the cone pulley free of gear G_1 and hence of the spindle. The back gears are put into mesh with the spindle gears by pulling in the eccentric shaft. Now the sequence of transmission of motion and power is such that the cone pulley revolves. This, being in mesh with gear G_2, transfers the motion to the latter which in turn, revolves the eccentric shaft and hence the pinion P_2. This, further being in mesh with gear G_1, transmits the motion to the latter and hence to the spindle.

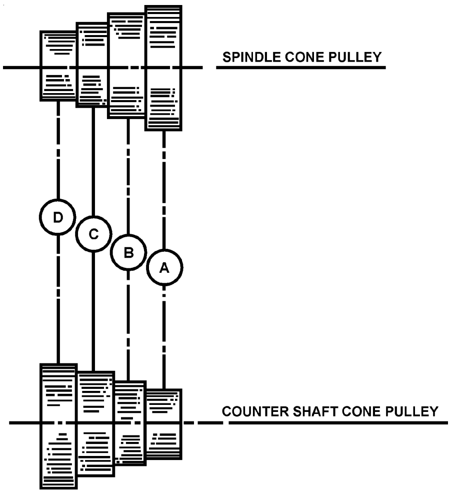


Fig. 6.6, Cone Pulleys.

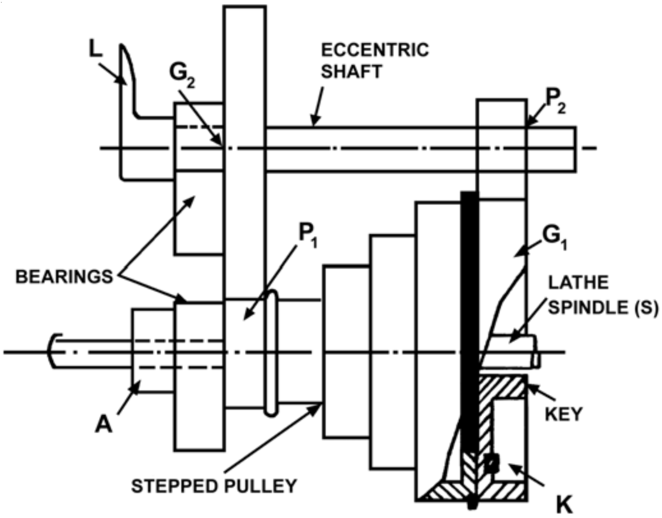


Fig. 6.7, Use of back gears.

Speed Ratios

Let us take a concrete example to illustrate as to how the spindle speeds change with the engagement of back gears. Fig. 6.7. illustrates different combinations of belt positions on the spindle cone pulley and the counter-shaft cone pulley. Suppose the countershaft revolves at a constant speed of 300 R.P.M. and the diameters of the steps of the two cone pulley are 25 cm, 20 cm 15 cm, and 10 cm respectively

Using the different combinations of the cone pulleys we get:

Belt in position A - spindle revolves at 120 R.P.M.
Belt in position B - " " at 225 R.P.M.
Belt in position C - " " at 400 R.P. M.
Belt in position D - " " at 740 R.P.M.

Now suppose the number of teeth in gears G_1 and G_2 are 100 each and in pinions P_1 and P_2 36 and 40 respectively. On meshing the back gears the corresponding spindle speeds to the above positions will be as follows :

Belt in position A - Spindle revolves at
$120 \times 36 \times 40 / 100 \times 100 =$ **17.3 R.P.M (approx.)**

Belt in position B - Spindle revolves at
$225 \times 36 \times 40 / 100 \times 100 =$ **32.4 R.P.M.**

Belt in position C - Spindle revolves at
$400 \times 36 \times 40 / 100 \times 100 =$ **57.6 R.P.M.**

Belt in position D - Spindle revolves at
$750 \times 36 \times 40 / 100 \times 100 =$ **108 R.P.M.**

The Spindle

The main spindle of the lathe is in the form of a hollow shaft and revolves in two bearings fixed one each of the front and rear ends of the head stock. The inside hole runs through entire length of the spindle and at the front end it is made tapered to accommodate the live centre. Also, at the front end, the outside surface of the spindle is made threaded to receive the job holding devices such as chuck, face plate or driving plate, etc. However some other methods are also adopted in place of making the spindle end threaded. One of these is to provide a flange at the end of spindle and secure the job holding device to it. Another method is to provide a draw nut at the end which receives the extended rear screwed part of the chuck or face plate. The advantages of using these methods are that the accuracy of the spindle is maintained for longer time, likelihood of the chuck and the face and strength and stiffness of the spindle is increased. Trueness of the spindle has a considerable effect on the accuracy of the job, and hence it should always be in perfect alignment.

Live Centre

It is the centre support which is fitted into the tapered inside portion of the spindle nose while using a driving plate or face plate. No such centre is required when the work is held in chuck. It acts as a bearing support for the work during the operation. It is usually softer than the 'dead centre' fitted in the tail stock for reason that there are no chances of any wear occuring on its surface as it always revolves along with the work. It is only due to its revolving with the work that the name 'Live Centre' has been given to it.

Feed Reverse Lever

This lever is primarily used for providing power feeds to the carriage. It is fitted on the left hand side of the head stock and has three position; central, top and bottom. In central position it is disengaged and the feed to the carriage is given by hand. In top and bottom positions it engages the power feeds to the carriage. In one position the carriage is moved from right to left and in the other in reverse direction. Such a change in the direction of feed is usually called for while cutting the left hand and right hand threads. An important point to note is that this lever should never be operated while the spindle is running. The machine should be stopped before operating this lever. This lever, in fact, effect the said change by changing the direction of rotation of the lead screw through a set of gears, while the spindle continues to revolve in the same direction always. If, however, the direction of the spindle is required to be altered this is done by means of reversible switch which makes the driving motor to revolve in a reverse direction, and hence the spindle.

Feed Mechanism and Change Gears

The gear mechanism operated by means of the feed reverse lever is called the tumbler reversing mechanism. This, as stated above, is used for providing power feeds to the carriage. This mechanism is shown by means of a diagrammatic sketch in Fig.6.8. It will be seen that the motion from the spindle to the lead screw or feed rod is transmitted through this mechanism. Refer Fig.6.8. Gear G_1 is mounted on the rear end of the spindle S. The feed mechanism consists of gear G_2, G_3 and G_4, and is operated by means of feed reverse lever P. When the lever F is moved from the central position to either the top or the bottom position one of the gear G_2 and G_3 will mesh with gear G_1 whereas these two gears always mesh with each other mutually, Thus, it will be seen that in the top position of lever F motion is transmitted from gear G_1 to G_4 through gear G_3 and gear G_2 plays no role. With the result gear G_4 will have the same direction of rotation as the spindle [Fig 6.8 (a)] . Against this, in the lower position of the lever F motion from G_1 is transmitted to G_4 through G_2 and G_3 respectively as shown in Fig 6.8 (b). This will enable G_4 to rotate in a direction opposite to that of the spindle S. It will be evident that when the lever F will be in its central position neither of the gear G_2 and G_3 will be meshing with G_1 and thus the feed mechanism will be disengaged. The above mechanism is usually enclosed in the headstock except the lever F which is kept projecting outside.

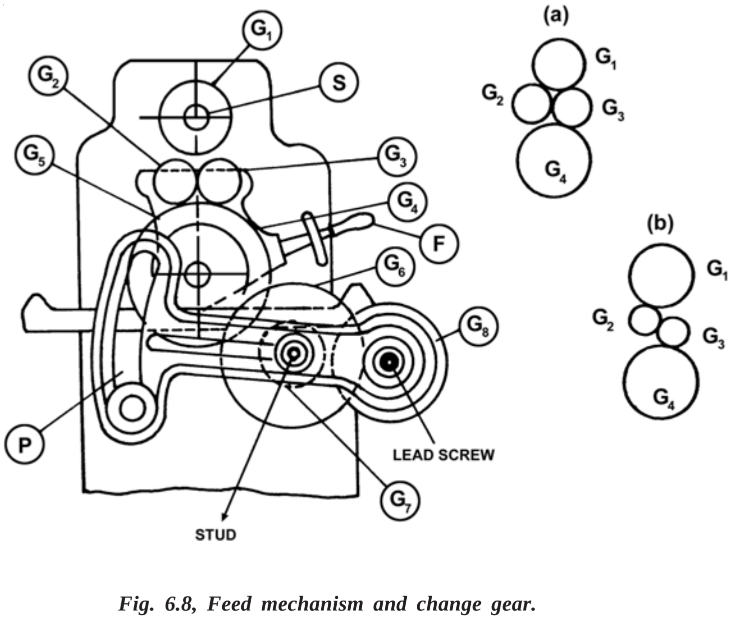


Fig. 6.8, Feed mechanism and change gear.

On the same end as the above mechanism, but outside the headstock, there is another set of gears called change gears. This consists of gears G_5, G_6, G_7, G_8, etc. Gear G_5 is mounted on the same spindle as G_4 and thus rotates at the same speed as the latter. This transmits motion to gear G_8 through G_6 and G_7, which further transmits it to the lead screw or the feed rod. These four gears are known as change gears for the reason that they can be removed and replaced by other gears having different number of teeth. A desired speed of lead screw or the feed rod can be obtained by selecting the suitable change gears having proper number of teeth. Gears G_6 and G_7 are usually mounted on a stud are known as stud gears. A quadrant is provided and the stud can be shifted along its straight slot to enable proper meshing of change gears. Also this quadrant can be swung vertically along the slot P to enable meshing of gear G_5 and G_6 . When proper mashing has been acquired the quadrant is locked in position. Gear G_8 is mounted directly on the lead screw on those lathes which do not have a feed gear box, where as it is mounted on the gear box driving shaft in those lathes which carry the gear box.

Geared head Stock

As discussed earlier, a lathe spindle may be required to operate at various different speeds. For this the head stock may be equipped with either a cone pulley drive and back gears, discussed earlier in this article, or an all geared head stock. The latter method is very commonly used in all modern lathes. In this method the desired speeds are obtained simply by shifting the position of sliding gears. These gears are actuated by two or more speed change levers. The main driving motor runs always at a constant speed and the desired variations in spindle speeds are provided through the above shifting of gears. The head stock has a rigid construction, compact design and incorporates a number of sliding clutches and breeds, etc. Some lathes sometimes are provided with a two speed motor in order to have a wider range of spindle speeds from the same head stock. This type of head stock is used not only in lathes but in almost all the other types of modern machine tools.

The common method of designing such a gear box is to arrange the spindle speeds in a Geometrical progression, which means that each spindle speed when multiplied by a constant number gives the next higher speed. For example if S be the first or lowest speed and C the constant number, then :

$$2^{nd}\text{speed} = SC$$

$$\underline{3^{rd}\text{speed} = S.C.C. = SC^2}$$

$$n^{th}\text{speed} = SC^{n-1}$$

Now, if n be the total number of speeds and N be the maximum speed, then :

$N = SC^{n-1}$

or $C = {}^{n-1}\sqrt{(N/S)}$

Internationally the standard values of C have been fixed as 1.12, 1.25, 1.4, 1.6 and 2.

A simple design of a nine speed all geared head stock is shown in Fig. 6.9. It consists of a splined shaft S_1, an intermediate shaft S_2 and the lathe spindle S_3. Shaft S_1 carries the fast and loose pulleys on its outside end, thorough which it receives power from the driving motor. Gear G_1, G_2 and G_3 are mounted on shaft S_1, gears G_4, G_5 and G_6 on shaft S_2 and gears G_7, G_8 and G_9 the spindle S_3. The spindle body is also splinded, as shown. Gear G_T is called translating gear. It is fitted on the main spindle for transmitting motion to the lead screw and feed shaft. The gear box shown in Fig.6.9 is said to have the sliding gear mechanism because the changes in spindle speeds are obtained by sliding a set of gear over a splined shaft to bring it in mesh with a cluster (combination) of gears mounted on the other shaft.

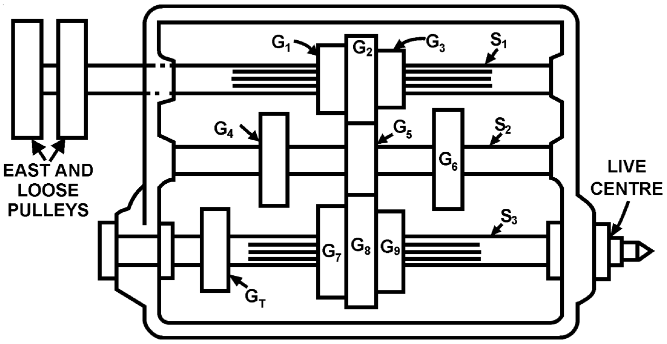


Fig. 6.9, Gear Box

In the above gear box the power is transmitted to shaft S_1 from the driving motor through the fast pulley mounted on the shaft extension. Gear G_1, G_2 and G_3 can be brought in mesh respectively with gears G_4, G_5 and G_6 by sliding the former over splined shaft S_1 by means of a lever. Similarly another lever can be used to slide Gears G_7, G_8 and G_9 over splined spindle S_3 to bring these gears in mesh respectively with gears G_4, G_5 and G_6. The power is, thus, transmitted from S_1 to S_2 and then to S_3. Gears G_4, G_5 and G_6 rotate freely on shaft S_2 in their own positions, but they cannot be shifted axially. The above shifting of gear enables nine different gear combinations to give nine different spindle speeds as follows :

1. $G_1 / G_4 \times G_4 / G_7$ 2. $G_2/G_5 \times G_4/G_7$ 3. $G_1 / G_4 \times G_5 / G_8$
4. $G_3 / G_6 \times G_4 / G_7$ 5. $G_2/G_5 \times G_5/G_8$ 6. $G_3/ G_6 \times G_5/ G_8$
7. $G_1 / G_4 \times G_6/ G_9$ 8. $G_2/G_5 \times G_6/G_9$ 9. $G_3/ G_6 \times G_6/ G_9$

An all geared drive has the following advantages over the cone pulley drive :

1. It provides a more compact design and enables a wider range of spindle speeds
2. The power available at the tool is almost constant for all the speeds, whereas in a cane pulley drive it varies with the speed.
3. The spindle speeds can be easily changed by simply moving a few levers, which is relatively safer and much quicker than shifting of belt in a cone pulley drive.
4. No line shaft or countershaft is required since the power is obtained from an independent motor housed in the machine itself.
5. Less vibrations are observed in the machine spindle since the driving pulley is not mounted directly over it. This type of drive , however, carries the following disadvantages also :
   a. The lathes incorporating this drive are costlier.
   b. There is some loss of power due to friction in gears.
   c. This being a positive drive, the chances of prevention of damage due to overloading are very bleak.

iii. Tailstock

It is also sometimes called the loose head-stock or puppet head. It is mounted on the bed of the lathe such that it is capable of sliding along the latter maintaining its alignment with the head stock. On common types of medium size and small lathes it is moved along the bed by hand, whereas in heavier types of lathes it is moved by means of a hand wheel through a pinion which meshes with the rack provided on the front of the lathe bed. The main function of the tail stock is to provide bearing and support to the job which is being worked between centres. To enable this the tail stock is made to possess a number of parts which collectively help in its successful function.

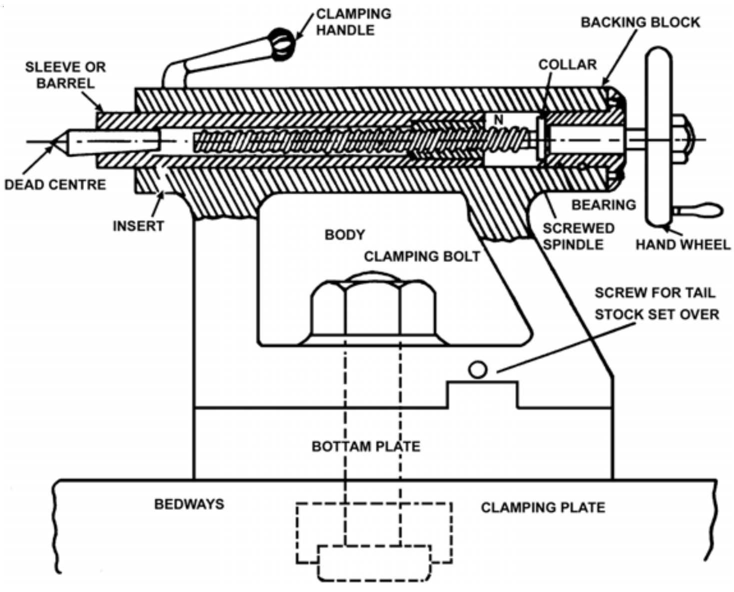


Fig. 6.10, Tail Stock of lathe.

A Simple design of tail stock is shown in Fig. 6.10. It illustrates all the principal parts of the tail stock and their working can be best understood with the help of this diagram. The body is a single piece casting to which is fitted a separate plate at the bottom, called the bottom plate. This plate carries a projection which fits into the corresponding slot in the body, as shown, in order to prevent the relative longitudinal movement of the two. Just above this projection is provided the screw for adjusting the tail stock set over for taper turning. Usually the front end of the bottom plate, / i.e., the one facing the head stock carries graduations and a mark is provided on the corresponding face of the body. With the help of these graduations the required set over the tail stock is adjusted. This whole is held over the bed by means of a single clamping bolt which carries a clamping plate at its bottom. When it is required to be clamped in position the nut is screwed up and the clamping plate is secured to the underside of the bed ways.

The upper part of the body is made hollow which carries a sleeve or barrel inside it. At the rear end of the sleeve a bush (usually of bronze) is provided which acts as a bearing for the screwed spindle inside it. This bush carries inside threads. On the front end of the sleeve is fitted the dead centre. The underside of the sleeve carries a slot (or key way), to a limited length, in which an insert (such as a set screw) is made to project from the bottom so as to prevent the rotation of the sleeve. The screwed spindle carries square threads along its stem with a collar at the rear end of the threaded portion. This collar limits the inward motion of the sleeve to a desired extent. A bushed bearing is provided at the rear end between the back plate and the collar. The back plate is firmly secured to the body by means of screws S_1 and S_2. This arrangement prevents the axial movement of the spindle. At the extreme rear end of spindle is provided a hand wheel for rotating the former.

In operation, when the hand wheel is rotated the spindle rotates about its own axis inside the nut N and in doing so it draws in or pushes forward the sleeve, depending upon the direction of rotation of hand wheel. It is so because the axial movement of the spindle has been prevented, as described above, while the sleeve is free to move longitudinally. After the sleeve has been made to project a desired length outside the body it can be secured in position by means of the clamping handle H.

iv. Carriage

The lathe carriage (Fig 6.11). serves the purpose of supporting guiding and feeding the tool against the job during the operation on the lathe. It consists of the following main parts.

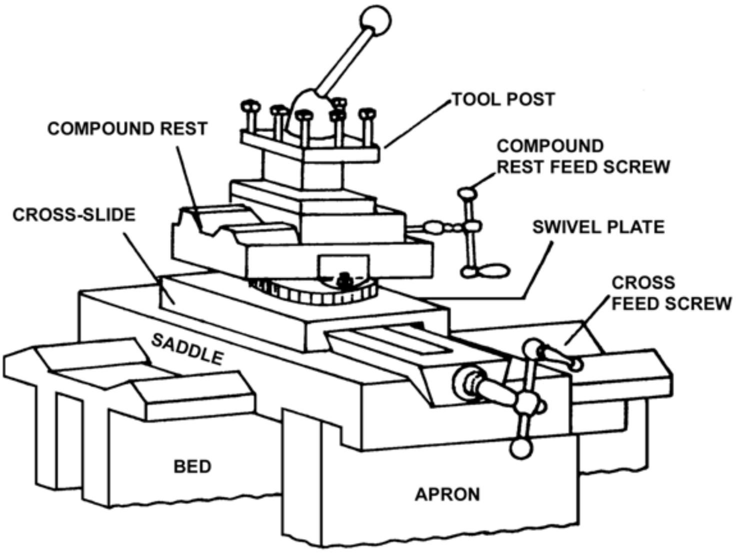


Fig. 6.11, The Carriage.

Saddle

It is that part of the carriage which slides along the bed ways and supports the cross-slide, compound rest and tool post.

Cross Slide

It is mounted on the top of the saddle and always moves in a direction normal to axis of the main spindle. It can either be operated by hand by means of the cross-feed screw or may be given power feed through the apron mechanism.

Compound Rest

It is known as tool rest. It is mounted on the cross-slide and carries a graduated circular base called the swivel plate. The latter is graduated in degree and enables the former to swivel to any angle in a horizontal plane. The upper part known as compound slide, can be moved by means of the compound rest feed screw.

Tool Post

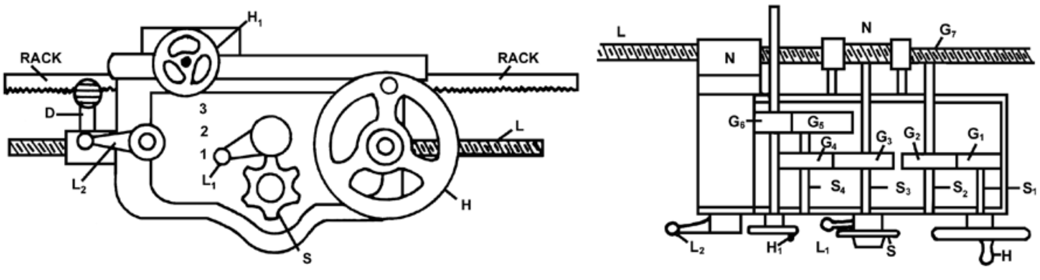
It is topmost part of the carriage and is used for holding the tools holder in position.

Apron

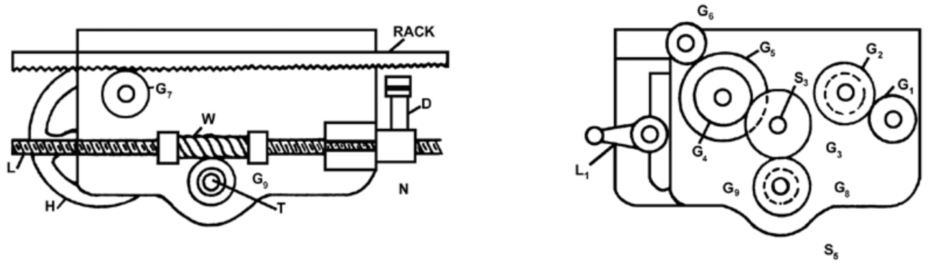
It is the hanging part in front of the carriage . It serve as housing for a number of gear trains through which power feeds can be given to the carriage and the cross-slide. Also it carries the clutch mechanism and the split half nut. Out of these two the former (clutch) mechanism is used to transmit motion from the feed rod whereas the latter, in conjunction with the lead screw, moves the whole carriage in thread cutting. For efficient operation of the machine it is important to understand the apron mechanism and its working in detail. The same will now be discussed fully in the following paragraphs.

Apron Mechanism

Fig. 6.12 illustrates the apron mechanism of lathe. The gearing mechanism is completely enclosed inside the apron and the controls for operating the same are shown in Fig. 6.12 (a), which is the Front (outside) view of the apron. H is the hand wheel for providing the longitudinal hand feed to the carriage .Similarly H_1 is the hand wheel for providing hand feed to the cross-slide. Lever L_1 is for engaging or disengaging the power feed. Star wheel S is operated when power feed is to be engaged. Lever L_2 operates the spilt half nut N to engage or disengage the same from the lead screw L. D is the chasing dial used in thread cutting. In order to make clear the relative positions of the internal gear . Further details of teeth, etc. of the gears have deliberately been avoided in all the views in order to make the diagrams simple . We will now discuss the mechanism in detail.



(a) Front outside **(b) Plan**



(c) **(d)**

Fig. 6.12, Apron mechanism of lathe.

Inside the apron there are 5 spindle S_1 , S_2, S_3, S_4 and S_5 (see plan Fig. 6.12 (b). Spindle S_1 carries gear G_1 at its rear end and hand wheel H at the front. G_1 is in mesh with gear G_2 mounted on spindle S_2. Spindle S_2 carries another gear G_7 at its rear end, outside the apron , which meshes with the rack provided at the front of the lathe . This can be clearly seen in the rear view [Fig.6.12 (d)]. Spindle S_3 carries gear G_3 which is operated by lever L_1 . This lever has three positions 1,2 and 3 [See Fig 6.12 (a)]. In position 1 i.e. lowest, it engages gear G_3 with G_4 mounted on spindle S_4. In position 2, i.e. middle, gear G_3 is free and does not mesh with any other gear. In position 3 i.e. , top, gear G_3 meshes with the gear G_2 . Spindle S_4, in addition to the gear G_4, carries another gear G_5 at its rear end. It is always in mesh with gear G_6 which is mounted on the screwed spindle of the cross-slide. Spindle S_5 is just below the spindle S_3 and it carries gears G_8 and G_9. G_8 is in mesh with G_3 and G_9 is not rigidly secured to S_5 . Instead of this a clutch or pushed out by rotating the spindle by means of the star wheel S. On account of the same, whenever it is desired to transmit motion from the lead screw to the spindle S_5 the clutch is drawn in. This enables a temporarily rigid fastening between S_5 and G_9 with the result that S_5 is driven by the lead screw through the worm W and gear G_9 .Whenever we want to disengage the same the star wheel is rotated in a reverse direction to push the clutch out of G_9 the transmission is stopped. Working of the split half nut mechanism will be described later.

In operation, when hand feed is required to be given , whether to the carriage or the cross-side, lever L_1 is put in position 2 so that gear G_3 is neither engaged with G_4 nor with G_2. When power feed is to be given to the carriage lever L_1 is put in position 3 so that G_3 meshes with G_8 and G_2 simultaneously. Star wheel is tightened to connect G_9 with S_5. Motion is transmitted from the lead screw to G_9 through the worm, and hence to S_5 and G_8. It is further transmitted to G_2 and hence to G_7, they being on the same spindle. G_7 meshes with the fixed rack and therefore the carriage is moved.

To give power feed to the cross-slide, lever L_1 is put in position 1, so that gear G_3 meshes with G_4 . Now the transmission of motion from the lead screw is to the worm, then to G_9 with G_8 and finally to G_3 through G_4 and S_5. Note that the mechanism explained above is not capable of providing power feeds both to carriage as well as the cross-slide simultaneously.

Split Nut

It has already been described above that the split nut is engaged to the lead screw to give power feed to the carriage when threads are cut. Its construction and working can be clearly understood with the help of Fig.6.13. The nut is made in two halves carries a pin at its back (P_1 and P_2) which engages into the cam slots provided in the plate at their back. When this plate is rotated by means of the lever L it, depending upon the direction of rotation of the lever, engages or disengages the split nut with the lead screw.

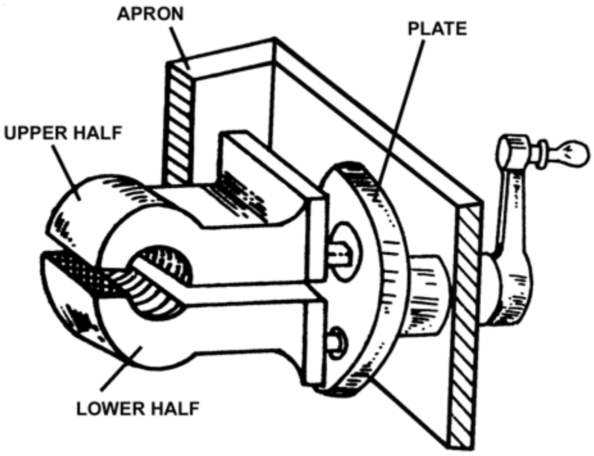


Fig. 6.13, Split half nut.

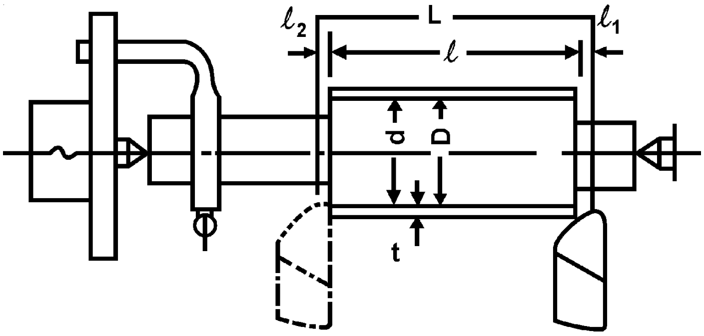


Fig. 6.14

An important feature of a apron mechanism is the provision of a foolproof arrangement to avoid the simultaneous operation of the split nut and the automatic feed to the carriage. To avoid this clash a lever is provided inside the apron which engages with both the mechanisms and acts in such a way that when automatic feed is given to the carriage the split nut will not close and when the latter will be engaged the automatic feed will not act.

v. Legs

They are the supports which carry the entire load of the machine over them. The prevailing practice is to use cast legs. Both the legs are firmly secured to the floor by means of foundation bolts in order to prevent vibrations in the machine. One of these legs, usually on the left hand side of the operator, serves as a housing for the electric motor and countershaft, etc. Both these legs should be of robust construction.

vi. Drive of the feed rod and the lead screw

Fig. 6.15 shows a complete driving arrangement of a feed rod and lead screw. The motion is transmitted from the spindle gear through the tumbler gears and change gears to the shaft 5 on which twelve gears are keyed. Twelve different speeds may be obtained by the shaft 7 by the sliding gear. With the use of the sliding key and four additional gears on shaft 7 and 12, the shaft 12 can receive $12 \times 4 = 48$ speeds, i.e. 48 different feeds. The clutch enables the lead screw to be engaged or disengaged only one at a time.

Feed Rod

The feed rod is a long shaft that has the keyway extending from the feed box across and in front of the bed. The power is transmitted from the lathe spindle to the apron gears through a feed rod via large number of gears. The feed rod is used to move the carriage of cross-slide for turning, boring, facing and all other operations except thread cutting.

Lead screw

The lead screw is a long threaded shaft used as a master screw, and is brought into operation only when threads have to be cut. In all other times the lead screw is disengaged from the gear box and remains stationary, but this may be used to provide motion for turning, boring, etc. in lathes that are not equipped with a feed rod.

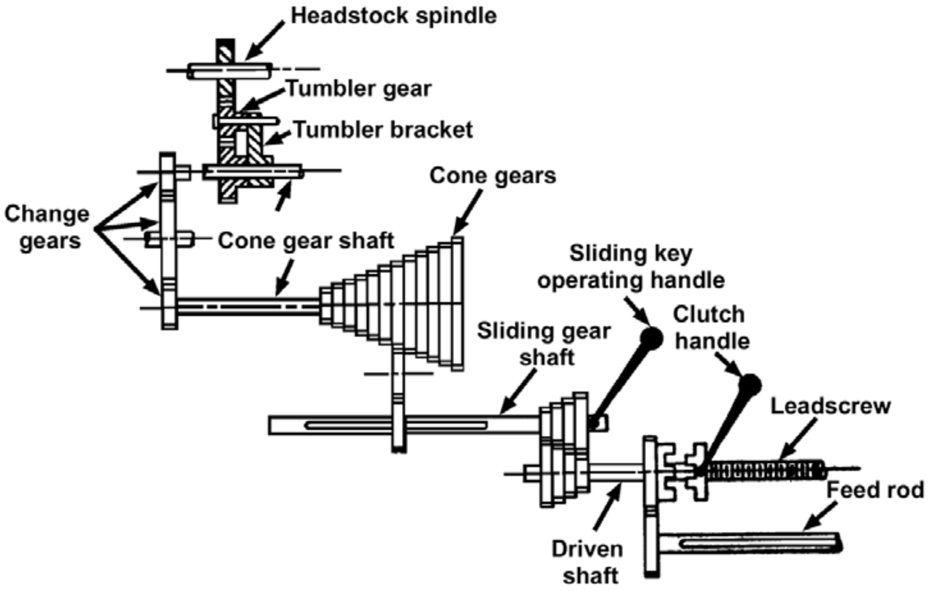


Fig. 6.15, Layout diagram of feed drive.

II. Lathe Accessories

i. Chucks

The commonly used chucks are three-jaw universal chuck, four-jaw independent chuck, and magnetic chuck.

Three jaw universal chuck

(Fig.6.16) holds cylindrical or hexagonal work. All three jaws move together to bring the work on centre. Two sets of interchangeable jaws are provided because the jaws are not reversible. These are called inside and outside jaws. One set is used to grip the work on the outside.

The slots on the chuck are numbered 1, 2 and 3. Each jaw has a corresponding number. Remove the jaws from the chuck by backing them out with the chuck wrench. Turn the chuck so that slot No. 1 is at the top. Turn the wrench until the top thread of the scroll plate is just short of entering the No. 1 slot. Insert the No. 1 jaw and set it down against the scroll thread. Turn the wrench to catch the thread into the thread or groove the jaw. Turn the wrench just enough to meet slot No. 2, no further. Insert and catch the No. 2 jaw. Repeat for the No. 3 jaw.

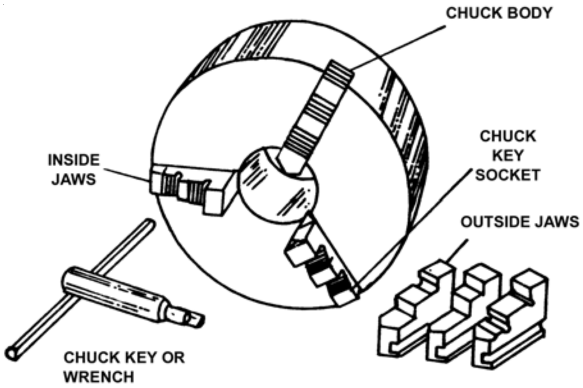


Fig. 6.16, Three jaw universal chuck.

Four-jaw independent chuck

(Fig.6.17) is used to hold most of the work for which a chuck is required. The hardened steel jaws are reversible and will hold work of different sizes and shapes. Each jaw may be moved independently of the others so that workpieces may be trued to run accurately.

A four-jaw independent chuck has several circular grooves around the face of the body. The jaws may be approximately centered by adjusting the jaws to these grooves. The workpiece is then inserted and the jaws tightened just enough to hold the work in place .Reverse the toolholder, tighten it finger-tight only, and turn it in until it just touches the workpiece.

Revolve the chuck by hand to locate the high or low spot of the workpiece. Adjust the jaws until the workpiece runs true. If greater accuracy is required use a test indicator.

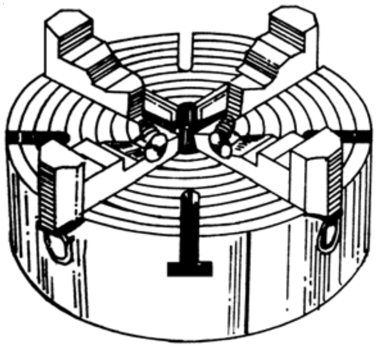


Fig. 6.17, Four jaw universal chuck.

Combination chuck

It is usually a four-jaw chuck in which the jaws may be adjusted either independently, as in a four-jaw independent chuck, or together, as in the three-jaw universal chuck. It is useful for holding duplicate workpiece. The first piece is located accurately by adjusting each of the jaws. The following piece are then positioned like the first piece and the self-centering socket in the chuck body is used to tighten the work in the chuck Figure 6.18 shows a six-jaw combination chuck.

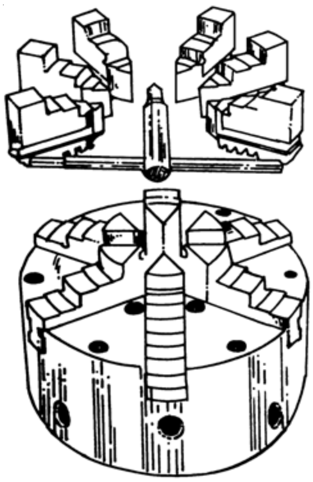


Fig. 6.18, Six jaw combination chuck.

Magnetic chuck

(Fig 6.19) holds steel workpieces by means of permanent magnets contained within the chuck. The face of the chuck is magnetized by inserting a key in the chuck and turning it 180°. The amount of magnetism may be controlled by turning the key only part of the required distance. In this manner, a workpiece may be held lightly on the face of the chuck while it is being adjusted or trued to the required position. Then, the full power of the magnet may be turned on. This type of chuck is suitable for work that requires only light cuts. The magnetic chuck is especially good for holding parts that are too thin to be held in an ordinary chuck. The size of a chuck is specified by the diameter of the chuck body.

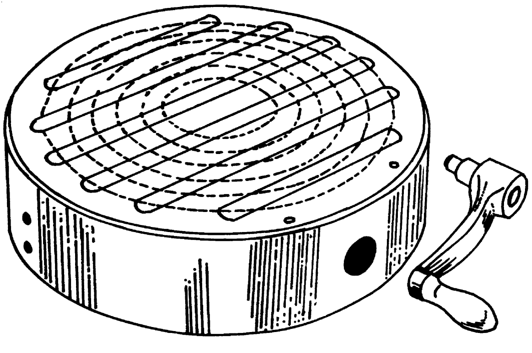


Fig. 6.19, Magnetic chuck.

ii. Mandrels

A lathe mandrel is a hardened and tempered steel work-holding device. It is used for the further machining of a workpiece between the centers after it has been bored or reamed while held in a chuck. The mandrel is ground to a taper of 0.006 inch per foot. It is pressed or driven into a finished hole tight enough so the work will not slip while it is being machined. The mandrel size is stamped on the large end.

An expanding mandrel consists of a solid tapered piece and a slotted tapered sleeve, which expands in diameter when forced onto the solid tapered mandrel. Usually made in sets, each mandrel can be used for a variety of hole sizes. The amount of expansion is from about 1/16 in. for the smaller size mandrels up to ½ in. for the larger size mandrels.

A nut mandrel is a straight mandrel threaded at one end so that a number of workpiece may be mounted and securely held for turning between centers.

While pressing mandrels into a finished hole, Lubricate both the mandrel and the hole to prevent the mandrel from freezing in the hole without the use of a lubricant both the hole and the mandrel may be damaged. Use an arbor press to drive and remove mandrels from workpieces.

Fig. 6.20, Plain mandrel.

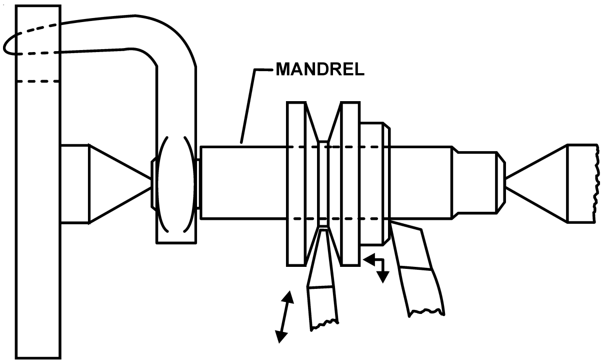


Fig. 6.21, Facing and turning a pulley held on a mandrel between centers.

iii. Dogs

Lathe dogs are devices attached to the workpieces to be turned between centers (See Fig. 6.22). A set screw, or two clamping screws, holds the dog securely to the workpiece. The bent tail fits loosely into one of the drive-plate slots to drive the work-piece.

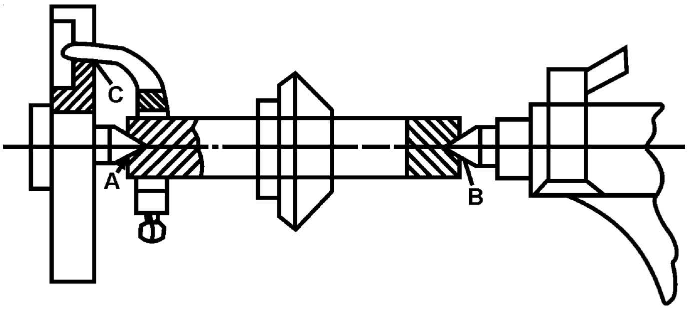


Fig. 6.22, Incorrect setup, Lathe dog tail is bearing on bottom of drive-plate slot, throwing work off center.

Bent-tail lathe dogs (Fig. 6.23) the most commonly used, are made in several styles and many sizes. The clamp-type dog is used for driving square or rectangular workpieces. Dogs with safety set screws are preferred.

Fig. 6.23, Bent-tail lathe dog.

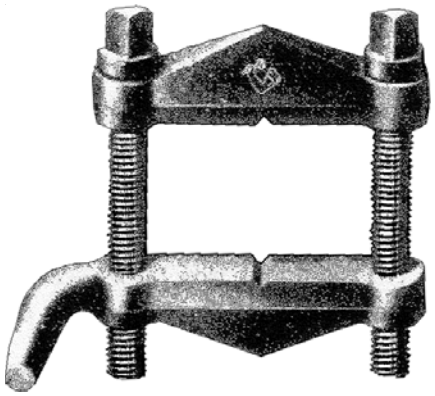


Fig. 6.24, Clamp-type dog.

Lathe dogs are devices attached to the workspieces to be turned between centers. A set screw, or two clamping screws, holds the dog securely to the workpiece. The bent tail fits loosely into one of the drive-plate slots to drive the work-piece.

Fig. 6.25, Bent-tail dog with safety set screw.

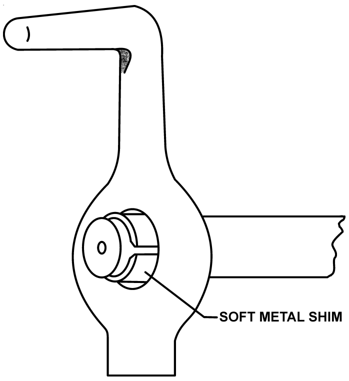


Fig. 6.26, A soft metal strip between dog screw and workpiece prevents damage to work.

iv. Face and Angle Plates

Faceplate

A faceplate (Fig. 6.27) is similar to a drive plate but larger in diameter. It contains more open slots or T slots so that bolts or T bolts may be used to clamp the workpiece to the face of the plate. Many type of work that cannot be held in chucks may be machined conveniently when mounted on a faceplate.

Place the faceplate on the bench face up. Set the workpiece on the plate. Arrange the bolts, washers, and nuts in the slots for suitable clamping. Arrange the clamps and step blocks or packing piece. Centre the workpiece by eye and tighten the clamping nuts just securely enough to hold the workpiece in place. Mount the faceplate on the spindle.True up the workpiece. Tighten all clamping nuts. Arrange and clamp the counterweights to balance the workpiece if necessary.

Counterweight are used to balance the faceplate when workpieces are mounted off-centre. They aid in distributing the weight evenly so that the face-plate will turn smoothly while machining takes place.

Angle Plates

An angle plate is simply a cast iron plate with two faces planed at right angles to each other and having slots in various positions for the clamping bolts. It is always used with the face plate for holding such parts which can not be clamped against the vertical surface fo the face plate.

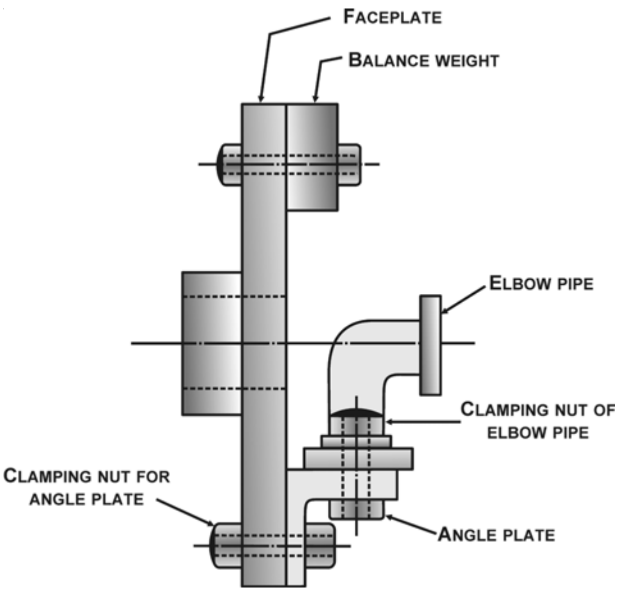


Fig. 6.27 & 6.28, Angle Plate

v. Taper Turning attachment

The Taper Attachment (Fig 6.29) is a fixed casting attached to the back of the lathe carriage. It is used to turn and bore tapers. Into the fixed casting is fitted a sliding part on top of which is guide bar. Either the guide bar or the sliding part is graduated in degrees at one end, and inches per foot of taper at the other. A clamp holds the sliding part to the ways of the lathe in a fixed position. When the guide bar is set to the desired taper, the cross-feed containing the cutting tool follows the set angle, or taper, and in turn produces this taper on the workpiece.

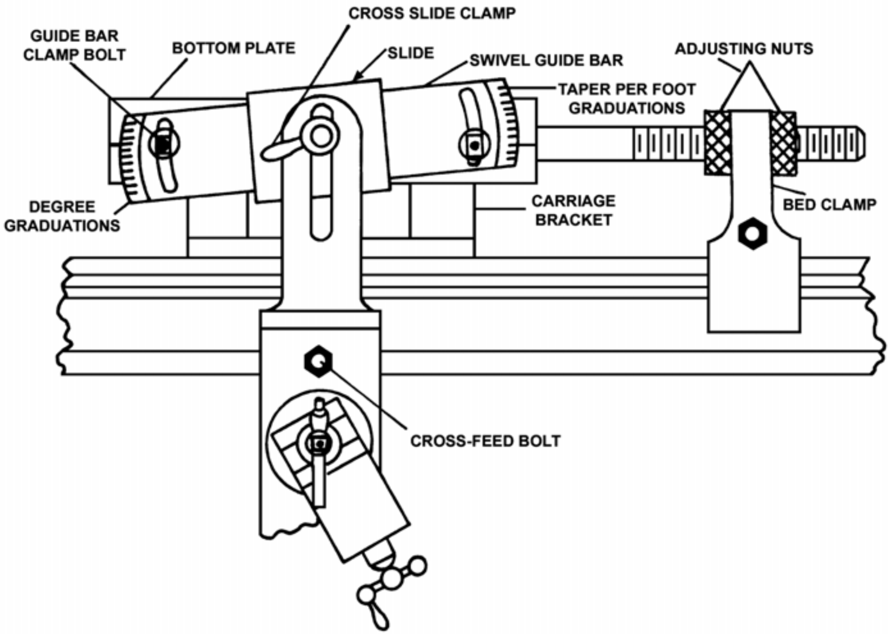


Fig. 6.29, Construction and parts of a lathe taper attachment.

III. Lathe Operations

Facing is the operation of machining the end of a workpiece to make the end square with the axis, or center line. Work may be faced while being held between centers, in a chuck, on a face plate, in a collet, or while being supported by a steady rest.

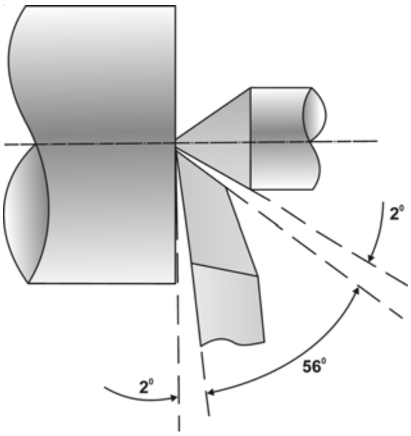


Fig. 6.30, Facing

Straight turning is the process of producing a cylindrical piece of work on which the diameter is uniform in size throughout its entire length. When the diameter at one of a cylinder differs from the diameter at the other end, it is said to be tapered.

Straight turning may be done while the work is held between centers, in chucks, in collets, or when using the steady or follower rests.

Rough turning is the operation of removing excess stock rapidly and efficiently, leaving enough stock for finishing to the specified size.

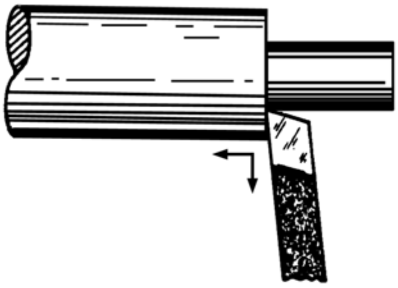


Fig. 6.31, Squaring the corner of a shoulder.

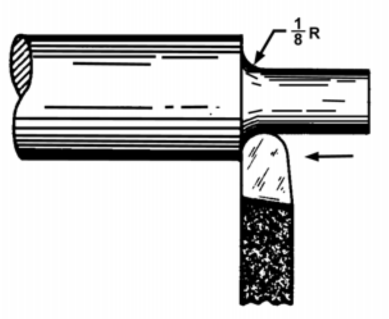


Fig. 6.32, Turning a shoulder radius, or fillet.

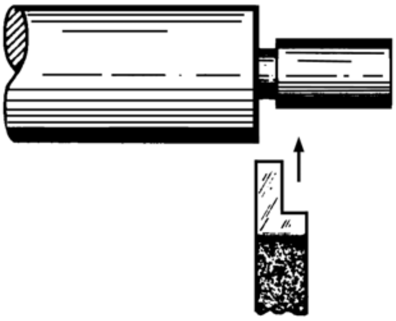


Fig. 6.33, Under cutting, or necking, a shoulder.

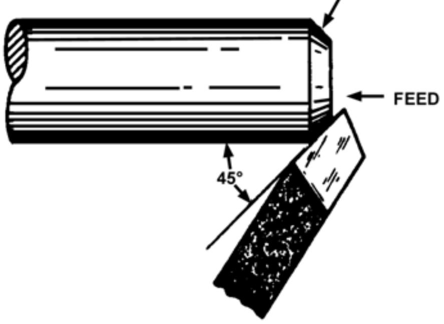


Fig. 6.34, Chamfering with the tool bit set at an angle.

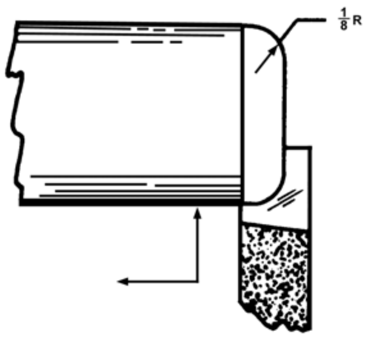


Fig. 6.35, Method of rounding a corner with a form-ground tool bit.

Finish turning is the operation of machining a work-piece to the required dimensions within the tolerance specified. The surface finish may be specified or may result from the machinist's judgment.

Shoulders are turned when two or more diameters are cut on a workpiece. The shoulder is formed at the point where the size changes from one diameter to another.

Taper turning : A taper may be defined as a uniform increase or decrease in diameter of a piece of work measured along its length. In a lathe, taper turning means to produce a conical surface by gradual reduction in diameter from a cylindrical workpiece. This tapering of a part has wide applications in the construction of machines. Almost all machine spindles have taper holes which receive taper shank of various tools and work holding devices.

Knurling is a process of rolling depressions or indentations of various shapes into metal by the use of revolving hardened-steel wheels pressed against the work. The design on the knurl will be reproduced on the work. A knurling tool (Fig. 6.36) held in the tool post is used for this operation. Knurling is done to provide a grip on handles, screw heads, and other cylindrical parts to be gripped by hand.

Knurls are classified according to patter- for example, diamond pattern or straight pattern-and according to pitch. Commonly used knurls are generally classed as coarse, medium, or fine (Figs. 6.37 and 6.38).

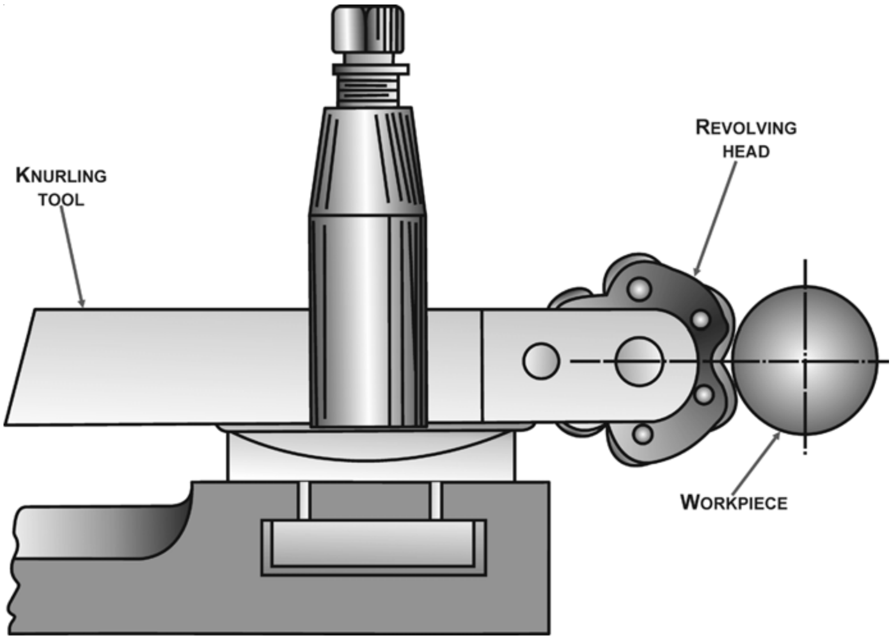


Fig. 6.36, Knurling open

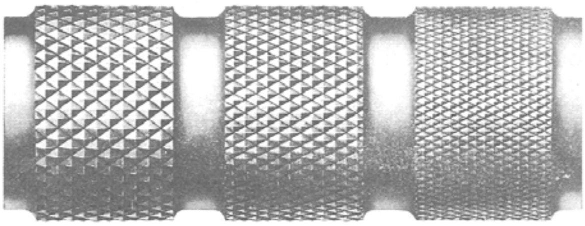


Fig. 6.37, Coarse, medium, and fine diamond pattern knurling.

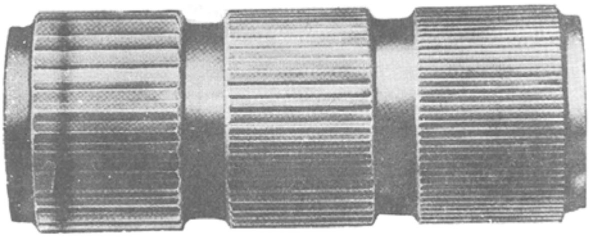


Fig. 6.38, Coarse, medium and fine straight-pattern knurling.

Position the knurling tool in the tool post so that it is at right angles to the work. The center of the knurling rolls should be set at the height of the work center to permit the knurling rolls to center themselves on the work and equalize the pressure on each of the rolls. The speed depends on the kind of material being knurled. Soft metals such as aluminum can be knurled at faster speeds than the hard alloy steels. The surface to be knurled should be machine finished. Force the knurling wheels slowly into the revolving work until a good impression is obtained; then feed the tool across the length to be knurled. After each pass, feed the tool in until a clean, clearly shaped knurl is obtained. Use a cutting lubricant while knurling.

Screw cutting is a very interesting and commonly performed operation on a lathe. It calls for a fairly high skill on the part of the operator. It is evident, therefore, that this process should be very carefully understood. Before we actually take up this operation practically on the lathe it is necessary that we should be fully conversant with the different types of threads used in engineering practice, their detailed specifications and use, various terms used in relation to them, their shapes and similar other relevant details. Such details can be obtained from any standard hand book. However, a brief outline of these is given in the appendix at the end of the book.

Threads can be produced by means of taps and dies also but the commonly used method on lathe is to cut threads by means of the cutting tool. One important point to remember is that, irrespective of the shapes and sizes, etc., there is one common factor in all threads that the basis of generation of all the threads is helix. All the threads are formed on the principle of helix which calls for a specified relative longitudinal movement of the cutting tool as the work revolves. Another prerequisite of thread cutting is that the tip or cutting edge of the tool should have an included angle corresponding to the included angle of the particular type of thread to be produced.

Both external and internal threads can be cut on lathe. For both of these the main requirement is to have a proper system of gearing between the lathe spindle and the lead screw so as to establish the required ratio of speeds between the two. For this some lathes are provided with quick-change gear box which enables the establishment of the required speed ratio very quickly. This is done by simply shifting the position of the gear change lever. Such gear boxes are made to have a number of gear inside them, mounted on two, three or more shafts, and the different combinations of these gears provide different speed ratios. These combinations are obtained by shifting the gear change lever to different positions. A chart is provided on the gear box which carries the complete information of speed and recommended feed corresponding to a particular position of the said lever. Whenever a certain ratio of speeds is to be obtained the relevant position of the said lever is readily noted from this chart and the lever shifted to that position in order to make the internal gears to have the proper combination.

In the absence of such a gearbox the change gears, provided at the left hand side of the head stock, are used to obtain the said ratio of speeds. The calculation of proper change gears and other details will be dealt with later in this article. Before proceeding on to the actual calculation work it would be certainly advisable to note a few important terms related to the threads. These terms are usually known as elements of threads. The chief elements of all the screw threads are the following: (Refer to Fig. 6.39).

i. Pitch (P)

It is the distance from one point on one thread to the corresponding point on the adjacent thread. This distance is measured parallel to the axis of the job and expressed in millimetres in metric threads and in inch for other threads.

ii. Major diameter (D)

It is the largest diameter of a screwed part, measured at right angle to the axis of the piece.

iii. Minor diameter (d)

It is the smallest diameter of the screwed part, measured normal to the axis of the piece.

iv. Pitch diameter (Pd)

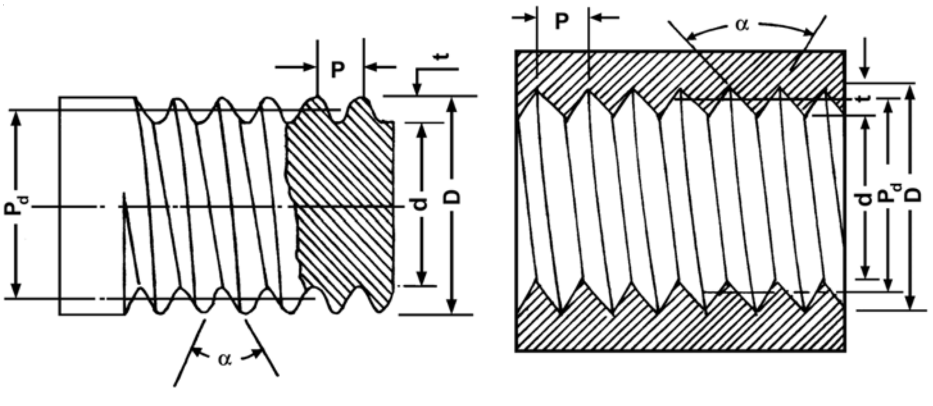
For cylindrical screwed parts this dimension represent the diameter of that imaginary cylinder of which the surface will intersect the threads at such points where the widths of the threads equal the adjacent widths of the space between them.

v. Depth of threads (t)

It is the distance, measured normal to the axis of the part, between the crest and root of the thread. Mathematically it can be expressed as, $t = (D - d) / 2$.

vi. Thread angle (α)

It is the total included angle between the flanks of a thread or two adjacent flanks of two threads.



Elements of external threads. Elements of internal threads.

Fig. 6.39

Grooving or ***necking*** is the operation through which a groove of approximately same width is produced on the job as that of the cutting edge of the tool, although larger grooves can also be made. For this, the reduction in diameter is effected by cross feed of the tool. Longitudinal feed is very rarely employed as the width of the groove generally corresponds to the cutting edge of the tool. The tool shape is similar to the one used for cutting square threads and a side relief angle of 1° to 2° is provided, so that the tool can cut freely without rubbing against the surfaces produced on the sides of the groove. For other shapes of groves, the tool cutting edges have to be shaped accordingly. In that case, it is very nearly a forming operation [Fig. 6.40 (b) and (c)]

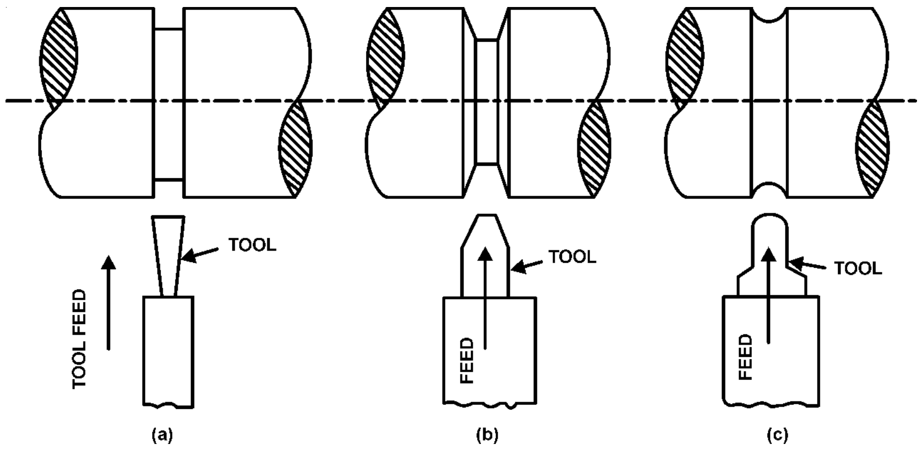


Fig. 6.40, Grooving on lathe (a) Square groove (b) A V-groove (c) A round groove.

Boring is the operation of enlarging a hole previously made by drilling, casting, or some other means. Usually a single-point tool is used to remove the stock as it is fed against the revolving work. Holes are bored to make them accurate in size and concentric with the outside surface. Tapered holes may be bored by adjusting the compound slide or the taper attachment in the same manner as for taper turning.

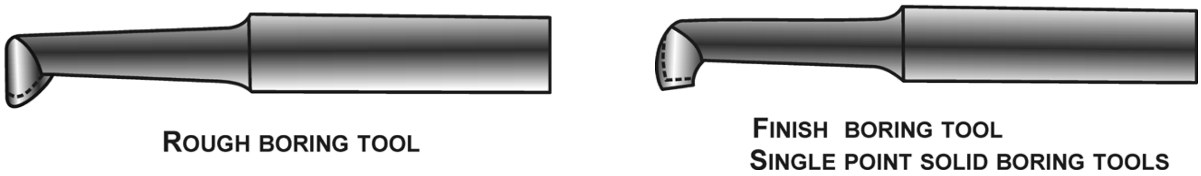


Fig. 6.41, Single point solid boring tools.

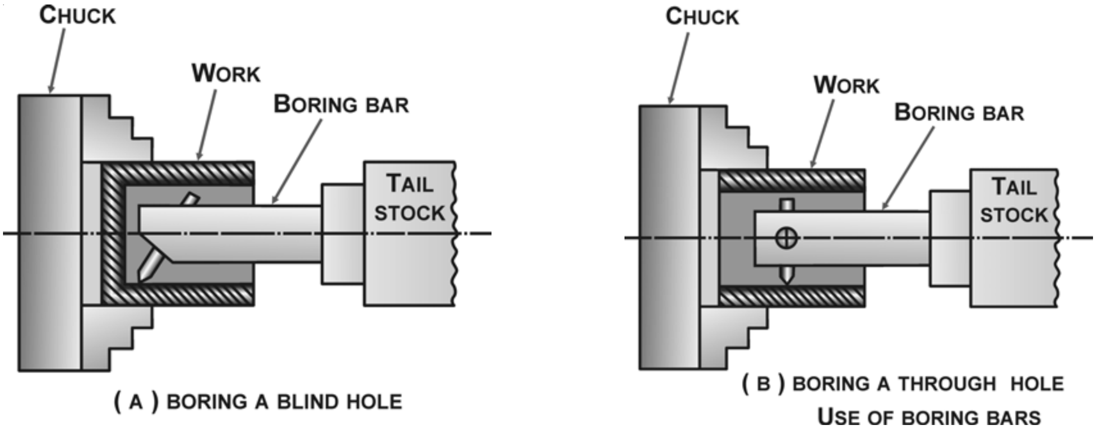


Fig. 6.42, Use of boring bars.

Drilling : Holes are **drilled** on a lathe in a manner opposite to the way holes are drilled on a drill press. On a lathe the work revolves and the drill is held stationary. Small sizes of drills are held in a drill chuck of the same design as those used on a drill press. The chuck is held in the tailstock spindle. Larger drills are held in a drill holder, which is supported by the toolholder on the left side of the handle, and by the dead center of the tail-sock on the right side.

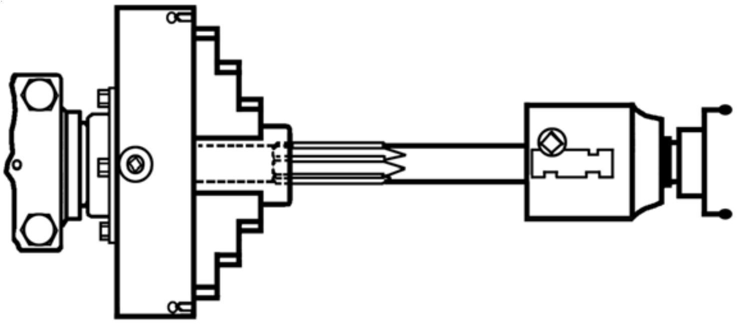


Fig. 6.43, Small straight-shank reamers may be held in a drill chuck.

Caution **:** Care must be taken to prevent the holder from slipping off the dead center.

When a drill holder is not available, a dog may be used. Holes may be reamed by holding a straight-shank reamer in the drill chuck (Fig. 6.43) or by inserting a taper-shank reamer in the tailstock spindle and feeding it slowly into the drilled hole. A cutting lubricant should be used when drilling and reaming all metals except cast iron.

Parting, or ***cutting-off***, is the operation of separating a piece of finished work from the bar stock from which the piece was machined. A parting tool with a long narrow blade is used. For small-diameter work, parting tools may be ground from a standard tool bit (Fig. 6.44). Parting tools are ground to cut on the end only (Fig. 6.45) as they are fed into the workpiece.

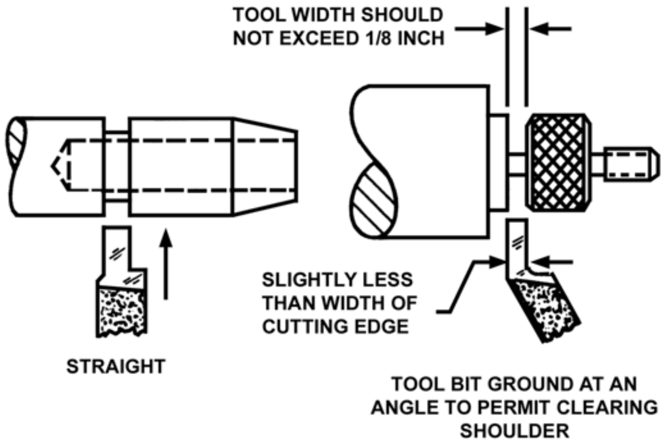


Fig. 6.44, Tool bits can be ground for cutting off small-diameter workpieces after machining.

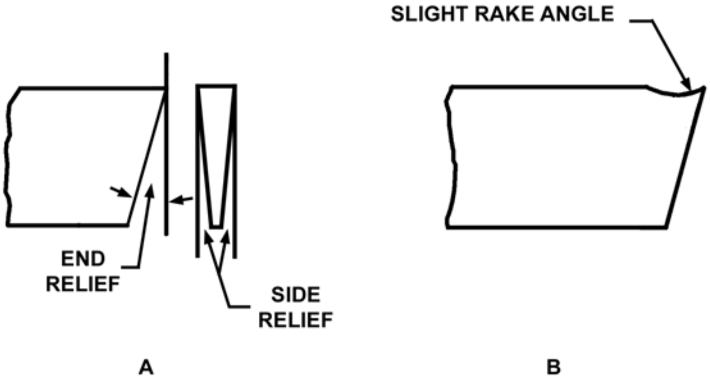


Fig. 6.45, (A) Side-relief angle on parting tool blade prevents binding. (B) Slight back-rake aids the cutting action.

■■■

CHAPTER : 7
MILLING MACHINE

7.1. MILLING MACHINE

Milling is the name given to the machining process in which the removal of metal takes place due to the cutting action of a revolving cutter when the work is fed past it. The revolving cutter is held on a spindle or arbor and the work, clamped on the machine table, fed past the same. In doing so, the teeth of the cutter remove the metal, in the form of chips, from the surface of the work to produce the desired shape.

Milling machine has acquired an indispensable position in all modern production workshops. Its specific significance lies in its capability to perform a large number of operations which no other single machine tool can perform. At the same time, it gives production at a fairly high rate and within very close limits of dimensions. That is why, in many cases, it has largely replaced other machine tools like shapers, planers, slotters, etc., but for small and medium size jobs only; as it will prove to be too slow for machining very long jobs. For small and medium jobs, the milling machine gives probably the fastest production with very high accuracy. For this reason, it has gained a very wide application in mass production work. Obviously, therefore, it is a very versatile machine tool.

Working principle in milling

The working principle, employed in the metal removing operation on a milling machine, is that the work is rigidly clamped on the table of the machine, or held between centres, and revolving multiteeth cutter mounted either on a spindle or an arbor. The cutter revolves at a fiarly high speed and the work fed slowly past the cutter, as shown in Fig. 7.1. The work can be fed in a vertical, longitudinal or cross direction. As the work advances, the cutter-teeth remove the metal from the work surface to produce the desired shape.

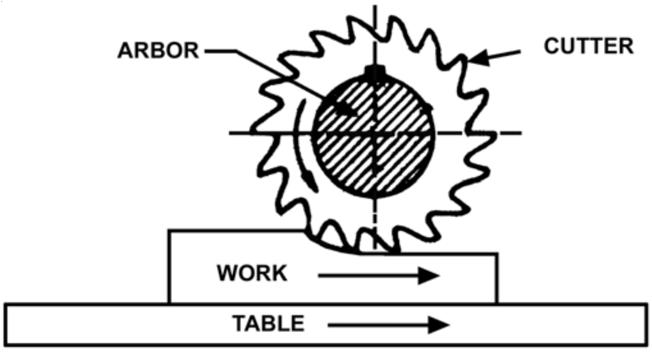


Fig. 7.1, Working principle on a milling machine.

Size and specifications

Size of a milling machine is usually denoted by the dimensions (length and breadth) of the table of the machine. Different manufacturers, however, denote these sizes by different numbers 0, 1, 2, 3, 4, 5, 6, etc. Each of these numbers indicates a particular standard size adopted by the manufacturer and the relevant literature from the manufacturer should be thoroughly consulted before ordering for a particular number. The corresponding dimensions to a particular number should be known before ordering for it so that it can meet the requirement fully. Other main specifications of the machine to be considered at the time of placing orders are the horse power of driving motor, number of spindle speeds, feeds, drive, taper of spindle nose, required floor area, gross weight, etc.

I. Types of Milling Machines

A large variety of different types of milling machines is available and it is really difficult to account for all these types in this small chapter. The broad classification of these machines can be done as follows :

a. Column and knee type milling machines.

These machines are all general purpose machines and have a single spindle only. They derive their name 'Column and knee' type from the fact that the work table is supported on a knee like casting, which can slide in vertical direction along a vertical column. These machines, depending upon the spindle position and table movements, are further classified as follows :

- Hand milling machine,
- Plain or horizontal milling machine,

- Vertical milling machine,
- Universal milling machine, and
- Omniversal milling machine.

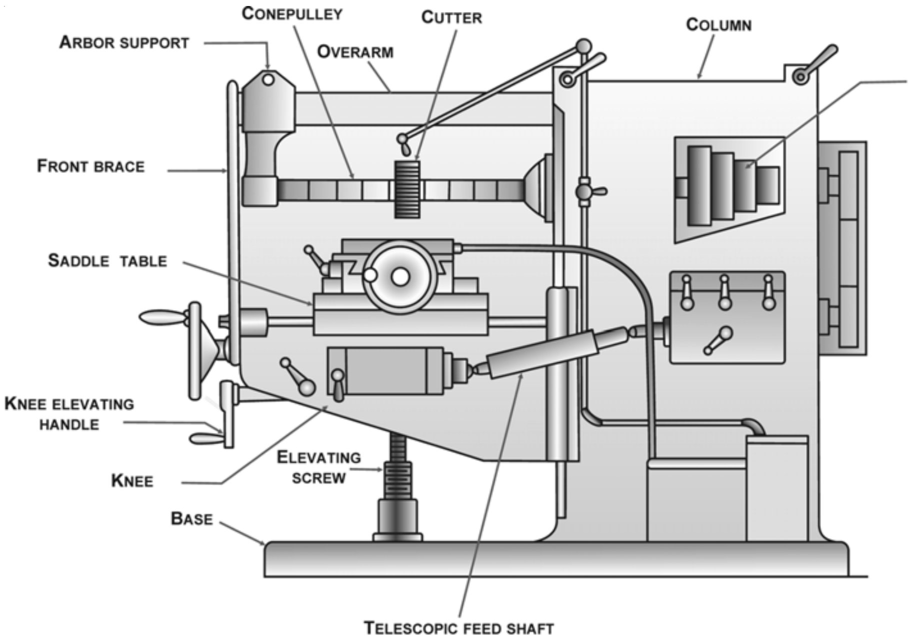


Fig. 7.2, Column and knee type milling machine.

b. Fixed bed type or manufacturing type milling machines.

These machines, in comparison to the column and knee type, are more sturdy and rigid, heavier in weight and larger in size. They are not suitable for tool room work. Most of these machines are either automatic or semi-automatic in operation. They may carry a single or multiple spindles. The common operations performed on these machines are slot cutting, grooving, gang milling and facing. Also, they facilitate machining of many jobs together, called multi-piece milling. Their further classification is as follows :

- Plain type (having single horizontal spindle).
- Duplex head (having double horizontal spindles).
- Triplex head (having two horizontal and one vertical spindle).
- Rise and fall type (for profile milling).

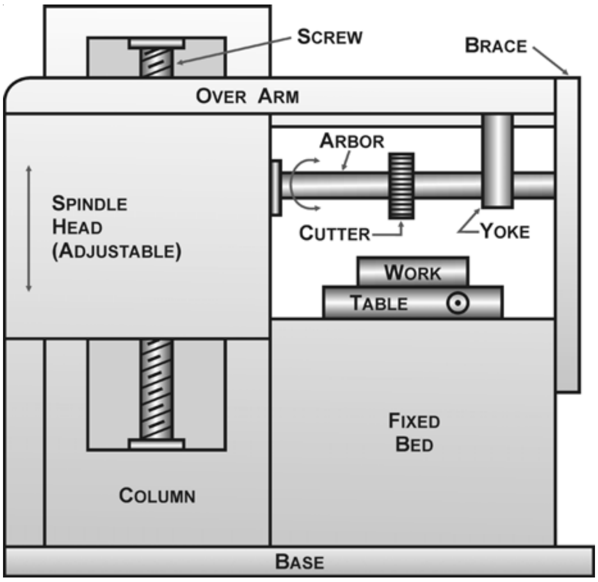


Fig. 7.3, Fixed bed type plain milling machine.

c. Planer type milling machines.

They are used for heavy work. Upto a maximum of four toolheads can be mounted over it, which can be adjusted vertically and transverse directions. It has a robust and massive construction like a planer. Its detailed description will follow in latter articles.

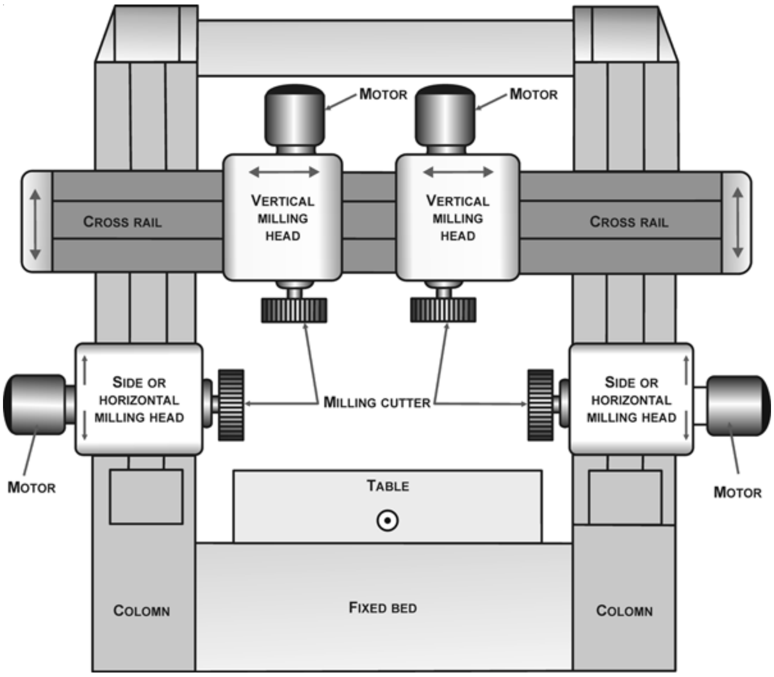
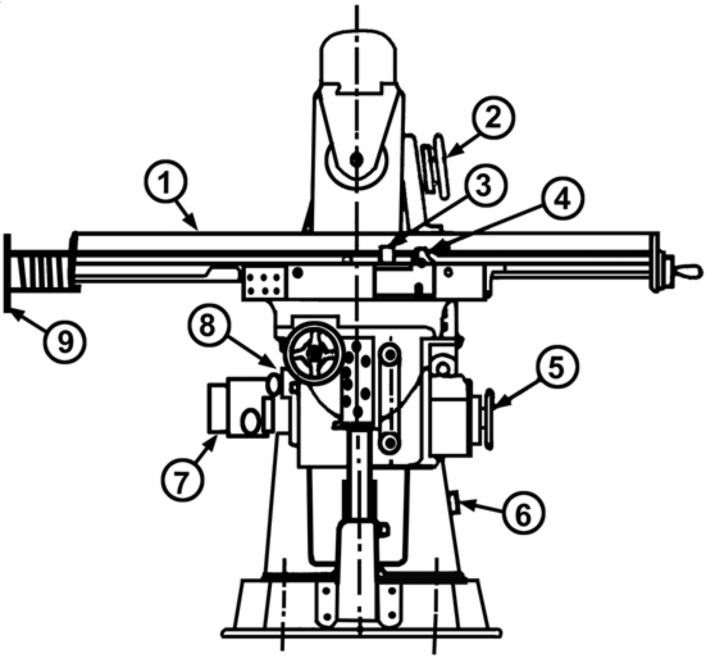
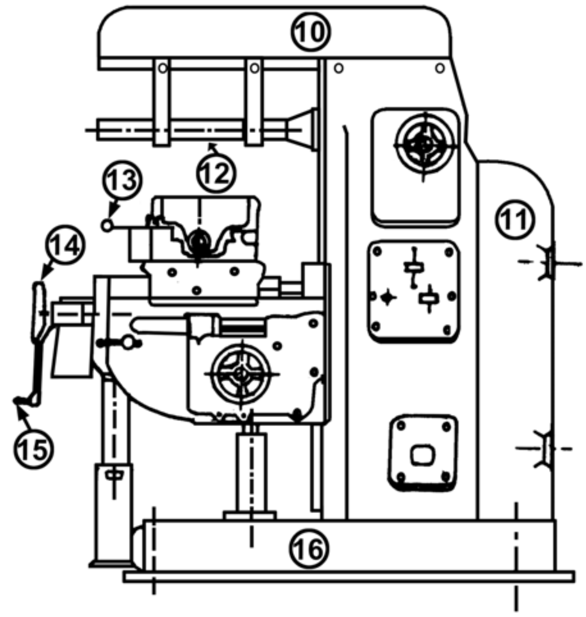


Fig. 7.4, Planer type milling machine or plan mill.

II. Parts of Milling Machines

Main parts of all the column and knee type milling machines are similar, although the movements of the moving parts differ in them, as described earlier. All these machines essentially consist of the following main parts (Fig. 7.5 & Fig. 7.6).





1. Table 2. Hand wheel for selection of spindle speeds 3. Adjustable stop for longitudinal movement 4. Table stop 5. Hand wheel for feed selection 6. Terminal box for mains connection 7. Motor for automatic feed 8. Lever for vertical and cross feed 9. Hand wheel for longitudinal table feed 10. Overam 11. Cover for the main drive 12. Arbor 13. Longitudinal feed changing lever 14. Hand wheel for cross traverse 15. Handle for vertical traverse of knee 16. Base.

Fig. 7.5, Universal milling machine.

a. Base

It is a heavy casting provided at the bottom of the machine. It is accurately machined on both the top and bottom surfaces. It actually acts as load bearing member for all other parts of the machine. Column of the machine is secured to it. Also, it carries the screw jack which supports and moves the knee. In addition to this, it also serves as a reservoir for the coolant.

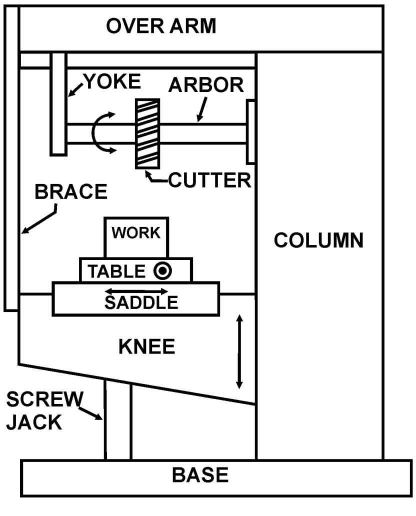


Fig. 7.6, Main parts of a plain milling machine.

b. Column

It is a very prominent part of a milling machine and is produced with enough care. To this, are fitted all the various parts and controls. On the front face of the column are made the vertical parallel ways in which the knee slides up and down. At its rear side, it carries the enclosed motor drive. A cover (No. 11. Fig. 7.5) is provided on this side, which can be opened to enable accessibility to the drive. Top of the column carries dovetail horizontal ways for the over arm.

c. Knee

It is a rigid casting, which is capable of sliding up and own along the vertical ways on the front face of the column. This enables the adjustment of the table height or, in other words, we can say the distance between the cutter and the job mounted on the table. The adjustment is provided by operating the elevating jack, provided below the knee, by means of hand wheel or application of power feed. Machined horizontal ways are provided on the top surface of the knee for the cross traverse of the saddle, and hence the table. For efficient operation of the machine, rigidity of the knee and accuracy of its ways play an important role. On the front face of the knee two bolts are usually provided for securing the braces to it to ensure greater rigidity under heavy loads.

d. Saddle

It is the intermediate part between the knee and the table and acts as a support for the latter. It can be adjusted crosswise, along the ways provided on the top of the knee, to provide cross feed to the table. At its top, it carries horizontal ways, along which moves the table during the longitudinal traverse.

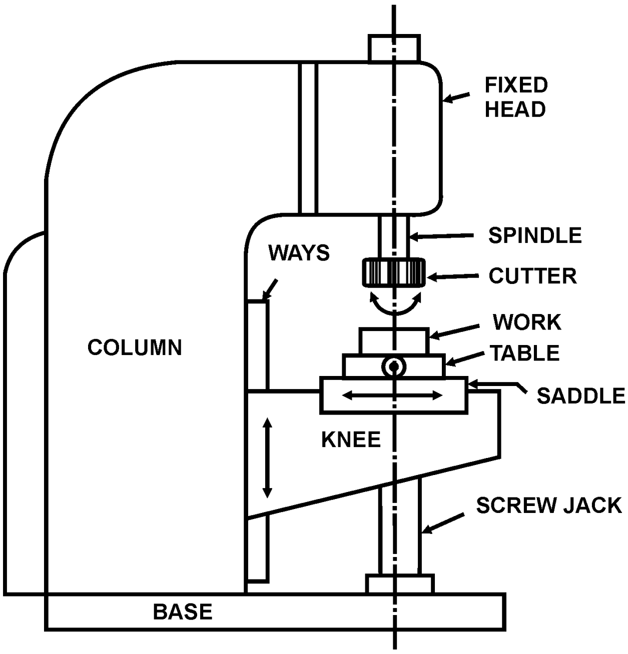


Fig. 7.7, Vertical milling machine with fixed head.

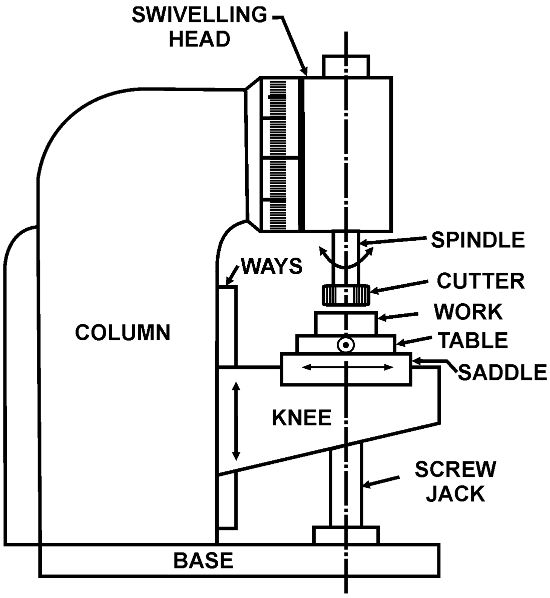


Fig. 7.8, Vertical milling machine with swivelling head.

e. Table

It acts as a support for the work. The latter is mounted on it either directly or held in the dividing head. It is made of cast iron, with its top surface accurately machined. Its top carries longitudinal T-slots to accommodate the clamping bolts for fixing the work or securing the fixtures. Also, the cutting fluid, after it is used, drains back to the reservoir through these slots and then the pipe fitted for this purpose. Longitudinal feed is provided to it by means of a hand wheel fitted on one side of the feed screw. Sometimes the hand wheels are provided on both sides or alternatively a detachable handle is provided, which can be engaged on either side. Cross feed is provided by moving the saddle and vertical feed by raising or lowering the knee. Both hand feed and power feed can be employed for all these movements. When power feeds are employed the adjustable stops should be used to trip out the same at the correct moment.

In addition to the above feeds, most of the modern milling machines carry mechanisms to provide rapid traverse in all the three directions to effect saving in time. In universal milling machines the table is made to have a graduated circular base resting on the saddle. Such a table can be swivelled in a horizontal plane around the centre of its base and the graduations on the latter help in adjusting the required swivel.

f. Overarm

It is the heavy support provided on the top of both plain and universal milling machines. It can slide horizontally, along the ways provided on the top of the column, and adjusted to a desired position in order to provide support to the projecting arbor by accommodating its free end in the yoke. If further support is needed, to have additional rigidity, braces can be employed to connect the overarm and knee. Such a requirement is always there when many cutters are employed simultaneously.

g. Front Brace

The front brace is an extra support that is fitted between the knee and the overarm to ensure further rigidity to the arbor and the knee. The front brace is slotted to allow for the adjustment of the height of the knee relative to the overarm.

h. Spindle

The spindle of the machine is located in the upper part of the column and receives power from the motor through belts, gears, clutches and transmit it to the arbor. The front end of the spindle just projects from the column face and is provided with a tapered hole into which various cutting tools and arbors may be inserted. The accuracy in metal machining by the cutter depends primarily on the accuracy, strength, and rigidity of the spindle.

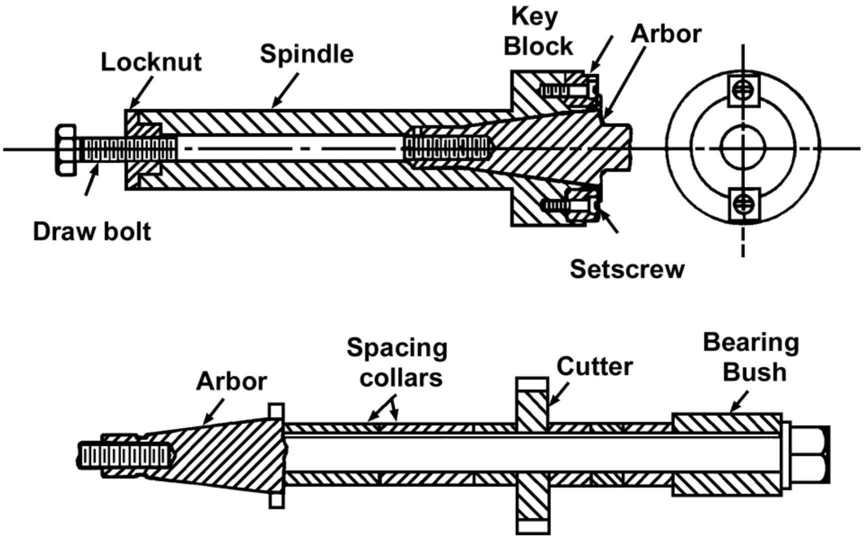


Fig. 7.9, Arbor assembly.

i. Arbor

An arbor may be considered as an extension of the machine spindle on which milling cutters are securely mounted and rotated, the arbors are made with taper shanks for proper alignment with the machine spindles having taper holes at their nose. The taper shank of the arbor conforms to the Morse taper or self release taper whose value is 7 : 24. The arbor may be supported at the farthest end from the overhanging arm or may be of cantilever type which is called stub arbor. According to the Indian standard specification, arbors with Morse taper shanks are available from 13 to 60 mm in diameter and arbors with self release type from 16 to 100 mm in diameter. The stub arbors are available from 13 to 16 mm in diameter. The arbor shanks are properly gripped against the spindle taper by a draw bolt 1 which extends throughout the length of the hollow spindle 3. The threaded end of the draw bolt 1 is fastened to the tapped hole of the arbor shank 5 and then locknut 2 is tightened against the spindle. This causes the arbor shank to be pulled inside gripping it firmly against the taper hole of the spindle. The spindle has also two keys 4 for imparting positive drive to the arbor in addition tot he friction developed in the taper surfaces. The ejection of the arbor is effected by unscrewing the locknut 2 and then rapping the draw bolt 1 lightly. The cutter 8 is set at the required position of the arbor by spacing collars 7 or spacers of various lengths but of equal diameter. The entire assembly of the milling cutter and the spacers are fastened to the arbor by a long key. The end spacer 9 on the arbor is slightly larger in diameter and acts as a bearing bush for bearing support which extends from the overarm. The whole set up is locked from the end by the arbor nut. Fig. 7.9 illustrates an arbor assembly the draw bolt arrangement for locking the arbor with the spindle.

III. Operations performed on Milling Machines

a. Plain Milling or Slab Milling

It is the process which is employed for machining a flat surface, parallel to the axis of the cutter, by using a plain or slab milling cutter, as shown in Fig. 7.10. When a very wide surface is to be machined, it is advisable to use the interlocking teeth plain milling cutters instead of simple slab mills. In using them, they should be so arranged that the axial forces are directed towards each other so as to force the cutters closer as the operation proceeds.

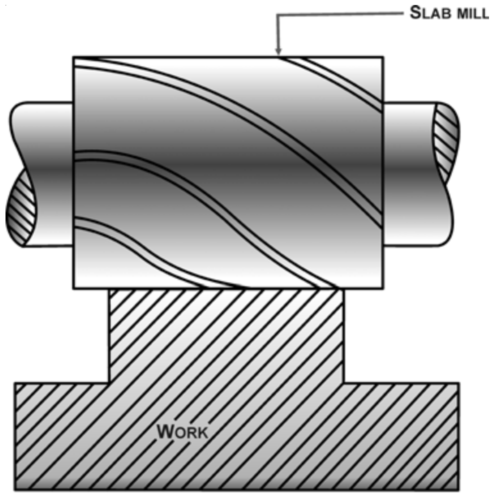


Fig. 7.10, Plain or slab milling

b. Face Milling

This milling process is employed for machining a flat surface which is at right angles to the axis of the rotating cutter. The cutter used in this operation is the face milling cutter (See Fig. 7.11).

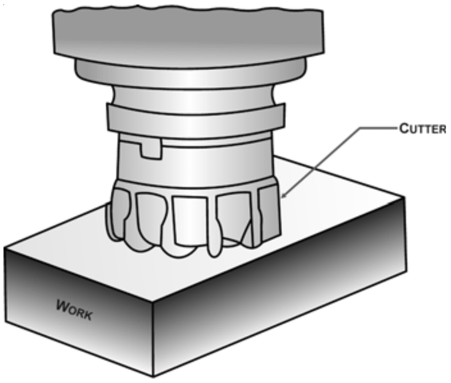


Fig. 7.11, Face milling.

c. Side Milling

In this operation, a side milling cutter is used to machine a flat vertical surface on a side of the workpiece. When two parallel vertical flat surfaces are required to be machine, the usual time saving practice is to use a pair of two side milling cutters to machine both the surfaces simultaneously. The space between the two cutters can be easily adjusted as per requirement by suing the spacers. This operation is then known as 'straddle milling' and is already explained earlier.

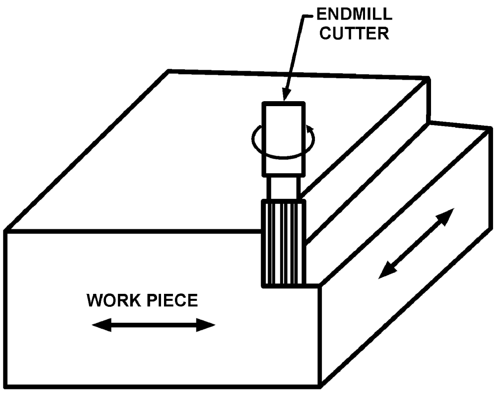


Fig. 7.12, Producing a single flat surface by using an End mill cutter.

d. Straddle Milling

It is a milling operation in which a pair of side milling cutters is used for machining two parallel vertical surfaces of a work-piece simultaneously.

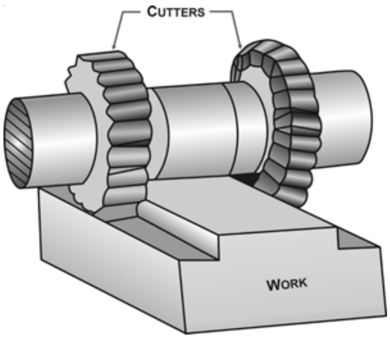


Fig. 7.13, Form milling.

e. Angular Milling

It is the milling process which is used for machining a flat surface at an angle, other than a right angle to the axis of the revolving cutter. The cutter used may be a single or double angle cutter, depending upon whether a single surface is to be machined or two mutually inclined surfaces simultaneously. (See Fig. 7.14).

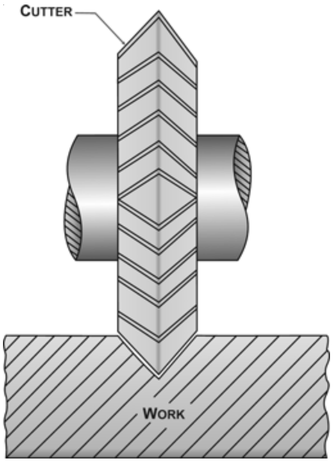


Fig. 7.14, Angular milling

f. Gang Milling

It is the name given to a milling operation which involves the sue of a combination of more than two cutters, mounted on a common arbor, for milling a number of flat horizontal and vertical surfaces of a work-piece simultaneously. This combination may consist of only side milling cutters or plain and side milling cutters both. Fig. 7.15 shows the gang milling operation.

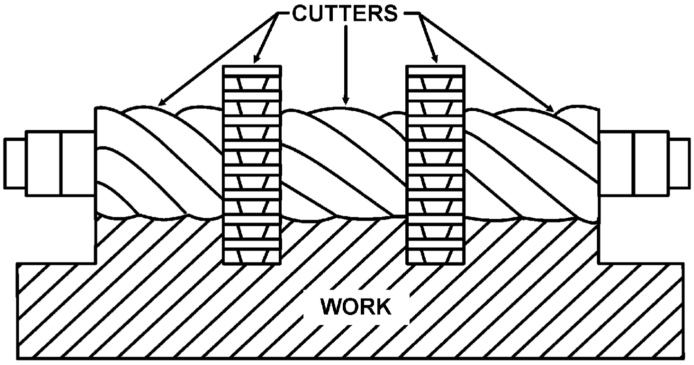


Fig. 7.15, Gang milling

g. Form Milling

This milling process is employed for machining those surfaces which are of irregular shapes. The cutter used, called a form milling cutter, will have the shape of its cutting teeth conforming to the profile of the surface to be produced. (See Fig. 7.16)

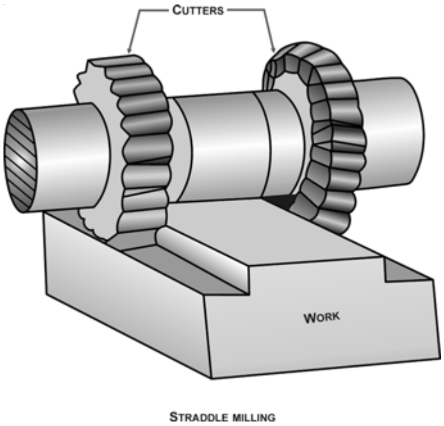


Fig. 7.16, Form milling.

h. Profile Milling

It is the operation in which the profile of a template or the shape of the cavity of a master-die is duplicated on the work surface. The movement of the cutter is guided by a tracer control unit which carries a contact finger. This finger runs in contact with the outline to be duplicated and the tracer mechanism guides the tool movement accordingly.

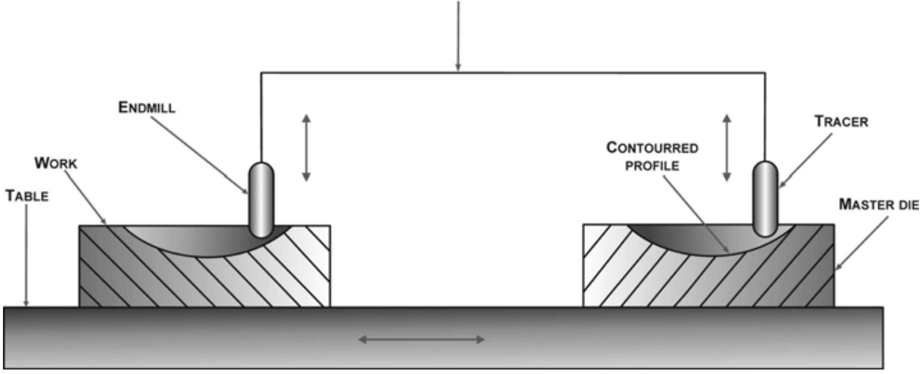


Fig. 7.17, Profile Milling

i. End Milling

In this operation, an end mill cutter is used to machine and produce a flat surface or a pair of parallel flat surfaces. When the operation is performed at the end of a workpiece, as shown in Fig. 7.18, a single flat surface is produced. If however, the operation is performed in such a way that cutting of metal takes place on both sides of the cutter, two parallel flat surfaces are produced, as happens in milling a plain slot. The surfaces produced may be horizontal, vertical or inclined with respect tot eh top of the machine table. For producing a horizontal surface, the axis of rotation of the cutter has to be horizontal, for vertical surface it remains vertical and for inclined surface it is to be set at proper inclination with the table top.

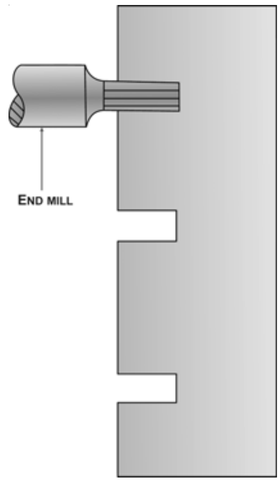


Fig. 7.18, End Milling

j. Saw Milling or Slitting Milling

A slitting saw or slitting cutter is used for many purposes on a milling machine, such as parting off a solid workpiece into two, cutting of narrow slots and grooves, etc. An important factor in any slitting operation is the rigidity of the workpiece. If the component has such across-section that no deflection is likely to be produced during cutting, it can be safely gripped in a vice such that the portion to be cut-off extends beyond the jaws of the vice. In other cases, the workpiece may be clamped directly on the machine table using suitable job holding devices. An important precaution in his case is to keep the line of cutting in the centre of a T-slot and running along its length. This will allow the slitting saw to project safely into the free space in the slot to prevent its teeth from being damaged. A parting off operation, being performed by means of a slitting saw, is shown in Fig. 7.19.

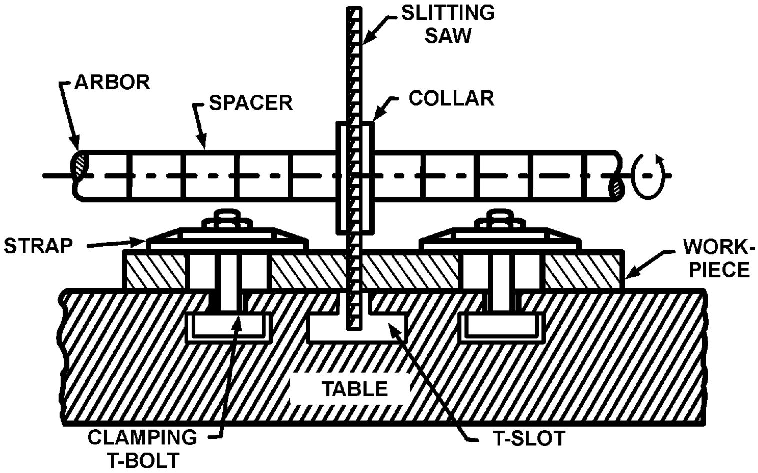


Fig. 7.19, A slitting saw being used for parting off operation.

k. Milling Keyway, groove & slots

Milling of a keyway is a commonly performed operation on a milling machine in which a groove is milled, usually on shafts and spindles. This groove is known as key seat. The groove can be open or closed, depending upon the type of key to be used and the position in which it is to be used. Fig. 7.20 shows the three common forms of key seats. At (a) is shown a woodruff key seat milled with a woodruff keyseat cutter. It is a closed groove with a rounded bottom. At (b) is shown a plain keyseat milled with a single plain or side milling cutter. It is an open groove. At (c) is shown the operation of milling a keyseat for a sunk key with the help of an endmill cutter. It is a closed groove with rounded ends. This type of key seat can be produced anywhere along the length of the workpiece. Same is the case with woodruff key seat.

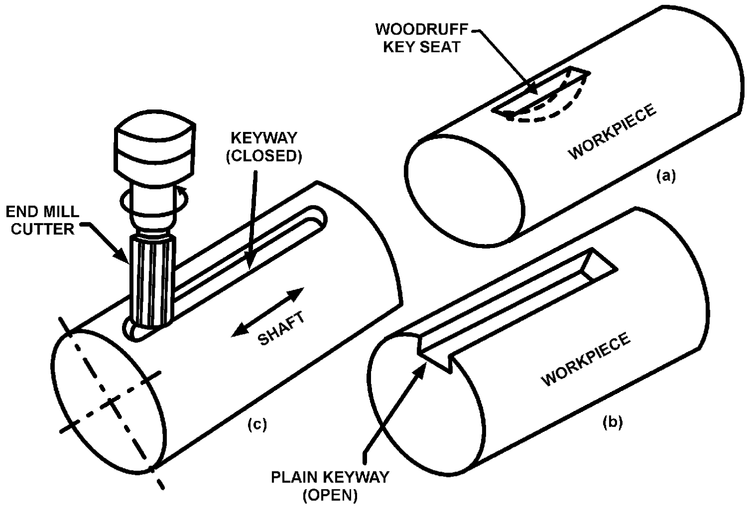


Fig. 7.20, Keyway milling
(a) A woodruff key seat (b) A plain (open) key seat (c) a sunk (closed) key seat.

Slot milling is the operation of producing slots in solid workpieces on a milling machine. These slots can be of varied shapes, such as plain slots, T-slots, Dovetail slots, etc. Similarly, groove milling is the operation of producing grooves of different shapes, such as plain grooves, curved grooves, V-grooves, etc. The cutter to be used is chosen according to the shape of the groove or slot to be produced. Milling of a V-groove. The same result can be obtained with two single angle cutters of opposite angles, used one after the other. Similarly, plain grooves or slots can be milled by means of a plain milling cutter, an end mill, a slitting saw or a side milling cutter (See Fig. 7.21).

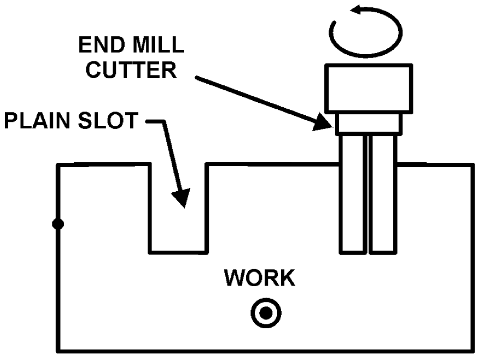


Fig. 7.21, Milling a plain slot by means of an End Mill Cutter.

Milling of T-slot and Dovetail slot is carried out in two or three stages. In the first stage an open slot, from one end of the solid workpiece to its other end, is first sage an open slot, from one end of the solid workpiece to its other end, is first milled with the help of a suitable cutter, say a plain milling cutter or an end mill. Then the slot is milled to the required shape by suing a special cutter- a T-slot cutter for T-slots and Dovetail milling cutter for dovetail slots. The operation of finish milling a T-slot is shown in Fig. 7.22. Production of a Dovetail slot in three stages is shown in Fig. 7.22. At (a) is shown a rectangular slot produced through rough machining by means of a plain milling cutter. The required angles of the dovetail re then rough machined by means of a form angle cutter and a rough machined dovetail slot obtained, as shown at Fig. 7.22 (b). The slot is finally finished by machining the base and sides of the slot with the help of a dovetail milling cutter.

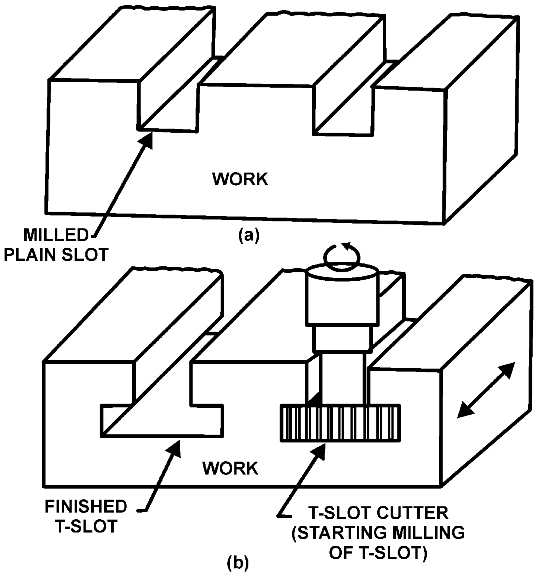


Fig. 7.22, Milling a T-slot, using a T-slot milling cutter
(a) Work having milled plain slots. (b) Milling T-slots with T-slot milling cutter.

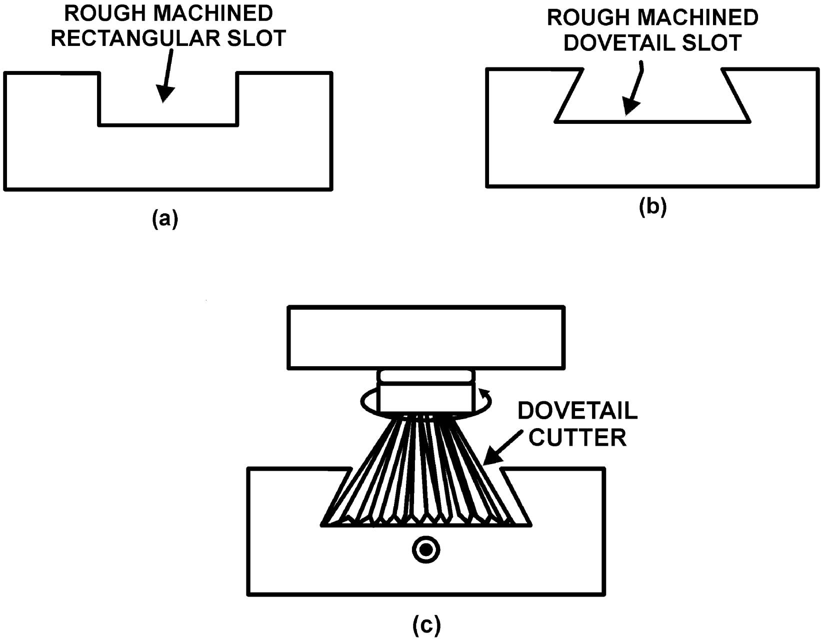


Fig. 7.23, Milling a Dovetail slot. (a) Rough machined rectangular slot, (b) Rough machined dovetail slot
(c) Finish machining the dovetail slot with the help of a dovetail milling cutter.

l. Gear Cutting

This operation, often referred to as Gear cutting, involves cutting of different types of gears on a milling machine. For this, either a end-mill cutter or a form relieved cutter is used, which carries the profile on its cutting teeth corresponding to the required profile of the gap between gear teeth. For dividing the periphery of the gear blank into required number of equispaced parts an indexing mechanism or dividing head is used, which is described later in this chapter.

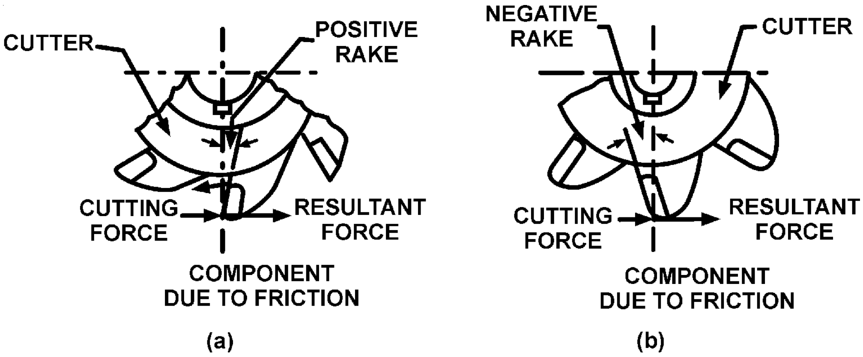


Fig. 7.24, Negative rake milling Vs positive rake milling.

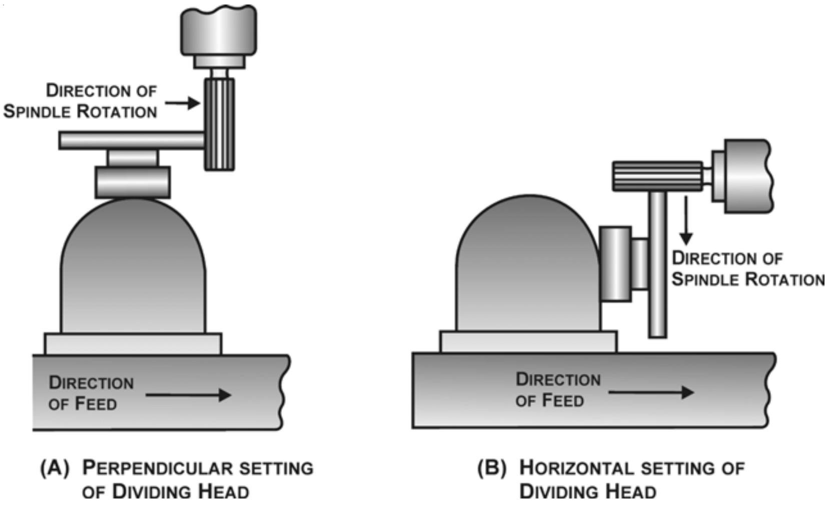
m. Helical Milling

The helical milling is the operation of production of helical flutes or grooves around the periphery of a cylindrical or conical workpiece. The operation is performed by swivelling the table to the required helix angle and then y rotating and feeding the work against rotary cutting edges of a milling cutter. The usual examples of work performed by helical milling operations are : the production of helical milling cutters, helical gears, cutting helical grooves or flutes on a drill blank or a reamer.

n. Cam Milling

The cam milling is the operation of production of cams in a milling machine by the use of a universal dividing head and a vertical milling attachment. The cam blank is mounted at the end of the dividing head spindle and an end mill is held in the vertical milling attachment. The axis of the cam blank and the end mill spindle should always remain parallel to each other when set for cam milling. The dividing head is geared to the table feed screw so that the cam is rotated about its axis while it is fed against the end mill. The axis of the cam can be set from zero to ninety degrees in reference to the surface of the table for obtaining different rise of the cam.

In the first case, when the dividing head spindle or the cam axis is set perpendicular to the table, as the table advances and the blank is turned, the centre distance between the dividing head spindle axis and the cutter axis is gradually reduced. This causes the radius of the cam to be shortened, and produces a spiral lobe with a lead which is same as that for which the machine is geared. The perpendicular setting of the dividing head spindle is shown in Fig. 7.25.



(A) PERPENDICULAR SETTING OF DIVIDING HEAD
(B) HORIZONTAL SETTING OF DIVIDING HEAD

Fig. 7.25, Cam milling - perpendicular and parallel setting.

In the second case, the setting of the dividing head spindle and the cutter axis is made horizontal and parallel to each other. If the cam, which is mounted at the end of the dividing head spindle, is now rotated and fed against the cutter, the centre distance between the two spindle axis will remain unaltered. This would result in the milling of a circle and the lead of the spiral would be zero. The horizontal setting of the dividing head is shown in Fig. 7.25.

It follows from the above two conditions that if the dividing head spindle or the cam axis is et at any angle between zero to ninety degrees, the amount of lead given to the cam will change from zero to the maximum lead for which the machine is geared. The angular setting of the dividing head spindle is shown in Fig. 7.26.

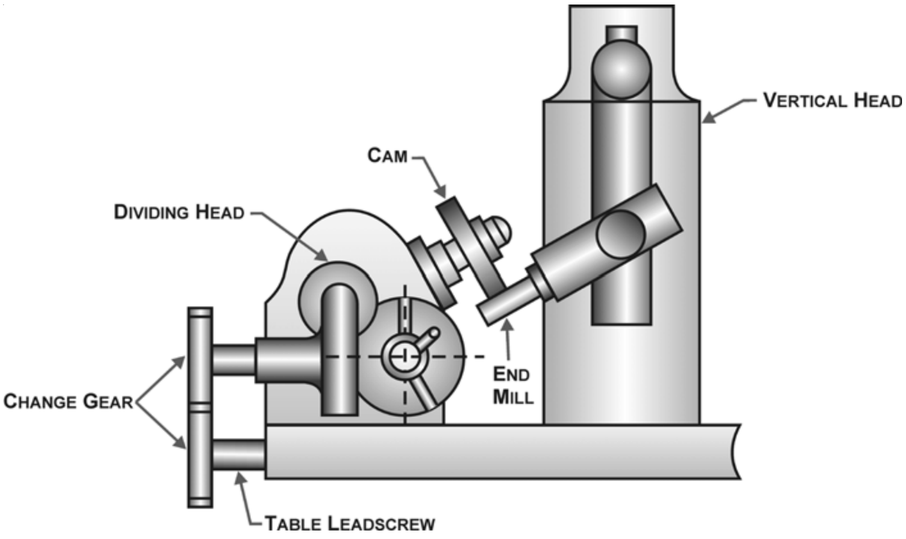
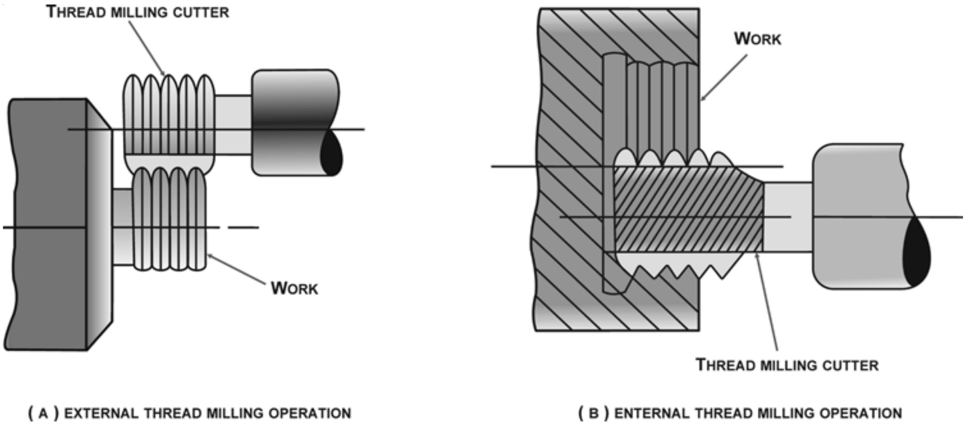


Fig. 7.26, Cam milling - angular setting.

Thus with one set of change gears only, the production of cams having different leads are possible by simply setting the dividing head spindle to the required angle.

o. Thread Milling

The thread milling is the operation of production of threads by using a single or multiple thread milling cutter. The operation is performed in special thread milling machines to produced accurate threads in small or large quantities. The operation requires three driving motions in the machine : one for the cutter, one for the work and the third for the longitudinal movement of the cutter.



(A) EXTERNAL THREAD MILLING OPERATION

(B) ENTERNAL THREAD MILLING OPERATION

Fig. 7.27, Thread milling operation.

When the operation is performed by a single thread milling cuter, the cutter head is swivelled to the exact helix angle of the thread. The cutter is rotated on the spindle and the work is revolved slowly about its axis. The thread is completed in one cut by setting the cutter to the full depth of the thread and then feeding it along the entire length of the workpiece.

When the thread is cut by a multiple thread milling cutter, the cutter axis and the work spindle are set parallel to each other after adjusting the depth of cut equal to the full depth of the thread. The thread is completed by simply feeding the revolving cutter longitudinally through a distance equal to the pitch length of the thread while the work is rotated through one complete revolution. Fig. 7.27 illustrates the thread milling operation.

■■■

CHAPTER : 8

TOOL GRINDING

To do a good job of grinding, one must be able not only to operate the machine but also to understand abrasives and grinding wheels. This portion will begin with a description of natural and manufactured abrasives - the bonds and abrasives used in making grinding wheels, the different grades and shapes of grinding wheels, and the selection of the proper grinding wheel for different types of work.

Abrasive

An abrasive is any material that can wear away a substance softer than itself. Sand and sandstone are perhaps the oldest abrasives known to mankind. Prehistoric man used sand and sandstone to form or shape edges of tools. As tools became more and more important for preservation of life, he became more dependent on natural abrasives for the maintenance of sharp tools.

Natural Abrasives

Emery and corundum are two natural abrasives commonly used in industry to sharpen tool edges. They occur as a mineral deposit in the earth's crust. These abrasives, formed into wheels, are superior to the old sand grindstones. Although they can cut faster and be made coarse or fine, they cannot meet the demands of modern manufacturing because they contain impurities that are difficult to extract and because the percentage of the important cutting element, aluminum oxide, is not constant. The only other element known to be harder than emery or corundum is the diamond, but its cost was prohibitive for industrial usage.

In 1891, Dr. Edward G. Acheson set to the task of trying to produce artificial diamonds by combining powdered coke and corundum clay at extremely high temperatures. He discovered that after the mass cooled it contained brightly colored crystals that cold cut glass and had a slight cutting effect on diamonds. Dr. Acheson called the new substance Carborundum because it was formed from carbon and corundum. Subsequent research established that its components are silicon and carbon, so it was called silicon carbide (chemical symbol SiC).

Silicon carbide was considered the answer to the quest for a better abrasive, but cost and limited methods of manufacture kept it from being used except as a lapping compound for finishing precious jewels. With the development of hydroelectric generators and cheap electric power, the cost of production was cut to a point where all industries could afford to used it.

About the same time that Dr. Acheson was experimentally producing silicon carbide, Charles P. Jacobs, an engineer in Ampere, New Jersey, was attempting to produce a better grade of emery. He used a small electric furnace to extract the impurities of sand, iron, and titanium oxides from clay deposits rich in aluminum oxide. The result was a product that consisted of about 95 percent pure aluminum oxide (chemical symbol Al_2O_3).

Although these two excellent abrasives are similar in some respects, their significant properties differ widely. Silicon carbide is extremely hard; it is rated at 9.87 on the 10-point Mohs scale, which is based on the hardness of the diamond. It is easily fractured by impact, and its excellence depends upon the purity of the ingredients used in making it. Aluminum oxide is less hard (9.6 on the Mohs scale), but it is much tougher than silicon carbide.

Silicon carbide is best suited for grinding materials that have low tensile strength but are very hard, such as ceramics, pottery, and tungsten carbide.

Because of its toughness aluminum oxide is resistant to shock and therefore suitable for grinding materials of high tensile strength such as tool steel and high-speed steel.

Man-made abrasives have a distinct advantage over natural abrasives because purity and grain size can be readily controlled. Grain size is important because undersize grains cannot do their share of work, and oversize grains give work a poor finish.

Electric furnaces are used to produce both types of abrasives. Silicon carbide is made in an open, trough like furnace by fusing a mixture of coke, saw-dust, sand, and salt. After the mass has cooled, the sides of the furnace are let down, exposing a big clinker. This clinker is broken with a drop weight, and the pieces are put through a crusher machine. As the abrasive particles leave the crusher, they are washed and magnetically cleaned. They then pass on to shaker screens, which have from 4 to 220 meshes to the lineal inch. By vibrating action the screens sort the grains according to size. If the abrasive passes through a screen with 30 meshes to the lineal inch, but is retained on a screen of 36 meshes, it is called a No. 30 abrasive. Abrasives finer than 220 are graded for size by hydraulic or sedimentation methods. After the abrasive has been graded to size, it is dried and placed in storage bins or hoppers for future use. Figure 8.1 shows various grain size classifications.

Very Coarse	Coarse	Medium	Fine	Very Fine	Flour Sizes
8	12	30	70	150	280
10	14	36	80	180	320
	16	46	90	220	400
	20	60	100	240	500
	24		120		600

Fig. 8.1, Grain-Size Classification.

Hardest Abrasive

Diamonds are the hardest known materials produced by nature. Chemists and laboratory technicians tried for 125 years to develop the combination of elements that would produced a man-made diamond. In 1955, the General Electric Company announced success in producing artificial diamonds suitable for industrial use. The diamond abrasive wheel has become a necessary tool in all production shops where cemented carbide cutting tools are used.

Grinding Wheels

Grinding wheels are formed by using a suitable material to cement, or bond, the abrasive grains together in the desired shape. The hardness of the wheel is dependent upon the amount and kind of bonding material used. Because the hardness rating of the abrasive is constant, the bond cannot have an effect on its rating. The hardness of a wheel is always understood to mean the strength of the bond.

There are many different kinds of bonds. Those most commonly used are vitrified, silicate, shellac, rubber, and resinoid. The vitrified and silicate are used more frequently than the others.

The ***vitrified bond*** has the strength and porosity to enable it to remove a considerable amount of stock from a job for each inch of wheel wear. It is not affected by water, acids, or ordinary temperature changes, and it is free from hard or soft spots. In the vitrified process, glass, feldspar, flint, or other ceramic substances are mixed with the abrasive and subjected to heat, which causes the bond to form a glasslike structure between each abrasive particle. The vitrified bond is used in 75 percent of all grinding wheels.

The ***silicate bond*** is made from sodium silicate. The hardness of a silicate-bond wheel is governed by the amount of bond material used, and by the amount of tamping or pressing. This kind of bond produces a wheel that is milder acting than the vitrified wheel. Because the abrasive grains are released more readily they do not heat up so fast. Silicate wheels can be made in larger diameters than vitrified wheels. They are generally used for grinding edged tools such as drills, reamers, milling cutters, and so forth.

Rubber wheels are made of a mixture of abrasive, rubber, and sulphur. The mass is then pressed into shape and given a mild vulcanizing treatment. Wheels of this bond are used for high-speed grinding operations. Because of their high safety factor rubber-bonded wheels can be made very thin for use in cutting off steel stock.

Shellac-bonded wheels are made by mixing the abrasive and the bond in a heated machine, which completely coats the abrasive with the bonding material. After the wheels are formed, they are placed in an oven, covered with sand, and baked for a short time at approximately 300°F. Wheels of this bond are used extensively for grinding mill rolls, and for jobs where a high-luster finish is required.

Resinoid-bonded wheels are made by mixing powdered resinoid with the abrasive particles and adding a plastic substance so that the wheels can be molded. The mold is then placed in an electric oven and heated to approximately 300°F, for a period ranging from a few hours to three or four days, depending on the size of the wheel. Upon cooling, the wheel becomes very hard. Wheels of this bond are generally used in foundries for snagging castings or for cleaning up steel billets.

Diamond wheels are made in three kinds of bonds : resinoid, metal, and vitrified. Each gives the wheel unique characteristics. The diamond wheel with the resinoid bond has a very cool and fast cutting action.

The metal-bonded wheel has unusual durability and a high resistance to grooving.

The vitrified-bonded diamond wheel has the fast cutting action of the resinoid-bonded wheel and the durability of the metal-bonded wheel.

The term wheel structure refers to the spacing of the abrasive grains. Two wheels of the same grade and grain size but of different grain spacing will have different cutting actions. Wheels with wide grain spacing should be used on soft materials or when stock is to be removed rapidly. Wheels with close spacing should be used on hard materials or when a fine finish is to be given to the work. Wheel life can often be increased without sacrificing grinding quality by using the same grain and grade of wheel but with a different structure, depending upon the job to be done.

Numbers are used to indicate wheel structure. The smaller the number, the closer the structure. In general, the ranges are 0 to 3 for close structure, 4 to 6 for medium structure, and 7 to 12 for coarse structure.

As noted previously, the amount of bond used in making a grinding wheel determines its hardness. Letters of the alphabet indicate the degree of hardness. Norton and several other companies use letters at the beginning of the alphabet to indicate soft wheels and letters at the end to indicate hard wheels. This lettering system for the grade of bond and the relationship to hardness in shown in Fig. 8.2. Figure 8.3 shows the grain sizes commonly used with various grades of bond. The Carborundum Company uses a letter system in the reverse order.

Very Soft	Soft	Medium	hard	Very Hard
E F G	H I J K	L M N O	P Q R S	T U W Z

Fig. 8.2, Grade of bond according to hardness.

	Surface	Internal	External	Cutter
Grades Grain Sizes	FGHIJKP 36-46-60-80 120	IJKL 34-46 60 -120	JKLMP* 46-60-80 120	IJKL 36-46 60

Fig. 8.3, Commonly used grades and grain sizes.

In the Norton system, a wheel marked 3860-K5BE has the following characteristics : 38 indicates the kind of abrasive, which in this case is alundum (aluminum oxide); 60 is the grain size, which is medium, K indicates the grade of the bond, which is soft (See Fig. 8.2); 5 indicates the wheel structure, which is medium; and BE indicates the kind of bond, which is vitrified. Other bond symbols are ; S, silicate bond; T, resinoid bond; R rubber bond; and I, shellac bond.

Several factors affect the selection of a grinding wheel : (a) the kind of material to be ground, (b) the amount of stock to be removed, (c) the accuracy as to size, (d) the kind of finish required, (e) the area of contact between the wheel and the work, and (f) the kind of grinding machine to be used.

The nature of the material to be ground affects the selection of the wheel because, generally speaking, hard, dense materials require wheels possessing a soft bond with silicon carbide abrasive; soft and tough materials require a hard bond with aluminum oxide abrasive.

The amount of material to be removed is important in selecting grinding wheel because, when a considerable amount of material is to be removed, the grains of a wide-spaced coarse-grain wheel will take a bigger, deeper cut without heating the work, but with a slight sacrifice as to surface finish. When the amount of stock to be removed is slight, a wheel of fine grain and narrow spacing will take a smaller bite and give a good finish.

Other factors affect the grinding operation- for example, the speed of the wheel, the speed of the work, the condition of the grinding machine, and the knowledge and skill of the machine operator.

Grinding is the act of dressing, shaping, or finishing surfaces with a rotating abrasive wheel. In modern machine shop operation, grinding costs vary as much as 100 percent on the same work with the same kind of machine in the same factory.

This is because some operators handle the machine more skillfully than others. A good machinist takes into consideration the factors involving the mounting, movement, size, and speed of the work and the mounting, movement, size, speed, and dressing, or truing, of the grinding wheel.

For precision grinding, the work must be held rigidly to avoid vibration and to produce a good finish. If the work is held between centers, the center holes must be free from nicks, burrs, or dirt. The machine centers must be held securely and be free from nicks. If held in a chuck or fixture, the work must be solidly supported and clamped so as to put the least strain on it. After the work is correctly mounted, the work speed must be selected so that it will move at approximately the right number of surface feet per minute to prevent distortion and excessive wear of the wheel face, and, at the same time, the traverse movement must be at a constant speed to prevent high and low spots on the work. The mechanism for moving the wheel must work smoothly and freely, without play or bind, to ensure an accurate depth of cut.

The grinding wheel mounting is important because it must give steady and true motion to the wheel. After it is trued, the wheel

a. Will be free from vibration
b. Will have steady cutting action
c. Can be accurately dressed
d. Will be able to produce a good surface finish.

The operations of truing and dressing are usually accomplished by using one of the following implements : (a) a commercial diamond or a piece of tungsten carbide inserted in the conical point of a piece of cold-rolled steel; (b) a diamond dust impregnated cement formed into a stick and encased in metal tubing; or (c) a piece of silicon carbide mounted as a small wheel on an axle and placed in a cast iron base. In using any of these implements, the point of the dresser is brought into contact with the face of the wheel by means of a special holder, and then moved mechanically or by hand across the face of the wheel at a rate of speed tat will produce the desired form or surface on the cutting edge.

A clean, true wheel of the proper bond and abrasive size is a very efficient cutting tool, but it can cause the work to heat up rapidly. In the case of the lathe tool, there is only one cutting point acting on the work, but even so, it is a well-known fact that the cutting tool, work, and chips get quite hot. In the case of a grinding wheel, there are thousands of cutting points, each doing its share of the work but all acting at the same time. The action of a grinding wheel generates a much greater heat than a lathe. A flood of lubricant-coolant at the point of contact between the wheel and work is often necessary to carry off the heat and to keep the temperature of both the wheel and work as nearly constant as possible. This is true on rough or finish grinding.

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CHAPTER : 9
WELDING AND ALLIED PROCESSES

WELDING INTRODUCTION

This chapter gives general guidance on the welding of ferrous and non-ferrous metals by various process. It should be read in conjunction with the approved drawings and any related instructions for the welding operation (s) concerned.

THE OXY-ACETYLENE WELDING PROCESS

In the oxy-acetylene welding process, oxygen and acetylene gases are fed through a welding 'blowpipe', the pressures and quantities of each being separately adjustable. The jet of mixed gas is ignited, and produces a flame with a temperature of approximately 3100°C (5600 °F), which is used to melt the adjacent material of the parts to be joined. Filler rods are normally used for materials of 0.9 mm (20 s.w.g.) and thicker, and a flux is generally used to remove oxides from the surface of the metals and to ensure a sound weld; different materials require different filler rods and \ or fluxes.

The oxy-acetylene welding process should not normally be used for welding magnesium or high-nickel alloys, and is not recommended for stainless steel; inert gas or plasma arc welding are more suitable for these materials.

The relevant approved drawings and any related instructions on the welding operations should be closely followed. The following details are generally provided on the drawing(s) : -

a. Specification of the material(s) to be welded.
b. Specification of filler rod.
c. Type of flux.
d. Details of joint preparation and cleaning procedure.
e. Welding instructions (e.g. tack weld, clamp, starting position).
f. Heat treatment and removal of flux.
g. Inspection and any related tests.

OXY-ACETYLENE GAS WELDING EQUIPMENT

Paragraphs below contain information of a general nature on the control, use and care of welding equipment.

Gas Cylinders

Special precautions are taken with oxygen and acetylene cylinders to ensure that confusion of identity cannot occur. Oxygen cylinders are painted black and have a right-handed valve thread, whilst acetylene cylinders are maroon in colour and have a left-handed valve thread. In addition, the cylinders are produced in distinctive shapes as shown in figure 9.1. Gas cylinders should be stored in the upright position in well ventilated rooms. Those standing in the open should be protected from extremes of temperature and should not be placed on wet soil.

Fig. 9.1, Cylinder Identification

Oxygen cylinders, valves, etc., should not be handled with greasy hands or greasy gloves, neither should any part of the welding equipment be lubricated with oil or grease, since these materials ignite spontaneously when in contact with oxygen under pressure.

Acetylene can form explosive compounds when in contact with certain metals and alloys (e.g. copper and silver), it is, therefore, important that all fittings through which actylene is to flow have been designed specially for that purpose.

Gas Generators

Where acetylene gas generators are in use, a daily check for gas purity is necessary. Blotting paper soaked in a 10 % aqueous solution of silver nitrate should show no darkening when placed in the gas stream .

Gas Feeding System

Oxygen vigorously supports combustion, but since it has no smell it is difficult to detect. Conversely, acetylene has an unmistakable smell and will ignite and burn instantly from a spark or even a piece of heated metal. It is clear that a dangerous condition could arise as a result of leakage in equipment, particularly in confined spaces, and the feed system should be checked periodically to ensure freedom from leaks. Tests for leaks should be made with soapy water and a brush, and not with a naked flame.

Pressure gauges should be checked periodically against a master instrument to ensure accuracy, and a record should be kept of these checks.

To avoid any possibility of confusion, it is usual for black hoses fitted with right-hand threaded connections to be used with oxygen equipment and red hoses fitted with left-hand threaded connections to be used with acetylene equipment.

Blow pipes

The selection of the proper blowpipe nozzle for the work in hand is largely a matter of experience. The various factors which govern the size of the nozzle include the nature of the work, the thickness and type of material and the skill of the welder. The instructions issued by the manufacturer of the equipment give the best guidance in this respect, but it is recommended that nozzles be checked periodically to ensure that they continue to conform to nominal dimensions.

Lighting the Blowpipe

Before lighting the blowpipe the regulators must be set to the correct pressures and the light must be applied only when a flow of gas is properly established, otherwise a flash-back may occur. The use of a spark lighter is recommended.

It is important that the instructions given by the manufacturer regarding the correct procedure for lighting up and operating the equipment, and the safety precautions to be taken in the event of a cylinder becoming heated due to a flash-back or other incident, should be followed. Failure to comply with such instructions and precautions may cause the cylinder to heat up and burst.

If the flame goes out when the blowpipe is in use, it may be caused by the regulator pressure and \ or the gas flow being incorrect, obstruction of the nozzle, the nozzle being held too close to the work or to overheating of the nozzle. When this occurs both blowpipe valves should be closed. Only when the condition has been rectified should the blowpipe be re-lit. However, if the blowpipe nozzle has becomes overheated it should be plunged into cold water with the oxygen valve slightly open prior to re-lighting.

Manipulation of the Blowpipe

The essential factors in the manipulation of the blowpipe are careful adjustment to give the required types of flame and holding the blowpipe and welding rod at the most suitable angles for the work in hand. Other factors to be observed are the control of the heating period to obtain a neat and uniform weld bead, adequate penetration without excess heating or burning (especially with thin sheets of non-ferrous metals) and good fusion of the materials being joined.

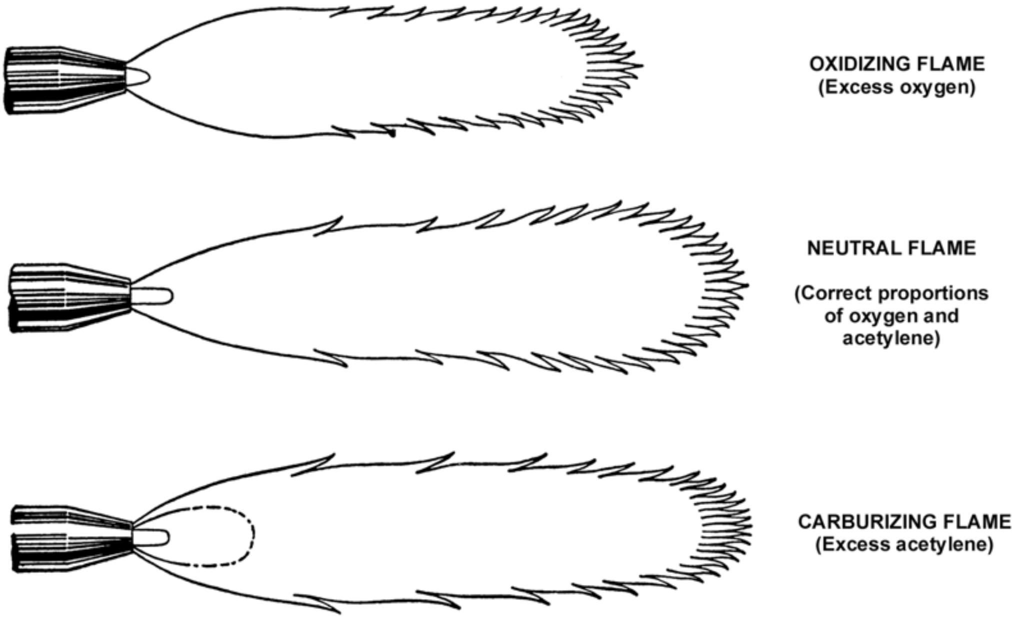


Fig. 9.2, Flame Adjustment

OXYACETYLENE FLAMES

A neutral flame should be used in all instance, except when copper-zinc, copper-zinc-silicon or copper-zinc-nickel-silicon filler alloys are employed, when a slightly oxidising flame is necessary.

i. An oxidising flame is produced by excess oxygen giving a considerably smaller inner flame than that obtained in the neutral condition.
ii. A neutral flame is composed of an equal amount of both oxygen and acetylene, giving a clearly-defined inner flame.
iii. A reducing, or carburizing, flame is produced by an excess of acetylene in proportion to oxygen, giving a furry edge to the inner flame.

The appearance of the various flames is shown in Figure 9.2.

MATERIALS

Because of the wide choice of available materials it is impracticable within the scope of this chapter to give a list of weldable metals. It is always essential to ensure that the material to be welded and the welding procedure used are those specified on the drawing.

Filler Rods

In general, filler rods are made of the same material composition as the metal to be welded but there are exceptions, thus the welding of aluminium alloys complying with different specifications with filler rods of the same composition could lead to cracking . Unless otherwise stated filler rods should comply with BS 1453 entitled ‘Filler Materials for Gas Welding’.

Filler rods should be stored in a warm, dry atmosphere, to prevent the pick-up of moisture which can cause porosity in welds.

Fluxes

With most metals, except steel, the melting temperature of the metal is much below the melting point of the oxides formed by heating and therefore the oxides remain as solid particles. Flux reduces the effects of oxidation, floats oxides and other impurities to the surface of the weld where they do no harm, and produces a stronger weld. Fluxes are not used for the welding of carbon steels because the oxides of the various elements unite and form a slag at a temperature lower than that of the molten metal, the slag floating to the surface of the weld.

The oxides of different materials vary considerably in physical and chemical properties and no one type of flux is suitable for use with all materials. Unless otherwise specified, it is usual to use the flux recommended by the filler rod manufacturer.

Most welding fluxes absorb moisture readily and their efficiency is reduced accordingly; damp flux will also cause porosity in the weld. It is essential therefore that fluxes are kept in airtight containers. Containers made of aluminium or glass are suitable but steel or brass should not be used as these materials cause contamination of the flux.

Cleaning Surfaces for Welding

All scale, grease, dirt, paint or other extraneous matter should be removed for a minimum distance of 25 mm (1 inch) each side of the edges to be welded. The methods of cleaning will vary with the material concerned. Some typical cleaning methods are given in following paragraphs.

Notes

1. When a pickling process is required for cleaning purposes, it is essential that the process to be used is approved by the Design organisation concerned.
2. It is imperative that suitable safety precautions are observed when handling the types of acid used in the pickling processes.

WELDING JIGS

The accurate assembly of welded parts may necessitate the use of special jigs which will be unaffected by changes in temperature.

The type of joint, the nature of metal to be welded, and accessibility are factors which influence the design of jigs. The jigs should permit free access to the area to be welded. The jig assembly should be fairly rigid, but not so rigid that the parts become stressed during cooling, and clearance should, therefore, be allowed for the expansion and contraction of the parts.

Where clamping or locking devices are incorporated in the jigs to control distortion, they should align the components to a degree of accuracy which does not permit the overall distortion to exceed the following:-

a. 0.075 mm (0.003 in) in material thinner than 0.7 mm (22 s.w.g.).
b. 0.125 mm (0.005 in) in material of thickness 0.7 to 1.2 mm (22 to 18 s.w.g).
c. 0.25 mm (0.010 in) in materials thicker than 1.2 mm (18 s.w.g).

When tubular sections are to be welded, the parts should be correctly fitted into the jig in relation to another. The jig should be so constructed that there is no possibility of misplacing the tubes from the intended position, otherwise uneven joints and unequal distribution of stresses may result.

WELDING ALUMINIUM ALLOYS

The oxy-acetylene welding process is used mainly for aluminium alloy sheet which is less than approximately 2.0 mm (14 s.w.g.) thick; sheets of greater thickness are normally welded by the inert gas arc welding process.

The melting point of aluminium is low and heat is conducted rapidly through the material. There is very little indication, by physical or colour change, that the material is approaching the melting point and when this stage is reached the material suddenly collapses. The material is very weak at temperatures near the melting point and collapses. The material is very weak at temperatures near the melting point and adequate support should be provided. However, rigid clamping should be avoided whenever possible, to reduce the risk of cracking due to contraction on cooling . Where rigid clamping cannot be avoided, a welding technique must be employed which will keep the stresses to a minimum.

Application of Flux

The flux may be prepared for application by mixing it with methylated spirit to a free-flowing consistency, and then applying it with a brush or dipping the filler rod into the mixture. The methylated spirit will dry off rapidly and will have no deleterious effects.

When it is necessary to apply dry flux to the filler rod, the end of the rod should be heated and dipped into the powder. The deposit of powder adhering to the rod should be melted and allowed to run over the rod surface for about 150 mm (6 in) of its length.

When welding alloys containing magnesium, it is recommended that, in addition to applying flux to the rod, a layer of flux paste should be applied to the edges of the work before welding is commenced. If possible, the flux should be applied to the underside also to ensure a smooth, oxide-free, penetrating bead.

The Welding Process

A slightly carborising flame should be used since an excess of oxygen will cause the rapid formation of aluminium oxide. However, the excess of acetylene should not be too great as it will be absorbed into the molten metal and result in a weakening of the joint. A low gas velocity; giving off a quiet hissing sound should be used. Frequent checks should be made to ensure that the correct type of flame is maintained.

The blowpipe nozzle is usually comparable to that used for steel of similar thickness, any increase or decrease in nozzle size being determined by the gauge and bulk of material involved.

To minimise the possibility of cracking and to reduce the effects of expansion, sheet material should be pre-heated by playing the flame over the joint area before welding. With thin sheets it is advisable to start the weld inside one edge of the work and to weld the short unwelded portion in the opposite direction later.

When starting to weld, the two joint edges should begin to melt before the filler rod is added. The work must be watched carefully for signs of melting, experience determining the proper time for adding the filler metal. The filler rod should be held in a direct line with the weld, with the flame near the material being welded. Both edges of the weld should receive an equal amount of heat, and the metal from the filler rod should fuse with the parent metal.

The blowpipe should be held at an angle of about 30^o to the plane of the weld, the angle being decreased as the end of the weld is approached. The tip of the inner cone of the flame should be held closely over the weld and should not be moved up and down. This practice results in heating a smaller area of the joint and minimises the possibility of ‘ blowing’ through, especially when welding thin sheets.

Any tendency to partial collapse or excessive penetration should be rectified by instantly lifting the flame well clear of the material and not by a gradual withdrawal, since this will only worsen the condition.

One of the main differences between aluminium welding and steel welding is in the speed of working with aluminium welding, as the weld progresses and the metal becomes hotter, the rate of welding should be increased, but in any case the welding speed should be as fast as possible. Where practicable it is better to complete the weld in one operation.

When welding long seams, the material should be tack welded at frequent intervals, e.g. for material of 1.6 mm (16 s.w.g.) and thinner at 25 to 38 mm (1 to 1.5 in intervals, and for materials between 1.6 and 2.5 mm (16 and 12 s.w.g.) at 75 mm (3 in) intervals. Tack welds should fully fuse the metal.

WELDING PLAIN CARBON AND LOW ALLOY STEELS

A neutral flame should be used and the inner cone should be held close to the material being welded. The blowpipe and welding rod should be held at angles of about 60^o and 30^0, respectively, to the plane of the weld.

Note

A completely neutral flame is difficult to recognise, and in order to avoid the detrimental effects of an oxidising flame, a flame carrying the slightest trace of excess acetylene should be used. This condition is obtained when the blue cone nearest the jet has a slight fringe or 'haze' of white flame.

Good fusion should be obtained evenly on each side of the weld; the rod should be fed into the molten metal and not melted off by the flame itself, otherwise too much material may be run and this will result in a reduction of temperature in the weld with consequent unsatisfactory fusion.

The welding rod should be of the correct size for the work in hand; if too large it will melt too slowly and produce excessive build up and poor penetration; if too small the rod will melt too quickly and cause difficulty in building up the weld.

WELDING CORROSION-RESISTING AND HEAT-RESISTING STEELS

The heat conductivity of corrosion-resisting steel is approximately 50% less than that of mild steel, whilst its coefficient of expansion is approximately 50% greater. Therefore, correspondingly greater allowance should be made during welding to prevent distortion.

A welding flame showing a faint haze of excess acetylene around the cone should be used to ensure non-oxidising condition is maintained. Excessive oxygen will produce a porous weld, while excessive acetylene will produce a brittle weld. A blowpipe nozzle comparable to that used for mild steel is recommended for light gauge sheet, and up to two sizes smaller than that used for comparable mild steel when welding thicker sections.

As the rate of heat conduction through the material is less than that of mild steel, the heat is localised and, to minimise the possibility of burning the material, the flame should be played over a larger area than usual. The tip of the inner cone of the flame should be kept very close to the surface but ' puddling' should be avoided. Care is necessary to prevent the flame penetrating thin gauge sheets. The welding rod should be kept in the flame throughout the welding operation, and on completion of the weld the flame should be withdrawn slowly to avoid cracking of the material.

REMOVAL OF FLUX

Unless the flux is specifically approved as being noncorrosive, it is essential that all traces should be removed.

Ferrous Metals

Where size permits, flux can be removed from ferrous parts by immersing them in boiling water for a period of not less than 30 minutes, the water being changed frequently to avoid contamination. Where immersion is not practical, the parts should be washed until all traces of flux are removed. If the flux residue is brittle its removal is sometimes made possible by lightly tapping it with a hammer.

HEAT TREATMENT

In general, steels having a carbon content in excess of 0.26% are liable to crack after welding unless suitable pre-welding and post-welding heat treatment procedures are employed. It is essential that when such steels welded the heat treatment prescribed in the relevant specification or drawing is followed.

Where heat treatment of a welded part is necessary, the part, or a control sample heat treated with the part, should be mechanically tested to ensure that the physical properties of the material still comply with the requirements of the material specification or the drawing.

The local application of heat for the purpose of final heat treatment is not permitted, neither should attempts be made to correct distortion by the application of local heat without the agreement of the Design Organization.

Parts made from carbon and low alloy steels, which can be used in the 'as welded' condition, are sometimes normalised, i.e. heat treated after welding with the object of refining the coarse grain structure in the weld and heat-affected areas.

INSPECTION

The production of satisfactory welded joints depends on close supervision of the welding process and careful inspection of the completed weld. The depth of inspection of a particular weld will depend to a large extent on the use for which the part is required, and may include visual inspection, pressure tests, radiography, fluorescent or dye penetrant, or magnetic flaw detection. The types of inspection or tests to be carried out should be as stated on the appropriate drawings or manufacturer's instructions.

Visual Inspection

All welds should be subjected to a visual inspection, and this may be all that is required on structures which are neither highly stressed nor critical from fatigue considerations. A visual inspection should ascertain the following:-

a. That fusion is satisfactory. Adhesion (i.e. as a result of the weld metal flowing on to the un fused parent metal outside the weld bead) may be caused by the use of too large a flame or careless manipulation of the blowpipe.

b. There should be no undercutting where the weld metal joins the parent metal. The welded part must not be reduced in thickness by the welding operation.

c. With butt welds, penetration should be obtained right through the joint; an under bead should appear through the full length of the weld.

d. The build up of the weld should be satisfactory; a concave surface on the face of the weld will indicate lack of metal with consequent weakness.

e. The weld should show regular surface ripples of close texture; it should be free from indentations, porosity, scale, slag or burn marks.

f. The dimensions of fillet welds should be correct, especially the leg length (spread of the weld on each side of the joint) and the throat thickness (depth of the weld at the angled joint). Lack of corner fusion or ‘ bridging’ is a common fault in fillet welds and can result in a weak joint; penetration of the weld through both sheets is also considered undesirable.

g. A weld which has been inspected and subsequently dressed by filing, grinding or machining, as specified on the drawing, should be re-inspected on completion of these operations.

Notes

1. Welds in certain alloys are improved by hammering during cooling, but this should only be done if specified on the drawing or in the process specification.
2. A visual examination may be carried out using a lens of low magnification.

Additional Tests

The type of examination applied to a weld subsequent to the visual inspection depends on the effect a failure would have, and whether the part is highly stressed or subject to fatigue. Any of the following examinations may be prescribed:-

a. Fluorescent dye or penetrant dye are used to reveal surface defects and are an amplification of the visual examination.

b. Magnetic flaw detection is used on magnetic materials in preference to dye penetrants as it is more selective and will reveal defects not reaching the surface.

c. Radiography, using X-rays or gamma rays , is used to reveal defects which are contained within the material and do not break the surface.

d. Alternative methods of detecting hidden defects, including ultrasonic and eddy current, may also be specified.

Note

In each case a technique suitable for the weld and the defects normally expected will have been decided upon, and should be carefully followed when carrying out an examination.

Pressure Tests

Pressure tests should be used on all welded pressure vessels, ducts and similar parts. The pressure to be used in a particular case should be as stated on the appropriate drawing.

SAFETY PRECAUTIONS

Because of the intensity of the flame used in welding and the fumes given off by certain alloys at high temperatures, special precautions are necessary to safeguard operators. These precautions include the following:-

a. All operators should wear protective clothing as a safeguard against burns from splashes of molten metal.

b. All operators should wear protective face masks or goggles and should ensure that they are kept in a satisfactory condition.

c. The precautions outlined in H.M. Factory Inspectorate Code of Practice for Health Precautions with regard to the welding of leaded steels, should be observed, as necessary.

d. The heating of steels containing certain alloying elements can result in potentially dangerous fumes, and Department of Employment Technical Data Note 2\73 should be taken into account when welding these materials.

In addition to the precautions necessary during welding, the use of X-ray or gamma ray inspection methods also calls for the careful attention to safety precautions. These precautions are outlined in the Radioactive Substances Act and in the Ionising radiations (Sealed Sources) Regulations. Radiographic inspections should be carried out by, or under the supervision of, a person who has satisfactorily completed a course of instruction in radiography and is acceptable to the CAA in accordance with BCAR.

ELECTRIC ARC WELDING

It is a fusion welding process in which no mechanical pressure is applied for joining the metals. In this, the metal pieces to be joined are heated locally to the melting temperature, by crating an electric arc, and then allowed to solidify to form the welded joint. In some cases only the metal of the pieces to be joined is made to form the joint while in the others additional metal is provided by melting a wire into the weld metal. The weld metal obtained from the work pieces is known as parent metal while the additional metal provided by melting the wire, as described above, is known as Filler metal. This additional material is provided by the core wire of the electrode in cases of metal arc welding and by a filler rod in case of carbon arc welding.

The electric arc welding process are divided into the following two main kinds :

1. Metallic arc welding
2. Carbon arc welding

METAL ARC WELDING

In this process a metal electrode is used and the arc is maintained between this electrode and the workpiece, which respectively form the two terminals. The electrode used can be either bare or coated type. Bare electrodes have the same or nearly the same composition as that of the parent metal. They have the disadvantage that their surfaces may be subjected to oxidation. Coated electrodes may either have a light coating of some material, which prevents their surface from being exidised, or may carry a strong coating of flux. For welding of ferrous metals the core of the electrodes is usually made of mild steel and the coating around it is made such that it acts as a flux as well as provides the necessary constituents to the weld metal.

ARC WELDING PRINCIPLE (SHIELDED METAL-ARC)

The principle of shielded metal arc welding consists of establishing an electric arc between a metal electrode and the workpiece to be welded. The arc can be described as a stream of incandescent vapour which acts as a conducting medium for electric current from one terminal to the other to complete the circuit. The electric current has a fairly high voltage to overcome the extra resistance offered by the vapour.

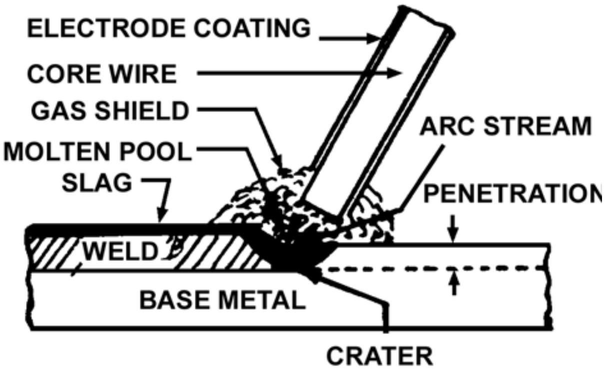


Fig. 9.3, Schematic diagram of shielded metal-arc welding.

The process is illustrated by means of a schematic diagram in 9.3. The metal of the workpiece to be joined is called base metal or parent metal, and that provided by the electrode as filler metal. The metal electrode is coated with flux which performs the following functions :

1. It produces a gas which provides a shield around the arc to protect it from atmosphere.
2. It forms slag by mixing with impurities of the molten metal and, thus, refines the metal.
3. The slag, being lighter, floats over the surface of the molten metal and on solidification forms a thin layer over the weldment, which helps in gradual and uniform cooling of weld and prevents its oxidation during cooling.
4. In some cases, it also carries necessary alloying elements which are added to the molten metal.
5. It promotes conduction of electric current across the arc and helps in stabilizing the arc.
6. It also helps in controlling the bead shape by providing necessary materials for this purpose.

Arc crater

This term refers to the depression caused by the penetration of electric arc into the parent metal. Its depth depends on the thickness of the parent metal. By observing this crater depth a welder can have an idea of arc penetration during welding. It should, however, be noted that if such a depression remains in the bead after welding the same is considered a defect. This defect (crater) occurs where an arc is broken. Care should, therefore, be exercised during welding to prevent the occurrence of this defect.

ARC BLOW

It is a typical characteristics of D.C. arc welding, which is normally not found when using A.C. During D.C. arc welding it is quite often observed that the arc fluctuates occasionally or is unstable. It is due to the magnetic forces acting on the arc on account of the magnetic fields set-up around it. When the electric current flows through the electrode, workpieces and the ground cable, magnetic fields are set up in planes perpendicular to the direction of flow of current. When these magnetic fields around the electrode or the workpiece are unbalanced they tend to bend the arc away from its intended path. This deflection of the arc from its intended path is called arc blow. This effect is more pronounced where there is a greater concentration of magnetic fields, that is where there id more crowding of lines of magnetic flux, causing a greater magnetic force to act on the arc to deflect it from its normal path. Since this concentration is always more at the ends the chances of arc blow are always greater at the beginning and the end of the weld. The reason of this phenomenon being present mainly in D.C. welding is that, due to the fixed polarity, the induced magnetic fields are constant in direction. In A.C. welding there is no fixed polarity and direction of current flow goes on changing . Therefore, there is no constant direction of magnetic fields and, hence, no chances of an arc blow.

The deflection of arc, or arc blow, can be in the following directions :

1. In the direction of electrode travel - called Forward blow.
2. Opposite to the direction of electrode travel - called the Backward blow.
3. Towards a side - called the Side blow.

Out of the above three, the chances of arc blow towards the side are very rare. The deflection is normally forwards or backwards. Backward blow occurs while welding towards the end of the joint, into a corner or towards the ground connection. Forward blow occurs while welding away from the ground connection or the beginning of the joint. This results in incomplete fusion of parent metal and excessive weld spatter. This, in turn, particularly in case of electrodes having thick coatings, allows heavy slag deposit in weld crater which runs forward under the arc. These factors sometimes become so troublesome that it becomes impossible to make a satisfactory weld. The problem is more severe at the end of the weld than at the start. In case of severe arc blow the following corrective measures may be adopted :

1. If possible, A.C. may e used instead of D.C.
2. The effect can be minimised by reducing the current and the arc length.
3. Arc blow can also be minimised by welding towards a heavy tack weld or an already existing weld.
4. The ground connections should be placed as far as possible from the joints to be welded.
5. If the problem is of backward blow the ground connection should be placed at the start of the weld and welding should proceed towards a heavy tack weld.
6. If forward blow is the trouble-maker the ground connection should be placed at the end of the weld.
7. The ground cable may be wrapped around the workpieces such that the current flowing in it sets up a magnetic field in a direction which will counteract the arc blow.
8. On long welds, back stepping may be used.

ARC WELDING EQUIPMENT

Both alternating current (A.C.) and direct current (D.C.) are used for arc welding. When D.C. arc welding is to be employed the current is generated by a D.C. generator. This generator can be driven by means of an electric motor or by means of a petrol or diesel engine. Whether it is a motor generator set or an engine generator set, both can be either of portable type or stationary type. With the result the D.C. arc welding processes can be employed irrespective of the fact whether the main A.C. supply is available or not. In absence of the same an engine driven D.C. generator set can easily by used.

For A.C. arc welding a step down transformer is used which receives current from the supply mains at 400-440 volts and transforms it to the required voltage for welding, i.e., 80 - 100 volts.

Apart from the above main equipment a number of other equipments, particularly for safety and clamping the work, holding the electrodes etc. are required as illustrated in Fig. 9.4. A brief list of this equipment is give below :

List of equipment

1. Well insulated electrode holders.
2. Wire cables and cable connectors.
3. Welding Helmet and hand screen or shield.
4. Safety goggles.
5. Welder’s chipping hammer.
6. Earthing clamps.

7. Cable lugs.
8. Hand gloves.
9. Aprons and sleeves, etc.
10. Wire brush.

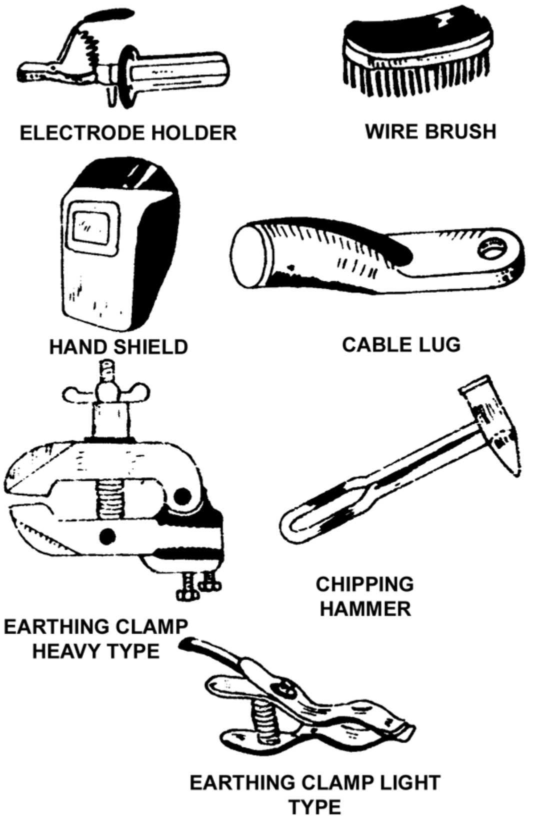


Fig. 9.4, Arc welding and safety equipment

USE OF A.C. AND D.C. FOR WELDING

As already described in the foregoing articles we receive A.C. supply from power mains at 400 - 440 volts whereas we require a much less voltage for welding. We, therefore, use a step-down transformer which lowers the voltage to about 80 - 100 volts. This voltage is actually required only for striking the arc and for maintaining the same we require a still lower voltage, say bout 30 to 40 volts. This is accomplished by means of the current regulator, through which we can adjust the flow of current and also the resistance and hence can obtain the desired voltage.

There is no fixed polarity at the terminals when using A.C. and they interchange in every cycle. Also the alternating current acquires zero value twice in each cycle. With the result, at these particular moments, the potential difference between he terminals is also zero and hence a higher voltage is required to maintain the arc at this moment.

Unlike A.C. in D.C. welding the electrode acts as one terminal and the job the other terminal (either +ve or -ve). The potential difference can be so adjusted that the heat developed at the positive terminal is higher, nearly 2/3rd and that on the negative terminal lower, nearly 1/3 rd of the total heat evolved. Here again the temperature of the arc is 3700°C to 4000°C. The voltage required in case of D.C. welding is 60 to 80 volts for striking the arc and 15 to 25 volts for maintaining the arc. Polarity is a very significant factor in all D.C. welding works. This polarity can be of two types :

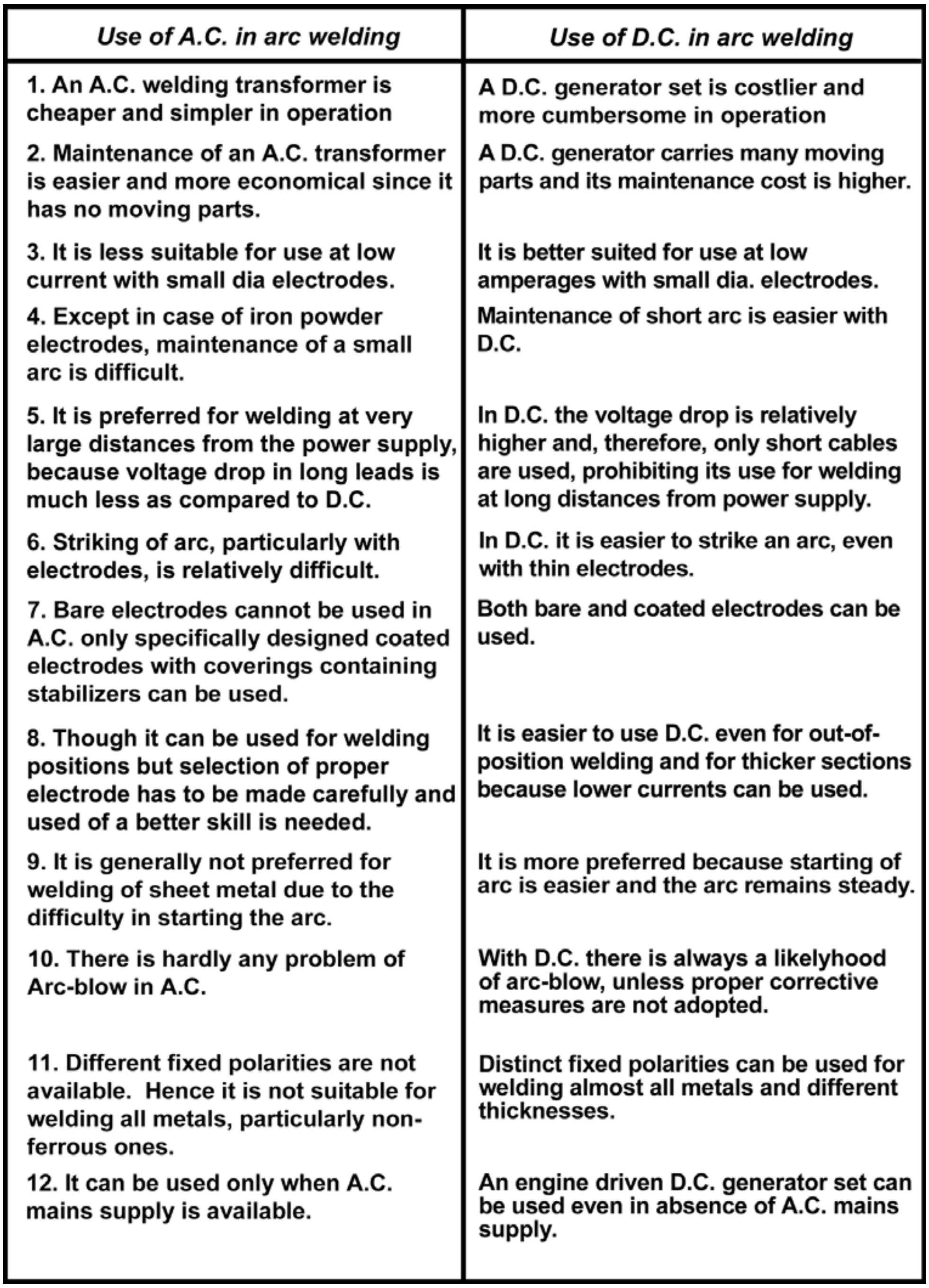
1. ***Straight polarity :*** In this, the electrode forms the negative terminal and the workpiece positive.
2. ***Reverse polarity :*** In this, the electrode forms the positive terminal and the workpiece negative.

These two polarities are known as Electrode negative and Electrode positive respectively. Selection of correct polarity plays a significant role in obtaining a successful weld. It is only due to this factor that almost all the metals can be welded by using D.C. as many metals require more heat to acquire the fusion state than the electrode used e.g. copper, and it is possible only through different polarities to have more heat on the job and less on the electrode.

RELATIVE MERITS AND DEMERITS OF A.C. AND D.C. WELDING

Both A.C. and D.C. welding sets have their own advantages and disadvantages as shown in Table 9.1 below :

Table 9.1, Comparison between A.C. and D.C.



Use of A.C. in arc welding	*Use of D.C. in arc welding*
1. An A.C. welding transformer is cheaper and simpler in operation	A D.C. generator set is costlier and more cumbersome in operation
2. Maintenance of an A.C. transformer is easier and more economical since it has no moving parts.	A D.C. generator carries many moving parts and its maintenance cost is higher.
3. It is less suitable for use at low current with small dia electrodes.	It is better suited for use at low amperages with small dia. electrodes.
4. Except in case of iron powder electrodes, maintenance of a small arc is difficult.	Maintenance of short arc is easier with D.C.
5. It is preferred for welding at very large distances from the power supply, because voltage drop in long leads is much less as compared to D.C.	In D.C. the voltage drop is relatively higher and, therefore, only short cables are used, prohibiting its use for welding at long distances from power supply.
6. Striking of arc, particularly with electrodes, is relatively difficult.	In D.C. it is easier to strike an arc, even with thin electrodes.
7. Bare electrodes cannot be used in A.C. only specifically designed coated electrodes with coverings containing stabilizers can be used.	Both bare and coated electrodes can be used.
8. Though it can be used for welding positions but selection of proper electrode has to be made carefully and used of a better skill is needed.	It is easier to use D.C. even for out-of-position welding and for thicker sections because lower currents can be used.
9. It is generally not preferred for welding of sheet metal due to the difficulty in starting the arc.	It is more preferred because starting of arc is easier and the arc remains steady.
10. There is hardly any problem of Arc-blow in A.C.	With D.C. there is always a likelyhood of arc-blow, unless proper corrective measures are not adopted.
11. Different fixed polarities are not available. Hence it is not suitable for welding all metals, particularly non-ferrous ones.	Distinct fixed polarities can be used for welding almost all metals and different thicknesses.
12. It can be used only when A.C. mains supply is available.	An engine driven D.C. generator set can be used even in absence of A.C. mains supply.

CARBON ARC WELDING

Only D.C. is used in carbon arc welding. The negative terminal of the supply is connected to the carbon electrode and the positive terminal to the workpiece. The use of A.C. is not advisable for the reason that no fixed polarity can be maintained. The reason of connecting the carbon electrode to the negative terminal is that the heat generated at the electrode tip is less than that at the job so that the carbon content of the electrode is not carried over to the job. If this happens the resultant weld will be very brittle and unsound.

This method is suitably used for joining steel sheets and repairing steel castings. Electrode holders used for holding carbon electrodes are usually provided with a magnetic coil inside which directs the arc properly and keeps it concentrated at the desired place. This process is carried out both by hands as well as machines. A flux is usually employed to prevent the weld metal from picking up carbon from the fused electrode.

ARC WELDING ELECTRODES

Electrodes commonly used are generally of two types :

1. Bare electrodes
2. Coated electrodes

Bare electrodes are cheaper but the welds produced through these are of poor quality and their use calls for a very high degree of skill on the part of welder if satisfactory results are to be expected. They are, therefore, very rarely used in modern welding practice. However, in coil form they are used with inert gases in a special welding process called Inert gas metal arc welding (MIG).

More popularly used in metal arc welding are the coated electrodes which carry a core of bare metallic wire provided with a coating or covering on the outside surface. Mild steel is the most commonly used material for core wire, but electrodes with core of other metals and alloys are also manufactured to suit welding of different metals and alloys under varying welding conditions and requirements. Some of the other metals and alloys used as core wire materials are low alloy steel, nickel steel, chromium-molybdenum steel, manganese-molybdenum steel, nickel-manganese-molybdenum - steel, nickel-molybdenum vanadium steel, aluminium, Albronze, lead-bronze, phosphor bronze, etc. Practically all the mild steel coated electrodes are almost similar in composition but differ in the type of covering and flux used on them. The coverings are provided by either dipping the wire cores in a bath or during extrusion. About 20 to 25 mm length at one end is left bare where the electrode is held in the electrode holder.

Electrode Coverings

It has been discussed in the earlier articles that the flux coating provided on the electrodes perform, may functions, such as providing a reducing atmosphere to prevent oxidation, forming slag with metal impurities, stabilising arc, providing necessary alloying elements to the weld metal and so on. To meet these requirements, many different materials are used for making electrode coverings. The common ingredients of a flux which help in slag formation and metal refining are asbestos, mica, silica, flourspar, stealite, titanium dioxide, iron oxide, magnesium carbonate, calcium carbonate and different aluminas. Ingredients used for producing the reducing atmosphere include cellulose, calcium carbonate, dolomite, wood floor, starch, dextrin, etc. Iron powder provides a higher deposition rate. Ferromanganese and manganese oxide provide alloying elements. The latter also helps in slag formation. Potassium silicate and potassium titanate are the principal arc stabilizers. Arc stability is also helped by titanium dioxide, feltspar and mica.

Normal thicknesses of these coverings on all commonly used light and medium coated electrodes vary from 10 percent to 55 percent of the total diameter of the coated electrode. However, in some heavy coated electrodes it may be as high as 100 percent and above.

Electrode size

Electrodes are commonly manufactured in standard lengths of 250 mm, 300 mm, 350 mm, and 450 mm. Similarly, the standard sizes of the electrodes being commonly manufactured in this country are 1.6 mm, 2 mm, 2.5 mm, 3.2 mm, 4 mm, 5 mm, 6 mm, 7 mm, 8 mm and 9 mm.

ELECTRODE CLASSIFICATION AND CODING

According to ISI coding system an electrode is specified by six digits with a prefix letter M, which indicates its suitability for metal-arc welding. These six digits stand for the following :

1. First Digit

Numbering from 1 to 8. Each number stands for a particular type of covering provided on the electrode.

2. Second Digit

It also carries numbers from 1 to 6 and each number represents a particular position or positions or welding in which the electrode can be used.

3. Third Digit

May carry any number from 0 to 7. Each number represents a particular current condition suitable for that particular electrode.

4. Fourth Digit

It indicates the minium tensile strength of the weld metal. It may carry any number from 1 to 8 and each number represents a particular tensile strength in kg/cm2.

5. Fifth Digit

It indicates the percentage elongation of deposited weld metal in tensile testing. Different percentages are represented by numbers from 1 to 5.

6. Sixth Digit

It indicates the minimum impact value of the weld metal. Different values are represented by numbers from 1 to 5.

SELECTION OF ELECTRODES

It is evident from foregoing discussions that welding has to be performed in various different conditions and selection of a proper electrode to suit those conditions is a vital factor for successful welding. The factors which influence the selection of particular electrode for metal are welding can be summarised as follows :

1. Availability of current - A.C. or D.C.
2. Composition of the base metal.
3. Thickness of the base metal.
4. Welding position - flat, horizontal, vertical or overhead.
5. Fit-up of the components to be welded.
6. Expected physical properties of welded joints - i.e., strength, ductility, soundness, appearance, etc.
7. Amount of penetration required in welding.
8. Skill of the welders in using particular types of electrodes under specific conditions.
9. Economic considerations - Welding costs are largely effected by deposition rate and also by electrode costs.

Low Hydrogen electrodes

Hydrogen adversely effects alloy-steels, causing intergranular underbead cracks. It is known as hydrogen embrittlement and leads to low strength and reduced fatigue resistance of welded joints. To avoid this low hydrogen electrodes are used in welding of such alloys. The coverings of these electrodes are made from such materials which will provide minimum or no hydrogen deposit in the weldment, such as cellulose, asbestos, iron powder, clays, lime, titania, etc. These electrodes should not be allowed to remain exposed to atmosphere for a long period otherwise they may absorb moisture. Also, as a precaution they should be stored in closed boxes and redried at a temperature of 120°C before using.

Carbon electrodes. These electrodes are used in carbon-arc welding and cutting. They are available in two varieties - carbon electrodes and graphite electrodes. The latter type is a better conductor and has more uniform structure. Bare carbon and graphite electrodes become hot during welding due to the resistance offered by the material tot he current flow. Their hot surface starts oxidising by coming in contact with atmospheric air, and this leads to a reduction in electrode size. To prevent this oxidation these electrodes are sometimes coated with copper.

INERT GAS-ARC WELDING

It is established that in any type of welding the quality of weld is effected to a considerable extent on the effectiveness with which the formation of oxides and the accumulation of these oxides and other contaminants on the metal surface can be prevented. The effort should always, therefore, be to keep atmospheric air and contaminants like dirt, dust, metal oxides, etc., away from the molten pool in welding operation. In the conventional arc welding processes the fluxes are relied upon for providing the shielding atmosphere around the molten pool to prevent the atmosphere from coming in contact with molten metal and prevent contaminants from outside to mix with molten metal.

In inert gas-arc welding processes inert gases, such as argon, helium, carbon dioxide, are used for surrounding the electric arc and, thus, keeping the atmospheric air and other contaminants away from the molten metal pool. This prevents oxidation and eliminates impurities from the weld. It not only results in production of sound welds but also enables welding of such metals which are otherwise difficult to weld or impracticable through the conventional arc-welding processes. To meet these requirements various inert gas-arc welding processes have been developed. Some of these are manual, semi-automatic and some automatic. Some common ones of these will now be discussed in the forthcoming articles.

INERT GAS TUNGESTEN-ARC WELDING (TIG WELDING)

This process was first introduced for industrial purposes in early 1940's. It is basically an arc welding process in which the arc is struck between a non-consumable tungsten electrode and the base metal. The electrode is held in a special type of electrode-holder which is so designed that apart from holding the electrode, it also carries a passage around the electrode for flow of inert gas to provide the protective shield around the arc. This gaseous shield protects the electrode, molten metal, the arc and adjacent heated areas of base metal from atmospheric contamination. The electrode holder also carries a provision for water cooling or air cooling. This process can be adopted for both manual and automatic operations.

This process is capable of producing continuous, intermittent or spot welds. Due to non-consumable nature of electrode no filler metal is provided by it. However, if needed, additional filler metal can be provided from outside by fusing a filler rod under the arc in the same way as in gas welding. This process is suitable for welding in all positions. Thin metal foils upto a minimum thickness of 0.125 mm can be easily welded with this process. It is suitable for welding of most metals and alloys except lead and zinc, which have very low melting points. Its specific applications include welding of Al-alloys, Cu-alloys, Mg-alloys, Nickel alloys, Zirconium alloys, Titanium alloys, Beryllium alloys, Refractory metals, Carbon steels, alloy steels and Stainless steels,. It is advisable to use manual welding for complex and irregular shapes and difficult to reach sections since manipulation of manual torch is easier in such cases. For regular shapes automatic welding can be easily adopted.

TIG welding Equipment

The following equipment is required in TIG welding :

1. An inert gas cylinder.
2. An inert gas regulator and flowmeter.
3. Inert gas hoses and hose connections
4. An inert gas shut-off valve.
5. An arc-welding machine.
6. Welding cables for electrode and ground connections.
7. A welding bench.
8. Electrode holder (water cooled or air cooled).
9. Water supply with inlet and outlet hoses (if water cooled holder is used).
10. Non-consumable tungsten electrodes.

In most of the cases the inert gas hose, welding cable for electrode and the water hose are all enclosed in a common jacket to form what looks like a single cable. Apart from the above equipment the welder should use proper eye-shield to protect his eyes since the arc in TIG welding is fully exposed.

Welding current

Both A.C. and D.C. are used in TIG welding. An important point to ensure is that a stable current be maintained throughout the operation particularly at lower ranges. D.C. welding machines are manufactured with this characteristic incorporated in them. But, it is necessary to use a high frequency generator in conjunction with an A.C. welding machine (transformer). This generator superimposes a high frequency current on the arc to re-establish it after the ‘zero’ period in each A.C. cycle.

A.C. enables good penetration and less surface oxidation. It is preferred for welding of aluminium, magnesium and beryllium copper. D.C. with straight polarity is most widely used in TIG welding. It is suitable for almost all the common metals and alloys. It enables deeper penetration but is incapable of removing surface oxides. D.C. with reverse polarity is the least used because it provides less penetration, enables flat and wide bead and needs maximum skill. A specific advantage associated with it is that it enables better removal of oxides from work surface.

Welding-procedure

before stating welding the joint should be prepared well and thoroughly cleaned to remove dirt, grease, oil, oxides, etc. from the work surface. Edges of thicker sections should be bevelled and lighter gauge metal should be provided with suitable backing. The workpieces should be firmly held, preferably in suitable fixtures.

Select a suitable electrode size, hold it firmly in the holder, set the current and proper polarity, if using D.C., turn on the cooling water or air, turn on the gas and adjust the flowmeter and then switch on the power supply.

After striking the arc make a small puddle of molten metal, at the place where welding is to commence, using a very small circular motion of the electrode. The electrode should be held at an angle of 60° to 80° with the workpiece and the filler metal (if used) at 15° to 20° with the workpiece. Then the welding may proceed almost in the same way as in oxy-acetylene welding. After the desired length has been welded the electrode holder should be lifted quickly to break the arc and the current flow switched off. However, the inert gas flow should be continued till the electrode cools down.

INERT GAS METAL-ARC WELDING (MIG WELDING)

This process, popularly known as Metal-Inert Gas (MIG) welding, involves welding of metals using a consumable metal electrode in an inert gas atmosphere. The arc is struck between the metal electrode and the workpiece. The electrode is in the form of a continuous wire which is fed into the arc, by an adjustable speed electric motor, at the same speed at which it is melted and deposited in the weld. A specially designed electrode holder is used which, in addition to a passage for wire electrode, also incorporates passages for supply of inert gas for shielding the electrode, molten weld metal, arc and the adjacent hot area of base metal from atmospheric contamination.

This method can be employed for welding carbon steels, low alloy steels, stainless steels, aluminium and al-alloys, heat resisting alloys, magnesium alloys, copper and Cu-alloys. With special techniques, like preheating of base metal, a more close control of inert gas, in some cases post-heating of parent metal and use of backing gas, etc., it is possible to weld cast iron, titanium and its alloys, refractory metals, magnanese bronze, etc., also. It is not suitable for welding of low melting point metals like lead, tin and zinc and also those metals which carry coatings of these low melting point metals. Economically welded metal thicknesses with this method range from 0.5 mm to 12.5 mm. Although larger thicknesses can also be welded, but other processes prove more economical. This process can be used for welding in all welding positions. However, best results are obtained in flat and horizontal positions. The main equipment needed in this process is as follows :

1. An inert gas cylinder.
2. Gas regulator and flowmeter.
3. Gas hoses and connections.
4. A power source and welding leads.
5. MIG welding gun.
6. A spool of electrode wire,
7. Electrode wire feeder.
8. Water supply with water hoses.

Usually, D.C. with reverse polarity is used in MIG welding. A.C. is not used in this method. Even D.C. with straight polarity is not often used. It is used only sometimes when a very small penetration is required. Use of D.C. reverse polarity enables a deeper penetration and a clean weld surface.

In MIG welding inert gases like argon, helium, carbon-dioxide or a mixture of these gases are used for providing the inert gas shield. Formerly only argon and helium were used, but now CO_2 is more widely used, both as a single gas and also in mixture with other inert gases.

Before starting welding a similar joint preparation and cleaning is necessary in MIG welding as in done in TIG welding. Two principal MIG welding methods are the following :

1. Spray arc method

This method uses a heavy flow of D.C. reverse polarity causing the electrode to melt in the form of a steady stream or spray of very minute droplets, which are transferred across the arc to the joint without interfering the stability of arc. It is used for good fit-up joints and faster welding.

2. Short circuiting method.

It is also known as Dip transfer method. In this method the melted filler metal from the electrode separates in the form of large drops which touch the base metal before separating from the electrode. As a result the arc is short circuited temporarily for an instant, and as soon as the drop is separated and proper gap between the electrode tip and workpiece restored the arc is re-established. This process is used for poor fit-up joints and thin sections.

Advantages of MIG welding

1. It is faster than shielded metal-arc welding due to continuous feeding of filler metal.
2. There is no slag formation.
3. It provides higher deposition rate.
4. The weld metal carries low hydrogen content.
5. Deeper penetration is possible.
6. More suitable for welding of thin sheets.
7. Welds produced are of better quality.

Disadvantags

1. Equipment used is costlier and less portable.
2. It is less adaptable for welding in difficult to reach portions.
3. It is less suitable for outdoor work because strong wind may blow away the gas shield.

CO_2-MIG WELDING

It is similar to the standard MIG welding described above except that in this process the electrode used is either flux cored or magnetized flux coated. CO_2 is used as a shielding gas. In either case the filler wire or electrode is fed into the arc in the same way as in MIG welding. The flux cored wire is a tubular metal electrode filled with flux inside. The arc is struck between the electrode and the workpiece and shielding is provided by the gas evolved during combustion of flux plus the CO_2 gas fed around the arc for this purpose.

While welding with flux coated electrode a magnetized grannular flux is fed into the arc through the gun nozzle, and there it attaches itself to the electrode. The coating so provided protects the electrode against atmospheric contamination. The arc and the weld are protected against the atmospheric contamination by the shield of CO_2 gas. The method of feeding the electrode wire into the arc is again similar to that in standard MIG welding process described in above. Thus, it will be observed that the CO_2 MIG welding process is exactly similar to the standard MIG welding process except that the electrode wire uses either magnetized flux coating or as its core.

Main advantages of CO_2 MIG welding process are :

1. It is a fast welding process.
2. The deposition rate is quite high.

3. Penetration of the arc is deep.
4. Minimum edge preparation is required, particularly in butt joints.

SUBMERGED-ARC WELDING

It is basically an arc-welding process in which the arc is struck between a consumable metal electrode and the workpiece. The process derives its name from the fact that the arc remains submerged (shielded) inside a layer of a granular and fusible flux. This blanket of flux, apart from shielding the arc, also protects the molten puddle and base metal near the welding against the atmospheric contamination. The arc is not visible to the welder. Other names given to this process are hidden-arc welding, submerged-melt welding, subarc welding and flux covered arc welding. The process can be automatic or semi-automatic.

Both D.C. and A.C. can be used in this process. While using A.C. the transformer should have a standard range of open circuit voltage. Its value varies from 65 to 75 volts for transformers with lower current capacities and from 80 to 100 volts for those having higher current capacities. A proper remote control unit is always incorporated in the power supply source with a switch near the welding head, so that power supply can be cut off or put on at will and the welding stopped or started as desired.

For starting welding, the pieces to be joined are placed in position. Flux from the hopper is then fed on to joint through a flux feeding tube The electrode wire is fed into this blanket of flux and the arc struck. The heat generated melts the surrounding flux granules and the filler metal. The latter forms the weld bead and the former fuses to form a covering of the slag over the bead. It protects the weld against atmosphere until it cools down. The process continues as the welding head advances along the joint with a proper speed, the flux hopper unit sliding ahead of the arc. The entire flux fed by the hopper is not melted. This unused part of the flux is collected by another unit, following the welding head, and fed back to the hooper for further use. After the weld cools down the slag is removed. The rate of feeding of electrode wire and flux grannules and the welding speed are automatically controlled in automatic-submerged arc welding machines, whereas in semi-automatic machines the welder has to manually guide a welding gun (which carries an attached flux hooper) and, thus, control all the feeding operations and welding speed manually.

This process is suitable for welding of plain low carbon steels, medium carbon and low-alloy steel, stainless steel, copper and copper alloys, nickel and nickel alloys. It is not suitable for lead, zinc, aluminium, al-alloys and magnesium alloys.

A specific limitation of application of this process is that it can be performed only in flat and horizontal welding positions. Some other disadvantages associated with this process are :

1. Flux may get contaminated and lead to porosity in weld.
2. Slag removal is an additional follow-up operation. In multipass beads it has to be done after every pass.
3. To obtain good weld the base metal has to be cleaned and made free of dirt, grease, oil, rust and scale.
4. It is normally, not suitable for welding of metal thicknesses less than 4.8 mm.

Advantages of submerged-arc welding process

1. As the arc is completely submerged no shielding is needed against the same, although it is advisable to protect the eyes as a precautionary measure.
2. Shallow grooves can be used for making joints, requiring less consumption of filler metal. In some cases no edge preparation is at all needed.
3. Higher welding speeds can be employed, effecting saving in welding time.
4. Deposition rate is very high.
5. There is no chance of weld spatter, since the arc is always covered under flux blanket.
6. Flux acts as a deoxidiser to purify the weld metal.
7. If required, the flux may contain alloying elements and transfer them to the weld metal.
8. It can be used with equal success for both indoor and outdoor welding work.

ELECTROSLAG WELDING

Through this method fairly thick metal plates can be welded without any edge preparation. In this process the joint is put in a vertical position with a little gap between the abutting ends of the workpieces. Fig. 9.5 illustrates a schematic diagram of this process. The weld is completed in a single pass. In this process there is no arc. It is the heat of the molten flux which melts the consumable metal electrode and the surface of the base metal to create the weld puddle.

The equipment basically consists of source of a power supply (A.C.) a suitable mechanism for feeding the electrode wire, a hopper to carry flux with a tube to feed this flux into the joint, a vertical rail along which the entire welding unit can travel in a vertical direction inside proper guides.

For commencing welding the flux is first fed into the joint and then the current is switched on, which passes through the layer of flux via the electrode wire. The resistance offered by the flux to the flow of this current creates heat and melts the flux which, in turn, heats and melts the electrode wire and the base metal. The molten metal pool so created is contained in the joint between two water-cooled copper slides, called shoes. One such shoe is located on each side of the joint. Molten metal puddle being in contact with both these shoes, solidifies between the base-metal pieces and forms the weld. The solidification is a directional one and non-metallic substances are pushed upwards into the molten flux (slag) pool. As the solidification of weld metal proceeds upwards, more flux is added from hopper, more melting of electrode wire and base metal takes place and more molten puddle is formed, both the shoes also slide upwards simultaneously so that the weld area, molten slag and weld puddle all remain confined within the mould formed by them. Thus, the process continues upwards till the whole length of the joint is welded.

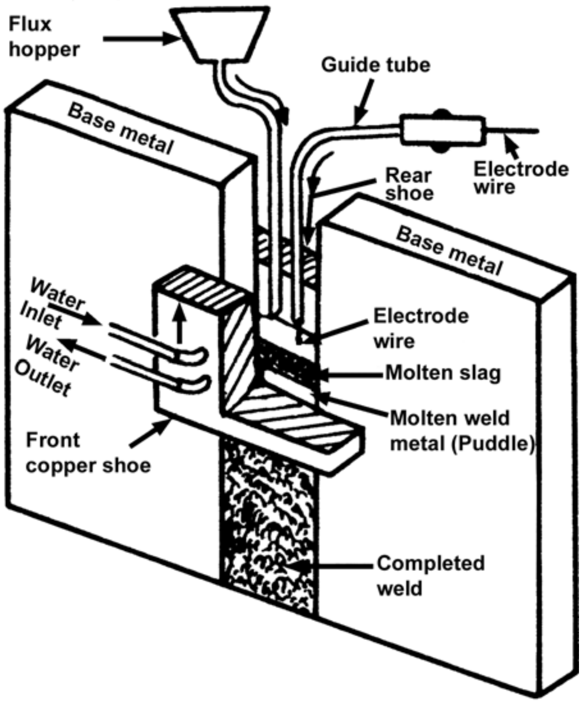


Fig. 9.5, Schematic diagram of electroslag welding. The copper shoe at the front side is shown in section to show the welding details.

In his process, according to requirement, one, two, or three electrode wires can be fed simultaneously into the joint. The electrode wire used can be of solid type or flux cored. This process is quite fast and needs no edge preparation on the base metal. This process is commonly used for welding metal plate thicknesses from 25 mm to 350 mm, although with special arrangements higher thicknesses also be successfully welded. Most common arc the butt joints to be made through this process. With use of modified shapes of shoes and techniques, however, it is possible to make other joints also, like circumferential joints, corner joints, T-joints, etc. Specific applications of this process are in welding of heavy steel forgings, large steel castings, thick steel plates and heavy structural members.

RESISTANCE WELDING

It is the process of joining metal pieces together by raising the temperature of the pieces to fusion point and applying a mechanical pressure to join them. In this, the pieces to be joined are held together and a strong electric current (A.C.) of high amperage and low voltage is passed through them. This current comes across a certain resistance in passing from one piece to the other and it is this resistance offered to the flow of current which results in raising the temperature of the two pieces to fusion or melting point at their junction. The mechanical pressure applied at this moment completes the weld. This method of welding is widely used in modern practice for making welded joints in sheet metal parts and bars and tubes etc. This type of welding is further sub-divided into six main methods as given below :

1. Spot Welding
2. Butt Welding
3. Flash Welding
4. Seam Welding
5. Projection Welding
6. Percussion Welding

Successful application of a resistance welding process depends upon correct application and proper control of the following factors :

1. Welding current

Enough current is needed to bring the metal to its plastic (or sometimes molten) state for welding. It should be properly adjusted on the current control device on the machine.

2. Welding pressure

In resistance welding mechanical pressure is required to be applied at two stages - first to hold the metal pieces tightly between the electrodes, while the current flows through them, and secondly when the metal has been heated to its plastic state, to forge or squeeze the metal pieces together to form the weld. The former is known as weld pressure and the latter forge pressure.

3. Time of application

It can also be described as cycle time and is the sum total of the following time periods allowed during different stages of welding :

a. ***Weld time :*** It is the time period during which the current flows through the metal pieces to raise their temperature.

b. ***Squeeze time or forging time :*** It is the time period during which the forge pressure is applied to the metal pieces to squeeze them together to form the weld.

c. ***Hold time :*** It is the time period during which the metal pieces are held together under forge pressure for a short while to enable the weld to solidify. It can, therefore, be called cooling time also.

d. ***Off-time :*** After cooling of weld the electrode pressure is released and the metal pieces removed for the next operation cycle. The time period between this release of electrodes and the start of next welding cycle is called off-time.

4. Contact area of electrodes

The weld size depends on the contact area of the face of the electrodes. It can be varied by selecting suitable sets of electrodes to provide the desired area of contact at their tips.

RESISTANCE SPOT WELDING

It is the simplest and probably the most commonly used method of making lap welds in thin sheets (upto a maximum thickness of 12.7 mm) using the principle of resistance welding. It owes its popularity to the fact that it can quite suitably replace riveting in sheet metal products without altering the design of the article.

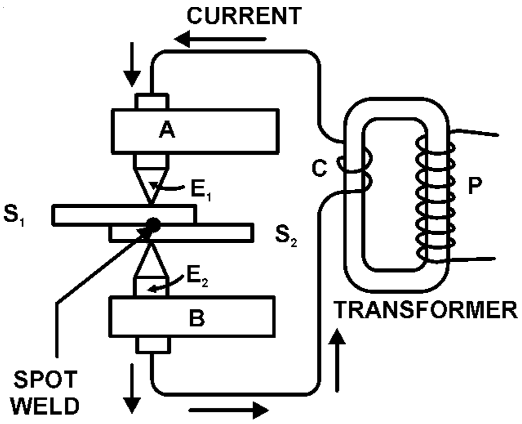


Fig. 9.6, Principle of Spot welding

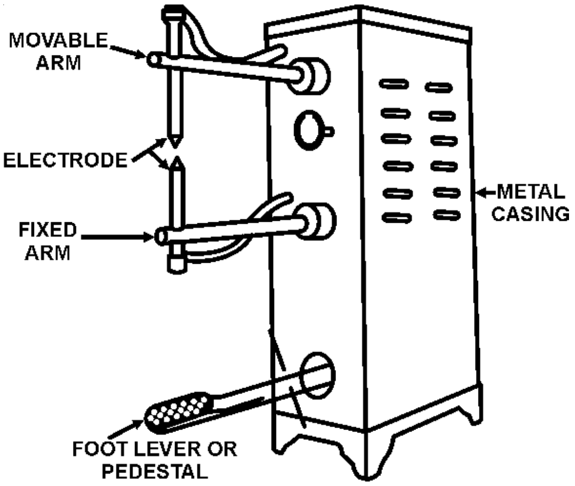


Fig. 9.7, Spot welding machine

The principle of spot welding is illustrated in Fig. 9.6, where a transformer core is shown having primary and secondary windings P and C respectively. One end of the secondary windings is connected to the upper electrode E_1 carried in the movable copper or bronze arm A and the other end to the lower electrode E_2 mounted on the fixed arm B. In operation, the metal sheets S_1 and S_2 are held and pressed between the electrodes and a strong current at low voltage is switched on. Due to the resistance offered by the sheet metal to the flow of this current the temperature at the contact surfaces rises to fusion point and the weld is completed under the contact pressure of the electrodes.

Spot welding machines are manufactured in various shapes and varying designs but they all work basically on the same principle as explained above. A simple but common type of these, known as Pedestal type spot welder, is shown in Fig. 9.7. It consists of a metallic casing having the transformer housed in it. The lower arm, called the fixed arm, is rigidly fixed to the machine body and the upper arm (or movable arm) is pivoted about a point inside the case. A pedestal at the bottom operates the upper arm through a spring. When this pedestal is pressed downwards the inside end of the upper arm is raised up and the outside projecting end, carrying the upper electrode, is brought down-wards to apply pressure on the sheets held between the electrodes. The foot lever (pedestal) in being pressed downwards also simultaneously switches on the current, thus enabling the production of the weld. The spring, described above, enables the application of a constant pressure so long as the current is flowing. After a weld is complete the pressure on the foot lever is released and the work moved to the next position where it is to be welded.

Gun welding

Many a times it is not feasible to use a stationary type of spot welding machine either due to difficulty in bringing the workpiece to the machine, difficulty in the manipulation of the workpiece or due to odd shapes of the workpieces. In such cases a portable type of spot welding machine, called the Gun Welder, is used, which can be easily transported to site. Also, manipulation of its electrodes into different positions is quite easy, which facilitates welding even in odd positions. Spot welding carried out with this machine is known as Gun Welding.

The specific use of this method is in welding of irregular surfaces, such as normally needed in the fabrication of automobile bodies. The electrodes are actuated either hydraulically or pneumatically. The equipment consists of a transformer (supported by an overhead rail), flexible leads connecting the transformer to the welding gun, the welding gun unit comprising of two electrodes and a trigger switch. Leads and the gun assembly are also supported by the overhead rail.

Shot welding

This term is used to denote a specific application of spot welding principle, wherein a very carefully controlled amount of electric current is allowed to flow through the metal pieces for a very small period of time. Such a requirement normally arises in spot welding of aluminium, aluminium alloys and stainless steel. Usually electronic timers are used for controlling the current flow because the flow interval is very brief. The purpose of keeping the current flow interval small is to heat and cool the metal pieces at a faster rate and, thus, minimise the disadvantages associated with oxidation and heat treating of metal.

SPOT WELDING ELECTRODES AND ELECTRODE HOLDERS

All resistance spot welding electrodes have to perform three major functions:

1. They conduct the electric current to the workpieces.
2. They hold the workpieces together and transmit the required amount of force to the work area to complete the weld.
3. They have to dissipate heat from the weld zone as quickly as possible.

Also, during the process of welding these electrodes are subjected to high compressive stresses at elevated temperatures. For successful welding the electrodes should be capable of resisting these stresses without much deformation in order to confine the conducted current to a fixed area within the workpieces. A frequent inspection of electrode tips, their regular dressing and, as and when needed, their replacement should, therefore, be made regularly. In order to perform the above functions successfully these electrodes should possess the following characteristics.

1. They should be good conductors of electricity.
2. They should be good conductors of heat.
3. They should possess high mechanical strength and hardness.
4. They should not have a tendency of alloying with the metal of the workpiece.

Electrode materials

Copper - base alloys and refractory metal-alloys are commonly used for manufacture of all resistance welding electrodes. Inspite of its good thermal and electrical conductivities pure copper is not used because it lacks in mechanical strength and tends to soften at elevated temperatures.

In all copper - base alloys the principal alloying element is copper and other elements are added in varying proportions. A few typical compositions of these alloys with their applications are given in Table 9.2.

The common refractory-metal alloys used as electrode materials are Cu-tungsten mixture, pure tungsten, pure molybdenum, etc. These materials are preferred where there is a likelihood of deterioration of electrodes made of Cu-base alloys on account of long welding time, excessive heat, insufficient cooling or application of high pressures. A typical example can be the spot welding of stainless steel which has a high electrical resistance.

A few other combinations of Cu-base alloys, like copper-zirconium and copper-cadmium-zirconium are also used as resistance welding electrode materials. Their properties and applications are similar to those described at serial nos. 1 and 2 in table 9.7.

Table 9.2, Characteristics and applications of Cu-base alloys

Sl. No.	Alloy Composition	Main Characteristics	Recommended Application
1.	Cadmium 1% Copper 99%	High strength and hardness with high thermal and electrical conductivities.	Used for making electrodes for spot welding of galvanised iron, brass, bronze, aluminium alloys, magnesium alloys, hot-rolled low carbon steel.
2.	Chromium 0.8% Copper 99.2%	Better mechanical properties than the former, but inferior thermal and electrical conductivities. Regarded as a better general purpose electrode material and suits for a wider range of metals and welding conditions.	For spot welding of low carbon steel, low alloy steels, nickel plated steel, stainless steel, nickel alloys, monel metal, copper base alloys.
3.	Beryllium 0.5% Nickel 1.0% Cobalt 1.0% Copper 97.5%	Better mechanical properties, but inferior thermal and electrical conductivities than the above two types. Good wear resistance.	Specifically suitable for electrodes used in spot welding in such conditions where pressures and workpiece resistance are high. Used on stainless steel, inconel, monel, thick sections of mixed-steel etc.

Electrode Holders

Spot welding electrode tips are held in suitable electrode holders. These holders are attached to the ends of the two arms of the spot welding machine. Most of these holders are water cooled, and so are the electrode tips which are made hollow for this purpose. Holders carry hose connections for supply of water for cooling. Ejector mechanisms are usually provided in holders for easy removal of electrode tips, when needed. In most of the spot welding machines these electrode holders can be adjusted for length and position. Multiple-electrode holders are also available which facilitate making of two or more spot welds simultaneously. All the electrode holders are made of copper alloys carrying good electrical conductivity and rigidity.

RESISTANCE BUTT WELDING

Also known as upset welding, it is used to join the metal pieces end to end. In this process the metal pieces, usually bars and rods of the same cross-section, are held in suitable clamps or vices with their previously squared ends abutting against each other. The projecting lengths of the pieces between the clamp are adjusted according to their cross-sections and the corresponding materials of which they are made. A longer projection will offer more resistance and a shorter length will provide less resistance. Abutting ends of the pieces having equal cross-section should be kept exactly in the middle of the clamps. The endeavour should be to adjust the projected lengths in such a way that the resistance offered by them to the flow of electric current is sufficient enough to generate the desired amount of heat at the respective ends. The clamps holding the pieces either form the electrodes themselves or are fitted with separate electrodes in them. One of these clamps is rigidly fixed to the frame of welding machine and the other is mounted on a movable slide operated by a hand lever in case of large machines and a spring in case of small machines having welding capacity upto 12.7 mm.

After abutting the ends together the current is switched on and the contacting surfaces heated to the fusion point. At this moment additional mechanical pressure is applied by means of the hand lever or the spring attachment and this completes the weld. This pressure should be maintained for a few seconds, actual time depending upon the cross-section of the pieces, to allow the metals to join together. In hydraulic type machines the hand lever is replaced by a hydraulic plunger. The butt-welding method is very suitable for joining end to end the items like bars, rods, tubes and wires etc. It is shown in Fig. 9.8.

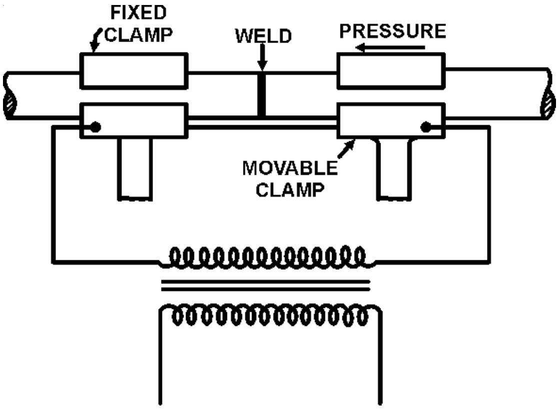


Fig. 9.8, Principle of Butt Welding

Application of correct pressure at right moment plays a vital role in making of a good quality weld. For welding of wires and rods upto 12.7 mm diameter the machine amy be spring operated. After clamping the parts in position the spring is released to forced the end forces against each other, current is switched on to heat the ends to plastic state and the spring pressure itself is sufficient enough to squeeze the ends and form the joint. A trip switch automatically breaks the circuit as soon as the upsetting is over.

For larger sizes of stock a better practice is to start the weld with a lower pressure to localise the heat at the joint. This can be accomplished by employing a hand wheel or lever in place of the spring. When molten metal is seen flowing from the outer surface the weld is consolidated by application of higher pressure, preferably hydraulically or pneumatically. Enough care should be taken in gripping very thin wires to ensure that the grip is at the edge of the clamp. Failing this, the wire may bend, instead of being upset, when the pressure is applied. Also, in such cases, it is a usual practice to mount the movable clamp on a swinging arm instead of the slide, which in turn is mounted on a ball bearing in order to reduce friction and prevent the chances of application of excessive pressure. Too much pressure may damage the wire by overheating.

But welding can be employed for welding of tubes, increasing lengths of wires and rods, making chains and in welding of those metals which have high electrical conductivity such as copper, brass, aluminium, etc.

RESISTANCE FLASH WELDING

Flash welding is also used for joining metal pieces end to end but it differs from the butt-welding process, described above, in the method of heating and sequence of operations. It has largely replaced the butt-welding method for welding articles having thin cross-sections. Of course, it is used for thick sections also with equal advantage.

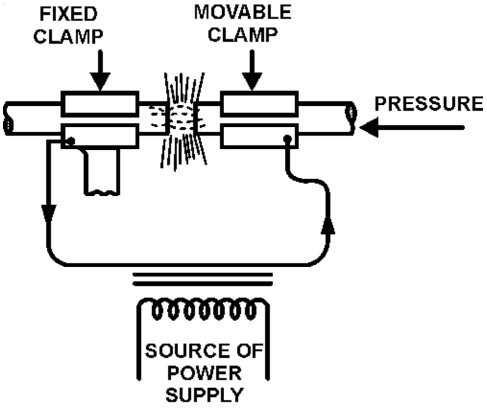


Fig. 9.9, Principle of Flash Welding

In this method, first the current is switched on and then the ends of the pieces to be welded are slowly brought closer until they finally come in contact with each other. This forces the heat generated to localise at the ends and thus raises the temperature of the ends quickly to the welding heat. The ends, after they have acquired the contact with each other, are then pressed against one another by applying mechanical pressure. This forces the molten metal and slag to be squeezed out in the form of sparks enabling the pure metal to form the joint and disallowing the heat to spread back. (See Fig. 9.9) Single phase A.C. machines are most commonly used for flash welding. The main advantages and disadvantages of flash welding over simple butt-welding are as follows :

Advantage of the Process

1. It is comparatively much quicker than butt-welding.
2. On account of only a small portion of the metal being heated the current consumption is less as compared to butt-welding.
3. A flash-welding joint is stronger than the butt-welding joint. It is also reckoned that the strength of the weld produced is comparable to or even more than that of the base metal.
4. The end faces of the metal pieces need not be squared which is a primary requirement in butt-welding.
5. Lengths and alignment of workpieces is maintained to a high degree of accuracy.

Disadvantages of the Process

1. During flashing particles of molten metal are thrown out, which may enter into the slideways and insulation, etc. This needs periodic maintenance of machine and replacement of insulation.
2. Operator has to take enough care against possible fire hazard due to flashing.
3. Additional stock has to be provided to compensate the loss of metal during flashing and upsetting. This adds to the cos to product.
4. Cost of removal of flash and upset metal by trimming, chipping, grinding, etc. further adds to the product cost.

Limitations of the Process

1. The upsetting pressure and power available in the machine limit the size and cross sectional are of the workpiece to be welded .
2. Opening between the jaws of the gripping clamps also limits the size of the workpiece.
3. For proper heat balance between workpieces it is necessary that their abutting ends should have same shape and size.
4. Surface of the workpieces, particularly where they come in contact with the gripping surfaces, should be clean otherwise they will restrict the flow of electric current.

Metals which can be welded

As a general rule it can be said that any metal which can be forged can also be flash welded. Also, it is possible to weld a number of dissimilar metals by controlling the welding conditions carefully. Metals commonly welded are low carbon steels, low-alloy steels, tool steels, stainless steel, copper alloys, aluminium alloys, nickel alloys, molybdenum alloys, magnesium alloys and titanium alloys. This process is unsuitable for welding of lead, tin, antimony, zinc, bismuth and their alloys.

Some applications

This process is widely used in automobile industry, welding of tubular and solid structural assemblies, etc. in air-craft industry, welding of band saw blades, welding of tool steel drills, reamers and taps etc. to mild steel of alloy steel shanks, welding of pipes and tubes to increase their lengths, in joining wire ends for producing coils of wires, and many other similar jobs.

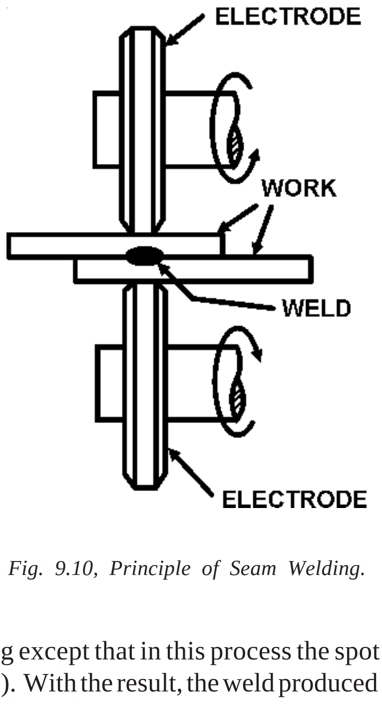


Fig. 9.10, Principle of Seam Welding.

RESISTANCE SEAM WELDING

In principle it is very similar to spot welding except that in this process the spot welding tips are replaced by continuously rotating wheel type electrodes (see Fig. 9.10). With the result, the weld produced is continuous instead of being intermittent;

yielding gas, air, water and steam light joints. A seam weld can best be described as consisting of a continuous series of spot welds produced by passing the workpieces between the revolving electrodes. In operation, the current is switched on and the metal pieces pushed together to travel between the revolving electrodes. The metal between the electrodes gets heated to welding heat and welded continuously under the constant pressure of rotating electrodes as it passes between them. This is a quicker operation than spot welding and gives a stronger joint than that. The surface to be joined should be cleaned before being subjected to this process.

This process is employed with equal advantage for making tap welds as well as butt welds. In welding thick sections the use of an 'Interrupter' is necessary. It is for the reason that if a continuous current is allowed to flow, the amount of heat generated. On account of the high resistance offered to its flow by the thick section, will be too much and the metal will get melted on its surface which will stick to the contacting surface of the electrodes. For thin sections, say upto 20 W.G. there is no need of using any interrupting device.

SEAM WELDING MACHINES

These machines are similar to spot welding machines except that they employ the use of disc type rotating electrodes. The work pieces are held between these electrodes and fed forward. The weld pressure is provided either hydraulically or pneumatically. Most of these machines work on single-phase A.C., although a few of them are designed to operate on 3-phase supply also. These machines are available in both - The stationary type as well as portable type. The essential equipment required for seam welding is as follows :

1. Power supply - to supply high-amperage low-voltage current.
2. A means of feeding the workpiece.
3. A means of rotating the electrode wheels.
4. A suitable support for electrodes and workpiece.
5. A means of providing weld pressure.
6. Proper controls for regulating timing, current flow, rate of work feed and application of weld pressure.

The following four types of resistance seam welding machines are popular :

1. Circular type

In this type the faces of electrode wheels are parallel to the plane of machine throat. This type is widely used for welding of circular jobs or such flat jobs which need long seams.

2. Longitudinal type

In this type the faces of electrodes wheels are parallel to the plane of machine throat. This type is used in welding of short longitudinal seams.

3. Universal type

In this type the faces of electrode wheels can be set either parallel or perpendicular to the plane of machine throat according to need. To facilitate this, the operating head is made swivel type and the lower arm interchangeable.

4. Portable type

It facilitates seam welding of objects at site. That is, instead of moving the work to the welding head the latter is moved to the work. Such a need may always arise with very bulky jobs.

Electrodes wheels

These wheels vary in diameter from 50 m to 600 mm. Their thicknesses also vary accordingly. Machines carrying knurl or friction drive use thinner wheels and those having gear drives use thicker wheels. Usual thickness vary from 10 mm to 20 mm. Materials for manufacture of seam welding electrode wheels are the same copper-base alloys as described in case of spot welding electrodes.

Metals which can be welded

The process of resistance seam welding can be successfully used for welding of mild steel, high carbon and low-alloy steels, stainless steel, a large range of coated steels, aluminium and its alloys, nickel and its alloys, magnesium alloys, and a fairly large combination of dissimilar metals. It is, however, not recommended for welding of copper and copper alloys having higher proportion of copper.

PROCESS LIMITATIONS OF SEAM WELDING

1. It cannot be applied to those portions where abrupt change in contour occurs along the path of electrode wheels, such as on sharp corners.
2. In longitudinal seam welding machines the maximum length of the seam joint that can be made equals the throat depth of the machine.
3. It is necessary to avoid obstructions in the path of electrode wheel or else a corresponding recess should be provided

on the wheel periphery to accommodate these.

4. It is necessary that the weld should proceed along a straight line or a uniform curve.
5. Stock thickness above 3 mm cannot be welded with normal ease.
6. For successful welding and production of defect free welds it is essential that the work surfaces should be perfectly clean and free from grease, paint, oil, rust and scale.

RESISTANCE PROJECTION WELDING

This process is similar to spot welding, but differs from the latter in that the spots at which welding takes place are previously located by providing projections at the desired locations on the surface of one of the work-pieces, as shown in Fig. 9.11. Thus, the surfaces of the workpieces are in contact with each other only at the projections. As current is switched on the projections are melted and the workpiece pressed together to complete the weld, by pressing the upper electrode downwards. The melted projections from the welds. This method enables production of several spot welds simultaneously. The electrodes, if required, may be designed and shaped to work as holding fixtures for workpieces and assemble them in proper relative location through welding. Closer welds than the rough spot welding can be obtained by this process. However, this process is economical only for large-scale production.

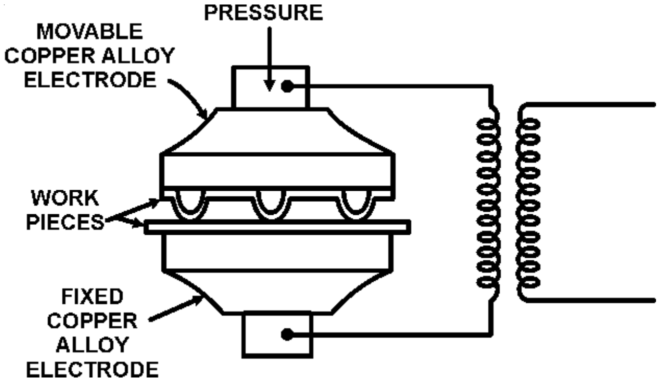


Fig. 9.11, Projection Welding

BRONZE WELDING

Bronze welding, also called braze welding is a process which is intermediate between true welding and true brazing. In brazing process, the edges or surfaces are not melted. Instead, a low melting alloy is introduced between them and a joint is produced by adhesion. In welding, the edges or surfaces are melted and a stronger joint is made of two similar metals.

In bronze welding, the edges or surfaces of the materials to be joined are only heated to a temperature which corresponds to the melting point of the bronze-filling rod used. The filler rod used for bronze-welding usually contains 60 per cent copper and 40 per cent zinc, a combination giving high tensile strength and ductility. Additional elements are silicon and tin which act as deoxidisers.

The process consists of cleaning the surfaces to be joined, heating them to a braze welding temperature that depends on the composition of the filler rod, and applying a flux for the purpose of removing any oxide present. Usually the source of heat is the oxy-acetylene flame, although bronze welding may be done with any suitable source of heat, such as muffle furnace, electric induction and the carbon-arc.

Metals with high melting points such as steel, cast iron, copper, brass and bronze, are bronze welded. The main advantage of bronze welding results from the low temperature of the operation. Less heat is needed and a joint can be made faster than by fusion welding. Dissimilar metals that cannot be joined by welding may be joined by bronze welding.

Bronze welding joints are not satisfactory for service at over about 250°C nor for dynamic loads of 1000 kgf per sq cm (100000 kN/m^2) or more.

SOLDERING

Soldering is a method of uniting two or more pieces of metal by means of a fusible alloy or metal, called solder, applied in the molten state. Soldering is divided into two classifications : soft and hard.

Soft soldering is used extensively in sheet-metal work for joining parts that are not exposed to the action of high temperatures and are not subjected to excessive loads and forces. Soft soldering is also employed for joining wires and small parts. The solder, which is mostly composed of lead and tin, has a melting range of 150 to 350°C. A suitable flux is always used in soft soldering. Its function is to prevent oxidation of the surfaces to be soldered or to dissolve oxides that settle on the metal surfaces during the heating process. Although corrosive, zinc chloride is the most common soldering flux. Rosin is non-corrosive, but it does not have the cleaning properties of zinc chloride. A blow torch or soldering iron constitutes the equipment for heating the base metals and melting the solder and the flux.

Hard soldering employs solders which melt at higher temperatures and are stronger than those used in soft soldering. Silver soldering is a hard soldering method, and silver alloyed with tin is used as solder. The temperatures of the various hard solders vary from about 600 to 900°C. The fluxes are mostly in paste form and are applied to the joint with a brush before heating. In hard soldering, a blow torch constitutes the equipment.

There are a number of soldering techniques, but in each and every case the parts to be soldered must be thoroughly cleaned. For small light parts, the heat may be supplied by a soldering iron which must be large enough to carry enough heat to heat up the parts to just above the melting point of the solder. This consists of a copper bit, bluntly pointed at one end and riveted to a steel shaft at the other, the steel shaft terminating in a wooden handle. Any source of clean heat is satisfactory for heating the bit. Usually, the bit is heated in gas or coke fire, cleaned, dipped in flux, and then rubbed on the solder to "tin" the bit. This coats the bit with solder and enables it to pick up molten solder and deposit it as required on the joint.

For larger parts, the surfaces may be tinned first by cleaning, heating, dipping in flux, and then by applying solder with a soldering iron or by dipping the parts in molten solder. The parts may then be assembled and heated together until the solder melts. The different compositions of solder for different purposes are as follows :

1. Soft Solder - Lead 37 percent, tin 63 percent.
2. Medium solder - lead 50 percent, tin 50 percent.
3. Plumber's solder - lead 70 percent, tin 30 percent.
4. Electrician's solder - lead 58 percent, tin 42 percent.

BRAZING

Brazing is essentially similar to soldering, but it gives a much stronger joint than soldering. The principal difference is the use of a harder filler material, commercially known as spelter, which fuses at some temperature above red heat, but below the melting temperature of the parts to be joined. Filler metals used in this process may be divided into two classes : copper-base alloys, and silver-base alloys. There are a number of different alloys in each class, but brasses (copper and zinc), sometimes with up to 20 percent tin are mostly used mainly for brazing the ferrous metals. Silver alloys (silver and copper or silver, copper and zinc) having a melting range of 600 to 850°C are suitable for brazing any metals capable of being brazed. They give a clean finish, and a strong ductile joint.

Like soldering, the parts to be joined by brazing are carefully cleaned, the flux applied, and the parts clamped in position for joining. Borax is widely used flux, but many proprietary brands are available. They are then heated to a temperature above the melting point of the spelter to be used, and molten spelter is allowed to flow by capillary action into the space between the parts and to cool slowly. The actual heating may be done in a number of ways. Torch brazing in which heating is done by a blow torch is very common. Furnace brazing, particularly in controlled atmospheres, is a favourite for production. Induction heating is useful to confine the heat to the joint, if general heating must be avoided. Resistance brazing is done on some small parts in production. Immersion brazing is used in large-scale production. The parts are cleaned and fluxed, clamped together, and then immersed into a tank of molten spelter.

WELDING OF VARIOUS METALS

Some welding methods as applied to different metals will now be described briefly.

Carbon Steel

Carbon steels can be readily welded by forge welding, resistance welding, arc welding and gas welding. The chief trouble likely to be encountered when welding carbon steels by any fusion welding method is cracking, due to carbon "pick-up". Weld penetration into the parent metal causes diffusion of carbon from the work into the weld metal, thus resulting in embrittlement of the weld. Consequently, longitudinal cracks are produced along the centre of the weld. This carbon pick-up in the main weld can be prevented by coating the surfaces with a layer of weld metal before they are joined together. This layer picks up some carbon, but as it is not highly stressed on cooling it does not crack.

Steels containing high proportion of carbon require the preheating the about 400°C to produce reasonably soft weld metal, and to avoid cracking; but steels with a carbon content of 0.25 to 0.3 percent can be welded without preheating, provided that large runs are made.

It should also be noted that rapid cooling makes the weld metal hard and brittle, and thus it is advisable to ensure slow cooling by protecting ti from chilling effects. It is possible to improve the properties of the weld by peening. This consists of subjecting it to a series of light, rapid blows by a small hammer. This should be done after the weld has solidified, but before it is cold. This helps to reduce distortion and to release internal stresses.

A neutral flame is used in gas welding, and different filler rods or electrodes are required for different qualities of carbon steel. A flux is always used except is the case of mild steel because of the presence of comparatively greater amount of silicon and manganese which act as deoxidisers and serve to protect the metal from being oxidised.

Alloy Steels

This group of steel contains small amount of nickel, chromium, molybdenum or other elements, in addition to carbon. Preheating is always advisable when welding such steels, and slow cooling is essential if brittle or cracked welds are to be avoided. The use of correct welding rod relative to the composition of the steel is also vitally important.

Stainless Steel

For stainless steels which harden on heating and cooling, the best method is electric butt welding, followed by prompt annealing at 750 to 800°C. They can also be welded by oxy-acetylene, and metal-arc welding methods. In all cases, oxidation must be prevented, and when oxy-acetylene welding stainless steel, a very slight acetylene surplus in the blowing flame is sometimes recommended to avoid the risk of having an oxidising flame, although carburisation produces brittle welds. The filler rod is usually fluxed before the operation, for protection of the weld.

A wide range of electrodes is available, in metal-arc welding, suitable for welding stainless steel of various composition. They nearly all contain niobium, titanium, columbium, etc. which prevent the occurrence of the defect known as weld decay, which is worst hazard when welding this material. Careful cleaning of the edges to be welded and slag removal after each run are essential for obtaining a good quality weld.

Cast Iron

Carbon may be present in cast irons in two forms : combined or free. During the formation of a weld in a cast iron base, both free and combined carbon go into the solution in the molten metal. Upon the removal of the welding heat, there is a quick solidification of the melted iron because of the cooling effect of the comparatively cold mass surrounding the place of welding and the cooling effect of the air to which it is exposed. Owing to the sudden cooling, a large amount of combined carbon is retained, and a hard metal in the weld is thus the result. Local preheating and slow cooling can overcome this difficulty. A preheating temperature of 600°C is recommended, and it is important that the full thickness to be welded is brought up to and kept at this temperature throughout the welding operation.

Before welding cast iron, a careful study of the job should be made to prevent uneven expansion or contraction of the casting. When one part of the casting is heated, the part expands, and considerable strain may be thrown on some other part. Since the metal has low ductility and will not stretch the strain may be sufficient to break the unheated part. Indirect preheating on the unheated portion will prevent stresses which might cause cracking. A temperature of 200°C is sufficient for this purpose. Fig. 9.12 shows the application of direct and indirect preheat when welding up a crack in a casting.

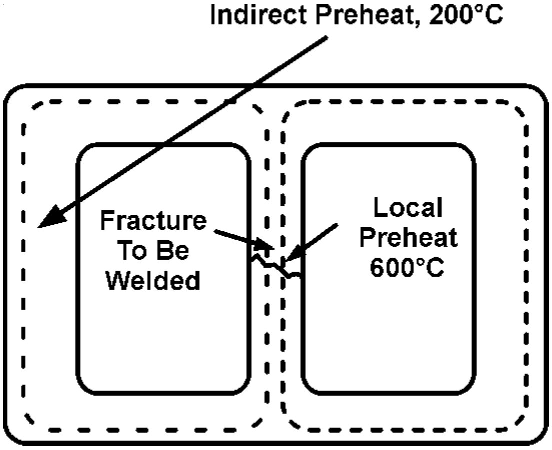


Fig. 9.12, Cast-iron welding.

Other metals such as copper, brass, bronze, nickel and nickel alloys and some other non ferrous metal require preheating before welding.

For welding cast iron, the practice of preparing the joint to the form of a Vee is followed in the same way as for steel. This may be done by chipping, machining, sawing, grinding, or any convenient method.

Aluminium

For purpose of welding, aluminium and aluminium alloys may be classified into two main groups : (1) cast, and (2) wrought (sheet, tube, etc.). One of the most important rules in welding aluminium is to ensure the complete absence of every trace of oil or grease, and for this reason the work must be given a de-greasing treatment or the edges cleaned down to bright metal by filing or wire brushing.

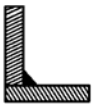
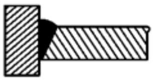
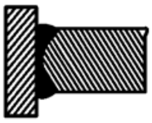
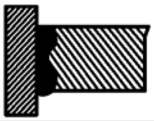
For sheet aluminium, a neutral flame and a filler rod of the same material as the sheet should be used. Sheet up to about 3 mm thickness is butt welded without bevelling, whilst for greater thickness bevelling to an included angle of 80 to 90° is necessary. Proprietary fluxes are available, and should be used sparingly by heating the rod and dipping it in the flux as required.

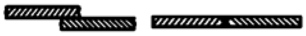
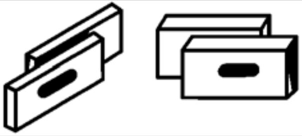
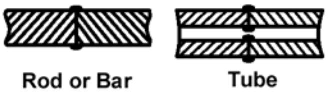
For castings, preheating is always necessary. The filler rod should be of the same composition as the casting, especially in the case of alloys containing copper or zinc, and a neutral flame should be used. The edges should be bevelled, wherever possible to an included angle of 80 to 90°. After welding, the castings should be cooled as slow as possible.

Copper

Only deoxidised copper can be welded satisfactorily. The flame should be neutral, and the filler rod should be an alloy of copper and silver. A deoxidising flux should be used and should be applied by coating the rod with it. The principal constituent of copper-welding fluxes is borax, but it is not advisable to use borax alone because it forms a hard scale which is difficult to remove. The work should be preheated owing to the high thermal conductivity of copper. Flanged joint or square edge preparation is usually done for thin plates, while double 'V' preparation is required for plates thicker than about 6 mm. After welding, the weld should be heated to a dull red heat and thoroughly hammered at this heat to restore its ductility.

WELDING SYMBOLS

S.No.	Form of Weld	Sectional Representation	Symbol
1.	Fillet		
2.	Square Butt		
3.	Single - V Butt		
4.	Double - V Butt		
5.	Single - U Butt		
6.	Double - U Butt		
7.	Single Bevel Butt		
8.	Double Bevel Butt		
9.	Single - J Butt		
10.	Double - J Butt		
11.	Bead (Edge or Seal)		
12.	Stud		

S.No.	Form of Weld	Sectional Representation	Symbol
13.	Sealing Run		○
14.	Spot		X
15.	Seam		
16.	Stitch		
17.	Mashed Seam		
18.	Plug		
19.	Backing Strip		=
20.	Projection		△
21.	Flash		И
22.	Butt Resistance or Pressure (Upset)		|

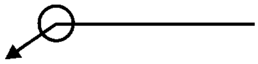
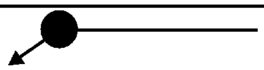
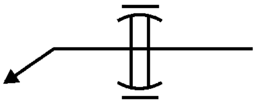
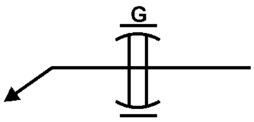
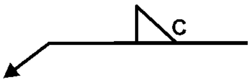
S.NO.	PARTICULARS	DRAWING REPRESENTATION	SYMBOL
1.	WELD ALL ROUND		○
2.	FIELD WELD		●
3.	FLUSH CONTOUR		—
4.	CONVEX CONTOUR		⌒
5.	CONCAVE CONTOUR		
6.	GRINDING FINISH		G
7.	MACHINING FINISH		M
8.	CHIPPING FINISH		C

TABLE 9.3, WELDING SYMBOLS

INTENTIONALLY BLANK

UNIT : II

(A) DETAILED KNOWLEDGE OF IDENTIFICATION, TERMINOLOGY, CORRECT USE AND INSPECTION OF AIRCRAFT BOLTS, NUTS, RIVETS, SCREWS & LOCKING DEVICES OF BRITISH & AMERICAN SYSTEM.

(B) DETAILED KNOWLEDGE OF VARIOUS TYPES OF GEARS & BEARINGS, THEIR USE & COMMON DEFECTS.

(C) KNOWLEDGE OF VARIOUS TYPES OF THREADS USED IN BRITISH & AMERICAN SYSTEM.

(D) KNOWLEDGE OF VARIOUS TYPES OF AIRCRAFT CABLES & SWAGING PROCEDURES USED.

CHAPTER : 10

IDENTIFICATION MARKING PROCESSES FOR AIRCRAFT PARTS

INTRODUCTION

This chapter gives general guidance on processes for marking aircraft parts for the purpose of identification. The information given is not applicable to individual items of equipment such as radio equipment and instruments, and does not override any instructions given on drawings.

Schedule 1 of the Air Navigation Order prescribes that all registered aircraft must have a metal nameplate fixed near the main entrance of the aircraft, upon which is stamped or engraved the nationality and registration marks and the registered owner's name and address. This metal plate must be fireproof so that there will be means of identification in the event of the aircraft being destroyed by fire. The CAA recommends the use of a stainless steel plate.

IDENTIFICATION MARKINGS

Identification markings consist basically of the drawing number, drawing issue number and the inspection acceptance stamp. With some parts further information is necessary, e.g. a batch number, a process symbol or reference number, a non-destructive examination symbol, an assembly drawing in number, a serial number, and a date. Organisations manufacturing parts should, therefore, have `in-house' procedures defining the form and method of part numbering and identification of details, parts and components, so as to ensure that suitable methods, related to the nature, material and form of the part, are consistently applied.

The procedures should recognise that the application of the inspection stamp alongside the part and issue number (being an indication that the part complies with the full requirements of the drawing) has to be permanently legible.

There may also be a need to mark other information on components progressively during manufacture, so as to indicate satisfactory completion of processes or tests. Their markings, however, may not need to be legible on the item in the fully finished condition

Company procedures should define the form of marking for inspection clearance of part-finished items in such a way as to ensure that such parts are not confused with finished parts.

Where the marking process indents the surface of the part, parts for non-destructive examination (such as radiography) should be marked prior to examination. Unless a marking medium which will not damage the coating is used, parts should also be marked prior to the application of a protective treatment, e.g. anodising.

MARKING MEDIUM

The medium selected for marking a part must be based on such factors as the purpose of the part, material from which it is made, and critical features such as fatigue and notch sensitivity. Marking should not be made on highly stressed areas, near edges or on sensitive surfaces which may be needed to seal or conjoin. Processes available include etching, engraving, embossing, grit blasting, stamping, transfers, adhesive labels, marking inks and the attachment of metal plates, clips or tags. The following sub-paragraphs give information on the application of the various processes.

Acid Etching

Acid etching is widely used for marking hardened or delicate steel parts. The etching fluid can be applied to the surface of the part either by a glass pen fitted with a rubber suction cap or by a rubber stamp. Alternatively, the surface of the part may be coated in a suitable substance, e.g. bees wax, and the required markings cut into this, followed by the application of etching fluid.

Before etching operations are commenced, the surface of the metal should be thoroughly cleaned. Immediately after marking is completed, the part should be thoroughly washed, dried, and protected from corrosion. Pens and stamps used for applying the etching fluid should not be used for any other purpose.

NOTE

During the etching process care should be taken to avoid contact of the etching fluid with hands or clothing.

A fluid often specified for etching steels, other than corrosion-resisting or nitrided steels, is of the following composition:-

Selenious Acid	20g
Copper Sulphate (Crystals)	10g
Concentrated Nitric Acid	15ml
Water	80ml

NOTE

When the fluid is applied to polished surfaces, a black, deposit of iron-copper selenite will result.

A fluid often specified for etching corrosion-resisting and nitrided steels is of the following composition:-

Selenious Acid	20g
Copper Sulphate (Crystals)	10g
Nitric Acid	25ml
Hydrochloric Acid	60ml
Water	10ml

a. The grey surface film of nitrided steels should be removed in the area to be etched. With corrosion-resisting steels, the fumes from the fluid tend to stain the surface of the parts; therefore, only the area to be marked should be free from storage grease or other protective compound.

b. The method of application of the fluid and the general precautions to be taken are similar to those given in above addition, special care must be taken not to inhale the etching fluid fumes.

Electro-Chemical Etching

This method of marking is generally restricted to corrosion-resisting steels, aluminium and its alloys, titanium and its alloys, and copper based alloys. This process utilises and electrolytic principle by which marks can be produced on metal surfaces by using an electrolyte in conjunction with a low-voltage, low-amperage current. The process is simple and easy to apply, and in general has no significant effect on the strength of metal parts. The colour and depth of marking is directly related to the voltage and amperage, to the direction and duration of current flow, and also to the electrolytic etching fluid used.

Equipment and materials should be checked at regular intervals by etching a test piece and measuring the depth of etched area. This depth should not normally exceed 0.001 in. In addition, different types of metals require different etching fluids, and the instructions given on the relevant drawing or process specification should, therefore, be closely followed. This method of marking can not be used on non-conductive surfaces.

The equipment required for the electro-chemical process consists of an electrical power-unit with a means of output adjustment (which usually embodies an automatic timing control), stencils and electrical contact devices. The marks to be etched can be produced either on paper stencils by typing, by stylus or metal stamp, or on plastics stencils by an electronic process. Paper stencils have an approximate life of 200 impressions, whereas plastics stencils have an approximate life of 2,000 impressions. Electrical contact devices may take the form of a bench pad, marking control head, roller, and various types of pen. Basically all contact devices provide a means of connecting the part to be marked to the power-unit via the stencil and a felt or cotton-wall pad impregnated with the electrolytic etching fluid. The circuit is completed by the attachment of a ground pin which may be embodied in the electrical contact device, but which, in any case, must make a good electrical contact and be attached adjacent to the area which is to be marked.

Before etching is commenced the surface of the part should be thoroughly cleaned. The stencils should be in good condition and should be discarded if they are distorted or ruptured, or the mark becomes obliterated. Pad holders should be used with the same electrolyte and renewed when discoloured. All electrical plugs, sockets and ground pins should be checked to ensure good electrical contact. After etching, the part must be neutralised by the application of a suitable agent and thoroughly washed and dried.

Electrical Etching

Etching by the use of an electrical pencil, employing either the constant contact or intermittent principle of operation, causes the material to be severely overheated locally and should not be used for the marking of aircraft parts.

Vibro-Etch Engraving

This is a vibro-percussive engraving process, also known as 'Vibro-Peen' or 'Vibro-Percussion'. Generally, an electrically or pneumatically operated hand tool with a vibrating stylus is used. Marking by this process avoids the local overheating caused by electrical etching and if lightly applied has little effect on the fatigue life of the part. Nevertheless, careful supervision is necessary to control the depth of marking, and to have strict control of tip radius. Its use in a highly stressed area is not recommended. Inspectors' personal identification letters and numbers should be encircled with a vibro-etched ring to distinguish them from part numbers, issue numbers or date codes.

Machine Engraving

In this process the identification marks are produced by a mechanically guided rotating cutter or grinder normally controlled via a pantograph. The mark dimensions are limited by the size of the cutter and the size of the pantograph used. This process is sometimes used or stressed parts of high-grade steels or high grade aluminium alloys. The depth of the marks is normally kept to the minimum compatible with clarity. The cutter or grinder used must be rounded, so that sharp corners or cuts are not produced on the part. This method is also used for engraving information or instructions on placards and nameplates.

Embossing

In this process, which is suitable for castings, forgings, and mouldings, the identification markings are inherent in the mould or die, and are, therefore, produced as part of the manufacturing process. The marks may either be raised or depressed but should not be located on an area of the part which is subject to subsequent machining.

The embossing process is also suitable for application to poly tetra fluoro ethylene (PTFE) and plastics materials after manufacture of parts. In this case the identification marks are produced by application of controlled heat and pressure via the medium of a die so as to transfer pigment from specially prepared coloured foils onto the prepared area of the part. Colours should be selected to contrast with the background colour of the part.

Grit Blasting

In this process, marks are produced by applying a controlled jet of abrasive material, in conjunction with rubber or plastics stencils, to specific areas. This process may be employed with advantage in certain circumstances, e.g. marking transparent plastics and hard anodised surfaces. The type and grade of abrasive material, air pressure, and period of application is normally specified on the drawing. The process is not suitable where contamination by the abrasive material can occur, e.g. parts containing ball, needle or roller bearings and hollow parts. The depth of marking produced by this process is slight and is, therefore, not suitable for parts of which a protective finish will subsequently be applied. This process is not normally permissible for magnesium alloy materials.

Stamping

In this process, steel stamps are used for marking and these can be applied either by mechanical means or by hand in accordance with the drawing instructions. There are various types of machines available for marking parts with steel stamps, and it is quite usual for a machine to be specified for this operation, as it can be preset to control the depth of the impression.

The indentations resulting from this form of marking can, unless carefully controlled, have a serious effect on the strength of parts, and may lead to a considerable reduction of resistance to fatigue. Normally steel stamps are not used on aluminium alloy sheet thinner than 20 swg or on high strength aluminium alloy parts or parts made from steel with an ultimate tensile strength in excess of 850 MN/m^2 (55 tonf/in^2).

When steel stamps are used, they should not be larger than is necessary for clarity and a type size of 1.58 mm (0.0625 in) or 2.38 mm (0.09375 in) is usually found to be satisfactory. The symbol should not embody sharp points, and should be shaped to produce a depression of ‘U’ rather then ‘V’ form. The depth of the impression produced should be kept to the minimum, and, particularly when applied to parts fabricated from sheet material, the impression should not result in embossment of the reverse surface. Worn stamps should not be used, since the additional hammering necessary to obtain an impression may affect the characteristics of the material. During any stamping operation, the part should be adequately supported by a backing block which has a smooth surface.

Transfers

In this process, marks are produced by the application of a prepared wet transfer, bearing the required markings, on the surface of the part to be marked. When dry, the transfer backing is removed leaving a film of the marking which is finally coated with a protective varnish. It is essential that the area of the part to be marked is thoroughly cleaned before the application of the transfer. Transfer markings do not physically alter the surface of the part, and, therefore, are suitable for application after completion of protective treatment. In general, this method can only be regarded as semipermanent, and its use is only recommended for the identification of assemblies.

Adhesive Labels

In this process, marks are produced by the application of a label consisting of a foil (backed with adhesive) on which the marks are impressed prior to its being attached to the part. Such labels are often used for the identification of highly stressed components, and, since the adhesive is unaffected by temperature and most fluids, they provide a permanent identification without any identation of the part. Where difficulty is experienced in the adhesion of such labels or where metal labels without adhesive backing are used, the application of a suitable flexible adhesive is specified. The possibility of dissimilar metals in juxtaposition setting up corrosion should be borne in mind, and, in particular, aluminium or zinc labels should not be used on parts manufactured from nickel base alloys, unless they have been cadmium plated.

Marking Inks

Marking by means of a suitable ink applied by rubber stamps or stencil is often specified for marking timber, plastics, fabrics, or metal parts which can only be marked after the completion of a protective treatment. It is common practice, particularly with metal parts, to have the area to be marked first painted with a white primer on to which the marks are applied; the area then being protected with an environmentally suitable clear varnish. To avoid deterioration of some materials, as a result of chemical reaction from the ink, it is important that only the ink specified is used.

Metal Clips, Plates or Tags

In general, marking of parts by the attachment of clips, plates or tags is used where the size, shape, finish or material of the part precludes the application of markings to the surface. Further information on metal clips, etc., and other special applications is given below under topic special applications.

POSITION OF MARKING

The position of the markings, and the process to be employed, is usually indicated on the drawing. The location selected for application of markings should always be remote from bearing surfaces, edges, holes, bends, changes of section, narrow of highly stressed areas and surfaces which have been hardened for a specific purpose. Certain manufacturers standardise the marking medium to be used on various materials and issue this information to the workshops as an internal specification, usually by adding a code number on the drawing. Any mark signifying inspection approval should be applied adjacent to the identification markings.

All markings should, if possible, be grouped together, and positioned where they will not be obliterated or concealed by subsequent machining or assembly.

When sheet metal parts are heat-treated prior to manipulation, it is usual, where steel stamping is permitted, to apply a cipher to the parts so that the particular heat treatment batch can be identified subsequently. The position of the cipher should be carefully selected before heat treatment and manipulation. If after manipulation the cipher appeared on a bend this would usually lead to rejection of the part.

There are several reasons why the marking of some parts is un practical, amongst these being size, hardness and fragility. Typical examples are hardened steel springs, bolts of less than 6.35 mm (0.25 in) diameter, nuts of less than 9.52 mm (0.375 in) diameter, split pins and taper pins. In such instances it is permissible to pack the parts in a suitable container, which should be sealed, and identification and inspection approval applied.

When individual parts are fabricated into assemblies, the appropriate assembly drawing number and drawing issue number should be applied, together with the inspection approval mark, in the manner, and position, indicated on the drawing.

Information on the application of serial numbers is given below under topic serial numbers..

SPECIAL APPLICATIONS

Because of factors such as shape, material characteristics, etc., it is not always possible to mark all parts in the normal way, and in the following paragraphs guidance is given on the marking of such items.

Bolts

Part numbers and inspection stamps should be marked on the flat portion of the head; marking of the shank is not permissible. With cold-headed bolts, the inspection stamp may be omitted, provided the bolts bear the maker's identification symbol and are packed in sealed containers bearing evidence of inspection approval.

Cable Assemblies

It is recommended that swaged-end cable assemblies should be marked on the swaged shank of the end fittings by a rolling process, but if the necessary equipment is not available, the markings should be applied by a vibro-etching process.

If identification tags are fitted on swaged-end cables, they would have to comply with a specification such as British Standard SP51-52, and should be fitted as shown in Figure 10.1 or, when fitted to cable ends without locking wire holes, in accordance with the approved cable assembly drawings. Tags not covered by a specification, or tags fitted in a manner other than as given above, are unacceptable.

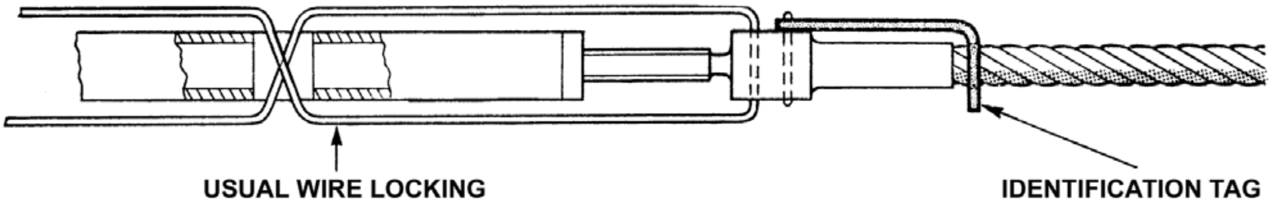


Fig. 10.1, Cable Assembly Identification

If identification tags should be attached to spliced cables as shown in Figure 10.2. Where cast or pulley type thimbles are used, the identification marks can be applied direct to these items.

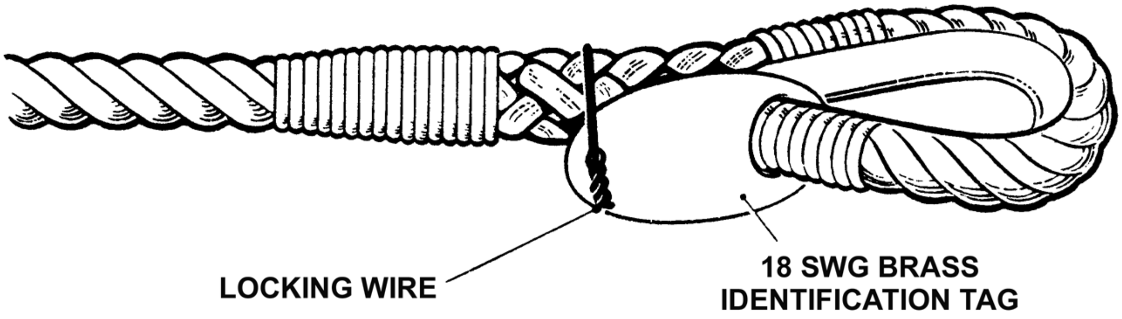


Fig. 10.2, Method of attaching identification tag to spliced cable.

NOTE

If after the installation of a cable in an aircraft there appears to be any likelihood of the tag subsequently coming loose or causing jamming, it should be removed and the particulars on the tag should be entered in the aircraft log book or maintenance record.

Castings

Castings should be marked, batched or tallied as soon as possible after removal from the mould, in a manner which will enable them to be correlated with the relevant mechanical tests and analytical records. The position of the marks should be in accordance with the relevant drawings, but if the position is not indicated on the drawing, thin sections liable to damage should be avoided and, if possible, the markings should be placed where they will not be removed by subsequent manufacturing processes.

In many instances raised panels are produced as part of a casting especially for the application of identification marks; in which case the casting should not be marked in any other position.

Small castings from the same batch and for which the size is inconsistent with the display of part marking with adequate clarity may be packed in bags or bundles, and the appropriate markings should be stamped on a metal label securely attached to each bag or bundle.

Nuts

Where identification marks are necessary, i.e. on nuts of 9.52 mm (0.375 in) diameter or more, they should always be applied to the hexagonal sides of the nuts, and in no circumstances to the mating surfaces, since this could result in the scoring of underlying metal when the nut is assembled.

Pipes

Pipes manufactured of material which may be soft soldered are usually marked by means of a brass plate bearing the appropriate data. The inspection stamp should be impressed on the plate just before it is assembled, but in instances where this procedure is un practical, the stamp may be impressed in a blob of solder beside the plate. It is essential to ensure a complete soldered bond between the plate and the pipe, since flux residue may cause corrosion.

Where soldering is un practical, pipes may be marked by electro-chemical etching, or by a rubber stamp using a non-corrosive dye, or by a specially made flexible slip-on sleeve. In some instances an adhesive label is used, but wrap-round or tie-on metal identification tags should not be used.

NOTE
Cases have occurred where metal identification tags have worn a pipe to paper thinness and in the course of time, have produced a pin hole leak under the tag.

Information on the identification marking of aircraft pipe systems is given in British Standard M23.

Plastics

The method of marking plastics parts depends on the thickness, shape and material of the part to be marked. With the majority of plastics produced by a moulding process, the identification markings are included in the moulding, but in the following paragraphs consideration is given to the marking of plastics produced by other processes.

Glass-fibre Reinforced Plastics Laminates

a. On equipment subject to stress, vibro-etching should not be used because it can break strands and create stress raisers. In such cases the component should be marked with either white paint and Indian ink, or a rubber stamp on a white painted surface.
b. In instances where the weave pattern of the reinforcing cloth stands slightly proud of the surface, a rubber stamp and marking ink may be used. Before applying the mark it is essential that the release agent should be removed from the surface of the sheet in the area where it is to be marked. White spirit will remove most release agents, which differ according to the type of material, but it will not remove all traces of silicone. For most purposes, it is recommended that the area to be marked should be lightly rubbed with fine abrasive cloth.
c. For non-stressed parts, and if the laminate has a smooth surface, the use of a vibro-etching process is suitable. An ink or dye can be wiped over the etched surface so that the letters show more clearly.

Thermoplastics

Thermoplastics, such as cellulose derivatives and vinyl resins, are materials which can be made pliable by heat and which retain their original properties when cooled, it being possible to repeat the process any number of times without appreciable change in properties. All thermoplastics, with the exception of certain forms of celluloid and vinyl acetates, can be marked satisfactorily with heated dies, but this method may not be suitable for tabular sections. However, the die temperatures vary with different materials, and the recommended temperature should be ascertained from the manufacturer.

Thermosetting Plastics

Thermosetting plastics are materials in which a chemical reaction takes place while they are being moulded under heat and pressure. The chemical and physical properties of the material are entirely changed and it is subsequently resistant to further applications of heat. The heated die process is not suitable for materials in this group, and for the majority of applications the vibro-etching method can be used, but where this may cause damage to the material, white paint and marking ink may be preferable.

Transparent Plastics

The marking of parts manufactured of transparent plastics materials should be avoided where possible. If the material is bonded permanently to a metal frame it is preferable to apply the marking to the metal portion. However, if it is necessary to apply identification markings to transparent plastics, these should be applied to the inner face of the panel by means of mild sandblasting and stencil. When it is necessary to mark a part temporarily, a label should be affixed by means of masking tape but labels should not be stuck directly to the material. When parts are annealed by the process prescribed in specification DTD 925, this should be indicated by marking the part in the manner described above, with the legend ‘‘DTD 925’’, followed by the date.

Propellers

In the case of wooden propellers, it is usual to apply steel identification stamps on the rounded portion of the boss, so positioned that the markings will not be obscured by the engine hub or the spinner. Inspection stamps are usually applied to indicate approval of the various stages of inspection, i.e. timber and cementing, inspection in the white, and final inspection.

In the case of metal propellers, identification marks may be applied by using a suitable acid etching process. It is essentials, however, that careful control of this process be exercised to avoid weakening the metal or setting up stress raisers as a result of etching to an excessive depth.

Radiators and Oil Coolers

With the exception of components manufactured of light alloy, the identification marking should be stamped on a brass plate soft soldered to the casting adjacent to the inlet neck. Inspection approval is usually indicated by the application of a metal stamp in a blob of solder adjacent to the plate.

Rescue Equipment

Rescue equipment such as dinghies and life jackets should be marked with the manufacturer's identification symbol, the date of manufacture, the serial number and inspection stamp. The marking medium used should have no deleterious effect on the fabrics to which they are applied. An ink containing phenol should not be used on nylon, and an ink containing copper should not be used on rubber fabric as it would cause considerable damage after ageing and exposure to the air.

A record should be maintained by the manufacturer by which the serial number of each component can be correlated with the roll numbers of the fabric from which it was made, and also with the batch number of such items as valves, CO_2 cylinders and webbing

When reuse equipment components are repaired, inspection approval should be signified by the application of an inspection stamp and the date of that repair along with the part number for that component, on a record label attached to the component. Where overhauls or inspections are completed in accordance with the time/life requirements of an approved Maintenance Schedule, it is recommended that the date when the next inspection or overhaul is due is also entered on the record label.

Tanks

Tanks manufactured of light alloy material not provided with a metal data plate should be marked by coloured paint or ink on a white paint background. A rubber inspection stamp should be used, and, when the markings are complete, they should be protected by a coat of clear varnish.

Timber

All timber parts should be marked with a rubber stamp and ink and should be data stamped to enable the age of the part to be subsequently as certained.

Tubes and Tubular Structures

Difficulty is sometimes experienced with marking steel tubes. A steel or brass plate applied in a manner similar to that described before for radiators and oil coolers is sometimes used, but it should be noted that soldering H.T. steel tubes can adversely affect the fatigue resistance. In some instances a rubber stamping procedure is used. This consists of applying a rubber stamp, using a suitable ink, to a white paint background and then protecting the markings with a specified clear varnish. Adhesive labels are also often used.

In instances where the diameter of the tube is sufficiently large and at least one end is open, the markings may be applied around the circumference of the tube near one end, while the tube is supported internally by means of a suitable mandrel.

If the structure is to be painted, the identification markings should be temporarily masked until painting is complete.

SERIAL NUMBERS

Company procedures should be raised to cover the allocation and control of serial numbers, so that traceability to assembly, test and overhaul records can be achieved. Additionally, it provides a reliable reference for general recording purposes.

Where possible, serial numbers should be prefixed by a combination of letters which enables the manufacturer to be identified, and in the majority to instances they should be identical to those used on the firm's inspection stamps. Where components are being produced by a subcontractor, the serial numbers may be allotted either by the main contractor or the subcontractor, but in no circumstances should the same combination of symbol and serial numbers be used by the main and subcontractors for identical components.

Where possible, the serial number of the item, together with the drawing number and issue number of the drawing and the date of inspection, should be stamped on a plate similar to that illustrated in Figure 10.3. The plate should be manufactured of a material compatible with the component, and should be attached to the component using a jointing compound to prevent corrosion. Where a plate cannot be used, the data should be painted on the component and protected with a coat of clear varnish.

Wherever possible, the serial number should be so positioned that it can be seen when the component is installed in the aircraft or on the engine; on certain components, the provision of a window, or a rip-off patch, may be necessary to achieve this.

The marking on the plate should be legible and not obliterated by paint, etc. During overhaul the plate should be checked for security since, should the plate be lost, difficulty may be experienced in proving the identity of the component and hence its state of serviceability. The identification plates of condemned components should be destroyed.

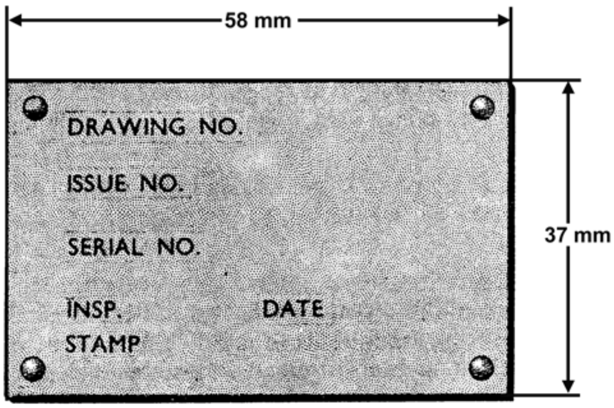


Fig.10.3, Identification Plate.

The serial numbers of fabric covered components are often reproduced externally on the fabric by stencils. Such markings are not necessarily permanent due to the periodical renewal of fabric and dope. Care is necessary to ensure that the markings correspond at all times with those displayed on the permanent plate.

Additional serial numbers must not be added to components by repair or overhaul organisations. When an area of a component bearing a serial number is renewed, or where extensive repairs are carried out, a copy of the original identification plate should be fitted, on which the letter ‘‘R’’ should be placed after the serial number as a stroke number. The inspection stamp signifying approval of the repair and the date on which the repair was inspected should also be added.

MODIFICATIONS

A record of modifications incorporated in a component should be listed on a modification record plate, so that the modification state of the component can be subsequently identified. Where possible, the plate should be positioned adjacent to the identification plate and should show the serial number and date of manufacture of the component with the modification numbers tabulated below. Where a plate cannot be used, the data should be painted on the component and protected with clear varnish.

■■■

CHAPTER : 11
STANDARD COLOUR SCHEMES FOR METALLIC MATERIALS

INTRODUCTION

This chapter gives guidance on a standard colour scheme for the identification marking of metallic materials. Guidance on the marking of metallic materials during manufacture is given in chapter entitled Identification Marking of Metallic Materials.

Since the identification markings detailed in above Chapter 24 are not readily seen when the material is handled under production conditions, it is necessary to use an additional method of identification which indicates the specification and the condition of each piece of material. The most suitable method is to employ a standard colour scheme such as that indicated in the following paragraphs and in the Appendices, but an acceptable alternative is overall marking by a suitable printing process. When not applied by the manufacturer, the colour coding should be applied before the material is placed in bonded store.

The colour scheme, as a means of ready identification, is additional to the identification requirements specified in the various specifications.

When overall marking is used as an alternative to colour code identification it should only be used if the surface condition is receptive to the printing and if such marking is durable under normal storage conditions. In order to permit the re-marking of material with the specification and condition after further heat treatment, the ink should be of a type which is obliterated by heat and does not etch the surface.

COLOUR CODES

Colour codes for all British Standards and DTD metallic materials were, until 31 March 1981, allocated by their Minister of Defence (MOD) and published in their Leaflet QTR 7/AQD (formerly QTR/AQD/D2). From that date the Minister of Defence has been unable to allocate colour codes for non-aerospace specifications (e.g. BS General Engineering Series Specifications) and has confined the allocation of colour codes to BS Aerospace Specifications only. Leaflet QTR 7/AQD is retained in its existing form, but those parts dealing with non-aerospace specifications will progressively become out of date; users have been advised to make alternative arrangements for the identification of materials to non-aerospace specifications.

This chapter follows the procedures of Mod Leaflet QTR 7/AQD and only the aerospace specifications can be considered to be up to date. Whenever amendments to MOD Leaflet QTR 7/AQD are published.

Certain materials differing only in surface condition or intended usage which are of the same metallurgical condition and properties are given the same colour code, e.g.:-

a. S82A, bars and billets for forging-softened; green, red, yellow.
b. S82B, black bars for machining-softened; green, red, yellow.
c. S82D, bright bars of machining-softened; green, red, yellow.

Materials with the same specification number but different conditions and properties have different colour codes, e.g.:-

a. S154 A, bars and billets for forging-softened; blue green, brown, green, blue.
b. S154 B, and D (black and bright) bars for machining-finally heat-treated; blue, green, yellow, green, blue.

It is sometimes necessary for material to be ordered to cancelled specifications, e.g. for repairs, and the colour coding for such material will be retained in this Leaflet for five years after cancellation of the specification.

When the specification reference of a material is changed, e.g. when a DTD Specification becomes a British Standard, the colour code will not be changed unless a significant difference is introduced by the new Specification.

This chapter lists colour codes for solid and cored cast stick to specifications BS 1400 and BS 1490 as used for the manufacture of bearings and bushings. These should not be confused with those listed in BS 1400 and BS 1490 for ingot supplies.

COLOURS

The colours used for current specifications are black, blue brown, green, red, white and yellow (and violet for light alloy rivet materials only).

Difficulties in identification may be caused by the colours fading, or being rendered indistinct or even obliterated during handling. In order that the markings may be as permanent as possible the use of paint complying with specifications DEF 1052 is recommended. This paint is available lead-free, and should be ordered in the shades shown in Table 11.1.

TABLE 11.1

Colour	BS 381C	
	Shade No.	Description
Blue	104	Blue Azure
Brown	410	Light Brown
Green	221	Brilliant Green
Orange	557	Light Orange
Red	537	Signal Red
Yellow	355	Lemon Yellow

APPLICATION OF THE COLOUR SCHEME

Bars and Tubes

Each bar and tube should be painted, preferably at both ends, with the stipulated colour or colours in the following manner:-

a. For one colour - 1 band 200 mm (8 in) wide.

b. For two colour - 2 band each 100 mm (4 in) wide.

c. For three colour - 3 band each 75 mm (3 in) wide.

d. For four colour - 4 band each 50 mm (2 in) wide.

e. For five colour - 5 band each 35 mm (1.5 in) wide.

Sheet and strips.

One of the following methods should be used:-

a. A band or bands of the required colour should be painted on each sheet or strip diagonally across the corner bearing the identification stamp marks. The width of the band or bands should be in accordance with that given in above paragraph and the painting should commence 150 mm (6 in) from the corner, measured at right angles to the band. Sheet and strips less than 300 m (12 in) wide should be painted at one end in a similar manner to bars.

b. Each sheet or strip should be painted with a disc. For a single colour the disc should be 75 mm (3 in) in diameter, additional colours when required being applied in concentric rings 35 mm (1.5 in) wide.

c. A method suitable for large scale production of sheets and flat strips is to stack the sheet and slide them endwise so that 35 mm (1.5 in) of each sheet is exposed. Bands of paint of the width specified in paragraph 4.1 should then be painted on the sheets in one operation, resulting in an identification mark on each. The paint must be applied to that face and end of the sheets which bears the identification stamp marks.

Wire and Rods

The required colours should be painted in bands on the outside of each bundle and the outer turns of each coil. The band or bands should be at right angles to the wires and rods and should not be less than 75 mm (3 in) total width, e.g. one band 75 mm (3 in) wide or three bands 25 mm (1 in) wide. The paint marks should extend at least halfway round the wires or rods at the selected part of the coil.

Protective Treatment

Contracts normally require metallic materials for aeronautical purposes to be colour identified by the manufacturer; such material may be required to be protected from corrosion by the application of a lanolin resin protective to Specification DTD 663. This protective is red, and to avoid confusion, the colour identification markings should be applied first and, at the edge of the colour bands remote from the edge of the material, an additional band of black paint 12 mm (0.5 in) wide should be added. The protective may then be added up to the black band. Leaving the colour code free of protective. When the protective treatment is applied by dipping, the protective should be cleaned from the colour code using white spirit or kerosene.

APPENDICES

Colour codes for the various materials and specifications are listed as follows:-

a. **Appendix I - British Standards**
Section I - Aluminium and Aluminium Alloys
Section II - Brass, Bronze and Copper Alloys
Section III - Nickel and Heat Resisting Alloys
Section IV - Titanium and Titanium Alloys
Section V - Solders
Section VI - Steels
Section VII - Welding-Filler Rods and Wires

b. **Appendix II- Other Specifications**
Section I - DTD Specification
Section II - American Specification
Section III - French Specification

c. **Appendix III - Reverse Colour Codes**
(List of all materials and Specification in Appendices I and II presented with the colour code first.)

APPENDIX I TO LAST CHAPTER
BRITISH STANDARDS
ALUMINIUM AND ALUMINIUM ALLOYS

SECTION-I

NUMBERS	DESCRIPTION	COLOUR
L16	Aluminium sheets (half hard)	Blue
L17	Aluminium sheets (soft)	Black
L25A	Aluminium alloy bars and billets for forging	Red, black, white
L34	99 per cent aluminium bars and sections	Black, red
L36	(Section 1) - Aluminium rods and wires for rivets	Black
L37	Aluminium alloy rivets:	
	Section II Rods and wires for rivets	Red, black, red
	Section III Tubes for rivets	Red, black, red
L44	Soft aluminium alloy extruded bars and sections	Green, white
L54	99 per cent aluminium tubes	Blue, red
L56	Aluminium 2 per cent magnesium alloy tubes (soft)	White, brown, yellow
L58	Aluminium 5 per cent magnesium alloy wire for rivets	Green
L59	Aluminium-manganese alloy sheets and strips	Black, red, blue
L60	Aluminium-manganese alloy sheets and strips (quarter hard)	Green, black, green
L61	Aluminium-manganese alloy sheets and strips (soft)	Blue, yellow, blue
L63	Aluminium-copper-magnesium-silicon-manganese alloy tubes (solution treated and precipitation treated)	Red, black, red
L65	Aluminium-copper-magnesium-silicon-manganese alloy bars, extruded sections and forgings (solution treated and precipitation treated):	
	Bars for Machining and extruded sections	Black, yellow, black
	Bars for Machining and extruded sections which have been solution treated but not precipitation treated	Red, green, red
L70	Aluminium-copper-magnesium-silicon-manganese alloy sheets and strips (solution treated and aged at room temperature):	Green, black, yellow
	Annealed	Green, yellow, red
	As rolled	Brown, red, green
L72	Aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy sheets and strips (solution treated and aged at room temperature)	Black, brown
	Annealed	Brown, yellow, red
	As rolled	Brown, yellow, green
L73	Aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy sheets and strips (solution treated and precipitation treated)	Black, green, blue
L77	Aluminium-copper-magnesium-silicon-manganese alloy billets and bars for forging	Brown, red, green
L80	Aluminium 2.1/4 per cent. magnesium alloy sheets and coils (soft)	Green, black, red
L81	Aluminium 2.1/4 per cent. magnesium alloy sheets and coils (1/2 hard)	Blue, brown, blue
L83	Aluminium-copper-nickel-magnesium-iron-silicon allow bars and extruded section:	
	Bars and billets for forging	Green, red, yellow
	Bars for machining and extruded sections	Red, black, yellow
	Bars for machining and extruded sections which have been solution treated but not precipitation treated	Red, blue, yellow

L84	Aluminium-copper-silicon-magnesium alloy bars and extruded sections: Bars for machining and extruded sections	Red, brown, red
L85	Aluminium-copper-silicon-magnesium alloy forging stock, bars and extruded sections:	
	Bars and Billets for forging	Green, black, red
	Bars for machining and extruded sections, solution treated and precipitation treated	Blue, yellow, blue
	Bars for Machining and extruded sections which have been solution treated but not precipitation treated	Blue, black, green
L86	Aluminium-copper-magnesium alloy for rivets	
	Annealed and drawn	Yellow
	Solution treated and naturally aged	Violet
L87	Aluminium-copper-magnesium-silicon-manganese alloy hexagonal bars for nuts, couplings, etc.	
	Solution treated precipitation treated	Black, red, black
L88	Aluminium alloy coated aluminium zinc magnesium-copper chromium alloy sheet and strip	
	Solution treated and precipitation treated.	Green, brown, green
	Annealed condition	Green, yellow, white
L89	Aluminium coated aluminium-copper magnesium-silicon-manganese alloy sheet and strip to close tolerances	
	Solution treated and aged at room temperature	Blue, green, red
	Annealed condition	Red, yellow, white
L90	Aluminium coated aluminium-copper-magnesium-silicon-manganese alloy sheet and strip to close tolerances. close tolerances.	
	Solution treated and precipitation treated	Black, blue, black
	Annealed condition	Brown, yellow, white
L93	Aluminium-copper-magnesium-silicon-manganese plate (Solution treated controlled stretched and precipitation treated):	Black, white, green
	(Solution treated and controlled stretched)	Black, red, white
	Solution treated condition	White, brown, white
L94	Aluminium-copper-magnesium-silicon-manganese plate	
	(Solution treated and precipitation treated not controlled stretched):	Blue, black, red
	(As rolled)	Blue, brown, yellow
	(Annealed):	Blue, red, brown
	(Solution treated):	Blue, black, white
L95	Aluminium-zinc-magnesium-copper-chromium alloy plate	
	(Solution treated, controlled stretched and precipitation treated):	Brown, green, brown
	(Solution treated):	Blue, yellow, white
L96	Aluminium-zinc-magnesium-copper-chromium alloy plate	
	(Solution treated and precipitation treated not controlled stretched):	Blue, white, red
	(As rolled):	Brown, white, brown
	(Annealed):	Blue, yellow, brown
	(Solution treated):	Brown blue, white

L97	Aluminium-copper-magnesium-manganese alloy plate (Solution treated, controlled stretched, aged at room temperature):	Red, white, red
L98	Aluminium-copper-magnesium-manganese alloy plate (Solution treated and aged at room temperature, not controlled stretched):	Green, red, green
	(As rolled A):	Green, white, yellow
	(Annealed):	Green, red, white
L102	Aluminium-copper-magnesium-silicon-Manganese Bars and section	Green, brown, green
L103	Aluminium-copper-magnesium-silicon-Manganese forging stock	Black, white, green
L104	Aluminium-copper-magnesium-silicon-Manganese Sheet and strip	Black, white, red
L105	Aluminium-copper-magnesium-silicon-Manganese tube	Blue, yellow, green
L106	Aluminium-copper-magnesium-silicon-Manganese Sheet and strip	Brown, red, green
L107	Aluminium coated aluminium-copper-magnesium-silicon-manganese Sheet and strip	Brown, yellow, green
L108	Close tolerance aluminium coated aluminium-copper-magnesium-silicon-manganese Sheet and strip	Red, black, white
L109	Aluminium coated aluminium-copper-magnesium-manganese Sheet and strip	Blue, green
L110	Aluminium coated aluminium-copper-magnesium-manganese Sheet and strip	Blue, red, white
L111	Aluminium-magnesium-silicon-manganese bars and section	Red, white, red
	Solution treated condition	Black, red, white, red
L112	Aluminium-magnesium-silicon-manganese Forging stock	white, green, white
L113	Aluminium-magnesium-silicon-manganese Sheet and strip	
	Solution treated condition	Black, white, yellow, black
	Solution treated, flattened, precipitation treated	Black, white, yellow
	Annealed condition	Yellow, black, white, yellow
L114	Aluminium-magnesium-silicon-manganese tube	
	Solution treated condition	Green, black, yellow, red
	Solution treated, drawn, precipitation treated	Green, black, yellow,
	Annealed condition	Green, black, yellow green
L115	Aluminium-magnesium-silicon-manganese Plate	
	Solution treated condition	Black, blue, black, brown
	Solution treated, controlled stretched precipitation treated	Blue, black, brown
L116	Aluminium Tube - Cold drawn	Black
L117	Aluminium-magnesium-silicon-copper-chromium alloy tube (not tested hydraulically)	
	Solution treated and artificially aged	Black, blue, brown, blue
L118	Aluminium-magnesium-silicon-copper-chromium alloy tube (tested hydraulically)	
	Solution treated and artificially aged	Black, blue, green, black
L150	Aluminium-copper-magnesium-silicon-manganese alloy sheet and strip	
	Solution treated and artificially aged	Black, blue, black, blue
L151	Aluminium coated aluminium-copper magnesium silicon-manganese alloy sheet and strip	
	Solution treated and aged at room temperature	Black, blue, white, black

L152	Aluminium coated aluminium-copper magnesium-silicon-manganese alloy sheet and strip	
	Solution treated and artificially aged	Black, brown, black, white
L153	Aluminium coated aluminium-copper magnesium-silicon-manganese alloy sheet and strip :	
	Supplied for solution treatment by the user	Black, brown, blue, brown
L156	Aluminium-copper-magnesium-silicon-manganese sheet and strip- (Solution treated and aged at room temperature).	
	Temper F - as rolled	Black, green, black, red
	T4 - Solution treated, straightened, naturally aged	Black, green, brown, green
	T42 - solution treated, naturally aged	Black, green, red, blue
L157	Aluminium-copper-magnesium-silicon-manganese sheet and strip- (Solution treated and artificially aged).	
	T6 - Solution treated, straightened, artificially aged	Black, red, black, blue
	T62 - solution treated, artificially aged	Black, red, green, brown
L158	Aluminium-copper-magnesium-silicon-manganese sheet and strip, close toleranced- (Solution treated and aged at room temperature).	
	Temper F as rolled	Brown, black, brown, green
	T4 - solution treated, straightened, naturally aged	Brown, black, red, brown
	T42 - solution treated, naturally aged	Brown, black, green, red
L159	Aluminium-copper magnesium-silicon-manganese sheet and strip, close toleranced - (Solution treated and artificially aged).	
	T6 - solution treated, straightened, artificially aged	Brown, blue, brown, red
	T62 - solution treated, artificially aged	Brown, blue, green, yellow
L160	Aluminium-zinc-magnesium-copper-chromium alloy	
	Bars and sections in T7251 condition	Black, blue, brown, blue
L163	Aluminium-coated aluminium-copper-magnesium-silicon-manganese sheet and strip - (Solution treated, cold worked for flattening and aged at room temperature).	
	T3 - solution treated, straightened, naturally aged	Black, brown
L164	Aluminium-coated aluminium-copper-magnesium-silicon-manganese sheet and strip - (Solution treated, and aged at room temperature).	
	Temper F - as rolled	Blue, black, blue, green
	T4 - solution treated, straightened, naturally aged	Blue, black, brown, blue
	T42 - solution treated, naturally aged	Blue, black, green, red
L165	Aluminium-coated aluminium-copper-magnesium-silicon-manganese sheet and strip - (Solution treated, and artificially aged).	
	T6 - solution treated, straightened, artificially aged	Blue, brown, blue, red
	T62 - solution treated, artificially aged	Blue, brown, green, red
L166	Aluminium-coated aluminium-copper-magnesium-silicon-manganese sheet and strip, close toleranced -	

	(Solution treated and aged at room temperature).	
	Temper F - as rolled	Green brown, green, red
	T4 - solution treated, straightened, naturally aged	Green, brown, yellow, green
	T42 - solution treated, naturally aged	Green, brown, blue, yellow
L167	Aluminium-coated aluminium-copper-magnesium-silicon-manganese sheet and strip, close toleranced - (Solution treated and artificially aged).	
	T6 - solution treated, straightened artificially aged	Green, blue, brown, green
	T62 - solution treated, artificially aged	Green, blue, red, yellow
L168	Bars and extruded sections of aluminium-copper-magnesium-silicon-manganese alloy- (Solution treated and artificially aged).	
	To the requirements of BS 3L100 Section 5:	
	T6 - solution treated and artificially aged	Blue, brown, blue, brown
	T6510 - solution treated, controlled stretched, no additional straightening after stretching, artificially aged	Brown, green, blue, red
	T6511 - solution treated, controlled stretched, straightened, artificially aged	Brown, green, red, green
L503	Magnesium-aluminium-zinc alloy extruded tubes	Black, blue, white
L504	Magnesium-3% zinc-zirconium alloy sheets and strip	Red, white
L505	Magnesium-3% zinc-zirconium alloy extruded bars and sections	Red, white
L508	Magnesium-1.1/4 zinc-zirconium alloy extruded bars and sections	Red, green, yellow
L509	Magnesium-1.1/4 zinc-zirconium alloy extruded tubes	Red, green, yellow
L512	Bars and extruded sections of magnesium -6% aluminium-zinc alloy	White, brown, white
L513	Forging stock (and forgings) of magnesium - 6% aluminium-zinc alloy	Blue, red, yellow, red
L514	Forging stock (and forgings) of magnesium - 3% aluminium-zinc alloy	Blue, white, yellow, blue
L515	Sheets and strip of magnesium 1.1/4% zinc-zirconium alloy	Blue, white, brown, white
BS 1470	Wrought a aluminium and aluminium alloy plate, sheets and strip :	
S1-0	Annealed (soft)	Red, green, red
-H4	Half hard	Red, green, yellow
-H8	Hard	Red, yellow, red
S1A-M	As manufactured	Brown, blue, yellow, brown
-0	Annealed (soft)	Brown, blue, yellow
-H4	Half hard	Brown, blue, red
-H8	Hard	Brown, blue, black
S1B-0	Annealed (soft)	Black, green, red
-H4	Half hard	Black, green brown
-H8	Hard	Black, green yellow
S1C-M	As manufactured	Yellow, black, blue, yellow
-0	Annealed (soft)	Black, blue
-H2	Quarter hard	Black, yellow, brown
-H4	Half hard	Black, yellow, green
-H6	Three quarter hard	Black, yellow, blue
-H8	Hard	Brown, red
NS3-0	Annealed (soft)	Blue, black, blue

-H2	Quarter hard	Blue, black, green
-H4	Half hard	Blue, yellow, red
-H6	Three quarter hard	Blue, green, blue
-H8	Hard	Blue, yellow, green
NS4-M	As manufactured	Brown, black, green brown
-0	Annealed (soft)	Brown, black, green
-H3		Brown, black, green yellow
-H6		Brown, green, blue, green
NSS-0	Annealed (soft)	Blue, green, yellow
-H2	Quarter hard	Blue, green, brown
-H4	Half hard	Blue, red
NS8-M	As manufactured	Green, yellow, green, red
-0	Annealed (soft)	Yellow, black, yellow
-H2	Quarter hard	Yellow, brown, yellow
-H4	Half hard	Black, yellow, brown, yellow
HS15-TB	Solution treated naturally aged	Blue, brown
-TF	Solution treated and precipitation treated	Blue, brown, blue, yellow
HC15-TB	Solution treated naturally aged	Red, black, yellow
-TF	Solution treated and precipitation treated	Red, yellow
HS30-0	Annealed (soft)	Black, brown, black
-TB	Solution treated naturally aged	Black, brown, blue
-TF	Solution treated and precipitation treated	Black, brown, green
BS 1471	Wrought aluminium and aluminium alloy drawn tube	
TIB - 0	Annealed (soft)	Black, green, red
-H4	Half hard	Green, black, green, red
-H8	Hard	Black, green, red, green
TIC-0	Annealed (soft)	Black, blue
-H4	Half hard	Black, blue, black, yellow
-H8	Hard	Green, black, blue, red
NT4-0	Annealed (soft)	Brown, black, green
-H4	Half hard	Brown, black, red
NT5-0	Annealed (soft)	Blue, green, yellow
-H4	Half hard	Blue, green, brown
NT8-0	Annealed (soft)	Red, green, red, yellow
-H2	Quarter hard	Red, yellow, brown, yellow
NT9-0	Annealed (soft)	Black, green
-TB	Solution treated naturally aged	Blue, black, green
-TF	Solution treated and precipitation treated	Brown, blue, green
HT15-TB	Solution treated naturally aged	Blue, brown
-TF	Solution treated and precipitation treated	Blue, brown, red
HT20-H4	Half hard	Brown, green, red, green
-TB	Solution treated naturally aged	Brown, green red
-TF	Solution treated and precipitation treated	Green, black, green
HT30-TB	Solution treated naturally aged	Blue, black, yellow
-TF	Solution treated and precipitation treated	Black, brown, yellow
BS 1472	Wrought aluminium and aluminium alloy forging stock	
FIB-M	As manufactured	Black, green red
NF4-M	As manufactured	Brown, black, green
NF5-M	As manufactured	Blue, green, yellow
NF8-M	As manufactured	Black, green, black
NF9-M	As manufactured	Brown, white, yellow
NF12-M	As manufactured	Red, blue, red
NF15-M	As manufactured	Brown, red, yellow
NF16-M	As manufactured	Green, yellow, blue, yellow
NF30-M	As manufactured	Blue, brown, yellow
BS 1773	Wrought aluminium and aluminium alloy rivet bolt and screw stock	
RIB-H5	Strain hardened	Black, white, black, yellow
NR5-0	Annealed (soft)	Brown, red, white
-M	As manufactured	Blue, green, yellow
	Annealed and drawn	Brown, yellow, brown

NR-0	Annealed (soft)	Green, brown, red
-M	As manufactured	Yellow, black, yellow
	Annealed and drawn	Black, red, white
HR15	Annealed and drawn	Brown, yellow, green
HR30	Annealed and drawn	Blue, brown, blue
NB6-H4	Half hard	Black, white, brown
HB15	Annealed and drawn	Brown, yellow, green
HB2C-TH	Solution treated-cold worked and precipitation treated	Black, blue, yellow, red
HB30	Annealed and drawn	Blue, brown, blue
HB30-TF	Solution treated precipitation treated	Black, red, blue, yellow
BS 1474	Wrought aluminium and aluminium alloy bar extruded round tube and sections	
EIB-M	As manufactured	Black, green, red
EIC-M	As manufactured	Black, brown, blue
NE4-M	As manufactured	Brown, black, green
NE5-0	Annealed (soft)	Blue, red, white, red
NE5-M	As manufactured	Blue, green, yellow
NE8-0	Annealed (soft)	Green, brown, white
NE8-M	As manufactured	Black, green, black
NE9-0	Annealed (soft)	Blue, red, blue, white
NE9-M	As manufactured	Brown, white, yellow
HE9-TB	Solution treated naturally aged	Blue, green, white
HE9-TE	Cooled from forming temperature, precipitation treated	Brown, green, brown, green
HE9-TF	Solution treated precipitation treated	Blue, green blue
HE15-TB	Solution treated naturally aged	Blue, brown
HE15-TF	Solution treated precipitation treated	Blue, brown, red
HE20-TB	Solution treated naturally aged	Black, yellow, brown
HE20-TF	Solution treated precipitation treated	Blue, black, yellow
NE30-0	Annealed (soft)	Brown, yellow, white, green
NE30-M	As manufactured	Blue, green brown
HE30-TB	Solution treated naturally aged	Brown, black, red
HE30-TF	Solution treated precipitation treated	Brown, black, yellow

BS 1475	Wrought aluminium and aluminium alloy -Wire:	
G1A-0	Annealed (soft)	Brown, blue, green
-M	As manufactured	Black, blue
-H8	Hard	Brown, blue, brown
G1B-0	Annealed (soft)	Brown, green, yellow
-M	As manufactured	Black, Green
-H8	Hard	Brown, green, brown
NG2-M	As manufactured	Black, yellow
NG21-M	As manufactured	Green, red
NG3-0	Annealed (soft)	Red, brown, white
-M	As manufactured	Black, yellow, blue
-H8	Hard	Red, green, yellow
NG4-0	Annealed (soft)	Brown, black, green
-M	As manufactured	Brown, black, green, brown
-H8	Hard	Green black, green yellow
NG5-M	As manufactured	Blue, green
NG6-0	Annealed (soft)	Green, brown, red
-M	As manufactured	Blue, red
NG6-H4	Half, hard	Black, white, brown
-H8	Hard	Black , white, red
NG9-M	As manufactured	Brown, blue, white, yellow
-TB	Solution treated naturally aged	Blue, green, white
-TF	Solution treated precipitation treated	Blue, green, blue
-TD	Solution treated cold worked naturally aged	Blue, green, red
HG15-TB	Solution treated naturally aged	Blue, brown
-TF	Solution treated precipitation treated	Blue, brown, red
HG20-TH	Solution treated cold worked precipitation treated	Green, white, red

BRASS, BRONZE AND COPPER ALLOYS
SECTION II

NUMBERS	DESCRIPTION	COLOUR
B8	Phosphor bronze, cast bars	Yellow
B11	Brass bars suitable for brazing or silver soldering	Brown
T51	High pressure seamless copper tubes	Black
BS1400 AB2	Aluminium bronze (copper aluminium) castings (solid and cored sticks)	Brown, blue, yellow
BS1400 PB1	Phosphor bronze castings (solid and cored sticks)	Black, red, black
BS1400 PB2	Phosphor bronze castings (solid and cored sticks)	Black, green, black
BS1400 PB3	Phosphor bronze castings (solid and cored sticks)	Black, white, black
BS1400 PB4	Phosphor bronze castings (solid and cored sticks)	Black, blue, black, yellow
BS1400 LPB1	Leaded phosphor bronze castings (solid and cored sticks)	Brown, blue, red
BS1400 LB1	76/9/0/5 leaded castings (solid and cored sticks)	Black, blue, red
BS1400 LB2	80/10/0/10 leaded bronze castings (solid and cored sticks)	Red, white, red
BS1400 LB3	85/10/0/5 leaded bronze castings (solid and cored sticks)	Green, brown, red
BS1400 LB4	85/5/10/10 leaded bronze castings (solid and cored sticks)	White, green, white, yellow
BS1400 LB5	75/5/0/20 leaded bronze castings (solid and cored sticks)	White, brown, yellow, white
BS1400 G1	88/10/2 gunmetal castings (solid and cored sticks)	Blue, green, blue
BS1400 G2	88/8/4 gunmetal castings (solid and cored sticks)	Blue, brown, blue
BS1400 LG1	83/3/9/5 leaded gunmetal castings (solid and cored sticks)	Green, black, green
BS1400 G2	85/5/5/5 leaded gunmetal castings (solid and cored sticks)	Green, brown, green
BS1400 G2	86/7/5/2 leaded gunmetal castings (solid and cored sticks)	Green, white, green
BS1432	Copper for electrical purposes. Sheets and Strips	
C101 and	Annealed	Red, black, red
C102	Medium hard	Blue, red
	Hard	Black, green, red
C103	Copper for electrical purposes. Sheets and Strips	
C101 and	Annealed, 0	Black
C102	Medium hard , 1/2H	Black, blue
	Hard, H	Black, blue, white
BS1433	Copper for electrical purposes. Bars and rod:	
	Annealed	Red, black, red
	Medium hard	Blue, red
	Hard	Black, green, red
BS1434	Copper for electrical purposes. Commutator bars	Green, blue, green
BS1977	Copper tubes for electrical purposes to BS1036 purity	
(C101)	Annealed	White, green, yellow
	As drawn	White, red, yellow

BS1977	Copper tubes for electrical purposes to BS1037 purity		
(C102)	Annealed		White, yellow, white
	As drawn		Yellow, black, yellow
BS1977	Copper tubes for electrical purposes to BS1861 purity		
(C103)	Annealed		Yellow, blue, yellow
BS2786	Round hard drawn brass wire		Blue, black, brown
	As drawn (M)		Blue, brown, green
BS2870	Rolled - copper and copper alloys, Sheet strip and foil		
C101	Electrolytic tough pitch HC Copper	0	Black, blue, red
C101	Electrolytic tough pitch HC Copper	0	Black, blue, red
C101	Electrolytic tough pitch HC Copper	0	Black, blue, red
C102	Fire refined tough pitch HC Copper	0	Black, yellow, blue
C102	Fire refined tough pitch HC Copper	0	Black, yellow, blue
C102	Fire refined tough pitch HC Copper	0	Black, yellow, blue
C103	Oxygen free HC Copper	0	Black, yellow, blue
C103	Oxygen free HC Copper	0	Black, yellow, blue
C103	Oxygen free HC Copper	0	Black, yellow, blue
C104	Tough pitch non-arsenical copper	M/O	Blue, red, white
C104	Tough pitch non-arsenical copper	1/2H	Blue, red, yellow
C104	Tough pitch non-arsenical copper	H	Blue, white, green
C105	Tough pitch arsenical copper	M/O	Blue, yellow
C105	Tough pitch arsenical copper	1/2H	Brown, black, brown
C105	Tough pitch arsenical copper	H	Brown, black, red
C106	Phosphorous deoxidized non-arsenical copper	M/O	Green, black, red
C106	Phosphorous deoxidized non-arsenical copper	1/2H	Green, blue, yellow
C106	Phosphorous deoxidized non-arsenical copper	H	Green, brown, white
C107	Phosphorous deoxidized non-arsenical copper	M/O	Green, yellow, green
C107	Phosphorous deoxidized non-arsenical copper	1/2H	White, black, yellow
C107	Phosphorous deoxidized non-arsenical copper	H	White, brown, white
CZ101	90/10 brass	O	Black red, brown, red
CZ101	90/10 brass	1/2H	Black, red, green red
CZ101	90/10 brass	H	Black, green, white, black
CZ102	85/15 brass	O	Black, red, yellow, brown
CZ102	85/15 brass	1/2H	Black, white, yellow, black
CZ102	85/15 brass	H	Black, white, green, white
CZ103	80/20 brass	O	Black, yellow, black,
brown			
CZ103	80/20 brass	1/2H	Black, yellow, black, white
CZ103	80/20 brass	H	Black, yellow, blue, yellow
CZ106	70/30 brass	O	White, green, yellow
CZ106	70/30 brass	1/2H	White, red, white
CZ106	70/30 brass	1/2H	White, red, yellow
CZ106	70/30 brass	H	White, yellow
CZ107	2/1 brass	O	Green, red
CZ107	2/1 brass	1/2H	Red, yellow, red
CZ107	2/1 brass	1/2	Blue, red, green
CZ107	2/1 brass	H	Blue, brown
CZ107	2/1 brass	EH	Blue, black, red
CZ108	Common brass	O	Green
CZ108	Common brass	1/2H	Yellow, black, yellow
CZ108	Common brass	1/2H	Red
CZ108	Common brass	H	Blue
CZ108	Common brass	EH	Brown, yellow, brown
CZ110	Aluminium brass	M	Black, yellow, brown, red
CZ110	Aluminium brass	O	Black, yellow, green yellow
CZ112	Naval brass	M	Black, blue, brown

CZ112	Naval brass	O	Black, red, green
CZ112	Naval brass	H	Green, blue, red
CZ118	Leaded brass 64% copper	1/2H	Black, yellow, white, yellow
CZ118	Leaded brass 64% copper	H	Blue, black, brown, green
CZ118	Leaded brass 64% copper	EH	Blue, black, green, white
CZ119	Leaded brass 64% copper	1/2H	Blue, black, yellow, blue
CZ119	Leaded brass 64% copper	H	Blue, black, white, blue
CZ119	Leaded brass 64% copper	EH	Blue, brown, black, brown
CZ120	Leaded brass 64% copper	1/2H	Blue, brown, blue, brown
CZ120	Leaded brass 64% copper	H	Blue, brown, blue, white
CZ120	Leaded brass 64% copper	EH	Blue, brown, red, blue
CZ123	60/40 brass	M	Blue, brown, white, brown
CZ125	Cap copper	O	Blue, brown, yellow, red
CB101	Copper-beryllium	O	Blue, black, brown, yellow
CB101	Copper-beryllium	W	Black, blue, yellow
CB101	Copper-beryllium	W(1/2H)	Black, brown, white
CB101	Copper-beryllium	W(1/2H)	Black, green, white
CB101	Copper-beryllium	W(H)	Black, yellow, white
CN102	90/10 copper-nickel-iron	M	Blue, green, white, blue
CN101	95/5 copper-nickel-iron	M	Blue, green, brown, green
CN102	90/10 copper-nickel-iron	O	Blue, red, black, red
CN103	85/15 copper-nickel	O	Blue, red, brown, white
CN104	80/20 copper-nickel	O	Black, blue, black, white
CN105	75/25 copper-nickel	O	Black, blue, brown, green
CN106	70/30 copper-nickel	O	Black, blue, green blue
CN107	70/30 copper-nickel	O	Black, blue, red, brown
CS101	Silicon bronze (copper-silicon)	M	Black, blue, white, green
NS103	10% nickel silver (copper-nickel-zinc)	1/2H	Black, blue, yellow, black
NS103	10% nickel silver (copper-nickel-zinc)	H	Black, brown, black, white
NS103	10% nickel silver (copper-nickel-zinc)	EH	Black, brown, blue, yellow
NS103	10% nickel silver (copper-nickel-zinc)	O	Black, brown, green, yellow
NS104	12% nickel silver (copper-nickel-zinc)	1/2H	Black, brown, red, white
NS104	12% nickel silver (copper-nickel-zinc)	H	Black, brown, white, yellow
NS104	12% nickel silver (copper-nickel-zinc)	EH	Black, brown, yellow, red
NS104	12% nickel silver (copper-nickel-zinc)	O	Blue, red, white, blue
NS105	15% nickel silver (copper-nickel-zinc)	1/2H	Blue, red, yellow, blue
NS105	15% nickel silver (copper-nickel-zinc)	H	Blue, white, black, brown
NS105	15% nickel silver (copper-nickel-zinc)	EH	Blue, white, blue, green
NS106	18% nickel silver (copper-nickel-zinc)	O	Black, blue, black, red
NS106	18% nickel silver (copper-nickel-zinc)	1/2H	Black, blue, red, green
NS106	18% nickel silver (copper-nickel-zinc)	H	Black, green, white, green
NS106	18% nickel silver (copper-nickel-zinc)	EH	Black, red, blue, red
NS107	18% nickel silver (copper-nickel-zinc)		Black, red, brown, yellow
NS108	20% nickel silver (copper-nickel-zinc)	O	Blue, white, green red
NS108	20% nickel silver (copper-nickel-zinc)	1/2H	Blue, white, red, brown
NS108	20% nickel silver (copper-nickel-zinc)	H	Blue, white, yellow, blue
NS108	20% nickel silver (copper-nickel-zinc)	EH	Blue, yellow, black, green
NS109	25% nickel silver (copper-nickel-zinc)	O	Blue, red, white, green
NS109	25% nickel silver (copper-nickel-zinc)	1/2H	Blue, red, yellow, green
NS109	25% nickel silver (copper-nickel-zinc)	EH	Blue, white, Blue, white
NS109	25% nickel silver (copper-nickel-zinc)	1/2H	Blue, white, black, red
PB101	3% phosphor bronze (copper-tin-phosphorous)	O	Black, green, yellow
PB101	3% phosphor bronze (copper-tin-phosphorous)	1/4H	Black, green, blue
PB101	3% phosphor bronze (copper-tin-phosphorous)	1/2H	Brown, blue, yellow
PB101	3% phosphor bronze (copper-tin-phosphorous)	H	Blue, black, white
PB101	3% phosphor bronze (copper-tin-phosphorous)	EH	Black, white, blue
PB102	5% phosphor bronze (copper-tin-phosphorous)	O	Black, brown, red
PB102	5% phosphor bronze (copper-tin-phosphorous)	1/4H	Black, red, blue

PB102	5% phosphor bronze (copper-tin-phosphorous)	1/2H	Blue, yellow, brown
PB102	5% phosphor bronze (copper-tin-phosphorous)	H	Blue, black, blue
PB102	5% phosphor bronze (copper-tin-phosphorous)	EH	Brown, blue, white
PB103	7% phosphor bronze (copper-tin-phosphorous)	O	Brown, red, green
PB103	7% phosphor bronze (copper-tin-phosphorous)	1/4H	Brown, blue, red
PB103	7% phosphor bronze (copper-tin-phosphorous)	1/2H	Black, brown, black
PB103	7% phosphor bronze (copper-tin-phosphorous)	H	Black, white, black
PB103	7% phosphor bronze (copper-tin-phosphorous)	EH	Brown, green white
PB103	7% phosphor bronze (copper-tin-phosphorous)	SH	Green, red, white
PB103	7% phosphor bronze (copper-tin-phosphorous)	ESH	Red, black, white

BS2871	Copper and copper alloys part 2 tubes for general purposes Table 2		
C101	Electrolytic tough pitch HC copper	M	Blue, brown, green
C101	Electrolytic tough pitch HC copper	00	Blue, brown, blue
C102	Fire refined tough pitch HC copper	M	Black, blue, black, red
C102	Fire refined tough pitch HC copper	0	Black, blue, red, blue
C103	Oxygen-free HC copper	M	Black, blue, white, black
C103	Oxygen-free HC copper	0	Black, brown, black, blue
C106	Phosphorous deoxidized non-arsenical copper	0	Black, green, white
C106	Phosphorous deoxidized non-arsenical copper	1/2H	Green, blue, yellow
C106	Phosphorous deoxidized non-arsenical copper	M	Black, red, green
C107	Phosphorous deoxidized arsenical copper	0	Black, blue, red
C107	Phosphorous deoxidized arsenical copper	1/2H	Black, brown, blue, brown
C107	Phosphorous deoxidized arsenical copper	M	Black, blue, black
CN102	90/10 copper-nickel-iron	M	Black, green, blue, green
CN102	90/10 copper-nickel-iron	0	Black, green, brown, green
CN107	70/30 copper-nickel	M	Black, green, red, green
CN107	70/30 copper-nickel	0	Black, green, white, black
CZ108	Brass 63% copper	0	Black, blue, black, yellow
		TA	Black, blue, brown, red
		M	Black, blue, green, black
CZ110	Aluminium brass	0	Black, brown, green black
CZ110	Aluminium brass	TA	Black, brown, red, brown
CZ110	Aluminium brass	M	Black, brown, white, black
CZ119	Leaded brass 62% copper 2% lead	M	Black, brown, yellow, black
CZ119	Leaded brass 62% copper 2% lead	0	Black, green, black, red
CZ126	Special 70/30 arsenical brass	0	Black, brown, yellow
CZ126	Special 70/30 arsenical brass	TA	Black, blue, yellow, red
CZ126	Special 70/30 arsenical brass	M	Black, blue, green red
CZ127	Special 18/20	0	Green, white, brown, white
CZ127	Special 18/20	M	Green, red, yellow, red
NT8-M	As manufactured		Blue, white, black, white

BS2872	Copper and copper alloys forging stock Table 1		
CA103	9% aluminium bronze (copper-aluminium)	M	Black, red, white, black
CA104	10% aluminium bronze (copper al-nickel-iron)	M	Black, white, black, blue
CA106	7% aluminium bronze (copper al-nickel-iron)	M	Black, , white, black, white
CS101	Copper silicon	M	Black, , white, green, blue
CZ109	Lead free 60/40 brass	M	Blue, brown, green
CZ112	Naval brass	M	Black, blue
CZ114	High tensile brass	M	Black, blue, green, yellow
CZ114	High tensile brass	0	Black, , blue, yellow, white

CZ115	High tensile brass (soldering quality)	M	Black, , green, white, brown
CZ116	High tensile brass	M	Black, , red, black, blue
CZ122	Leaded brass 58% copper 2% lead	M	Black, red, black, yellow
CZ123	60/40 brass	M	Black, red, blue, yellow
NS101	Leaded 10% nickel brass	M	Black, white, blue, white

BS2873	Copper and copper alloys - Wire		
C101	Electrolytic tough pitch HC copper	0	Brown, blue, black, green
C102	Fire refined tough pitch HC copper	H	Brown, blue, brown, green
C103	Oxygen-free HC copper		Brown, blue, brown, yellow
C106	Phosphorous deox non-arsenical copper		Brown, blue, green, brown
C108	Copper-cadmium	H	Brown, blue, red, green
CZ101	90/10 brass	0	Brown, blue, white, brown
CZ101	90/10 brass	1/2H	Brown, blue, yellow, green
CZ101	90/10 brass	H	Brown, green, black, white
CZ102	85/15 brass	0	Brown, green, blue, red
CZ102	85/15 brass	1/2H	Brown, green, Brown, green
CZ102	85/15 brass	H	Brown, green, red, brown
CZ103	80/20 brass	0	Brown, green, white green
CZ103	80/20brass	1/2H	Brown, green, yellow, white
CZ103	80/20 brass	H	Brown, red, black, green
CZ106	70/30 brass	0	Brown, red, black, yellow
CZ106	70/30 brass	1/2H	Brown green, white, red
CZ106	70/30 brass	H	Brown, red, blue, white
CZ107	2/1 brass	0	Brown, red, green, red
CZ107	2/1 brass	1/2H	Brown, red, white, green
CZ107	2/1 brass	H	Brown, red, yellow, brown
CZ107	2/1 brass	EH	Brown, white, black, green
CZ108	Common brass	0	Brown, white, blue, red
CZ108	Common brass	1/2H	Blue, green red, brown
CZ108	Common brass	H	Red, brown, red
CZ108	Common brass	EH	Brown, white, brown, red
CZ119	Leaded brass 62% copper 2% lead	0	Brown, white, red, green
CZ119	Leaded brass 62% copper 2% lead	1/2H	Brown, white, yellow, brown
CZ119	Leaded brass 62% copper 2% lead	H	Brown, yellow, black, green
CB101	Copper-beryllium	W	Brown, yellow, blue, red
CB101	Copper-beryllium	W(H)	Brown, yellow, blue, yellow
CB101	Copper-beryllium		Brown, yellow, brown, red
NS103	10% nickel silver (copper-nickel-zinc)	1/2H	Brown, yellow, red, green
NS103	10% nickel silver (copper-nickel-zinc)	0	Brown, yellow, Brown, yellow
NS103	10% nickel silver (copper-nickel-zinc)	H	Brown, yellow, white, red
NS104	12% nickel silver (copper-nickel-zinc)	0	Green, black, blue, green
NS104	12% nickel silver (copper-nickel-zinc)	1/2H	Green, black, brown, red
NS104	12% nickel silver (copper-nickel-zinc)	H	Green, black, green, white
NS105	15% nickel silver (copper-nickel-zinc)	0	Green, black, red, yellow
NS105	15% nickel silver (copper-nickel-zinc)	1/2H	Green, black, white, red

NS105	15% nickel silver (copper-nickel-zinc)	H	Green, blue, black, red
NS106	18% nickel silver (copper-nickel-zinc)	0	Green, blue, brown, green
NS106	18% nickel silver (copper-nickel-zinc)	1//2H	Green, blue, brown
NS106	18% nickel silver (copper-nickel-zinc)	H	Green, blue, brown, yellow
NS107	18% nickel silver (copper-nickel-zinc)	0	Green, blue, red, green
NS107	18% nickel silver (copper-nickel-zinc)	1/2H	Green, blue, white, yellow
NS107	18% nickel silver (copper-nickel-zinc)	H	Green, brown, black, red
NS108	20% nickel silver (copper-nickel-zinc)	0	Green, brown, black, yellow
NS108	20% nickel silver (copper-nickel-zinc)	1/2H	Green, brown, green, red
NS108	20% nickel silver (copper-nickel-zinc)	H	Green, brown, red, green
NS109	25% nickel silver (copper-nickel-zinc)	0	Green, brown, white, red
1/2H			
NS109	25% nickel silver (copper-nickel-zinc)	1/2H	Green, brown, yellow, white
NS109	25% nickel silver (copper-nickel-zinc)	H	Green, red, black, red
PB101	3% phosphor bronze (copper-tin-phosphorous)	0	Green, red, blue, red
PB101	3% phosphor bronze (copper-tin-phosphorous)	1/2h0	Green, red, brown, white
PB101	3% phosphor bronze (copper-tin-phosphorous)	H	Green, red, green red
PB101	3% phosphor bronze (copper-tin-phosphorous)	EH	Green, red, white, green
PB103	7% phosphor bronze (copper-tin-phosphorous)	0	Green, red, yellow, green
PB103	7% phosphor bronze (copper-tin-phosphorous)	1/2H	Green, red, yellow, white
PB103	7% phosphor bronze (copper-tin-phosphorous)	H	Green, white, black, yellow
PB103	7% phosphor bronze (copper-tin-phosphorous)	EH	Green, white, blue, white

BS2874	copper and copper alloys Rods and sections (other than forging stock)		
C101	Electrolytic tough pitch HC copper	0	Black, red, yellow, black
C102	Fire refined tough pitch HC copper	1/2H	Blue, green, yellow
C103	Oxygen-free HC copper	H	Black, red, yellow, red
C106	Phosphorous deoxidized non-arsenical copper	M	Black, white, black, green
C106	Phosphorous deoxidized non-arsenical copper	0	Black, white, blue, brown
C109	Copper-tellurium	M	Black, white, brown, blue
C109	Copper-tellurium	0	Black, white, green, brown
C111	Copper sulphur	M	Black, white, green, yellow
C111	Copper sulphur	0	Black, white, red, blue
CA103	9% aluminium bronze (copper-aluminium)	M	Black, green, brown
CA104	10% aluminium bronze (copper-alu-nickel-iron)	M	Blue, brown, red
CA106	7% aluminium bronze (copper-aluminium-iron)	M	Black, yellow, green, white
CA106	7% aluminium bronze (copper-aluminium-iron)	0	Black, yellow, red, blue
CS101	Copper-silicon	M	Black, yellow, white, brown
CS101	Copper-silicon	0	Blue, black, blue, brown
CZ103	80/20 brass	M	Black, white, yellow, black
CZ104	Leaded 80/20 brass	M	Black, yellow, black, blue
CZ106	70/30 brass	M	Black, yellow, black, red
CZ109	Lead free 60/40 brass	M	Black, blue, black,
CZ112	Naval brass	M	Blue,
CZ113	Naval brass (special mixture)	M	Black, yellow, blue, brown
CZ114	High tensile brass	M	Black, brown, white
CZ114	High tensile brass	H	Black, brown, red, black
CZ115	High tensile brass	M	-
		(Hot)	Blue, red, yellow, white

CZ115	High tensile brass	M	-
		(C&SR)	Blue, white, blue, yellow
CZ116	High tensile brass	M	Black, yellow, blue, white
CZ119	Leaded brass 58% copper 2% lead	M	Black, yellow, brown, red
CZ121	Leaded brass 58% copper 3% lead	M	Black,
CZ122	Leaded brass 58% copper 2% lead	M	Black, yellow, green, blue
CZ122	Leaded brass 58% copper 2% lead	H	Black, brown, black
CZ123	60/40 brass	M	Black, blue, brown
CZ124	Leaded brass 62% copper 3% lead	M	Black, red, black, red
CZ124	Leaded brass 62% copper 3% lead	1/2H	Blue, white, red
CZ124	Leaded brass 62% copper 3% lead	H	Black, green, yellow, green
NS101	Leaded 10% nickel brass	M	Blue, black, brown, blue
NS102	Leaded 14% nickel brass	M	Blue, black, green, brown
NS111	Leaded 10% nickel silver	M	Blue, black, red, blue
NS112	Leaded 15% nickel silver	M	Blue, black, red, green
NS113	Leaded 18% nickel silver	M	Blue, yellow, white, red
PB102	5% phosphor bronze (copper-tin-phosphorous)	M	Green, yellow, green

BS4109	Copper for electrical purposes - Wire		
	Wire for general electrical purposes and for insulated cables		
C101	Electrolytic tough pitch HC copper	0	Green, yellow, black, yellow
	Electrolytic tough pitch HC copper	H	Green, white, yellow, red
C102	Fire refined tough pitch HC copper	0	Green, white, yellow,
	Fire refined tough pitch HC copper	H	Green, white, brown, yellow
C103	Oxy free HC copper	0	Green, yellow, black, red
	Oxy free HC copper	H	Green, yellow, blue, red

NICKELS AND HEAT RESISTING ALLOYS
SECTION III

NUMBERS	DESCRIPTION	COLOUR
HR1	Nickel base heat resisting alloys:	
	Solution treated bar and section for machining	White, blue, black, yellow
	Softened section for forming	Blue, green , blue, green
	Forging stock	Red, brown, white, yellow
HR2	Nickel base heat resisting alloys:	
	Solution treated bar and section for machining	White, blue, black, yellow
	Softened section for forming	Blue, green , red, brown
	Forging stock	Green, black white,
HR3	Nickel base heat resisting alloys:	
	Heat treated (Stage 1 & 2) bar and section for machining	Blue, green, red, white
	Softened section for forming	Blue, green, white, blue
	Forging stock	Blue, green, yellow, brown
HR4	Nickel base heat resisting alloys:	
	Fully heat treated bar and section for machining	Black, blue, brown, blue
	Forging stock	Black, blue, brown, black
HR5	Nickel base heat resisting alloys:	
	Annealed bar for machining	Black, green, blue, red
	Softened section for forming	Black, brown, yellow, green
	Forging stock	Black, green, brown, white
HR6	Nickel base heat resisting alloys:	
	Annealed bar and section for machining	Blue, green, yellow, red
	Forging stock	Blue, red, blue, white

HR10	Nickel base heat resisting alloys:	
	Solution treated bar and section for machining	Blue, red, black, brown
	Softened section for forming	Blue, red, black, yellow
	Forging stock	Blue, red, green, brown
HR11	Nickel base heat resisting alloys:	
	Solution treated bar and section for machining	Blue, red, white, yellow
	Softened section for forming	Blue, red, yellow, brown
	Forging stock	Brown, green, black, green
HR40	Cobalt base heat resisting alloys:	
	Annealed bar and section for machining	Green, black, blue, red
	Forging stock	Green, black, blue, white
HR51	Nickel chromium iron heat resisting alloys:	
	Annealed bar and section for machining	Green, black, brown, red
	Forging stock	Green, black, brown, white HR52
	Nickel chromium iron heat resisting alloys:	
	Annealed bar and section for machining	Green, black, green, red
	Forging stock	Green, black, green, yellow
HR53	Nickel chromium iron heat resisting alloys:	
	Annealed bar and section for machining	Green, black, blue, yellow
	Forging stock	Green, black, white, red
HR54	Heat resistant martensitic steel :	
	Heat treated bars for machining	Yellow, black, white, yellow
	Forging stock	Yellow, blue, green, yellow
HR201	Nickel base heat resisting alloy plate sheet and strip:	
	Softened and descaled	Green, white, black, white
HR202	Nickel base heat resisting alloy plate sheet and strip: Softened and descaled	Blue, yellow, white, yellow
	Solution treated	Brown, black, yellow, brown
HR203	Nickel base heat resisting alloy plate sheet and strip:	
	Softened and descaled	Blue, yellow, red
HR204	Nickel base heat resisting alloy plate sheet and strip:	
	Softened and descaled	Black, green, black, yellow
HR206	Nickel base heat resisting alloy plate sheet and strip:	
	Softened and descaled	Black, red, yellow, black
HR207	Nickel base heat resisting alloy plate sheet and strip:	
	Softened and descaled	Black, brown, red, brown
HR240	Cobalt base heat resisting alloy plate sheet and strip:	
	Annealed and descaled	Black, white, black, blue
HR251	Nickel chromium iron heat resisting alloy plate sheet and strip:	
	Solution treated and descaled	Black, white, blue, yellow
HR401	Nickel base heat resisting alloy tube cold worked and softened	Green white, black, white
HR402	Nickel base heat resisting alloy tube cold worked and softened	Black, white, black, yellow
HR403	Nickel base heat resisting alloy tube cold worked and softened	Black, red, yellow, red
HR404	Nickel base heat resisting alloy tube cold worked and softened	Black, blue, green, black
HR501	Nickel base heat resisting alloy wire for springs	
	Cold drawn	Black, white, brown, white

HR502	Nickel base heat resisting alloy wire for springs	
	Cold drawn and solution treated	Black, white, red, blue
HR503	Nickel base heat resisting alloy wire for thread inserts	
	Cold drawn	Black, white, yellow, brown
HR504	Nickel base heat resisting alloy wire for revets	
	Annealed	White, red, yellow, white
HR601	Nickel-chromium-titanium-aluminium heat resisting bar and wire of fasteners:	
	Cold worked and ground	Black, green, yellow, blue
	Cold worked, solution treated and ground or descaled	Black, yellow, green, blue
HR	Nickel base heat resisting bar for bolts and nuts	
	Solution treated and machined	Blue, red, blue, green
	Fully heat treated and machined	Black, green yellow, red
	forging stock	Black, yellow, red, white
BS1824	Nickel silver strip and foil for the Telecommunication Industries	
NS104	12% nickel silver - Temper grade 2	Yellow, black, brown, yellow
NS104	12% nickel silver - Temper grade 3	Yellow, black, green, yellow
NS104	12% nickel silver - Temper grade 4	Yellow, black, red, yellow
NS104	12% nickel silver - Temper grade 5 (soft)	Yellow, black, white, yellow
NS104	12% nickel silver - Temper Extra Hard (non-standard condition)	Blue, yellow, white
NS107	18% nickel silver - Temper grade 1 (Extra Hard)	Red, white, black, yellow
NS107	18% nickel silver - Temper grade 2	Red, green, brown white
NS107	18% nickel silver - Temper grade 3	Red, green, black, yellow
NS107	18% nickel silver - Temper grade 4	Red, white, blue, white
NS107	18% nickel silver - Temper grade 5 (soft)	Red, white, green, yellow
BS2857	Nickel-iron transformer and choke laminations	
	Class A - 76% Ni	Black, brown, blue
	Class B - 50% Ni, 50% Fe	Blue, white, red
BS372	Nickel and nickel alloy sheet and plate	
NA13	Cold rolled and annealed	Green, white, green, yellow
BS3073	Nickel and nickel alloy strip	
NA11	Cold rolled, Hard	Brown, green, red
BS3074	Nickel and nickel alloys, tubes	
NA11	Cold drawn and annealed	Blue, white, blue
NA12	Cold drawn and annealed	Blue, white, green
NA13	Cold drawn and annealed	Blue, white, yellow
NA14	Cold drawn and annealed	Blue, yellow, brown
BS3075	Nickel and nickel alloy wire	
NA11	Cold drawn	Brown, green, red
NA11	Cold drawn and annealed	Blue, white, blue
NA13	Cold drawn	Blue, black, white
NA13	Cold drawn and annealed	Blue, brown, red
BS3076	Nickel and nickel alloy rods and sections	
NA13	Cold drawn	Black, red, brown
	Cold drawn and annealed	Black, red, green
	Hot-rolled	Black, blue, white
	Hot -rolled and annealed	Brown, white, brown

NA14	Cold drawn	Blue, yellow, brown
NA18	Cold worked and precipitated	Green, white, blue, red
NA18	Cold worked, solution treated and precipitated	Green, yellow, black, white

TITANIUM AND TITANIUM ALLOYS
SECTION IV

TA1	Commercially pure titanium sheets and strips (Tensile strength 19-27 tonsf/inch 2)	Black, white, blue, white
TA2	Commercially pure titanium sheets and strips (Tensile strength 390-540 N/mm 2)	Black, brown, black, green
TA3	Commercially pure titanium bars for machining (Tensile strength 390-540 N/mm2)	Green, brown, red, green
TA4	Commercially pure titanium forging stock (Tensile strength 390-540 N/mm2)	Green, brown, white, yellow
TA6	Commercially pure titanium sheets and strips (Tensile strength 570-730 N/mm2)	Green, blue, red, green
TA7	Commercially pure titanium bars for machining (Tensile strength 540-740 N/mm2)	Green, blue, brown, green
TA8	Commercially pure titanium forging stock (Tensile strength 540-740 N/mm2)	Green, black, yellow, white
TA10	Titanium-aluminium-vanadium alloy sheets (Tensile strength 62-82 tonsf/inch2)	Black, blue, yellow, blue
TA11	Titanium-aluminium-vanadium alloy bars for machining (Tensile strength 58-75 tonsf/inch2)	Brown, red, brown, green
TA12	Titanium-aluminium-vanadium alloy forging stock (Tensile strength 58-75 tonsf/inch2)	Green, black, brown, yellow
TA18	Titanium-tin-zirconium-aluminium-molybdenum-silicon alloy bars for machining (Tensile strength 111-134 hbar) (Limiting Ruling Section 50 mm)	Red, blue, black, yellow
TA19	Titanium-tin-zirconium-aluminium-molybdenum-silicon alloy forging stock (Tensile strength 111-134 hbar) (Limiting Ruling Section 50 mm)	Green, black, white, yellow
TA21	Titanium-copper alloy sheet (Tensile strength 54-77 hbar)	Brown, green, brown, yellow
TA22	Titanium-copper alloy bars for machining (Tensile strength 54-77 hbar)	Brown, blue, yellow, brown
TA23	Titanium-copper alloy forging stock (Tensile strength 54-77 hbar)	Green, yellow, brown, white
TA25	Titanium-tin-zirconium-aluminium-molybdenum-silicon bars for machining (Tensile strength 103-127 hbar) (Limiting Ruling Section 75 mm)	Red, blue, black, yellow
TA26	Titanium-tin-zirconium-aluminium-molybdenum-silicon forging stock (Tensile strength 1103-127 hbar) (Limiting Ruling Section 75 mm)	Green, black, white, yellow
TA28	Titanium-aluminium-vanadium alloy forging stock (Tensile strength 110-130 hbar) (Limiting Ruling Section 19 mm)	Blue, green, yellow, blue
TA38	Titanium-aluminium-molybdenum-tin-silicon carbon alloy bar for machining (Tensile strength 1250-1420 N/mm2) (Limiting Ruling Section 25 mm)	White, black, blue, white
TA39	Titanium-aluminium-molybdenum-tin-silicon carbon alloy forging stock (Tensile strength 1250-1420 N/mm2) (Limiting Ruling Section 25 mm)	White, black, blue, yellow

TA40	Titanium-aluminium-molybdenum-tin-silicon carbon alloy bar for machining (Tensile strength 1205-1375 N/mm2) (Limiting Ruling Section 25 mm up to and including 75mm)	White brown ,red, yellow
TA41	Titanium-aluminium-molybdenum-tin-silicon carbon alloy bar forging stock (Tensile strength 1205-1375 N/mm2) (Limiting Ruling Section 25 mm up to and including 75mm)	Yellow, brown, re, yellow
TA43	Forging stock of titanium-aluminium-zirconium-molybdenum-silicon alloy (Tensile strength 99-1140 N/mm2) (Limiting Ruling Section 65mm)	Yellow, green, red, yellow
TA45	Bar and section after machining of titanium-aluminium-molybdenum-tin-silicon alloy (Tensile strength 1100-1280 N/mm2) Limiting Ruling Section 25mm)	Red, green, white, yellow
TA46	Bar and section for machining of titanium-aluminium-molybdenum-tin-silicon alloy (Tensile strength 1050-1220 N/mm2) Limiting Ruling Section over 25 mm up to and including 100 mm)	Red, white, brown, yellow
TA47	Forging stock of titanium-aluminium-molybdenum-tin-silicon alloy (Tensile strength 1050-1220 N/mm2) (Limiting Ruling Section 100 mm)	Yellow, red, white, yellow
TA49	Bar and section for machining of titanium-aluminium-molybdenum-tin-silicon alloy (Tensile strength 1000-1200 N/mm2) Limiting Ruling Section over 100mm up to and including 150 mm)	Red, yellow, black, white
TA50	Forging stock of titanium-aluminium-molybdenum-tin-silicon alloy (Tensile strength 1000-1200 N/mm2) (Limiting Ruling Section over 100 mm up to and including 150 mm)	Yellow, brown, green, yellow
TA52	Sheet and strip of titanium copper alloy for machining (Tensile strength 690-920 N/mm2)	Red, yellow, brown, white
TA53	Bar and section for machining of titanium copper alloy (Tensile strength 65-880 N/mm2) (Limiting Ruling Section 75 mm)	Red, yellow, brown, white
TA54	Forging stock of titanium copper alloy (Tensile strength 650-880 N/mm2) (Limiting Ruling Section 75 mm)	White, black, red, white
TA56	Titanium-aluminium-vanadium alloy plate (Tensile strength 895-1150 MPa)	Black, blue, white, brown
TA57	Titanium-aluminium-molybdenum-tin-silicon alloy plate (Tensile strength 1030-1220 MPa)	Black, blue, green, yellow
TA58	Titanium-copper alloy plate (Tensile strength 520-640 MPa)	Black, blue, yellow, green

SOLDERS
SECTION V

NUMBERS	DESCRIPTION	COLOUR
BS219	Soft Solders	
	Tin-Lead	
	Grade A	Blue
	AP	Blue, green
	K	Brown, red
	KP	Blue, yellow
	F	Black, red
	R	Brown, re, brown
	G	Green
	H	Black, green, black
	J	Brown, green
	V	Green, black, green
	W	Green, yellow
	Tin-lead-antimony	
	Grade B	Yellow
	M	Red
	C	Black
	L	Blue, brown, blue
	D	Brown
	N	Blue, red, blue
	Tin-Antimony	
	Grade 95A	Black, blue
	Tin-Silver	
	Grade 965	Brown, black, brown
	Tin-lead-silver	
	Grade 5S	Black, green
	62S	Black, red, black.
	Tin-lead-cadmium	
	Grade T	Blue, black, blue

STEELS
SECTION VI

NUMBERS	DESCRIPTION	COLOUR
S1	Bright 35/45-ton carbon steel bars	Yellow
S14	Carbon case-hardening steel bars	Brown, yellow
S15	3 per cent nickel case-hardening steel bars: Bars and billets for forging	Brown, yellow, brown
S15(B)	3 per cent nickel case-hardening steel bars: Black and bright bars for machining	Yellow, brown, yellow
S21	"20" carbon steel	Blue, yellow
S28	Air hardening 4.1/2 per cent, nickel-chromium-molybdenum steel bars	Blue, red
S61A	35-ton, 12 per cent chromium steel (corrosion-resisting) bars for forging	Black, yellow, red
S61B	35-ton, 12 per cent chromium steel (corrosion-resisting) bars for machining	Brown, yellow, red
S62A	45/55-ton, 12 per cent chromium steel (Corrosion-resisting) bars for forging	Yellow, red, yellow
S62B	45/55-ton, 12 per cent chromium steel (corrosion-resisting) bars for machining	Yellow, black, yellow
S70A	"55" carbon steel bars for forging	Blue, green
S70B	"55" carbon steel (normalised)	White, blue, yellow
S79A	"55" carbon steel bars for forging	Blue, red, green

S79A	"55" carbon steel bars for forging : Hardened and tempered	Red, green, white
S80A	55-ton high chromium-nickel steel (corrosion-resisting) bars for forging	Black, yellow, brown
S80B & D	55-ton high chromium-nickel steel (corrosion-resisting) bars and machining	Brown, black, red
S82	4.1/2 per cent nickel-chromium-molybdenum case-hardening steel bars	Green, red, yellow
S91A	Mild steel bars for forging	Black, green, brown
S91B	Mild steel bars for forging	Black, green, white
S92A	40-ton carbon-manganese steel bars for forging	Brown, green, yellow
S92B	40-ton carbon-manganese steel bars for forging	Black, white
S93A	35-ton steel (normalised) bars for forging	Brown, green
S93B	35-ton steel (normalised) bars for machining	Red, white
S95A	55-ton, 1/2 per cent nickel-chromium-molybdenum steel bars for forging	Black, green, blue
S95B	55-ton, 1/2 per cent nickel-chromium-molybdenum steel bars for forging	Black, green, red
S96A	55-ton, 2.1/2 per cent nickel-chromium-molybdenum steel bars for forging	Black, red, black
S96B	55-ton, 2.1/2 per cent nickel-chromium-molybdenum steel bars for forging	Black, red, blue
S97A	65-ton, 2.1/2 per cent nickel-chromium-molybdenum steel bars for forging	Black, white green,
S97B	65-ton, 2.1/2 per cent nickel-chromium-molybdenum steel bars for forging	Black, white, red
S98A	75-ton, 1/2 per cent nickel-chromium-molybdenum steel (high carbon) bars for forging	Blue, green, yellow
S98B	75-ton, 1/2 per cent nickel-chromium-molybdenum steel (high carbon) bars for forging	Blue, brown, blue
S99	80-ton, 2.1/2 per cent nickel -chromium-molybdenum steel, high carbon (limiting ruling section 6-ins) :	
	Bars and billets in the softened condition	Blue, green, brown
	Bars and billets in hardened and tempered condition	Blue, brown, yellow
S102	Carbon-molybdenum steel (bar for forged bolts only)	Blue, black, green
S105	Carbon steel wires:	
	Type 1	Black, blue, green
	Type 2	Black, blue, red
	Type 3	Black, blue, yellow
S106A	60-ton, 3 per cent chromium-molybdenum steel (suitable for nitrogen hardening) bars for forging	Blue, brown, red
S106B	60-ton, 3 per cent chromium-molybdenum steel (suitable for nitrogen hardening) bars for machining	Brown, red, green
S107	3 per cent nickel-chromium-molybdenum case-hardening steel bars	Green, white
S111A	High nickel high chromium steel bars for forging	Red, yellow, red
S111D	High nickel high chromium steel bars for machining (valve steel)	Yellow, blue, white, yellow
S112	40-ton semi-free cutting steel. Bright bars for machining	Black, blue, green
S113	45-ton carbon steel. Bright bars for machining	Black, blue, yellow
S114	55-ton manganese-molybdenum steel. Bright bars for machining	Black, brown, green
S116	55-ton carbon steel. Bright bars for machining	Black, blue, black
S117	55-ton, 1 per cent chromium steel :	
	Bars and billets for forging	Blue, green, red
	Bars for machining	Black, yellow, blue

S119	65-ton, 1.1/2 per cent nickel-chromium-molybdenum steel (limiting rulling section 2.1/2-ins):	
	Bars and billets in soft condition	Black, white, yellow
	Bar in hardened and tempered condition	Black, brown, black
S120	100-ton, 2.1/2 per cent nickel-chromium-molybdenum steel (oil hardening) (limiting ruling section 2.1/2-ins)	Blue, white, red
S124	Corrosion-resisting chromium steel. Bars and billets for forging :	
	Softened condition	Brown, yellow, green
	Bright and black bars for machining hardened and tempered	White, red, white
S125	23/14 chromium nickel heat resisting steel (Ti stabilised) :	
	Bars and billets for forging (S125A) (as rolled or forged)	Black, blue
	Bars for machining (S125B &D) (Fully heat treated)	Black, blue, red
S126	23/14 chromium-nickel heat resisting steel (Nb stabilised) :	
	Bars and billets for forging (S126A) (as rolled or forged)	Black, brown
	Bars for machining (S126B & D) (fully heat treated)	Black, brown, red
S127	24/17 chromium-nickel heat resisting steel (Ti stabilised) :	
	Bars and billets for forging (S127A) (as rolled or forged)	Black, green
	Bars for machining (S127B & D) (fully heat treated)	Black, yellow
S128	24/17 chromium-nickel heat resisting steel (Nb stabilised) :	
	Bars and billets for forging (S128A) (as rolled or forged)	Blue, brown
	Bars for machining (S128B & D) (fully heat treated)	Brown, blue, brown
S129	18/9 chromium-nickel heat resisting steel (Ti stabilised) :	
	Bars and billets for forging (S129A) (as rolled or forged)	Green, blue, green
	Bars for machining (S129B & D) (fully heat treated)	Brown, blue, red
S130	18/9 chromium-nickel heat resisting steel (Nb stabilised) :	
	Bars and billets for forging (S130A) (as rolled or forged)	Red, black, white
	Bars for machining (S130B & D) (fully heat treated)	Brown, green, red
S131A, B & D	High Thermal Expansion steel	
	Bars and billets for forging	Blue, green, white
	Bars for machining	Blue, red, blue
S132	3% chromium-molybdenum steel (suitable for nitriding)	
	Bars for forging, black, and bright bars for machining	Black, white, blue
	Fully heat treated - not nitrided	Green, brown, red, yellow
S133	3/4% nickel-chromium case hardening steel	
	Bars for forging, black, and bright bars for machining	Brown, red, brown
S134	3% per cent chromium molybdenum-vanadium steel (air hardening) bars for forging, black, and bright bars for machining	Brown, white, red

S135	1 per cent carbon-chromium steel bars for forging	
	Black and bright bars for machining	Black, red, green
S136	1 per cent chromium steel vacuum re-melted	Green, red
S137	High chromium nickel corrosion resisting steel bright bars (free machining)	White, brown, white
S138	3% chromium-molybdenum-vanadium steel vacuum re-melted air hardening (softened)	Red, brown, red
S139A	1.1/2 nickel-chromium-molybdenum steel bars for forging - softened	Black, green, black
S139B&D	1.1/2 nickel-chromium-molybdenum steel black and bright bars for machining	Black, green, yellow
S140A	2.1/2 nickel-chromium-molybdenum steel bars for forging - softened	Blue, black, white
S140B & D	2.1/2 nickel-chromium-molybdenum steel black and bright bars for machining	Blue, white, green
S141A	12. chromium corrosion resisting steel bars for forging - softened	Brown, black, brown
S141B & D	12. chromium corrosion resisting steel black and bright bars for machining	Blue, black, green
S142A	1% chromium-molybdenum steel (suitable for welding)	
	Bars for forging - softened	Green, white, green
S142B & D	1% chromium-molybdenum steel (suitable for welding)	
	Black, and bright bars for machining	Green, black, red
S143	Chromium-nickel-copper-molybdenum corrosion resisting steel (precipitation hardening)	
A	Bars for forging	Brown, black, white
B and D	Bars for machining	Green, brown, green
S144	Chromium-nickel-copper-molybdenum corrosion resisting steel (precipitation hardening)	
A	Bars for forging	Green, white, yellow
B and D	Bars for machining	Blue, white, brown
S146	4% nickel-chromium-molybdenum steel (air hardening vacuum melted)	Brown, black, green
S147	Nickel-chromium-molybdenum steel bar	Blue, black, blue
S148	Low nickel chromium steel bar	Black, red, yellow
S149	1.75% nickel -chromium-molybdenum steel bar	Brown, blue, green
S150	Chromium-molybdenum-vanadium-niobium heat resisting steel	
	Bars and billets for forging (softened)	Blue, black, blue, black, blue
	Bright and black bars for machining	Blue, black, green, black, blue
S151	Chromium-nickel-molybdenum-vanadium heat resisting steel	
	Bars and billets for forging (softened)	Blue, black, red, black, blue
	Bright and black, bars for machining	Blue, black, yellow, black, blue
S152	Chromium-cobalt-molybdenum-vanadium-niobium heat resisting steel	
	Bars and billets for forging (softened)	Blue, brown, black, brown, blue
	Bright and black bars for machining	Blue, brown, red, brown, blue
S153	Nickel-chromium-molybdenum steel	
	Bars and billets for forging (softened)	Blue, brown, white, brown, blue
	Bright and black bars for machining	Blue, green, yellow, green, blue
S154	2.1/2 nickel -chromium-molybdenum steel	
	Bars and billets for forging (softened)	Blue, green, brown, green, blue
	Bright and black bars for machining	Blue, green, yellow, green, blue
S155	Nickel-silicon-chromium-molybdenum-vanadium steel (Vacuum arc remelted)	
	Normalised and softened bars for machining	Blue, red, blue, red, blue
	Softened forging stock	Blue, red, brown, red, blue

S156	4% nickel-chromium-molybdenum case-hardening steel (Vacuum arc remelted)	
	Black or bright bars for machining	Blue, red, green, red, blue
	Softened forging stock	Blue, red, white, red, blue
S157	3% nickel-chromium-molybdenum case-hardening steel	
	Black or bright bars for machining	Blue, yellow, blue, yellow, blue
	Softened forging stock	Blue, yellow, black, yellow, blue
S201	Patented cold drawn carbon steel wire and springs	Red, black, brown, red
S202	Patented cold drawn carbon steel wire and springs	Red, brown, white, red
S203	Carbon steel wire and springs	Red, green, white, red
S204	Chromium vanadium steel wire and springs	Yellow, black, brown, yellow
S205	Austenitic chromium-nickel steel wire and springs	
	Rods	Black, brown, yellow, black
	Wire	Black, blue, yellow, black
S510	28-ton carbon steel sheets and strips (suitable for welding)	Green
S511	Deep drawing carbon steel sheets and strips (suitable for welding)	Black, green, blue
S513	Spring steel strips :	
	Softened condition	Black, green, red
	Hardened and tempered	Blue, black, yellow
S514	50-ton carbon manganese steel sheets and strips (40-ton 0.1 per cent proof stress) (suitable for welding) :	
	Softened condition	Green, red, white
	Hardened and tempered or cold rolled and tempered	Green, blue, red
S515	30-ton carbon-manganese steel sheets and strips (softened) (suitable for welding)	Red, blue, yellow
S516	60-ton carbon-manganese steel sheets and strips (50-ton 0.1 per cent proof stress) :	
	Softened condition	Green, blue, white
	Hardened and tempered or cold-rolled and tempered	Brown, blue, red
S517	75-ton carbon-manganese steel sheets and strips (65-ton 0.1 per cent proof stress) :	
	Softened condition	White, black, white
	Hardened and tempered	Blue, green, red
	(40-ton 0.1 per cent proof stress) (suitable for welding)	
	Softened condition	Green, yellow, red
	Hardened and tempered or as cold-rolled and tempered	Green, yellow, white
S518	50-ton chromium-molybdenum steel sheets and strips (40-ton 0.1% proof stress) (suitable for welding) :	
	Softened condition	Green, yellow, red
	Hardened and tempered or cold-rolled and tempered	Green, yellow, white
S524	Cold-rolled 18/10 chromium-nickel corrosion-resisting steel sheet and strip (titanium stabilized : 80 hbar)	Blue, brown, yellow
S525	Cold-rolled 18/10 chromium-nickel corrosion-resisting steel sheet and strip (titanium stabilized : 80 hbar)	Blue, green, yellow

S526	Softened 18/10 chromium-nickel corrosion-resisting steel sheet and strip (titanium stabilized: 54 hbar)	Red, yellow, red
S527	Softened 18/10 chromium-nickel corrosion-resisting steel sheet and strip (niobium stabilized: 54 hbar)	Red, green, yellow
S528	23/14 chromium-nickel heat resisting steel sheet and strip (titanium stabilized: 54 hbar)	Black, red, yellow
S529	23/14 chromium-nickel heat resisting steel sheet and strip (niobium stabilized: 54 hbar)	Black, brown, red
S530	24/17 chromium-nickel heat resisting steel sheet and strip (titanium stabilized: 54 hbar)	Black, red, green
S531	23/14 chromium-nickel heat resisting steel sheet and strip (niobium stabilized: 54 hbar)	Black, yellow, blue
S532	Chromium-nickel-copper-molybdenum corrosion resisting steel sheet and strip (precipitation hardening 98/118 hbar)	Blue, yellow, green
S533	Chromium-nickel-copper-molybdenum corrosion resisting steel sheet and strip (precipitation hardening 118/137 hbar)	Black, brown, red
S534	Chromium-molybdenum steel sheet and strip (88/108 hbar) (suitable for welding) :	
	Softened condition	Green, blue, green
	Hardened and tempered	Brown, red, green
S535	Chromium-molybdenum steel sheet and strip (115/130 hbar) (suitable for welding) :	
	Softened condition	Green, brown, green
	Hardened and tempered	Brown, blue, yellow
S536	Low carbon 18/10 chromium-nickel corrosion resisting steel sheet and strip (50 hbar)	Red, brown, white
S537	Low carbon 17/12 chromium-nickel corrosion resisting steel sheet and strip (50 hbar)	Green, yellow, green
S538	Chromium-nickel-molybdenum-vanadium heat resisting steel sheet and strip:	
	Softened condition	Red, brown, yellow
T2	85-ton nickel-chromium steel tubes	Red
T45	45-ton steel tubes (suitable for welding)	Black, brown, blue
T50	50-ton steel tubes	Brown, yellow
T53	45-ton chrome-molybdenum steel tubes (suitable for welding)	Black, green, yellow
T57	75-ton nickel-chromium steel tubes	Black, brown, yellow
T60	75-ton chrome-molybdenum steel tubes (suitable for welding)	Red, white
T62	Mild steel tube	Red, blue, yellow
T63	Softened mild steel tube for hydraulic purposes	Brown, yellow, red
T64	Carbon manganese steel tube	Blue, yellow, green
T65	Chromium-molybdenum steel tube	Green, blue, yellow
T66	18/10 Chromium-nickel corrosion resisting steel tube	Green, brown, white
T67	18/10 Chromium-nickel corrosion resisting steel tube	Green, yellow, red
T68	Cold drawn 18/10 chromium-nickel corrosion resisting steel tube (niobium stabilised)	Red, green, red
T69	Cold drawn 18/10 chromium-nickel corrosion resisting steel tube (titanium stabilised)	Yellow, black, yellow

T70	24/17 chromium-nickel heat resisting steel tube (niobium stabilised)	Brown, black, red
T71	24/17 chromium-nickel heat resisting steel tube (titanium stabilised)	Green, white, green
T72	18/10 chromium-nickel corrosion resisting steel tube for hydraulic purposes niobium stabilised 550 MPa	Black, blue, brown
T73	18/10 chromium-nickel corrosion resisting steel tube for hydraulic purposes niobium stabilised 550 MPa	Black, red, yellow
T74	Low carbon 18/10 chromium-nickel corrosion resisting steel tube	Yellow, red, yellow
T75	Low carbon 18/10 chromium-nickel-molybdenum corrosion resisting steel tube	White, blue, yellow
T76	Chromium-molybdenum steel tube (770 MPa) (weldable)	Green, brown, blue, red
BS970 Pt 1	Carbon steels :	
015 A03	Low carbon : As rolled or forged (black bars)	White, black, green, black, white
030 A04	Low carbon : As rolled or forged (black bars)	White, black, yellow, black, white
040 A04	Low carbon : As rolled or forged (black bars)	Green, red, green, red
050 A04	Low carbon : As rolled or forged (black bars)	White, blue, white, blue, white
040 A10	Low carbon : As rolled or forged (black bars)	Red, yellow, red, yellow
045 A10	Low carbon : As rolled or forged (black bars)	White, brown, green, brown, white
060 A10	Low carbon : As rolled or forged (black bars)	White, green, brown, green, white
040 A12	Low carbon : As rolled or forged (black bars)	Black, white, green, blue
050 A12	Low carbon : As rolled or forged (black bars)	White, green, yellow, green, white
060 A12	Low carbon : As rolled or forged (black bars)	White, red, white, red, white
040 A15	Low carbon : As rolled or forged (black bars)	White, red, blue, red, white
050 A15	Low carbon : As rolled or forged (black bars)	White, red, brown, red, white
060 A15	Low carbon : As rolled or forged (black bars) white	White, yellow, white, yellow,
080 A15	Low carbon : As rolled or forged (black bars) white	White, yellow, black, yellow,
040 A17	Low carbon : As rolled or forged (black bars) white	White, yellow, brown, yellow,
050 A17	Low carbon : As rolled or forged (black bars) white	White, yellow, green, yellow,
060 A17	Low carbon : As rolled or forged (black bars) yellow	Yellow, black, yellow, black,
080 A17	Low carbon : As rolled or forged (black bars)	Yellow, black, blue, black, yellow

040 A20	'20' carbon :	
	As rolled or forged (black bars)	Yellow, black, brown, black, yellow
050 A20	'20' carbon :	
	As rolled or forged (black bars)	Green, white, green, white
060 A20	'20' carbon :	
	As rolled or forged (black bars)	Yellow, black, green, black, yellow
070 A20	'20' carbon :	
	As rolled or normalized	Brown, white, brown, white
	P condition	Black, brown, yellow, white
	Cold drawn from hot rolled	Black, yellow, blue, yellow, black
080 A20	'20' carbon :	
	As rolled or forged (black bars)	Yellow, black, red, black, yellow
040 A22	'22' carbon :	
	As rolled or forged (black bars)	Red, white, red, white
050 A22	'22' carbon :	
	As rolled or forged (black bars)	Yellow, black, white, black, yellow
060 A22	'22' carbon :	
	As rolled or forged (black bars)	Yellow, blue, yellow, blue, yellow
080 A22	'22' carbon :	
	As rolled or forged (black bars)	Yellow, blue, black, blue, yellow
060 A25	'25' carbon :	
	As rolled or forged (black bars)	Yellow, blue, brown, blue, yellow
080 A25	'25' carbon :	
	As rolled or forged (black bars)	Yellow, blue, green, blue, yellow
070 A26	'26' carbon :	
	As rolled or forged (black bars)	Yellow, blue, red, blue, yellow
	Normalized condition	Yellow, brown, blue, brown, yellow
	P condition	Yellow brown, green, brown,
	yellow	
	Q condition	Yellow green, blue, green, yellow
	Cold drawn from hot rolled	Yellow, red, yellow, red, yellow
060 A27	'27' carbon :	
	As rolled or forged (black bars)	Yellow, blue, white, blue, yellow
080 A27	'27' carbon :	
	As rolled or forged (black bars)	Blue, white, black, red
060 A30	'30' carbon :	
	As rolled or forged (black bars)	Yellow, brown, black, brown, yellow
080 A30	'30' carbon :	
	As rolled or forged (black bars)	Blue, yellow, black, white
080 A30	'30' carbon :	
	As rolled or forged (black bars)	Blue, yellow, white, green
	Normalized condition	White, yellow, white, yellow
	P condition	Black, black, black, brown
	Q condition	Black, blue, brown, green
	Cold drawn from hot rolled	Yellow, brown, red, brown, yellow
060 A32	'32' carbon :	
	As rolled or forged (black bars)	yellow, brown, white, brown, yellow
080 A32	'32' carbon :	
	As rolled or forged (black bars)	Blue, white, brown, green
060 A35	'35' carbon :	
	As rolled or forged (black bars)	Yellow, green, yellow, green, yellow
080 A35	'35' carbon :	
	As rolled or forged (black bars)	Brown, blue, black, red

080 A36	'36' carbon :	
	As rolled or forged (black bars)	Yellow, white, black, white, yellow
	Normalized condition	Yellow, green, black, green, yellow
	Q condition	Yellow, red, blue, red, yellow
R condition	Yellow, white, blue, white, yellow	
	Cold drawn from hot rolled	Yellow, green, brown, green, yellow
060 A37	'37' carbon :	
	As rolled or forged (black bars)	Yellow, red, black, red, yellow
080 A37	'37' carbon :	
	As rolled or forged (black bars)	Brown, blue, black, white
060 A40	'40' carbon :	
	As rolled or forged (black bars)	Yellow, green, red, green, yellow
080 A40	'40' carbon :	
	As rolled or forged (black bars)	Brown, blue, black, yellow
080 A40	'40' carbon :	
	As rolled or forged (black bars)	Blue, white, brown, red
	Normalized condition	Black, blue, white, red
	Q condition	Blue, white, blue, black
	R condition	Black, blue, red, black
	Cold drawn from hot rolled	Brown, blue, black, green
060 A42	'42' carbon :	
	As rolled or forged (black bars)	Yellow, red, brown, red, yellow
060 A42	'42' carbon :	
	As rolled or forged (black bars)	Blue, white, black, yellow
060 M46	'46' carbon :	
	As rolled or forged (black bars)	Yellow, white, yellow, white, yellow
	Normalized condition	Yellow, red, green, red, yellow
	Q condition	Yellow, white, green, white, yellow
	R condition	Yellow, red, white, red, yellow
	S condition	Yellow, white, red, white, yellow
	Cold drawn from hot rolled	Green, red, brown, white
060 A47	'47' carbon :	
	As rolled or forged (black bars)	Yellow, green, white, green, yellow
080 A47	'47' carbon :	
	As rolled or forged (black bars)	Brown, blue, white, red
080 M50	'50' carbon :	
	As rolled or forged (black bars)	Brown, black, white, red
	Normalized condition	Red, yellow, red, green
	R condition	Red, yellow, red, white
	S condition	Blue, brown, black, green
	T condition	Green, white, brown, yellow
	Cold drawn from normalized	Brown, black, white, yellow
060 A52	'52' carbon :	
	As rolled or forged (black bars)	Yellow, white, brown, white, yellow
060 A52	'52' carbon :	
	As rolled or forged (black bars)	Brown, blue, white, yellow
060 M55	'5 ' carbon :	
	As rolled or forged (black bars)	Green, red, white, yellow
	Normalized condition	Green, yellow, blue, red
	R condition	Green, red, brown, yellow
S condition	Green, red, yellow, white	
	T condition	Green, yellow, blue, white
	Cold drawn from normalized	Green, red, blue, yellow

060 A57	`57' carbon: As rolled or forged (black, bars)	Green, yellow, brown, red
080 A57	`57' carbon: As rolled or forged (black, bars)	Green, yellow, red, white
060 A62	`62' carbon: As rolled or forged (black, bars)	Green, yellow, white, red
080 A62	`62' carbon: As rolled or forged (black, bars)	Brown, red, white, green
060 A67	`67' carbon: As rolled or forged (black, bars)	Red, black, blue, white
080 A67	`67' carbon: As rolled or forged (black, bars)	Brown, red, white, yellow
060 A72	`72' carbon: As rolled or forged (black, bars)	Red, black, brown, white
070 A72	`72' carbon: As rolled or forged (black, bars)	Red, black, brown, yellow
080 A72	`72' carbon: As rolled or forged (black, bars)	Red, black, green, red
060 A78	`78' carbon: As rolled or forged (black, bars)	Red, black, green, yellow
060 A78	`78' carbon: As rolled or forged (black, bars)	Red, black, white, red
080 A78	`78' carbon: As rolled or forged (black, bars)	Red, black, white, yellow
060 A83	`83' carbon: As rolled or forged (black, bars)	Red, black, yellow, white
080 A83	`83' carbon: As rolled or forged (black, bars)	Red, blue, black, white
050 A86	`86' carbon: As rolled or forged (black, bars)	Red, blue, brown, white
060 A86	`86' carbon: As rolled or forged (black, bars)	Red, blue, brown, yellow
080 A86	`86' carbon: As rolled or forged (black, bars)	Red, blue, green, white
060 A96	`96' carbon: As rolled or forged (black, bars)	Red, blue, green, yellow
060 A99	1% carbon: As rolled or forged (black, bars)	Red, blue, white, yellow
120 M19	`19' carbon -1.2% manganese : As rolled or forged (black bars)	Red, blue, yellow, red
	Normalized condition	White, black, green, yellow
	P condition	Red, yellow, green, white
	Q condition	White, red, blue, yellow
	R condition	Black, green, blue, yellow
	Cold drawn from hot rolled	Red, brown, blue, yellow

150M19	`19' carbon -1.5% manganese :	
	As rolled or forged (black bars)	Brown, black, blue, yellow
	Normalized condition	Blue, brown, blue, yellow
	P condition	Red, blue, yellow, white
	Q condition	Blue, green, blue, yellow
	R condition	Black, brown, blue, yellow
120M28	`28' carbon -1.2% manganese :	
	As rolled or forged (black bars)	Red, brown, black, white
	Normalized condition	Red, brown, yellow, red
	P condition	White, black, red, yellow
	Q condition	White, red, green, yellow
	Cold drawn from hot rolled	Black, green, blue, green
150M28	`28' carbon -1.5% manganese :	
	As rolled or forged (black bars)	Brown, green, blue, red
	Normalized condition	Blue, white, blue, brown
	Q condition	Brown, black, brown, green
	R condition	Black, brown, blue, white
	S condition	Red, brown, black, yellow
120M36	`36' carbon -1.2% manganese :	
	As rolled or forged (black bars)	Brown, red, blue, white
	Normalized condition	Red, brown, blue, white
	Q condition	Blue, white, blue, red
	R condition	Black, brown, green, yellow
	S condition	Black, brown, red, green
	Cold drawn from hot rolled	White, green, yellow, white
150M36	`36' carbon -1.5% manganese :	
	As rolled or forged (black bars)	Brown, green, blue, yellow
	Normalized condition	Red, brown, green, white
	Q condition	Blue, white, blue, green
	R condition	Black, brown, blue, yellow
	S condition	Black, brown, green, black
	T condition	White, black, brown, white
220M07	Low carbon, free cutting :	
	Hor rolled	Black, yellow, black, yellow
	Cold drawn	Blue, white, yellow, brown
230M07	Low carbon, free cutting :	
	Hor rolled	Black, green, blue, white
	Cold drawn	Black, red, green, blue
240M07	Low carbon, free cutting :	
	Hor rolled	Brown, green, brown, green
	Cold drawn	Brown, black, green, brown
216M28	`28' carbon, free cutting	
	As rolled or forged (black bars)	Red, green, black, yellow
	P condition	Red, green, blue, white
	Q condition	Red, white, blue, yellow
	Cold drawn from hot rolled	Red, yellow, blue, white
212M36	`36' carbon, free cutting	
	As rolled or forged (black bars)	Brown, green, black, yellow
	P condition	Red, green, blue, yellow
	Q condition	Black, white, black, brown
	R condition	Black, blue, white, brown
	Cold drawn from hot rolled	Brown, red, black, green
216M36	`36' carbon, free cutting	
	As rolled or forged (black bars)	Brown, red, blue, green
	P condition	Red, white, brown, yellow
	Q condition	Red, green, brown, yellow
	R condition	Blue, yellow, blue, brown
	Cold drawn from hot rolled	White, green, black, yellow

225 M36	`36' carbon, free cutting	
	As rolled or forged (black bars)	Red, green, yellow, red
	Q condition	Red, white, yellow, red
	R condition	White, green, red, yellow
	Cold drawn from hot rolled	White, blue, yellow, white
212 M37	`37' carbon, free cutting	
	As rolled or forged (black bars)	Brown, red, black, yellow
212 M42	`42' carbon, free cutting	
	As rolled or forged (black bars)	Brown, white, black, green
212 M44	`44' carbon, free cutting	
	As rolled or forged (black bars)	Red, green, yellow, white
	Q condition	White, black, yellow, white
	R condition	White, brown, blue, yellow
	S condition	White, red, brown, yellow
225 M44	`44' carbon, free cutting	
	As rolled or forged (black bars)	White, blue, brown, yellow
	R condition	White, brown, red, white
	S condition	Black, brown, yellow, blue
	T condition	Black, green, brown, blue
BS970 Pt 2	Alloy steels	
503 M40	1% nickel :	
	As rolled	Blue, white, green, brown
	Normalized	Black, red, black, yellow
	Q condition	Black, white, black, yellow
	R condition	Red, black, red, black, red
	S condition	Red, black, blue, black, red
503 M37	1% nickel :	
	As rolled	Brown, black, blue, green
	Hardened and tempered	Blue, brown, blue, white
503 M42	1% nickel :	
	As rolled	Brown, black, blue, red
	Hardened and tempered	Blue, green, blue, white
503 M37	1% nickel :	
	As rolled	Black, blue, white, blue, black
	Hardened and tempered	Black, brown, black, brown, black
503 M42	1% nickel :	
	As rolled	Black, brown, blue, brown, black
	Hardened and tempered	Black, brown, green, brown, black
526 M60	3/4% chromium :	
	As rolled	Brown, yellow, black, white
	T condition	Black, red, black, white
	V condition	Black, brown, blue, green
530 M40	1% chromium :	
	As rolled	Blue, white, green, yellow
	R condition	Brown, blue, brown, black
	S condition	Black, green, white, yellow
	T condition	Black, green, yellow, black
530 A30	1% chromium :	
	As rolled	Brown, yellow, blue, red
	Hardened and tempered	Green, yellow, green, brown
530 A32	1% chromium :	
	As rolled	Brown, yellow, blue, green
	Hardened and tempered	Brown, blue, brown, green
530 A36	1% chromium :	
	As rolled	Brown, yellow, blue, red
	Hardened and tempered	Brown, blue, brown, red

530 A40	1% chromium :	
	As rolled	Brown, yellow, blue, white
	Hardened and tempered	Brown, blue, brown, white
530 H30	1% chromium :	
	As rolled	Black, brown, red, brown, black
	Heat treated	Black, brown, yellow, brown, black
530 H32	1% chromium :	
	As rolled	Black, brown, white, brown, black
	Heat treated	Black, green, black, green, black
530 H36	1% chromium :	
	As rolled	Black, green, blue, green, black
	Heat treated	Black, green, brown, green, black
530 H40	1% chromium :	
	As rolled	Black, green, yellow, green, black,
	Heat treated	Black, red, blue, red, black
534 A99	1.1/2% chromium (1% carbon) :	
	As rolled	Brown, blue, red, yellow
535 A99	1.1/2% chromium (1% carbon) :	
	As rolled	Red, white, red, white, red
605 M30	1.1/2% manganese molybdenum (water hardening) :	
	As rolled	Brown, white, blue, red
	R condition	Brown, black, brown, red
	S condition	Black, green, brown, yellow
	T condition	Black, green, red, brown
	U condition	Black, green, red, white
	V condition	Black, green, red, yellow
605 M36	1.1/2% manganese molybdenum :	
	As rolled	Blue, white, brown, yellow
	R condition	Blue, white, blue, yellow
	S condition	Black, brown, red, yellow
	T condition	Black, brown, white, blue
	U condition	Black, brown, white, green
	V condition	Black, brown, white, red
905 A32	1.1/2% manganese molybdenum :	
	As rolled	Brown, white, blue, brown
	Hardened and tempered	Blue, yellow, blue, red
605 A37	1.1/2% manganese molybdenum :	
	As rolled	Brown, white, blue, green
	Hardened and tempered	Blue, yellow, blue, white
605 H32	1.1/2% manganese molybdenum (water hardening) :	
	As rolled	Red, white, green, white, red
	Heat treated	Red, white, brown, white, red
605 H37	1.1/2% manganese molybdenum (water hardening) :	
	As rolled	Red, white, green, white, red
	Heat treated	Red, white, yellow, white, red
606 M36	1.1/2% manganese molybdenum (free cutting) :	
	As rolled	Brown, white, blue, yellow
	R condition	Brown, black, brown, white
	S condition	Black, blue, brown, blue, black
	T condition	Black, blue, yellow, blue, black
605 M36	1.1/2% manganese molybdenum (higher molybdenum) :	
	As rolled	Blue, white, green, red
	R condition	Brown, black, brown, yellow
	S condition	Black, green, white, black
	T condition	Black, green, white, blue
	U condition	Black, green, white, brown
	V condition	Black, green, white, red

608 H37	1.1/2% manganese molybdenum (higher molybdenum) :	
	As rolled	Red, brown, blue, brown, red
	Heat treated	Red, brown, green, brown, red
640 M40	1.1/4% nickel chromium :	
	As rolled	Red, black, red, brown
	R condition	Yellow, white, yellow, red
	S condition	Blue, red, brown, yellow
	T condition	Blue, red, green, black
	U condition	Blue, red, green, blue
640 A35	1.1/4% manganese molybdenum (higher molybdenum) :	
	As rolled	Green, blue, green, yellow
	Hardened and tempered	Green, brown, green, black
640 H35	1.1/4% manganese molybdenum (higher molybdenum) :	
	As rolled	Red, green, brown, green, red
	Heat treated	Red, brown, blue, yellow, red
653 M31	3% nickel chromium :	
	As rolled	Brown, red, green, brown
	S condition	Brown, red, brown, yellow
	T condition	Black, yellow, white, blue
	U condition	Black, yellow, white, brown
708 M40	1% chromium molybdenum :	
	As rolled	Brown, black, green, white
	R condition	Brown, green, brown, black
	S condition	Black, red, green, yellow
	T condition	Black, red, white, black
	U condition	Black, red, white, blue
708 A37	1% chromium molybdenum :	
	As rolled	Brown, black, green, yellow
	Hardened and tempered	Brown, green, brown, blue
708 A42	1% chromium molybdenum :	
	As rolled	Brown, blue, green, red
	Hardened and tempered	Brown, green, brown, white
708 H37	1% chromium molybdenum :	
	As rolled	Red, brown, yellow, brown, red
	Heat treated	Red, brown, white, brown, red
708 A42	1% chromium molybdenum :	
	As rolled	Red, green, red, green, red
	Heat treated	Red, green, black, green, red
709 M40	1% chromium molybdenum :	
	As rolled	Brown, black, green, red
	R condition	Brown, blue, brown, yellow
	S condition	Black, red, brown, black
	T condition	Black, red, brown, green
	U condition	Black, red, brown, white
	V condition	Black, red, brown, yellow
722 M24	3% chromium molybdenum (suitable for nitriding) :	
	As rolled	Brown, white, red, yellow
	T condition	Blue, black, yellow, blue
	U condition	Blue, black, yellow, brown
785 M19	1.1/2% manganese nickel molybdenum :	
	As rolled	Brown, black, blue, white
	Q condition	Blue, brown, blue, black
816 M40	1.1/2% nickel chromium molybdenum (low molybdenum) :	
	As rolled	Green, white, black, yellow
	S condition	Yellow, white, yellow, green
	T condition	Blue, red, brown, black

	U condition	Blue, red, brown, blue
	V condition	Blue, red, brown, green
817M40	1.1/2% nickel chromium molybdenum :	
	As rolled	Blue, yellow, black, green
	T condition	Black, yellow, white, red
	U condition	Black, red, yellow, blue
	V condition	Black, red, yellow, brown
	W condition	Black, red, yellow, green
	X condition	Black, red, yellow, white
	Z condition	Black, white, blue, green
823M30	2% nickel chromium molybdenum :	
	As rolled	Red, black, white, black, red
	T condition	Red, blue, red, blue, red
	U condition	Red, blue, brown, blue, red
	V condition	Red, blue, green, blue, red
	W condition	Red, blue, yellow, blue, red
	X condition	Red, blue, white, blue, red
	Z condition	Red, brown, red, brown, red
826M31	2.1/2% nickel chromium molybdenum (medium carbon) :	
	As rolled	Blue, yellow, black, red
	T condition	Brown, white, brown, blue
	U condition	Black, white, blue, red
	V condition	Black, white, blue, yellow
	W condition	Black, white, brown, black
	X condition	Black, white, brown, green
	Z condition	Black, white, brown, yellow
826M40	2.1/2% nickel chromium molybdenum (high carbon) :	
	As rolled	Brown, white, green, brown
	U condition	Brown, white, brown, green
	V condition	Black, white, green, brown,
	W condition	Black, white, green, red
	X condition	Black, white, green, yellow
	Y condition	Black, white, red, brown
	Z condition	Black, white, red, green
830M31	3% nickel chromium molybdenum :	
	As rolled	Brown, white, green, yellow
	T condition	Brown, white, brown, red
	U condition	Black, white, red, yellow
	V condition	Black, white, yellow, blue
	W condition	Black, white, yellow, brown
835M30	4% nickel chromium molybdenum :	
	As rolled	Blue, white, red, brown
	Z condition	Black, blue, green, white
897M31	3.1/4% chromium molybdenum vanadium (suitable for nitriding in 85-ton condition) :	
	As rolled	Brown, yellow, red, brown
	85 tonf/in2	Red, brown, red, yellow
	Z condition (100 tonf/in2)	Red, black, green, black, red
905M31	1.1/2% chromium aluminium molybdenum nitriding (medium carbon) :	
	As rolled	Brown, yellow, red, white
	R condition	Red, green red, black
	S condition	Blue, black, yellow, green
945M38	1.1/2% chromium aluminium molybdenum nitriding (high carbon) :	
	As rolled	Brown, black, white, green
	R condition	Red, green, red, blue
	S condition	Blue, black, yellow white
	T condition	Blue, brown, black, blue

945M38	1.1/2% manganese nickel chromium molybdenum :	
	As rolled	Blue, brown, blue, brown
	R condition	Yellow, red, yellow, brown
	S condition	Blue, green, black, yellow
	T condition	Blue, green, brown, black
	U condition	Blue, green, brown, red
	V condition	Blue, green, brown, white
945M38	1.1/2% manganese nickel chromium molybdenum :	
	As rolled	Red, black, red, green

BS970 Pt 3	Steels for case hardening :	
045M10	`10' carbon steel:	
	As rolled or forged and bright bars	Green, black, green, blue
080M15	`15' carbon steel:	
	As rolled or forged and bright bars	Blue, white, red, yellow
210M15	`15' carbon steel:	
	As rolled or forged and bright bars	Green, black, green, yellow
130M15	`15' carbon 1.3% manganese :	
	As rolled or forged and bright bars	Green, brown, green white
214M15	`15' carbon 1.4% manganese, free, cutting :	
	As rolled or forged and bright bars	Green, brown, green, yellow
523A14	1/2% chromium :	
	As rolled or forged and bright bars	Green, red, green, black
523M15	1/2% chromium :	
	As rolled or forged and bright bars	Black, red, brown, red, black
527A19	3/4% chromium :	
	As rolled or forged and bright bars	Green, red, green, blue
527A20	3/4% chromium :	
	As rolled or forged and bright bars	Black, red, green, red, black,
635A14	3/4% nickel chromium :	
	As rolled or forged and bright bars	Black, red, yellow, red, black,
635H15	3/4% nickel chromium :	
	As rolled or forged and bright bars	Black, red, white, red, black,
635M15	3/4% nickel chromium :	
	As rolled or forged and bright bars	Green, red, green, white
637A16	1% nickel chromium :	
	As rolled or forged and bright bars	Black, yellow, green, yellow, black
637H17	1% nickel chromium :	
	As rolled or forged and bright bars	Black, yellow, red, yellow, black
637M17	1% nickel chromium :	
	As rolled or forged and bright bars	Green, red, green, yellow
655A12	3.1/4% nickel chromium :	
	As rolled or forged and bright bars	Black, yellow, white, yellow, black
655H13	3.1/4% nickel chromium :	
	As rolled or forged and bright bars	Black, white, black, white, black
655M13	3.1/4% nickel chromium :	
	As rolled or forged and bright bars	Black, white, blue, white, black
659A15	4% nickel chromium :	
	As rolled or forged and bright bars	Black, white, brown, white, black
659H15	4% nickel chromium :	
	As rolled or forged and bright bars	Black, white, green, white, black
659M15	4% nickel chromium :	
	As rolled or forged and bright bars	Red, brown, red, black
665A17	1.3/4% nickel chromium :	
	As rolled or forged and bright bars	Black, white, red, white, black
665H17	1.3/4% nickel chromium :	
	As rolled or forged and bright bars	Black, white, yellow, white, black
665M17	1.3/4% nickel chromium :	
	As rolled or forged and bright bars	Blue, yellow, brown, green

665 A19	1.3/4% nickel molybdenum : As rolled or forged and bright bars	Green, black, blue, black, green
665 H20	1.3/4% nickel molybdenum : As rolled or forged and bright bars	Green, black, brown, black, green
665 M20	1.3/4% nickel molybdenum : As rolled or forged and bright bars	Green, black, yellow, black, green
665 A22	1.3/4% nickel molybdenum : As rolled or forged and bright bars	Green, blue, green, red
665 H23	1.3/4% nickel molybdenum : As rolled or forged and bright bars	Green, black, white, black, green
665 M23	1.3/4% nickel molybdenum : As rolled or forged and bright bars	Green, blue, green, brown
665 A24	1.3/4% nickel molybdenum : As rolled or forged and bright bars	Green, blue, green, white
805 A15	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, blue, green, blue, green
805 A17	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, blue, brown, blue, green
805 H17	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, blue, red, blue, green
805 M17	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, white, green, red
805 A20	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, blue, yellow, blue, green
805 H20	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, blue, white, blue, green
805 M20	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, white, green yellow
805 A22	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, brown, black, brown, green
805 H22	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, brown, blue, brown, green
805 M22	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, brown, red, brown, green
805 A24	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, brown, yellow, brown, green
805 H25	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, red, green, red, green
805 M25	1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, yellow, green, black
815 A16	1.1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, red, black, red, green
815 H17	1.1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, red, blue, red, green
815 M17	1.1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, white, green, black
820 A16	1.3/4% nickel chromium molybdenum : As rolled or forged and bright bars	Green, red, brown, red, green
820 H17	1.3/4% nickel chromium molybdenum : As rolled or forged and bright bars	Green, red, yellow red, green
820 M17	1.3/4% nickel chromium molybdenum : As rolled or forged and bright bars	Green, white, green, blue
822 A17	2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, red, white, red, green
822 H17	2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, yellow, green, yellow, green
822 M17	2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, white, green, brown
832 H13	3.1/2% nickel chromium molybdenum : As rolled or forged and bright bars	Green, yellow, black, yellow, green

832 M13	3.1/2% nickel chromium molybdenum :	
	As rolled or forged and bright bars	Red, blue, red, green
835 A15	4% nickel chromium molybdenum :	
	As rolled or forged and bright bars	Green, yellow, blue, yellow, green
835 H15	4% nickel chromium molybdenum :	
	As rolled or forged and bright bars	Green, yellow, brown, yellow, green
835 M15	4% nickel chromium molybdenum :	
	As rolled or forged and bright bars	Red, brown, red, blue
BS 970 Pt 4	Stainless, heat resisting and valve steels :	
302	Cr Ni 18/9, C O.12 austenitic steel :	
	As rolled	Blue, yellow, brown, yellow, blue
	Softened	Brown, blue, black, blue, brown
	Cold drawn	Brown, blue, brown, blue, brown
303 S21	Cr. Ni 18/9, S bearing, free machining austenitic steel :	
	As rolled	Brown, blue, red, blue, brown
	Softened	Red, yellow, green, yellow, red
	Cold drawn	Brown, blue, yellow, blue, brown
303 S41	Cr Ni 18/9. Se bearing, free machining austenitic steel :	
	Softened	Yellow, green, yellow, red, yellow
	Cold drawn	Brown, white, blue, brown
304 S12	Cr Ni 18/9, C 0.03 austenitic steel :	
	As rolled	Brown, green, blue green, brown
	Softened	Red, green, white, green, red
304 S15	Cr Ni 18/9, C 0.06 austenitic steel :	
	As rolled	Green, black, green, brown, green
	Softened	Red, yellow, brown, yellow, red
	Cold drawn	Brown, green, black, green, brown
310 S24	Cr Ni 25/20 austenitic steel :	
	As rolled	Brown, green, brown, green, brown
	Softened	Brown, green, yellow, green, brown
315 S16	Cr Ni Mo 17/10/1.1/2, C 0.07 austenitic steel :	
	As rolled	Brown, green, white, green, brown
	Softened	Brown, red, blue, red, brown
316 S12	Cr Ni Mo 17/12/2.1/2, C 0.03 austenitic steel :	
	As rolled	Brown, red, black, red, brown
	Softened	Brown, red, brown, red, brown
316 S16	Cr Ni Mo 17/11/2.1/2, C 0.07 austenitic steel :	
	As rolled	Brown, red, green, red, brown
	Softened	Brown, red, yellow, red, brown
	Cold drawn	Brown, red, white, red, brown
317 S12	Cr Ni Mo 18/15/3.1/2, C 0.03 austenitic steel :	
	As rolled	Brown, yellow, blue, yellow, brown
	Softened	Brown, yellow, black, yellow, brown
317 S16	Cr Ni Mo 18/15/3.1/2, C 0.06 austenitic steel :	
	As rolled	Brown, yellow, brown, yellow
	brown	
	Softened	Brown, yellow, green, yellow, brown
320 S17	Cr Ni Mo 17/12/2.1/2 + Ti, C 0.08 austenitic steel :	
	As rolled	Brown, yellow, red, yellow, brown
	Softened	Brown, yellow, white, yellow, brown

321 S12	Cr Ni 18/9/ Ti, C 0.08 austenitic steel :	
	As rolled	Black, blue, black, blue, black
	Softened	Black, blue, green, blue, black
	Cold drawn	Black, blue, red, blue, black,
321 S20	Cr Ni 18/9/Ti, C 0.12 austenitic steel :	
	As rolled	Black, green, white, green, black,
	Softened	Black, red, black, red, black
	Cold drawn	Black, yellow, black, yellow, black
325 S21	Cr Ni 18/9/Ti, S bearing, free machining austenitic steel :	
	Softened	Red, yellow, red, yellow, red
	Cold drawn	Brown, white, blue, white, brown
326 S36	Cr Ni 17/11/2.1.2, Se bearing, free machining austenitic steel :	
	Softened	Brown, white, black, white, brown
	Cold drawn	Brown, white, brown, white, brown
331 S40	Ni Cr W 14/14 2.1/2 valve steel	
	As rolled or soft	Brown, white, green, white, brown
331 S42	Ni Cr W 14/14 2.1/2 + Mo valve steel	
	As rolled or softened	Brown, white, red, white, brown
347 S17	Cr Ni 18/9/Nb, C 0.08 austenitic steel :	
	As rolled	Brown, black brown, black, brown
	Softened	Brown, black, blue, black, brown
349 S52	Cr Mn Ni, 21/4 N valve steel :	
	As rolled and strees relieved	Brown, black, green, black, brown
349 S54	Cr Mn Ni, 21/4 N, S bearing valve steel :	
	As rolled and strees relieved	Brown, black, red, black, brown
352 S52	Cr Mn Ni, 21/4 N + Nb valve steel :	
	As rolled and strees relieved	Brown, black, yellow, black, brown
352 S54	Cr Mn Ni, 21/4 N + Nb, S bearing valve steel :	
	As rolled and strees relieved	Brown, black, red, black, brown
381 S34	Cr Mn Ni, 211 + N valve steel :	
	As rolled and strees relieved	Brown, white, yellow, white, brown
401 S45	Si Cr 3/8 valve steel :	
	As rolled and strees relieved	Blue, black, brown, black, blue
403 S17	13 Cr, C 0.08 max ferritic steel :	
	Softened	Blue, black, white, black, blue
410 S21	13 Cr, Co.12 martensitic steel :	
	P condition	Blue, brown, blue, brown, blue
	Softened	Blue, brown, green, brown, blue
416 S21	13 Cr, Co.12, S bearing free machininmg martensitic steel :	
	P condition	Red, green, yellow, green, red
416 S29	13 Cr, Co.17, S bearing free machininmg martensitic steel :	
	R condition	Blue, green, black, green, blue
	S condition	Blue, green, red, green, blue
416 S37	13 Cr, Co.24, S bearing free machininmg martensitic steel :	
	R condition	Blue, red, black, red, blue
	S condition	Blue, red, yellow, red, blue
416 S41	13 Cr, Co.12, S bearing free machininmg martensitic steel :	
	P condition	Red, white, black, white, red
	R condition	Red, black, yellow, black, red
420 S29	13 Cr, Co 17, martensitic steel :	
	Softened	Blue, yellow, green, yellow, blue
	P condition	Blue, brown, yellow, brown, blue
	S condition	Blue, green, white, green, blue

420 S37	13 Cr, C 0.24, martensitic steel :	
	R condition	Blue, yellow, red, yellow, blue
	S condition	Blue, yellow, white, yellow, blue
	Softened	Blue, white, blue, white, blue
420 S45	13 Cr, C 0.32, martensitic steel :	
	R condition	Blue, white, black, white, blue
	S condition	Blue, white, brown, white, blue
	Softened	Blue, white, green, white, blue
430 S15	17 Cr, C0.10 ferritic steel :	
	Softened	Blue, white, red, white, blue
431 S29	17 Cr, 2.1/2 Ni, C0.15 martensitic steel :	
	Softened	Green, blue, black, green
	Hardened and tempered, & T condition	Yellow, blue, yellow, red
441 S29	17 Cr, 2.1/2 Ni, C0.15, S bearing, free machining martensitic steel :	
	Softened	Red, yellow, white, yellow, red
	Hardened and tempered	Red, green blue, green, red
	T condition	Red, blue, black, blue, red
441 S49	17 Cr, 2.1/2 Ni, C 0.15, Se bearing free machining martensitic steel :	
	Softened	Red, black, brown, black, red
	Hardened and tempered	Red, brown, black, brown, red
	T condition	Blue, yellow, black, yellow, red
443 S65	Cr Ni Si, 20/1.1/2/2 valve steel :	
	As rolled and stress relieved	Blue, white, yellow, white, blue
BS970 Pt 5	Carbon and alloy spring steels :	
080 A52	`52' carbon :	
	As rolled or forged	Red, yellow, red, black
080 A67	`67' carbon :	
	As rolled or forged	Green, yellow, red, yellow, green
070 A72	`72' carbon :	
	As rolled or forged	Red, green, red, brown
070 A78	`78' carbon :	
	As rolled or forged	Green, yellow, white, yellow, green
060 A96	`96' carbon :	
	As rolled or forged	White, blue, white, red
250 A53	Silico-manganese `53' carbon :	
	As rolled or forged	White, brown, white, red
250 A58	Silico-manganese `58' carbon :	
	As rolled or forged	White, brown, white, yellow
250 A61	Silico-manganese `61' carbon :	
	As rolled or forged	Green, white, green, white, green
527 A60	3/4% chromium :	
	As rolled or forged	Green, white, black, white, green
527 H60	3/4% chromium :	
	As rolled or forged	Green, white, blue, white, green
735 A50	1% chromium vanadium :	
	As rolled or forged	Blue, yellow, red, green
805 A60	1/2% chromium molybdenum :	
	As rolled or forged	Green, white, brown, white, green
805 H60	1/2% chromium molybdenum :	
	As rolled or forged	Green, white, red, white, green
925 A60	Silicon-manganese chromium molybdenum :	
	As rolled or forged	Green, white, yellow, white, green

BS980	Steel tubes for automobile purposes :	
CDS-1	Mild steel, soft :	
	Annealed or normalized	Blue, brown, blue
CDS-2	Mild steel, hard :	
	As drawn, tempered	Red, black, yellow
CDS-3	Low carbon case-hardening steel :	
	As drawn, or as drawn and tempered	Blue, brown, red
CDS-3A	Low carbon case-hardening steel :	
	Annealed or normalized	Blue, brown, white
CDS-4	Low carbon case-hardening steel (free machining) :	
	As drawn, or as drawn and tempered	Blue, brown, yellow
CDS-5	`30' carbon steel, soft :	
	Annealed or normalized	Blue, green, brown
CDS-6	`30' carbon steel, hard :	
	As drawn, or as drawn and tempered	Blue, green, red
CDS-7	`45' carbon steel, soft :	
	Annealed or normalized	Blue, green, yellow
CDS-8	`45' carbon steel, hard :	
	As drawn, or as drawn and tempered	Blue, red, blue
CDS-9	Carbon-manganese steel, soft (suitable for welding) :	
	Annealed	Blue, red, white
CDS-10	Carbon-manganese steel, hard (suitable for welding) :	
	As drawn, or as drawn and tempered	Blue, red, yellow
CDS-11	`26' carbon-manganese-molybdenum steel (suitable for welding)	
	As drawn, or as drawn and tempered	Blue, white, brown
CDS-12	1 per cent chromium-molybdenum steel (suitable for welding) :	
	As drawn, or as drawn and tempered	Blue, yellow,, blue
CDS-13	1 per cent chromium-molybdenum steel, hard (suitable for welding) :	
	As drawn or heat treated	Blue, yellow, white
	3 per cent nickel steel, hard (suitable for welding) :	
	As drawn or heat treated	Brown, blue, brown
CDS-15	70 ton steel :	
	Heat treated	Brown, blue, green
CDS-16	75 ton nickel-chromium steel :	
	Hardened and tempered	Brown, blue, red
CDS-17	85 ton nickel-chromium steel :	
	Hardened and tempered	Brown, blue, white
CDS-18	12 per cent chromium steel, soft :	
	Annealed and descaled	Brown, blue, yellow
CDS-19	Austenitic chromium-nickel steel, soft :	
	Softened and descaled	Brown, green, red
CDS-20	Austenitic chromium-nickel steel, soft : (suitable for welding) :	
	Softened and descaled	Brown, green, white
ERW1	Carbon steel :	
	As welded	Brown, green, yellow
ERW2	Carbon steel :	
	As welded	Brown, red, brown

ERW3	Carbon steel :	
	As welded	Brown, red, green
CEW1	Mild steel, soft :	
	Annealed or normalized	Brown, white, brown
CEW2	Mild steel, hard :	
	As drawn or as drawn and tempered	Brown, white, green
CEW3	`30' carbon steel, hard :	
	Annealed or normalized	Brown, white, red
CEW4	`30' carbon steel, hard :	
	As drawn or as drawn and tempered	Brown, yellow, brown
BS1052	Mild steel wire for general engineering purposes :	
	Annealed condition	Black, blue, white, green
BS1408	High duty unground steel spring wire	
	Range 3	Green, white, green, yellow
BS1449	Steel plate sheet and strip :	
En 21A	3 per cent nickel steel :	
	As rolled, normalized and/or tempered	Red, white, red, white
En 42E	Carbon spring steel (hardening and tempering quality) :	
	Cold-rolled and annealed	Red, yellow, red, white
	As cold-rolled	Green, black, green, blue
	Hardened and tempered	Red, yellow, red, yellow
	Hor-rolled or normalized	Green, black, green, brown
En42F	Cold-rolled and annealed	Red, brown, red, green
	As cold-rolled	Green, black, green, red
	Hardened and tempered	Red, brown, red, white
	Hor-rolled or normalized	Green, black, green, yellow
En42G	Cold-rolled and annealed	White, blue, white, blue
	As cold-rolled	Green, blue, green, black
	Hardened and tempered	White, blue, white, brown
	Hor-rolled or normalized	Green, blue, green, brown
En42J	Cold-rolled and annealed	White, blue, white, green
	As cold-rolled	Green, blue, green, red
	Hardened and tempered	White, blue, white, red
	Hor-rolled or normalized	Green, blue, green, yellow
En 43G	Carbon spring steel (hardening and tempering quality) :	
	Cold-rolled and annealed	Red, white, red, yellow
	As cold-rolled	Green, brown, green, black
	Hardened and tempered	Red, yellow, red, blue
	Hor-rolled or normalized	Green, brown, green, red
En 43J	Cold-rolled and annealed	Red, yellow, red, brown
	As cold-rolled	Green, brown, green, yellow
	Hardened and tempered	Red, yellow, red, green
	Hor-rolled or normalized	Green, red, green, black
En 44D	Carbon spring steel (hardening and tempering quality) :	
	Cold-rolled and annealed	White, blue, white, yellow
	As cold-rolled	Green, red, green, blue
	Hardened and tempered	White, brown, white, blue
	Hor-rolled or normalized	Red, green, red, brown
En 44E	Cold-rolled and annealed	White, brown, white, brown

	As cold-rolled	Green, white, green, black
	Hardened and tempered	White, brown, white, green
	Hor-rolled or normalized	Green, yellow, green, black
En 56A	Chromium rust-resisting steel sheet and strip :	
	Softened	White, brown, white, red
	Hardened and tempered	White, brown, white, yellow
En 56B	Softened	White, green, white, blue
	Hardened and tempered	White, green, white brown
En 56C	Softened	White, green, white, green
	Hardened and tempered	White, green, white, red
En 56D	Softened	White, green, white, yellow
	Hardened and tempered	White, red, white, blue
En 56R	Hardened and tempered	Yellow, blue, yellow, red
En 56T	Hardened and tempered	Yellow, brown, yellow, black
En 56V	Hardened and tempered	Yellow, brown, yellow, green
En 57	Martensitic chromium-nickel rust-resisting steel sheet and strip :	
	Softened	White, red, white, brown
	Hardened and tempered	White, red, white, green
En 58A	Austenitic chromium-nickel rust, acid and heat resisting steel sheet and strip :	
	Softened	Blue, green, blue, black
	Cold-rolled	White, red, white, yellow
En 58B	Softened	White, yellow, white, blue
	Cold-rolled	White, yellow, white, brown
En 58C	Softened	White, yellow, white, green
	Cold-rolled	White, yellow, white, red
En 58D	Softened	White, yellow, white, yellow
	Cold-rolled	Blue, brown, blue, brown
En 58E	Softened	Blue, brown, blue, green
	Cold-rolled	Blue, brown, blue, red
En 58F	Softened	Blue, brown, blue, white
	Cold-rolled	Blue, brown, blue, yellow
En 58G	Softened	Blue, green, blue, brown
	Cold-rolled	Blue, green, blue, green
En 58H	Softened	Blue, green, blue, red
	Cold-rolled	Blue, green, blue, white
En 58J	Softened	Blue, green, blue, yellow
	Cold-rolled	Blue, red, blue, brown
En 60	Ferritic chromium rust-resisting steel sheet and strip :	
	Softened	Blue, red, blue, green
En 61	Softened	Blue, red, blue, white
BS1449 1962	Steel plate sheet and strip, Grades :	
	HR1, HRPI) HR11, HRP11)	Blue, green, red, white
EN2A/1	HR2, HRP2) HR12, HRP12)	Blue, green, white, blue
	HR2-VE	Blue, green, yellow, blue
	NHR12	Blue, green, white, brown
	HS23B	Green, red, blue, white
	HS23C	Red, brown, white, red
	CS12A	Red, blue, black, white
	CS12B	Red, black, green, yellow
	CS12C	Green, brown, black, white
	CS17A	Blue, brown, black, white
	CS17B	Blue, brown, green, blue

	CS17C	Blue, green, black, brown
	CS22A	White, blue, black, yellow
	CS22B	White, green, yellow, white
	CS22C	White, yellow, red, yellow
	NHR22	White, brown, green, yellow
	HR6A, HRP6A) HR17A, HRP17A)	Green, yellow, blue, red
	HR6B, HRP6B) HR17B, HRP17B)	Green, red, yellow, green
	HR6C, HRP6C) HR17C, HRP17C)	Green, red, brown, yellow
	HR17/1	Green, white, green, red
	NHR23	Green, yellow, blue, white
	EN2D	Brown, red, blue, red
	EN2D/A	Green, brown, red, green
	EN2D/B	Green, brown, yellow, green
	HR7A, HRP7A	Green, yellow, green, white
	HR7B, HRP7B	Green, yellow, white, yellow
	HR7C, HRP7C	Red, yellow, red, white
	NHR24	Red, white, brown, yellow
	EN5 (Part 2B)	Yellow, blue, brown, yellow
	HS30	White, green, red, white
	HR8B, HRP8B	Red, blue, green, yellow
	HR8C, HRP8C	Red, brown, blue, white
	NHR25	Red, brown, white, yellow
	EN5 (Part 2B)	Brown, red, white, red
	EN14a (Part 2B)	Green, red, white, red
	HS20	Brown, green, yellow, white
	HS40	Brown, red, green, white
	CS30	Brown, red, black, white
	CS40	Brown, red, blue, green
	HS50	White, yellow, green, yellow
	HS60	Yellow, blue, green, yellow
	HS70	White, blue, red, yellow
	HS80	Green, yellow, red, white
	HS90	Red, brown, blue, yellow
	HS100	Green, white, yellow, green
	CS50	Brown, red, brown, yellow
	CS60	Brown, red, green, yellow
	CS70	Brown, red, yellow, brown
	CS80 Annealed	Brown, white, black, yellow
	CS80 Hardened and tempered	Green, white, black, yellow
	CS90	Brown, white, brown, green
	CS100	Brown, white, green, yellow
	HS1	Blue, green, red, yellow
	HS2	Blue, green, white, green
	CRI/GP	Blue, red, black, brown
	CRI/FF	Blue, red, black, green
	CRI/VE	Blue, red, black, red
	CR2/GP	Blue, green, yellow, brown
CR2/FF	Blue, green, yellow, green	
	CR2/VE	Blue, green, yellow, red
	CS1	Blue, green, white, red
	CS2	Blue, green, white, yellow
EN2A	HR3, HRP3) HR13, HRP13)	Blue, red, white, green
	HR3/VE	Blue, red, white, yellow
	NHR13	Blue, red, yellow, blue
	HS3	Blue, red, yellow, brown
	CR3-GP	Blue, white, blue, brown
	CR3-FF	Blue, white, blue, green

CR3-VE	Blue, white, blue, red
EN2A Part 2B	Blue, red, blue, red
CS3	Blue, white, black, brown
HR4, HRP4)	
HR14, HRP14)	Blue, white, green, white
HR4-VE	Blue, white, green, yellow
NHR-14	Blue, white, red, green
HS4A	Blue, white, red, white
HS4B	Blue, white, yellow, blue
CR4-GP	Blue, white, yellow, brown
CR4-FF	Blue, white, yellow, green
CR4-VE	Blue, white, yellow, red
CS4- Annealed	Blue, white, red, yellow
-Skin passed	Blue, white, yellow, white
-1/4 H	Blue, yellow, black, brown
-1/2 H	Blue, yellow, black, green
-H	Blue, yellow, black, red
EN2B	Blue, yellow, blue, green
EN2B/B	Blue, white, green, red
NHR15	Red, green, white, red
EN2 (Part 2B0	Brown, yellow, brown, red
HR5A, HRP5A)	
HR16A, HRP16A)	Red, white, yellow, red
HR5B, HRP5B)	
HR16B, HRP16B)	Red, yellow, brown, yellow
HR5C, HRP5C)	
HR16C, HRP16C)	Red, green, yellow, whit
HR16/1, HRP16/1	Red, yellow, green, white
NHR21	White, green, red, yellow
EN2C/2 (Part 2B)	Red, black, yellow, red
EN2C	Black, yellow, green, yellow
EN2C/A	Black, yellow, green, yellow
EN2C/B	Red, yellow, green, yellow
HS12A	Brown, yellow, green, yellow
HS12B	Brown, white, yellow, brown
HS12C	Brown, yellow, blue, green
HS17A	Brown, yellow, white, green
HS17B	Brown, yellow, red, yellow
HS17C	Red, blue, white, yellow
HS22A	Brown, yellow, green, red
HS22B	Red, blue, brown, white
HS22C	Green, yellow, white, red
HS23A	Green, brown, red, white

BS1554	Rust, acid and heat-resisting steel wire :	
En56A	Martensitic chromium rust-resisting steel :	
	Softened	Red, blue, black, red
	Hardened and tempered	White, blue, black, white
	Drawn	Brown, green, black, red
En56B	Softened	Red, blue, black, white
	Hardened and tempered	White, blue, black, yellow
	Drawn	Brown, green, black, white
En56C	Softened	White, blue, black, yellow
	Hardened and tempered	White, brown, blue, white
	Drawn	Brown, green, black, yellow
En56D	Softened	Red, green, black, red
	Hardened and tempered	White, brown, blue, yellow
	Drawn	Black, green, black, brown
En57	Martensitic chromium-nickel rust-resisting steel, high tensile :	

	Softened	Red, green, black, white
	Hardened and tempered	White, green, blue, white
	Drawn	White, red, blue, white

En 58A	Austenitic chromium-nickel steel :	
	Softened	Red, green, black, yellow
	Drawn	White, red, blue, yellow
En 58B	Softened	Red, white, black, red
	Drawn	White, yellow, blue, white
En 58C	Softened	Red, white, black, yellow
	Drawn	White, black, brown, yellow
En 58D	Softened	Red, yellow, black, red,
	Drawn	White, blue, brown, yellow
En 58E	Softened	Red, black, blue, white
	Drawn	White, green, brown, white
En 58F	Softened	Red, black, blue, yellow
	Drawn	White, green, brown, yellow
En 58G	Softened	Red, brown, blue, red
	Drawn	White, red, brown, white
En 58H	Softened	Red, brown, blue, white
	Drawn	White, red, brown, yellow
En 58J	Softened	Red, brown, blue, yellow
	Drawn	White, yellow, brown, white

BS1775	Steel tubes for mechanical structural and general engineering purposes :	
CDS 11	Cold drawn seamless Grade 11	Blue, brown, green, blue
CDS 13	Cold drawn seamless Grade 13	Blue, brown, red, green
CDS 16	Cold drawn seamless Grade 16	Blue, brown, green, white
CDS 20	Cold drawn seamless Grade 20	Blue, brown, green, red
CDS 23	Cold drawn seamless Grade 23	Blue, brown, black, red
CDS 24	Cold drawn seamless Grade 24	Blue, brown, white, brown
CDS 28	Cold drawn seamless Grade 28	Blue, brown, white, yellow
CDS 35	Cold drawn seamless Grade 35	Blue, brown, yellow, red
CDS 11	Cold drawn electrical resistance welted Grade 11	Black, brown, red, blue
CDS 16	Cold drawn electrical resistance welted Grade 16	Black, brown, red, white
CDS 23	Cold drawn electrical resistance welted Grade 23	Black, blue, white, red
CDS 24	Cold drawn electrical resistance welted Grade 24	Black, brown, red, brown
CDS 28	Cold drawn electrical resistance welted Grade 28	Black, brown, red, black

EFW 16	Electric fusion welded Grade 16	Blue, black, yellow, green
ERW 11	Electrical resistance welded Grade 11	Black, brown, green, blue
ERW 16	Electrical resistance welded Grade 16	Black, brown, green, white
ERW 20	Electrical resistance welded Grade 20	Black, brown, green, red
ERW 23	Electrical resistance welded Grade 23	Black, blue, green, brown
HFS 11	Hot finished seamless Grade 11	Blue, black, brown, blue
HFS 13	Hot finished seamless Grade 13	Blue, black, brown, green
HFS 16	Hot finished seamless Grade 16	Blue, black, brown, white
HFS 20	Hot finished seamless Grade 20	Blue, black, brown, red
HFS 23	Hot finished seamless Grade 23	Blue, black, blue, green
HFW 11	Hot finished welded Grade 11	Black, blue, brown, blue
HFW 13	Hot finished welded Grade 13	Black, blue, brown, green
HFW 16	Hot finished welded Grade 16	Black, blue, brown, white
HFW 20	Hot finished welded Grade 20	Black, blue, brown, red
HFW 23	Hot finished welded Grade 23	Black, blue, brown, yellow

HLW 16	Hydraulic lap welded Grade 16	Blue, brown, black, yellow
QAW 11	Oxy-acetylene welded Grade 11	Blue, black, white, blue

BS 2056	Rust, acid and heat-resisting steel wire for springs :	
	Martensitic chromium rust-resisting steel :	
	Softened	White, brown, white, red
	Drawn	Black, blue, black, brown
En 56B	Softened	White, green, white, blue
	Drawn	Black, blue, black, green
En 56C	Softened	White, green, white, green
	Drawn	Black, blue, black, red
En 56D	Softened	White, green, white, yellow
	Drawn	Black, blue, black, yellow
En 57	Martensitic chromium-nickel rust-resisting steel, high tensile :	
	Softened	White, red, white, brown
	Drawn	Black, blue, black, white
En 58A	Austenitic chromium-nickel steel :	
	Drawn	Blue, yellow, brown, white
En 58B	Drawn	Black, brown, black, blue
En 58C	Drawn	Black, brown, black, brown
En 58D	Drawn	Black, brown, black, green
En 58E	Drawn	Black, brown, black, red
En 58F	Drawn	Black, green, black, green
En 58G	Drawn	Black, brown, black, yellow
En 58H	Drawn	Black, brown, black, white
En 58J	Drawn	Black, green, black, blue

BS 3601	Steel tubes for pressure purposes - Carbon steel with specified room temperature properties :	
BW 320	Butt welded Grade 320	Red, black, brown, white
ERW 320	Electric resistance welded and induction welded Grade 320	Red, black, green, white
ERW 360	Electric resistance welded and induction welded Grade 360	Red, black, brown, yellow
ERW 410	Electric resistance welded and induction welded Grade 410	Red, black, blue, white
S 320	Seamless Grade 320	Red, blue, brown, yellow
S 360	Seamless Grade 360	Red, blue, green, white
S 410	Seamless Grade 410	Red, blue, black, yellow
SAW 410	Submerged arc welded Grade 410	Red, black, white, yellow

BS 3602	Steel tubes for pressure purposes Carbon steel : High duties	
CDS23	Cold drawn seamless Grade 23	Green, red, brown, red
CDS27	Cold drawn seamless Grade 27	Green, red, white, red
CDS35	Cold drawn seamless Grade 35	Green, red, white, yellow
ERW23	Electric resistance welded Grade 23	Black, red, green, brown
ERW27	Electric resistance welded Grade 27	Black, red, green, red
HFS23	Hot finished seamless Grade 23	Brown, red, white, brown
HFS27	Hot finished seamless Grade 27	Brown, red, white, red
HFS35	Hot finished seamless Grade 35	Brown, red, white, yellow

BS3603	Steel tubes for pressure purposes Carbon and alloy steel : Low temperature duties :	

CDS27LT30	Cold drawn seamless Grade 27LT30	Green, white, yellow, green
CDS27LT50	Cold drawn seamless Grade 27LT50	Green, white, yellow, red
CDS503LT100	Cold drawn seamless Grade 503LT100	Green, white, yellow, white
HFS27LT30	Hot finished seamless Grade 27LT30	Brown, white, black, green
CDS27LT50	Hot finished seamless Grade 27LT50	Brown, white, black, red
CDS503LT100	Hot finished seamless Grade 503LT100	Brown, white, black, white

BS3604	Steel tubes for pressure purposes	
	Low and medium alloy steel	
CD620	Cold drawn seamless 1% chromium-molybdenum steel	Green, yellow, black, red
CD621	Cold drawn seamless 1.1/4% chromium-molybdenum steel	Green, yellow, black, white
CD622, 27	Cold drawn seamless 2.1/4% chromium-molybdenum steel - annealed	Green, yellow, blue, red
CD622, 35	Cold drawn seamless 2.1/4% chromium-molybdenum steel - normalized	Green, yellow, blue, yellow
CD625	Cold drawn seamless 5% chromium-molybdenum steel	Green, yellow, brown, red
CD660	Cold drawn seamless chromium-molybdenum vanadium steel	Green, yellow, red, white
HF620	Hot finished seamless 1% chromium-molybdenum steel	Brown, yellow, black, green
HF621	Hot finished seamless 1.1/4% chromium-molybdenum steel	Brown, yellow, black, white
HF622, 27	Hot finished seamless 2.1/4% chromium-molybdenum steel - annealed	Brown, yellow, blue, red
HF622, 35	Hot finished seamless 2.1/4% chromium-molybdenum steel - normalized	Brown, yellow, blue, yellow
HF625	Hot finished seamless 5% chromium-molybdenum steel	Brown, yellow, brown, green
HF660	Hot finished seamless chromium-molybdenum vanadium steel	Brown, yellow, red, green

BS4360	Weldable structural steels	
43A	Bar and plate	*Green, brown, yellow
43C	Bar, plate and hollow sections	*Red, white, green, yellow
50B	Bar, plate and hollow sections	*Black, green, yellow, brown

*These colours are in addition to any that may be applied with reference to Appendix D of the specification

WELDING - FILLER RODS AND WIRES
SECTION VII

NUMBERS	DESCRIPTION	COLOUR
BS1453	Filler materials for gas welding :	
	Ferritic steels	
A1		Black
A2		Black, blue
A3		Yellow
A4		Black, red
A5		Black, white
A6		Black, yellow
A7		Black, brown
A32		Black, brown, black
A33		Black, brown, blue

	Cast iron	
B1		Green, black, green
B2		Green, blue, green
B3		Green, red, green
	Austenitic stainless steels	
309 S94		Blue, white, blue
310 S94		Blue, white, yellow
311 S94		Blue, white, green
313 S94		Blue, yellow, red
316 S96		Blue, green, blue
318 S96		Blue, red, white
447 S96		Black, white, yellow
	Copper and copper alloys	
C1		Black
C2		Black, white
C2B		Blue, black, green
C2C		Blue, brown, blue
C3		Black, green, brown
C4		Black, red
C5		Black, blue
C6		Black, yellow
	Aluminium and aluminium alloys	
G1B		Black, green
NG2		Black, yellow
NG3		Black, yellow, blue
NG5		Blue, green
NG6		Blue, red
NG21		Green, red
NG52		Blue, yellow, brown
	Magnesium alloys	
D1		Green, yellow,
D2		Red

BS2901	Filler rods and wires for gas sheilded arc welding :	
Pt 1	Ferritic steels	
A15		Black, blue, black
A16		Black, green, black
A17		Black, white, black
A18		Black, blue, green, blue
A19		Black, green, blue
A30		Black, green, brown
A31		Black, green, red
A32		Black, brown, black
A33		Black, brown, blue
A34		Black, red, blue
Pt 2	Austenitic stainless steels	
308 S92		Black, red, brown,
308 S93		Black, white, blue
308 S96		Black, red, green
309 S94		Blue, white, blue
310 S94		Blue, white, yellow
310 S98		Blue, yellow, green
311 S94		Blue, white, green
313 S94		Blue, yellow, red
316 S92		Blue, green, red
316 S93		Blue, brown, white
316 S96		Blue, green, blue
317 S96		Blue, brown, yellow

318 S96		Blue, red, white
347 S96		Black, white, yellow
Pt 3	Copper and copper alloys	
C7		Blue
C8		Blue, green
C9		Blue, red
C10		Blue, yellow
C11		Green, red
C12		Green, white
C12 Fe		Blue, green, white
C13		Green, yellow
C16		Red, yellow
C18		Red, black, red
C20		Red, white, red
C21		Red, yellow, red
C22		Blue, red, green
Pt 4	Aluminium and aluminium alloys	
G1A		Black, blue
G1B		Black, green
NG3		Black, yellow, blue
NG5		Blue, green
NG6		Blue, red
NG21		Green, red
NG52		Blue, yellow, brown
NG61		Red, yellow, white
Pt 4	Magnesium alloys	
D1		Green, yellow
D2		Red
D3		Red, yellow
D4		Green, black, green
D5		Green, blue, green
D6		Green, red, green
D7		Green, yellow, green
D8		Blue, red, blue
Pt 5	Nickel and nickel alloys	
NA32		Yellow, blue, yellow
NA33		White
NA34		Yellow, green, yellow
NA35		White, black, white
NA36		White, blue, yellow
NA37		White, green, white
NA38		Yellow, red, yellow
NA39		Yellow, white, yellow
NA40		Red, black, white
NA41		Red, black, yellow
NA42		Red, brown, red

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APPENDIX II TO LAST CHAPTER
OTHER SPECIFICATION
DTD SPECIFICATION

SECTION I

NUMBERS	DESCRIPTION	COLOUR
DTD10	High nickel-copper alloy sheets	Blue, red
DTD97	Low tensile corrosion-resisting steel tubes	Black, yellow, red
DTD118	Magnesium alloy sheets (suitable for welding)	Black, blue, red
DTD142	15-ton magnesium alloy bars	Black, blue, red
DTD150A	Bars for forging	White, green, yellow
DTD161	Corrosion-resisting steel rods and wire	Brown, yellow, white
DTD164	Aluminium-nickel-iron bronze bars	Black, blur, white
DTD167	45-ton steel tubes	Blue, yellow, red
DTD189	Chromium-nickel corrosion-resisting steel rods	Black, white, brown
DTD192	High nickel-copper alloy hot-rolled or forged bars	Black, red, blue
DTD196	Cold-rolled or cold-drawn and annealed high nickel-copper alloy bars (suitable for cold bending)	Blue, red, white
DTD197	Aluminium-nickel-iron bronze bars :	
	(Section II) bars and billets for forging	Green
	(Section III) bars for machining	Black, yellow, white
DTD200	Hard-drawn high nickel-copper alloy bars and strips	Black, red, white
DTD203	50-ton corrosion-resisting steel tubes	Black, brown, white
DTD204	High nickel-copper alloy rods, wire and tubes :	
	(Section II) rods and wires for rivets	Black, white, green
	(Section III) tubes for rivets	Black, white, green
DTD232	45 per cent nickel alloy sheets and strips of 40/50 tons 0.1 per cent proof stress	Red, white, red
DTD237	45 per cent nickel alloy sheets and strips of 15 tons 0.1 per cent proof stress	Red, white, yellow
DTD246	Aluminium-copper-nickel-magnesium-iron silicon alloy bars and billets for forging	Green, red, yellow
DTD253	Aluminium-nickel-silicon brass tubes	Red, green, white
DTD265	Hard drawn phosphor-bronze bars and tubes (suitable for bushes)	Blue, black, white
DTD267	Silico brass sheets (half hard)	Brown, black, white
DTD268	45 per cent nickel alloy rods and tubes	Black, white, red
DTD271	Corrosion-resisting steel strips (suitable for magneto contact breaker springs)	White, black, yellow
DTD283	Aluminium-nickel-silicon bras sheets (annealed)	White, blue, white
DTD297	7 per cent magnesium-aluminium alloy bars and extruded section (softened):	
	(Section II) bars and billets for forging	Black, blue, black
	(Section III) bars for machining and extruded sections	Black, brown, green
DTD319	Aluminium-nickel-silicon brass bars	Black, green
DTD324B	Aluminium-silicon-magnesium-copper nickel alloy forgings (forgins stock)	Black, blue, white
DTD326	Corrosion-resisting steel wire	Blue, yellow, blue
DTD328	Nickel-chromium alloy sheets and strips	White, yellow, white
DTD372B	Aluminium-magnesium-silicon alloy extruded bars and section (suitable for welding) :	
	Quenched at the extrusion die, straightened and aged at room temperature	Brown, black, brown
	Solution treated, straightened and aged at room temperature	Black, blue, yellow
DTD412	Aluminium bronze cast billets for forgings	See DTD197 (Section II)

DTD477	High nickel-copper alloy tubes	Blue, green
DTD487	Aluminium-copper nickel alloy cold headed bolts :	
	(Section II) rod and wire	Red, green, red
DTD498	Silicon-nickel -copper alloy bars and forgins :	
	Bars and billets for forging	Black, yellow, red
	Bars for machining	Blue, red, green
DTD503	Steel tubes (suitable for high-pressure hydraulic systems)	Yellow, white, yellow
DTD504	Silicon-nickel-copper alloy bars	Green, red, green
DTD607	Copper strip for radiators and coolers	Green, black, green
DTD627	Brass rod or wire for machined components subject to a riveting operation	Blue, white, blue
DTD713	2.1/2 per cent nickel-chromium-molybdenum steel tubes (75 tons) :	
	Softened condition	Brown, yellow, green
DTD717	Aluminium-copper-magnesium-nickel-iron alloy forgings - Forging stock	Brown, blue, white
DTD720	``15" carbon steel (not exceeding 3/4-in diameter)	Black, red, white
DTD723	2.1/2 per cent nickel-chromium-molybdenum steel tubes (90 tons) :	
	Softened condition	Brown, red, white
DTD731	Aluminium-copper-magnesium-nickel-iron alloy bars and billets for forging	Brown, blue, red
DTD734	Chromium-nickel non-corrodible steel wire (suitable for wire thread inserts)	Black, brown, green
DTD737	Magnesium-manganese alloy tubes	Black, blue, red
DTD740	40-ton molybdenum-boron steel tubes (suitable for welding)	Red, yellow, red
DTD745	Aluminium-copper-magnesium-nickel-iron alloy bars and billets for forging	Brown, blue, red
DTD5004	Bars for forging	White, blue, white
DTD5010	Aluminium-copper-magnesium-silicon-manganese alloy plate (solution treated and aged at room temperature)	Green, blue, yellow
DTD5013	Commercially pure titanium bars and billets (ultimate tensile stress not greater than 30-tons)	Red, yellow, white
DTD5014	Aluminium-copper-magnesium-nickel-iron alloy bars and extruded section	Green, blue, yellow
DTD5016	Stainless steel tubing	Black, blue, brown
DTD5019	Aluminium-nickel-silicon brass tubes	Red, black, red
DTD5023	Commercially pure titanium sheets and strip (25/40-tons ultimate stress) (suitable for welding)	Black, white, brown
DTD5024	Aluminium-zinc-magnesium-copper-manganese alloy forgings	
	Extruded and rolled bars and billets for forging	Green, black, yellow
DTD5030	Aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy plate (solution treated and aged at room temperature)	Black, red, yellow
DTD5032	Carbon steel for tierods	Black, green, yellow, white
DTD5037	Iron-nickel-chromium-molybdenum-weldable-heat resisting alloy sheet and strip	Black, brown, black, brown
DTD5040	Aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy plate (solution treated and precipitation treated)	Blue, brown, red
DTD5041	Magnesium-zinc-zirconium bars and sections	Red, brown, white
DTD5042	80-ton nickel-chromium-molybdenum-vanadium steel	White, yellow, white
DTD5044	Aluminium-zinc-magnesium-copper-manganese alloy bars and extruded section. Not exceeding 10 inches diameter or minor sectional dimensions. (Solution treated and precipitation treated)	Yellow, brown, yellow

DTD5046	12 per cent chromium-molybdenum-vanadium-oxidation resistant and corrosion resistant steel sheet and strip - softened	Red, brown, yellow
DTD5052	80-ton nickel-chromium-molybdenum-vanadium steel plate (limiting ruling section 6-ins)	Green, blue, yellow
DTD5056	Chromium-nickel corrosion resistant steel for cold headed bolts and set screws - Rod	White, brown, green, white
	- Wire	Brown, white, blue, white
DTD5057	Nickel-chromium-cobalt-molybdenum weldable heat resisting alloy sheet and strip	Black, brown, green, brown
DTD5062	Forty ton molybdenum-boron steel sheet and strip suitable for welding	Blue, brown, blue
DTD5066	12 per cent chromium heat resisting steel for bolts -studs-set screws and nuts	
	Bars for machining (heat treated)	Yellow, blue, yellow
	Bars for forging (softened)	White, black, white
DTD5070	Aluminium-coated aluminium-copper- magnesium-nickel-iron sheet and strip (solution treated and precipitation treated)	Black, red, brown
DTD5073	Commercially pure titanium tubes (suitable for pipe lines and high pressure etc.)	Black, red, blue
DTD5076	High expansion heat resisting steel for the manufacture of bolts, studs, set screws and nuts vacuum melted-limiting ruling section 20 mm	
	Annealed cold reduced and solution treated	Yellow, black, green, yellow
	Annealed cold reduced and finally heat treated	Yellow, blue, brown, yellow
	Annealed and cold reduced	Brown, red, brown
DTD5081	Magnesium-zinc-zirconium alloy plate	Brown, red, brown
DTD5082	75-ton, 1 per cent chromium-molybdenum steel :	
	Softened condition	Brown, white, green
	Softened and cold rolled	Blue, white, blue
DTD5084	Aluminium-copper magnesium-nickel-iron alloy bars and billets for forging	Brown, blue, red
DTD5086	17-7 chromium-nickel precipitation hardening stainless steel, rod wire and springs	
	Rod-solution annealed	Yellow, black, blue, yellow
	Wire-cold drawn	White, yellow, brown, yellow
DTD5091	Magnesium-zinc-manganese alloy sheet and strip (soft)	Green, yellow, green, yellow
DTD5092	Soft iron for dynamo-electric machines (Type A) :	
	As manufactured	Green, black, yellow
	Heat treated	Black, blue, white
DTD5094	Aluminium-zinc-magnesium-copper manganese alloy bars and billets for forging	Yellow, white, yellow
DTD5100	Aluminium coated aluminium-copper-magnesium manganese alloy plate	Brown, red, brown, red
DTD5010	Magnesium-zinc-manganese alloy sheet and strip (Half hard)	Blue, white, blue, white
DTD5102	Soft iron for dynamo-electric machines (Type B) :	
	As manufactured	Black, yellow, white
	Heat treated	White, red, yellow
DTD5104	Aluminium-zinc-magnesium-copper manganese alloy bars and billets for forging	Yellow, white, yellow
DTD5110	Aluminium-alloy coated plate of aluminium-zinc-magnesium-copper-chromium alloy (solution treated, controlled stretched and precipitation treated)	Black, blue, red, blue
DTD5112	80-ton, 1 per cent chromium-molybdenum steel sheet :	
	Hot-rolled	Blue, red, yellow
	Cold-rolled	Brown, blue, brown
DTD5114	Bars and extruded section of aluminium-zinc-magnesium-copper-chromium alloy (solution treated and precipitation treated)	Black, blue, red, black

DTD5122	75-ton, 1 per cent chromium-molybdenum steel :	
	Softened condition	Brown, white
DTD5124	Bars and extruded section of aluminium-zinc-magnesium-copper-chromium alloy (solution treated and precipitation treated)	Black, brown, black, blue
	Solution treated	Black, red, blue, brown
DTD5132	80-ton 1% chromium-molybdenum steel tubes (as drawn and tempered condition)	Black, blue, yellow, blue
DTD5142	80-ton 1 per cent chromium-molybdenum steel tubes	
	Hot-rolled	Yellow, black, blue, yellow
DTD5152	1 per cent chromium-molybdenum steel wire	White, blue, yellow, white
DTD5192	Nickel-chromium-molybdenum-vanadium steel softened	Green, white, yellow, green
DTD5202	0.5 per cent molybdenum-boron steel - normalized	Green, red, yellow, green
DTD5212	Maraging steel 18 per cent nickel-cobalt - molybdenum (double vacuum melted) solution treated :	
	Bars for machining	Green, red, black, red
	Bars for forging	Green, brown, white, green
DTD5222	5 per cent chromium-molybdenum-vanadium steel suitable for forged bolts (vacuum re-melted)	Red, brown, green red
DTD5232	Maraging steel 18 per cent nickel-cobalt-molybdenum (vacuum re-melted) solution treated	
	Bars for machining	Blue, green, yellow, green
	As forged bars for forging	Blue, green, brown, yellow
DTD5273	Bars for machining or commercially pure titanium	
	Annealed condition	Black, blue, red, yellow
DTD5283	Forging stock of commercially pure titanium bars and billets for forging	Black, brown, yellow, red
DTD5303	Bar and section for machining of titanium-aluminium-vanadium alloy. Annealed condition	Black, green, brown, red
DTD5313	Forging stock of titanium-aluminium-vanadium alloy bars and billets for forging	Black, brown, white, yellow

AMERICAN SPECIFICATION
SECTION II

NUMBERS	**DESCRIPTION**	**COLOUR**
AMS 4900F	Titanium sheet, strip and plate annealed 379 MPa yield strength	Black, green, blue, yellow
AMS 5572C	Steel tube, seamless, corrosion and heat resistant, 25 Cr - 20 Ni	White, blue, green, blue, white
AMS 5643	Steel bars (and forging) - corrosion resistant 17/4 P.H.	White, green, black, green, white
MIL-S-6758A	Steel - chromium molybdenum (4130) - bars and reforging stock (aircraft quality)	
	A and B condition (forged or rolled)	White, black, white, black, white
	C condition (annealed)	White, blue, black, blue, white
	F condition (hardened and tempered)	White, brown, blue, brown, white
MIL-S-7220A	Steel, corrosion resistant (18-8) bars, wire and forging stock (aircraft quality)	
	A condition (annealed)	White, green, white, green, white
	B condition (cold finished)	White, blue, yellow, blue, white
	C condition (hot rolled or forged)	White, blue, brown, blue, white
MIL-T-6736B	Steel - chromium molybdenum (4130) - tube, seamless and welded (aircraft quality)	
	A condition (annealed)	White, red, blue, red, white
	N condition (normalized)	White, green, red, green, white
	HT 125 condition	White, brown, green, brown, white
	HT 150 condition	White, black, red, black, white
	HT 185 condition	White, yellow, white, yellow, white

MIL-T-8504	Steel 18/8 corrosion resistant tube Annealed condition	Green, blue, black, blue, green
MIL-T-9047E	Titanium an titanium alloy bars, (forging) and forging stock composition 6 (6AL, 4V) Annealed condition	Black, blue, red, green
QQ-A-200/3D	Aluminium alloy bar, rod, section, tube and wire extruded, 2024. Bar and section - T351.	White, blue, brown, blue, white
QQ-A-200/8D	Aluminium alloy bar, rod, section, tube and wire extruded, 6061 Temper 6511 - as supplied.	Brown, red, green, red.
QQ-A-225/6D	Aluminium alloy bar, rod and wire, rolled, drawn, or cold finished, 2024. Wire and rod - T351	White, black, red, black, white
QQ-A-225/9D	Aluminium alloy bar, rod, wire, and special Section, rolled drawn or cold finished, 7075. Condition - T7351.	White, yellow, black, yellow, white
QQ-A-250/4E	Aluminium alloy 2024, plate and sheet Condition - 0	White, red, white, red, white
	Condition - T3 (as supplied)	White, green, brown, green, white
	Condition - T351	White, black, green, black, white
QQ-A-250/5F	Aluminium alloy Alclad 2024, plate and sheet Condition - T351	White, blue, white, blue, white
QQ-A-250/11E	Aluminium alloy 6061, plate and sheet Condition - Temper 0	White, brown, black, brown, white
	Condition - T4 (as supplied)	White, red, brown, red, white
	Condition - T6 (as supplied)	White, yellow, brown, yellow, white
QQ-B-673A/485	Naval brass : bar, rod, sections, strip, wire 1/2 hard	Blue, red, green, white
QQ-C-530	Copper - beryllium alloy bar, rod, and wire (copper alloy numbers 172 and 173) H condition (hot worked, or cold worked, Solution treated and worked hard)	Black, blue, white, blue
QQ-S-763	Steel bars, sections (and forgings) - corrosion resisting Type 440C - condition A (annealed)	Green, brown, green, brown, green
QQ-S-764B	Steel bar, corrosion resisting, free machining	
303 SE	Austenitic chromium-nickel-steel Condition A - cold finished	Brown, green, red, green, brown
QQSA-766C	Steel plates, sheets and strip, corrosion resisting	
301	Sheet - temper full hard (cold rolled)	Brown, green, brown, red

FRENCH SPECIFICATION
SECTION III

NUMBERS	DESCRIPTION	COLOUR
AIR 9050C	Aluminium alloy	
A-U4GI	Tube T4 condition	Black, blue, brown, black
AIR 9160B	Steel - corrosion resisting	
15CDV6	Low alloy steel, bar, sheet, tube Annealed condition	Brown, blue, green, blue, brown
	Hardened and tempered - 980/1130 MPa	White, black, blue, black, white
	Hardened and tempered - 1030/1180 MPa	White, black, brown, black, white
35NC6	Low alloy steel bar Annealed condition	Green, blue, black, blue, green
	Hardened and tempered - 880/1080 MPa	White, blue, green, blue, white
	Hardened and tempered - 1030/1180 MPa	White, blue, red, blue, white
AIR 9160C	Steel - corrosion resisting	
25CD45	Low alloy steel, bar, sheet, tube Hardened and tempered - 880/1080 MPa	Green, brown, white, brown, green

30CD12	3% Cr nitriding steel bar	
	Annealed condition	Blue, green, white, yellow
	Hardened and tempered - 880/1080 MPa	Green, blue, yellow, red
	Hardened and tempered - 1030/1180 MPa	Green, blue, white, red
35CD4	Low alloy steel bar	
	Annealed condition	White, yellow, red, yellow, white
30NCD16	Low alloy steel bar	
	Annealed condition	White, black, red, black, white
	Hardened and tempered - 1080/1230 MPa	Black, red, blue, brown
	Hardened and tempered - 1200/1370 MPa	Black, red, blue, yellow
Z100CD17	Rolled steel bar, sheet	
	Annealed condition	White, brown, white, brown, white

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APPENDIX III TO LAST CHAPTER
REVERSE COLOUR CODES

COLORS	SPECIFICATIONS
Black	L17, L36, L67, L116, T51, BS219-C, BS249, BS1432-C103-0, BS1453-A1, BS1453-C1, BS2874-CZ121 (3% pb) - M.
Blue	L16, BS219-A, BS251-CZ112, BS885 (annealed), BS2870-CZ108-H, BS2874-CZ112-M, BS2901-C7.
Brown	B11, BS219-D.
Green	L58, L121, S510, BS219-G, BS2870-CZ108-0, DTD197 (Section II), DTD412 (cast billets for forging).
Red	T2, BS219-M, BS1453-D2, BS2901-D2, BS2870-CZ108
1/2H.	
White	BS2901-NA33.
Yellow	B8, L86 (annealed and drawn), S1, BS219-B, BS1453-A3.
Violet	L86 (solution treated and naturally aged).
Black, blue	S125-A, BS219-95A, BS251-CZ112 (forging stock), BS378-70/30, BS1432-C103-1/2H, BS1453-A2, BS1453-
C5.	
	BS1470-SIC-0, BS1471-TIC-0, BS1475-GIA-M, BS2872-CZ112-M, BS2901-GIA.
Black, brown	L72, S126A, BS1453-A7.
Black, green	S127, BS219-5S, BS1453-GIB, BS1471-HT9-0, BS1475-GIB-M, BS2870-C101-1/2H, BS2901-GIB, DTD319, DTD5070 (annealed).
Black, red	L34, T55, BS219-F, BS1453-A4, BS1453-C4.
Black, white	S93B, BS1453-A5, BS1453-C2.
Black, yellow	S127 B & D, BS219-IS, BS1453-A6, BS1453-C6, BS1453-NG2, BS1475-NG2-M.
Blue, brown	S128A, T59, BS1470-HS15-TB, BS1471-HT15-TB, BS1474-HE15-TB, BS1475-HG15-TB, BS2870-CZ107-H.
Blue, green	L109, S70A, BS219-AP, BS1453-NG5, BS1475-NG5-M, BS2901-C8, BS2901-NG5, DTD477.
Blue, red	L54, S28, BS885 (as drawn), BS1432-C101 (medium hard), BS1432-C102 (medium hard), BS1433 (medium hard), BS1453-NG6, BS1470-NS5-H4, BS1475-NG6-M, BS2901-C9, BS2901-NG6, DTD10.
Blue, white	B21, BS384
Blue, yellow	S21, T26 (Section II), BS219-KP, BS2870-C105-M/O, BS2901-C10.
Brown, green	S93A, BS219-J.
Brown, red	BS219, BS1470-SIC-H8
Brown, white	L128, DTD5122 (Softened).
Brown, yellow	S14, T50.
Green, red	S136, BS1453-NG21, BS1475-NG21-M, BS2901-C11, BS2901-NG21, BS2870-CZ107-0.
Green, white	L44, S107, BS2901-C12, DTD214, DTD5005.
Green, yellow	BS219-W, BS1453-DI, BS1470-NS3-M, BS2901-DI, BS2901-C13.
Red, white	L504, L505, S93B, T60.
Red, yellow	T26 (Section III), BS1470-HC15-TF, BS2901-C16,
White, yellow	BS2870-CZ106-H
Black, blue, black	L90 (Solution treated and precipitation treated), S116, BS374 (Class I), BS2871-C107-M, BS2874-CZ109-M, BS2901-A15, DTD297 (Section II).
Black, blue, brown	T72, BS409 (as rolled), BS1470-SIA-H8, BS2874-CZ123 M, DTD5016, BS2870-CZ112-M.
Black, blue, green	S105 (Type I), S112, T58.
Black, blue, red	S105 (Type), S125 B and D, BS1400-LB1, BS2870-C101-0, BS2871-C107-0, DTD118, DTD142, DTD737.

Black, blue, white	L503, BS1432-C103-H, BS3076-NA13 (hot rolled), DTD164, DTD324B, DTD5070-W, DTD5092 (heat treated).
Black, blue, yellow	S105 (Type3), S113, BS2870-CB101-W, DTD372B (solution treated, straightened and naturally aged).
Black, brown, black	S119 (hardened and tempered), T35, BS407-PB103-1/2H, BS1453-A32, BS1470-HS30-0, BS2870-PB103-1/2H, BS2874-CZ122-H, BS2901-A32
Black, brown, blue	T45, BS1453-A33, BS1470-HS30-TB, BS1474-EIC-M, BS2857 (Class A), BS2901-A33.
Black, brown, green	S114 B & D, BS1470-HS30-TF, DTD297 (Section III), DTD734.
Black, brown, red	S126 B and D, S529, BS407-PB102-0, BS2870_PB102-0.
Black, brown, white	BS2870-CB101-W (1/4H), BS2874-CZ114-M, DTD203.
Black, brown, yellow	T57, BS1471-HT30-TF, BS2871-CZ126-0, DTD5074-W.
Black, green, black	S139A, BS219-H, BS374 (Class 2), BS885 (AL-BRASS, annealed), BS1400-PB2, BS1472-NF8-M, BS1474-NE8-M, BS2901-A16,
Black, green, blue	L73, S95A, S511, BS407-PB101-1/4, BS2870-PB101-1/4H, BS2901-A19.
Black, green, brown	S91A, BS1470-SIB-H4, BS2874-CA103-M, BS2901-A30.
Black, green, red	S95B, S513 (softened), T45 (annealed), BS659-C106-M, BS1432-C101-H, BS1432-C102-H, BS1433 (hard), BS1470-SIB-0, BS1471-TIB-0, BS1472-FIB-M, BS1474-EIB-M, BS2901-A31.
Black, green, white	S91B, BS1001, BS2870-CB101-W(1/2H), BS2871-C106-0, DTD5044 (annealed).
Black, green, yellow	S139 B & D, T53, BS407-PB101-0 BS1471-SIB-H8, BS1475-HG9-0, BS2870-PB101-0.
Black, red, black	L87 (solution treated and precipitation treated), S96A, BS219-62S, BS374 (Class 3), BS1052 (tinned), BS1400-PB1, DTD604.
Black, red, blue	L59, S96B, BS407-PB102-1/4H, BS659-C107-M, BS2870-PB102-1/4H, BS2901-A34, DTD192, DTD5073.
Black, red, brown	BS2901-308-S92, BS3076-NA13 (cold drawn), DTD5070
Black, red, green	S135 B and D, S530, BS409 (annealed), BS2870-CZ112-0, BS2871-C106-M, BS2901-308-S96, BS3076-NA13 (cold drawn and annealed).
Black, red, white	L93 (solution treated and controlled stretched), BS1473-NR6 (annealed and drawn), DTD200, DTD720.
Black, red, yellow	S148, S528, T73, BS2870-C101-H, DTD5030.
Black, white, black	BS407-PB103-H, BS1400-PB3, BS2870-PB103-H, BS2901-A17.
Black, white, blue	L501, S132 (black and bright), BS407-PB101-EH, BS2870-PB101-EH, BS2901-308-S93.
Black, white, brown	BS1473-NB6-H4, BS1475-NG6-H4, DTD189, DTD5023.
Black, white, green	L93 (solution treated, controlled stretched, precipitation treated), L103, S97A, DTD204 (Section II and III).
Black, white, red	L104, S97B, BS1475-NG6-H8, DTD268.
Black, white, yellow	L113 (solution treated, flattened, precipitation treated), S119 (softened), BS1453-347-S96, BS2901-347-S96.
Black, yellow, black	L65 (solution treated and precipitation treated), BS374 (Class 4).
Black, yellow, blue	S117 (bars for machining), S531, BS1453-NG3, BS1470-SIC-H6, BS1475-NG3-M, BS2870-C102-0, BS2901-NG3.
Black, yellow, brown	S80A, BS1470-SIC-H2, BS1474-H E20-TB, BS2870-C102-1/2H.
Black, yellow, green	BS1470-SIC-H4.
Black, yellow, red	S61A, BS2870-C102-H, BS4300/5-TF, DTD97, DTD498 (bars and billets for forging).
Black, yellow, white	BS2870-CB101-W(H), DTD197 (Section III), DTD5051, DTD5102 (as manufactured).
Blue, black, blue	S147, BS219-T, BS252-CZ113-M, BS407-PB102-H, BS1470-NS3-0, BS1473-HR30 (annealed and drawn), BS2870-PB102-H.
Blue, black, brown	115 (solution treated, controlled stretched, precipitation treated), BS2786.

Blue, black, green	L85 (bars for machining and extruded sections solution treated but not precipitation treated), S141 B and D, S102, BS1453-C2B, BS1470-NS3H2, BS1471-HT9-TB, BS2870-C103-0.
Blue, black, red	L94 (solution treated and precipitation treated, not controlled stretched), BS1845-ALI, BS2870-CZ107-EH.
Blue, black, white	L94 (solution treated), S140a, BS407-PB101-H, BS2870-PB101-H, BS3075-NA13 (cold drawn), DTD265.
Blue, black, yellow	S513 (hardened and tempered), BS1471-HT30-TB, BS1474-HE20-TF.
Blue, brown blue	L81, S98B, BS219-L, BS980-CDS-1, BS1400-G2, BS1453-C2C, BS1473-HB30 (annealed and drawn), BS1473-HR30 (annealed and drawn), BS2870-C103-1/2H, BS2871-C101-0, DTD5062.
Blue, brown, green	BS2871-C101-M, BS2872-CZ109-M.
Blue, brown, red	S106A, BS980-CDS-3, BS1471-HT15-TF, BS1474-HE15-TF, BS1475-HG15-TF, BS2874-CA104-M, BS3075-CA13 (cold drawn and annealed), DTD5040.
Blue, brown, white	BS980-CDS3A, BS2901-316-S93, DTD5061.
Blue, brown, yellow	L94 (as rolled), S99 (bars and billets, hardened and tempered, S524, BS980-CDS-4, BS1472-HF30-M, BS2901-317-S96.
Blue, green, blue	NS1400-G1, BS1453-316-S96, BS1470-NS3-H6, BS4-1474-H9-TF, BS1475-HG9-TF, BS2901-316-S96.
Blue, green, brown	S99 (softened), BS980-CDS-5, BS1453-C3, BS1470-NS5-H2, BS1471-NT5-H4, BS1474-HE30-M, BS2870-C103-H.
Blue, green, red	L89 (solution treated and aged at room temperature) S117 (bars and billets for forging), S517 (hardened and tempered), BS980-CDS-6, BS1475-HG9-TD, BS2901-316-S92
Blue, green, white	S131A, BS1474-HE9-TB, BS1475-HG9-TB, BS2901-C12Fe, DTD5071.
Blue, green, yellow	S98A, S525, BS980-CDS-7, BS1470-NS5-0, BS1471-NT5-0, BS1472-NF5-M, BS1473-NR5-M, BS1474-NE5-M, BS2874-C102-1/2H.
Blue, red, blue	S131B and D, BS219-N, BS980-CDS-8, BS2901-D8.
Blue, red, brown	L94 (annealed).
Blue, red, green	S79A, BS2870-CZ107-1/2H, BS2901-C22, DTD498 (bars for machinining), DTD5074-WP.
Blue, red, white	L110, BS980-CDS-9, BS1453-318-S96, BS2870-C104-M/O, BS2901-318-S96, DTD196.
Blue, red, yellow	BS980-CDS-10, BS2870-C104-1/2H, DTD5112 (hot rolled).
Blue, white, blue	BS1453-309-S94, BS2901, 309-S94, BS3074-NA11, BS3075-NA11 (cold drawn, and annealed), DTD627, DTD5082 (softened and cold rolled).
Blue, white, brown	S145 B and D, BS980-CDS-11.
Blue, white, green	S140 B and D, BS1453-311-S94, BS2901-311-S94, BS2870-C104-H, BS3074-NA12.
Blue, white, red	L96 (solution treated and precipitation treated, not controlled stretched), S120, BS2857 (Class B), BS2874-CZ124-1/2H.
Blue, white, yellow	BS1453-310-S94, BS2901-S94, BS3074-NA13.
Blue, yellow, blue	L61, L85 (Solution treated and precipitation treated), BS980-CDS-12, DTD326.
Blue, yellow, brown	L96 (annealed), BS407-PB102-NG52, BS3074-NA14, BS3076-NA14.
Blue, yellow, green	L105, S532, T64, BS1470-NS3-H8, BS2901-310-S98, DTD5074 (softened).
Blue, yellow, red	HR203 (softened and descaled), BS1453-313-S94, BS1470-NS3-H4, BS2901-313-S94, DTD167.
Blue, yellow, white	L95 (solution treated), S144A, BS980-CDS-13, BS1824-NS104 (extra hard), DTD5054 (annealed)
Brown, black, brown	S141A, BS219-96S, BS2870-C105-1/2H, DTD372B (quenched at die, straightened and aged at room temperature).
Brown, black, green	S146, BS1470-NS4-0, BS1471-NT4-0, BS1472-NF4-M, BS1474-NE4-M, BS1475-NG4-0.
Brown, black, red	S80 B and D, S533, T70, BS1471-NT4-H4, BS1474-HE30-TB, BS2870-C105-H.

Brown, black, white	S143, T61, DTD267.
Brown, black, yellow	BS1474-HE30-TF.
Brown, blue, brown	S128 B and D, BS885 (al brass, as drawn), BS980-CDS-14 BS1475-G1A-H8, DT5112 (cold drawn).
Brown, blue, green	S149, BS980-CDS-15, BS1471-HT9-TF, BS1475-G1A-0.
Brown, blue, red	S129 B and D, S516 (hardened and tempered or cold rolled and tempered), BS407-PB103-1/4H, BS980-CDS-16, BS1400-LPB1, BS1470-S1A-H4, BS2870-PB103-1/2H, DTD731, DTD745, DTD5084.
Brown, blue, white	L96 (solution treated), BS407-PB102-EH, BS980-CDS-17, BS2870-PB102-EH, DTD717.
Brown, blue, yellow	S535 (hardened and tempered). BS407-PB101-1.2H, BS980-CDS-18, BS1400-AB2, BS1470-S1A-0, BS2870-PB101-1/2H.
Brown, green, brown	L95 (solution treated, controlled stretched and precipitation treated), BS1475-G1B-H8.
Brown, green, red	S130B and D, BS980-CDS-19, BS1471-HT20-TB, BS3073-NA11, BS3075-NA11.
Brown, green, white	BS407-PB103-EH, BS980-CDS-20, BS2870-PB103-EH.
Brown, green, yellow	S92A, BS980-ERW-1, BS1475-G1B-0.
Brown, red, brown	S133, BS219-R, BS980-ERW-2, DTD5040, DTD5081.
Brown, red, green	L70 (as rolled), L77, L106, S106B, S534 (hardened and tempered), BS407-PB103-0, BS980-ERW-3, BS2870-PB103-0.
Brown, green, white	L511, BS1473, NR5-0, DTD723 (softened).
Brown, white, yellow	BS1472-HF15-M.
Brown, white, brown	L96 (as rolled), BS980-CEW-1, BS3076-NA13 (hot rolled and annealed).
Brown, white, green	BS980-CEW-2, DTD5082 (softened).
Brown, white, red	S134, BS980-CEW-3.
Brown, white, yellow	BS1472-HF9-M, BS1474-HE9-M.
Brown, yellow, brown	S15A, BS980, CEW-4, BS14732-NR5 (annealed and drawn), BS1475-NG61-M, BS2870-CZ108-EH.
Brown, yellow, green	L72 (as rolled), L107, S124 (softened), BS1473-HB15-OD, BS1473-HR15-OD, DTD713 (softened),
Brown, yellow, red	L72 (annealed), S61B and D, T63.
Brown, yellow, white	L90 (annealed), DTD161.
Green, black, green	L90, BS219-V, BS1387-C, BS1400-LG1, BS1453-B1, BS1471-HT20-TF, BS2901-D4, DTD607.
Green, black, red	L80, L85 (bars and billets for forging)), S142 B and D, BS2870-C106-M/O.
Green, black, white	HR2 (forging stock).
Green, black, yellow	L70 (solution treated and aged at room, temperature), L114 (solution treated , drawn, precipitation treated), DTD5024, DTD5092 (as manufactured).
Green, blue, green	S192, S534 (softened), BS713 (annealed), BS1434, BS1453-B2, BS2901-D5.
Green, blue, white	S516 (softened), BS1824-T2-3/4H, L502.
Green, blue, yellow	T65, BS2870-C106-1/2H, BS2871-C106-1/2H, DTD5010, DTD5014, DTD5052.
Green, brown, green	L88 (solution treated and precipitation treated), L102, S143B and D, S535 (solution), BS713-1/2H, BS1400-LG2.
Green, brown, red	S144B and D, BS1400-LB3, BS1473-NR6-0, BS1475-NG6-0.
Green, brown white	T66, BS1474-NE8-0, BS2870-C106-H.
Green, brown, yellow	BS713 (hard), BS4360-43A.
Green, red, green	L98 (solution treated and aged at room temperature, not controlled stretched), BS1453-B3, BS2901-D6, DTD504.
Green, red, white	L98 (annealed), S514 (softened), BS407-PB102-SH, BS2870-PB103-SH.
Green, red, yellow,	L83 (bars and billets for forging), S82, DTD246.
Green, white, green	S142A, T71, BS1400-LG3.
Green, white, red	BS1475-HG20-TH.
Green, white, yellow	L98 (as rolled), S145A.

Green, yellow, green	S537, BS1407, BS2870-C107-M/0, BS2874-PB102-M, BS2901-D7.
Green, yellow, red	L70 (annealed), S518 (softened), 67.
Green, yellow, white	L88 (annealed), S518 (hardened and tempered , or as cold rolled and tempered).
Red, black, red	l37 (Section II and III), L63, BS1432-C101 (annealed), BS1432-C102 (annealed), BS1433 (annealed), BS2901-C18, DTD5019.
Red, black, white	L25, L108, S130A, BS407-PB103-ESH, BS2870-PB103-ESH, BS2901-NA40.
Red, black, yellow	L83 (bars for machining and extruded section), BS980-CDS-2, BS1470-HC15-TB, BS2901-NA41.
Red, blue, red	BS14720HF12-M.
Red, blue, white	
Red, blue, yellow	L83 (bars for machining and extruded section soluttion treated but not precipitation treated), S515, T62
Red, brown, red	L84 (bars for machining and extruded sections), S138, BS2873-CZ108-H, BS2901-NA42.
Red, brown, white	S536, BS1475-NG3-0, DTD5041.
Red, brown, yellow	S538 (softened), DTD5046 (softened).
Red, green, red	L65 (bars for machining and extruded section solution treated but not precipitation treated), T68, BS1470-S1-0, DTD1487 (Section II).
Red, green, white	S79B, DTD253.
Red, green, yellow	L508, L509, S527, BS1470-S1-H4, BS1475-NG3-H8.
Red , white, red	L97 (solution treated, controlled, stretched, aged at room temperature), L111, S114A, BS1400-LB2, BS2901-C20, DTD232.
Red, white, yellow	DTD237.
Red, yellow, red	S111A, S526, BS1470-S1-H8, BS2870-CZ107-1/4H, BS2901-C21, DTD740.
Red, yellow, white	L89 (annealed), BS2901-NG61, DTD5013.
White, black, white	S517 (softened), BS2901NA35, DTD5066 (softened).
White, black, yellow	L506, BS2870-C107-1/2H, DTD271.
White, blue, white	D283, DTD5004 (bars for forging).
White, blue, yellow	S70B, T75, BS2901-NA36.
White, brown, white	L93 (solution treated, not controlled stretched), L512, S137, BS2870-C107-H.
White, brown, yellow	L56.
White, green, white	L112, BS2901-NA37.
White, green, yellow	BS1977-C101 (annealed), BS2870-CZ106-0, DTD150A (bars for forging).
White, red, white	L507, S124 (bright and black bras for machining, hardened and tempered), BS2870-CZ106-1/4H.
White, yellow, white	BS1977-C102 (annealed), DTD328, DTD5042.
Yellow, black, yellow	S62B, T69, BS1470-NS8-0, BS1473-NR6-M, BS1977-C102 (as drawn) , bs2870-CZ108-1/4H.
Yellow, blue, yellow	BS1977-C103-0, BS2901-NA2, DTD5066 (bars for machining, heat treated).
Yellow, brown, yellow	S15B and D, BS1470-NS8-H2, DTD5044.
Yellow, green, yellow	BS1977-C103 (as drawn), BS2901-NA34.
Yellow, red, yellow	S62A, T74, BS2901-NA38.
Yellow, white, yellow	BS2901-NA39, DTD503, DTD5094 (bars and billets for forging), DTD5104 (bars and billets for forging).
Black, blue, black, blue	L150.
Black, blue, black, brown	L115 (solution treated), BS970-080-M30-P, BS2056-En 56A (drawn), BS3601-BW22.
Black, blue, black, green	BS2056- En 56B (drawn).
Black, blue, black, red	BS2056- En 56C (drawn), BS2870-NS106-0, BS2871-C102-M.
Black, blue, black, white	BS2056- En 57 (drawn), BS2870-CN104-0.
Black, blue, black, yellow	BS1400-PB4, BS1471-TIC-H4, BS2056-En 56 D (drawn), BS2871-CZ108-0.
Black, blue, brown, black,	HR4 (forging stock), AIR9050C-A-U4GI-T4.
Black, blue, brown, blue	L117, L160, HR4 (FHT bar and section for machining), BS1775-HFW11.

Black, blue, brown, green	BS970-080-M30-Q, BS1775-HFW-13, -BS2870-CN105-0 .
Black, blue, brown, red	BS1775-HFW-20, BS2871-CZ108-TA.
Black, blue, brown, white	BS970-785-M19-Q, BS1449-302-S25 (annealed), BS1775-HFW-16.
Black, blue, brown, yellow	BS1449-321-S12 (soft), BS1775-HFW-23.
Black, blue, green, black	L118, HR404 (cold worked and softened), BS2871-CZ108-M.
Black, blue, green, blue	BS1449-304-S16 (softened), BS2870-CN106-0, BS2901-A18, DTD5017 (bars and billets for forging).
Black, blue, green, brown	BS1775-ERW-23.
Black, blue green, red	BS1449-302-S25 (Cold rolled), BS2871-CZ126-M.
Black, blue, green, white	BS970-835-M30-Z, BS1470-NS3-M.
Black, blue, green, yellow	TA57, BS2872-CZ114-M.
Black, blue, red, black	BS970-080-M40-R, DTD5114.
Black, blue, red, blue	BS2871-C102-0, DTD5017 (bars for machining), DTD5110 (solution treated, controlled stretched and precipitation treated).
Black, blue, red, brown	BS2870-CN107-0.
Black, blue, red, green	BS2870-NS10601/2H, MIL-T-9047E (6AL, 4V) (annealed).
Black, blue, red, white	
Black, blue, white, yellow	DTD5273 (annealed).
Black, blue, white, black	L151, BS2871-C103-M.
Black, blue, white, blue	QQ-C530-H.
Black, blue, white, brown	TA56, BS970-212-M36-R.
Black, blue, white, green	BS1052 (annealed), BS2870-CS101-M.
Black, blue, white, red	BS970-080-M40 (normalised), BS1775-CEW-23.
Black, blue, white, yellow	BS1449-302-S17 (annealed).
Black, blue, yellow, black	S205 (wire), BS2870-NS103-1/2H.
Black, blue, yellow, blue	TA10, DTD5132 (as drawn and tempered).
Black, blue, yellow, brown	
Black, blue, yellow, green	TA58
Black, blue, yellow, red	BS1473-HB20-TH, BS2871-CZ126-TA.
Black, blue, yellow, white	BS2872-CZ114-0.
Black, brown, black, blue	BS2056-En58B (cold drawn), BS2871-C103-0, DTD5124 (solution treated and precipitation treated).
Black, brown, black, brown	BS2056-En58C (cold drawn), BS3601-ERW-22, DTD5037.
Black, brown, black, green	TA2, BS2056-En58D (cold drawn).
Black, brown, black, red	BS2056-En58E (cold drawn), BS3601-ERW-27.
Black, brown, black, white	L152, BS2056-En58H (cold drawn), BS2870-NS103-H.
Black, brown, black, yellow	BS2056-En58G (cold drawn).
Black, brown, blue, brown	L153, BS2871-C107-1/2H.
Black, brown, blue, green	BS970-526-M60-V
Black, brown, blue, red	BS970-150-M19-R
Black, brown, blue, white	BS970-150-M28-R
Black, brown, blue, yellow	BS970-150-M36-R, BS2870-NS103-EH.
Black, brown, green, black	BS970-150-M36-S, BS2871-CZ110-0.
Black, brown, green, blue	BS1775-ERW-11
Black, brown, green, brown	DTD5057.
Black, brown, green, red	BS1775-ERW-20
Black, brown, green, white	BS1775-ERW-16
Black, brown, green, yellow	BS970-120-M36-R, BS2870-NS103-0.
Black, brown, red, black	BS1775-CEW-28, BS2874-CZ114-H.
Black, brown, red, blue	BS1775-CEW-11.
Black, brown, red, brown	HR207, BS1775-CEW-24, BS2871-CZ110-TA.
Black, brown, red, green	BS970-120-M36-S.
Black, brown, red, white	BS1775-CEW-16, BS2870-NS104-1/2H.
Black, brown, red, yellow	BS970-605-M36-S.
Black, brown, white, black	BS2871-CZ110-M.
Black, brown, white, blue	BS970-605-M36-T.
Black, brown, white, brown	
Black, brown, white, green	BS970-605-M36-U.
Black, brown, white, red	BS970-605-M36-V.
Black, brown, white, yellow	BS2870-NS104-H, DTD5313.

Black, brown, yellow, black	S205, BS2871-CZ119-M.
Black, brown, yellow, blue	BS970-225-M44-S.
Black, brown, yellow, brown	
Black, brown, yellow, green	HR5 (softened section for forming).
Black, brown, yellow, red	BS2870-NS104-EH, DTD5283.
Black, brown, yellow, white	BS970-070-M20-P.
Black, green, black, blue	BS2056-En 58J (cold drawn).
Black, green, black, brown	BS1554-En56D (drawn).
Black, green, black, green	BS2056-En58F (cold drawn), BS3601-HLW-26.
Black, green, black, red	L156 (as rolled), BS2871-CZ119-0.
Black, green, black, white	
Black, green, black, yellow	HR204 (softened and descaled).
Black, green, blue, brown	
Black, green, blue, green	BS970-120-M28 (cold drawn from hot rolled), BS2871-CN102-M.
Black, green, blue, red	HR5 (annealed bar fore machining).
Black, green, blue, white	BS970-230-M07 (hot rolled).
Black, green, blue, yellow	BS970-120-M19-R, AMS4900F.
Black, green, brown, blue	BS970-225-M44-T.
Black, green, brown, green	L156-T4, BS2871-CN102-0.
Black, green, brown, red	DTD5303 (annealed).
Black, green, brown, white	HR5 (forging stock).
Black, green, brown, yellow	BS970-605-M30-S.
Black, green, red, black	BS2898-EIE-M.
Black, green, red, blue	L156-T42.
Black, green, red, brown	BS970-605-M30-T.
Black, green, red, green	BS1471-TIB-H8, BS2871-CN107-M.
Black, green, red, white	BS970-605-M30-U.
Black, green, red, yellow	BS970-605-M30-V.
Black, green, white, black	BS970-608-M38-S, BS2870-CZ101-H, BS2871-CN107-0.
Black, green, white, blue	BS970-608-M38-T.
Black, green, white, brown	BS970-608-M38-U, BS2872-CZ115-M.
Black, green, white, green	BS2870-NS106-H.
Black, green, white, red	BS970-608-M38-V, BS2873-CZ106-1/2H.
Black, green, white, yellow	BS970-530-M40-S.
Black, green, yellow, black	BS970-530-M40-T.
Black, green, yellow, blue	HR601 (cold worked and ground).
Black, green, yellow, brown	BS4360-50B.
Black, green, yellow, green	BS2874-CZ124-H.
Black, green, yellow, red	HR650 (fully heat treated and machined).
Black, green, yellow, white	DTD5032.
Black, red, black, blue	L157-T6, BS2872-CZ116-M.
Black, red, black, brown	
Black, red, black, green	BS3601-EFW-26.
Black, red, black, red	BS2874-CZ124-M, DTD5110 (solution treated and controlled stretched).
Black, red, black, white	BS970-526-M60-T.
Black, red, black, yellow	BS970-503-M40 (normalised), BS2872-CZ122-M.
Black, red, blue, brown	DTD124 (solution treated), AIR9160C-30NCD16 (hardened and tempered -1080/1230 MPa.)
Black, red, blue, green	HR650 (solution treated and machined).
Black, red, blue, red	BS2870-NS106-EH.
Black, red, blue, white	
Black, red, blue, yellow	BS1473-HB30-TF, BS2872-CZ123-M, AIR9160C-30NCD16 (hardened and tempered - 1220/1370 MPa.).
Black, red, brown, black	BS970-709-M40-S.
Black, red, brown, blue	
Black, red, brown, green	BS970-709-M40-T.
Black, red, brown, white	BS2870-CZ101-0.
Black, red, brown, red	BS970-709-M40-U.
Black, red, brown, yellow	BS970-709-M40-V, BS2870-NS107.
Black, red, green, blue	BS970-230-M07 (cold drawn).
Black, red, green, brown	L157-T62, BS3602-ERW-23.
Black, red, green, red	BS2870-CZ101-1/2H, BS3602-ERW-27.
Black, red, green, white	
Black, red, green, yellow	BS970-708-M40-S.
Black, red, white, black	BS970-708-M40-T, BS2872-CZ103-M.

Black, red, white, blue	BS970-708-M40-U.
Black, red, white, brown	
Black, red, white, green	
Black, red, white, red	L111 (solution treated).
Black, red, white, yellow	
Black, red, yellow, black	HR206 (softened and descaled), BS2874-C101-0.
Black, red, yellow, blue	BS970-817-M40-U.
Black, red, yellow, brown	BS970-817-M40-V, 2870-CZ102-0.
Black, red, yellow, green	BS970-817-M40-W.
Black, red, yellow, red	HR403 (cold worked and softened), BS2874-C103-H.
Black, red, yellow, white	BS970-817-M40-X.
Black, white, black, blue	HR240 (annealed and descaled), BS2872-CZ104-M.
Black, white, black, brown	BS970-212-M36-Q.
Black, white, black, green	BS2874-C106-M.
Black, white, black, red	BS2989 (Class 1B).
Black, white, black, white	BS2872 - CA106-M.
Black, white, black, yellow	HR402 (cold worked and softened), BS970-503-M40-Q, BS1473-RIB-H5.
Black, white, blue, brown	BS2874-C106-0.
Black, white, blue, green	BS970-817-M40-Z.
Black, white, blue, white	BS970-826-M31-U.
Black, white, blue, red	TAI, BS2872-NS101-M.
Black, white, blue, yellow	HR251 (solution treated and descaled), BS970-826-M31-V.
Black, white, brown, black	BS970-826-M31-W.
Black, white, brown, blue	BS2874-C109-M.
Black, white, brown, green	BS970-826-M31-X.
Black, white, brown, red	
Black, white, brown, white	HR501 (cold drawn).
Black, white, brown, yellow	BS970-826-M31-Z.
Black, white, green, blue	BS970-040-A12 (as rolled or forged), BS2872-CS101-M.
Black, white, green, brown	BS970-826-M40-V, BS2874-C109-0.
Black, white, green, red	BS970-826-040-W.
Black, white, green, white	BS2870-CZ102-H.
Black, white, green, yellow	BS970-826-M40-X, BS2874-C111-M.
Black, white, red, blue	HR502 (cold drawn and solution treated), BS2874-C111-0.
Black, white, red, brown	BS970-826-M40-Y.
Black, white, red, green	BS970-826-M40-Z.
Black, white, red, white	
Black, white, red, yellow	BS970-830-M31-U.
Black, white, yellow, black	L113 (solution treated), BS2870-CZ102-1/2H, BS2874-CZ103-M.
Black, white, yellow, blue	BS970-830-M31-V.
Black, white, yellow, brown	HR503 (cold drawn), BS970-830-M31-W.
Black, white, yellow, green	
Black, white, yellow, red	
Black, white, yellow, white	
Black, yellow, black, blue	BS2874-CZ104-M.
Black, yellow, black, brown	BS2870-CZ103-0.
Black, yellow, black, green	BS3601-SFW-26.
Black, yellow, black, red	BS2874-CZ106-M.
Black, yellow, black, white	BS2870-CZ103-1/2H.
Black, yellow, black, yellow	BS970-220-M07 (hot rolled).
Black, yellow, blue, brown	BS2874-CZ113-M.
Black, yellow, blue, green	
Black, yellow, blue, red	
Black, yellow, blue, white	BS2874-CZ116-M.
Black, yellow, blue, yellow	BS2870CZ103-H.

Black, yellow, brown, blue	BS2898-EIE-1/4H.
Black, yellow, brown, green	
Black, yellow, brown, red	BS2870-CZ110-M, BS2874-CZ119-M.
Black, yellow, brown, white	
Black, yellow, brown, yellow	BS1440-NS8-H4.
Black, yellow, green, blue	HR601 (cold worked, solution treated and ground or descaled), BS2874-CZ122-M.
Black, yellow, green, brown	
Black, yellow, green, red	
Black, yellow, green, white	BS2874-CZ106-M.
Black, yellow, green, yellow	BS1449 - En 2C/A, BS2870-CZ110-0.
Black, yellow, red, blue	BS2874-CA106-0.
Black, yellow, red, brown	
Black, yellow, red, green	
Black, yellow, red, white	HR650 (forging stock).
Black, yellow, red, yellow	
Black, yellow, white, blue	BS970-653-M31-T.
Black, yellow, white, brown	BS970-653-M31-U, BS2874-CS101-M.
Black, yellow, white, green	
Black, yellow, white, red	BS970-817-M40-T, BS2874-NS113-M.
Black, yellow, white, yellow	BS2870-CZ118-1/2H.
Blue, black, blue, brown	BS2874-CS101-0, BS3601-HFS-22.
Blue, black, blue, green	L164 (as rolled), BS1775-HFS-23.
Blue, black, blue, red	BS3601-HFS-27.
Blue, black, blue, white	
Blue, black, blue, yellow	BS3601-HFS-35.
Blue, black, brown, blue	L164-T4, BS1775-HFS11, BS2874-NS101-M.
Blue, black, brown, green	BS1775-HFS-13, BS2870-CZ118-H.
Blue, black, brown, red	BS1775-HFS-20
Blue, black, brown, white	BS1775-HFS-16.
Blue, black, brown, yellow	BS2870-CB101-0.
Blue, black, green, blue	
Blue, black, green, brown	BS2874-NS102-M.
Blue, black, green, red	L164-T42.
Blue, black, green, white	BS2870-CZ118-EH.
Blue, black, red, blue	BS2874-NS111-M.
Blue, black, red, brown	
Blue, black, red, green	BS2874-NS112-M.
Blue, black, red, white	
Blue, black, red, yellow	
Blue, black, white, blue	BS1775-OAW-11, BS2870-CZ119-H.
Blue, black, white, brown	
Blue, black, white, green	
Blue, black, white, red	
Blue, black, white, yellow	
Blue, black, yellow, blue	BS970-722-M24-T, BS2870-CZ119-1/2H.
Blue, black, yellow, brown	BS970-722-M24-U.
Blue, black, yellow, green	BS970-905-M31-S, BS1775-EFW-16.
Blue, black, yellow, red	
Blue, black, yellow, white	BS970-905-M39-S
Blue, brown, black, blue	BS970-905-M39-T.
Blue, brown, black, brown	BS2870-CZ119-EH.
Blue, brown, black, green	BS970-080-M50-S.

Blue, brown, black, red	BS1775-CDS-23.
Blue, brown, black, white	BS1449-CS17A.
Blue, brown, black, yellow	BS17750HLW-16.
Blue, brown, blue, brown	L168-T6 (3L100, Section 5), BS970-945-M38 (as rolled), BS1449 - En 58D (cold rolled), BS2870-CZ120-1/2H.
Blue, brown, blue, green	L165-T6, BS1449-En 58E (softened).
Blue, brown, blue, red	BS1449 - En 58E (cold rolled).
Blue, brown, blue, white	BS970-503-A37 (hardened and tempered), BS1449- En 58F (softened), BS2870-CZ120-H.
Blue, brown, blue, yellow	BS970-150-M19 (normalised), BS1449 - En 58F (cold rolled), BS1470-HS15-TF.
Blue, brown, green, blue	BS1449-CS17B, BS1775-CDS-11.
Blue, brown, green, brown	
Blue, brown, green, red	L165-T62, BS1775-CDS-20.
Blue, brown, green, white	BS1775-CDS-16.
Blue, brown, green, yellow	
Blue, brown, red, blue	BS2870-CZ120-EH.
Blue, brown, red, brown	
Blue, brown, red, green	BS1775-CDS-13.
Blue, brown, red, white	
Blue, brown, red, yellow	
Blue, brown, white, blue	
Blue, brown, white, brown	BS1775-CDS-24, BS2870-CZ123-M.
Blue, brown, white, green	
Blue, brown, white, red	
Blue, brown, white, yellow	BS1775-CDS-28.
Blue, brown, yellow, blue	
Blue, brown, yellow, brown	
Blue, brown, yellow, green	
Blue, brown, yellow, red	BS1775-CDS-35, BS2870-CZ125-0.
Blue, brown, yellow, white	
Blue, green, black, brown	BS1449-CS17C.
Blue, green, black, green	
Blue, green, black, red	
Blue, green, black, white	
Blue, green, black, yellow	BS970-945-M38S.
Blue, green, blue, black	BS1449 - En 58A (softened).
Blue, green, blue, brown	BS1449 - En 58G (softened).
Blue, green, blue, green	HRI (softened section for forming), BS1449 -EN 58G (cold rolled).
Blue, green, blue, red	BS1449-En 58H (softened).
Blue, green, blue, white	BS970-503-A42 (hardened and tempered), BS1449 - En58H (cold rolled).
Blue, green, blue, yellow	BS970-150-M19-Q, BS1449 - En 58J (softened).
Blue, green, brown, black	BS970-945-M38-T.
Blue, green, brown, green	BS2870-CN101-M.
Blue, green, brown, red	BS970-945-M38-U.
Blue, green, brown, white	BS970-945-M38-V.
Blue, green, brown, yellow	DTD5232 (bars for forging).
Blue, green, red, blue	BS1449-304-S12 (softened).
Blue, green, red, brown	HR2 (softened section for forming), BS2873-CZ108-1/2H.
Blue, green, red, green	
Blue, green, red, white	HR3 (heat-treated bar and section for machining), BS1449-HRI, BS1449-HRPI, BS1449-HR11, BS1449-HRPI11.
Blue, green, red, yellow	BS1449-HSI.
Blue, green, white, blue	HR3 (softened section for forming), BS1449-HR2, BS1449-HRP2, BS1449-HR12, BS1449-HRP12, BS2870-CN102-M.

Blue, green, white, brown	BS1449-NHRI12.
Blue, green, white, green	BS1449-HS2.
Blue, green, white, red	BS1449-CSI
Blue, green, white, yellow	AIR9160-30CD12 (annealed), BS1449-CS2.
Blue, green, yellow, blue	TA28, BS1449-HR2-VE.
Blue, green, yellow, brown	HR3 (forging stock), BS1449-CR2/GP.
Blue, green, yellow, green	BS1449-CR2/FF, DTD5232 (bars for machining).
Blue, green, yellow, red	HR6 (annealed bar and section for machining), BS1449-CR2/VE.
Blue, green, yellow, white	
Blue, red, black, brown	HR10 (solution treated bar and section for machining), BS1449-CRI/GP.
Blue, red, black, green	BS1449-CRI/FF.
Blue, red, black, red	BS1449-CRI/VE, BS2870-CN102-0.
Blue, red, black, white	
Blue, red, black, yellow	HR10 (softened section for forming).
Blue, red, blue, brown	BS1449 - En 58J (cold rolled).
Blue, red, blue, green	BS1449 - En 60 (softened).
Blue, red, blue, red	BS1449 - En 2A.
Blue, red, blue, white	HR6 (forging stock), BS1449 - En 61 (softened), BS1474-HE9-0.
Blue, red, blue, yellow	
Blue, red, brown, black	BS970-816-,40-T.
Blue, red, brown, blue	BS970-816-M40-U.
Blue, red, brown, green	BS970-816-M40-V.
Blue, red, brown, red	
Blue, red, brown, white	BS2870-CN103-0.
Blue, red, brown, yellow	BS970-640-M40-S.
Blue, red, green, black	BS970-640-M40-T.
Blue, red, green, blue	BS970-640-M40-U.
Blue, red, green, brown	HR10 (forging stock)
Blue, red, green, white	QQ-B-637A-485-1/2H.
Blue, red, green, yellow	
Blue, red, white, blue	BS2870-NS104-0.
Blue, red, white, brown	
Blue, red, white, green	BS1449-HR3, BS1449-FRP3, BS1449-HR13, BS1449-HRP13 BS2870-NS109-0.
Blue, red, white, red	BS1474-NE5-0.
Blue, red, white, yellow	HR11 (solution treated bar and section for machining), BS1449HR3/VE.
Blue, red, yellow, blue	BS1449-NHR13, BS2870-NS105-1/2H.
Blue, red, yellow, brown	HR11 (softened section for forming), BS1449-HS3.
Blue, red, yellow, green	BS2870-NS109-1/2H.
Blue, red, yellow, red	L513.
Blue, red, yellow, white	BS2874-CZ115-M (hot worked).
Blue, white, black, brown	BS1449-CS3, BS2870-NS105H.
Blue, white, black, green	
Blue, white, black, red	BS970-080-A27 (as rolled or forged), BS2870-NS109-H.
Blue, white, black, white	
Blue, white, black, yellow	BS970-080-A42 (as rolled or forged), BS2870-NS105-0.
Blue, white, blue, black	BS970-080-M40-Q.
Blue, white, blue, brown	BS970-150-M28 (normalised), BS1449-CR3-GP, BS3601-CDS22.
Blue, white, blue, green	BS970-150-M36-Q, BS1449-CR3-FF, BS2870-NS105-EH.
Blue, white, blue, red	BS970-120-M36-Q, BS1449-CR3-V3E, BS3601-CDS27.
Blue, white, blue, white	BS2870-NS109-EH, DTD5101.

Blue, white, blue, yellow	BS970-605-M36-R, BS3601-CDS35, BS2874-CZ115-M(C&SR).
Blue, white, brown, green	BS970-080-A32 (as rolled or forged).
Blue, white, brown, red	BS970-080-M40 (as rolled or forged).
Blue, white, brown, white	L515.
Blue, white, brown, yellow	BS970-605-M36 (as rolled).
Blue, white, green, brown	BS970-503-40 (as rolled).
Blue, white, green, red	BS970-608-M38 (as rolled), BS1449 - En 2B/B, BS2870-NS108-0.
Blue, white, green, white	BS1449-HR4, BS1449-HRP4, BS1449-HR14, BS1449-HRP14.
Blue, white, green, yellow	BS970-530-M40 (as rolled), BS1449-HR4-VE.
Blue, white, red, brown	BS970-835-M30 (as rolled), BS2870-NS108-1/2H.
Blue, white, red, green	BS1449-NHR14.
Blue, white, red, white	BS1449-HS4A.
Blue, white, red, yellow	BS970-080-M15 (as rolled or forged and bright bars), BS1449-CS4 (annealed).
Blue, white, yellow, blue	L514, BS1449-HS4B, BS2870-NS108-H.
Blue, white, yellow, brown	BS970-220-M07 (cold drawn), BS1449-CR40GP.
Blue, white, yellow, green	BS1449-CR4-FF.
Blue, white, yellow, red	BS1449-CR4-VE.
Blue, white, yellow, white	BS1449-CS4 (skin passed).
Blue, yellow, black, brown	BS1449-CS4-1/4H.
Blue, yellow, black, green	BS970-817-M40 (as rolled), BS1449-CS4-1/4H. BS2870-NS108-EH.
Blue, yellow, black, red	BS970-826-M31 (as rolled), BS1449-CS4-H.
Blue, yellow, black, white	BS970-080-A30 (as rolled or forged).
Blue, yellow, black, yellow	
Blue, yellow, blue, brown	BS970-216-M36-R.
Blue, yellow, blue, green	BS1449- En 2B.
Blue, yellow, blue, red	BS970-695-A32 (hardened and tempered).
Blue, yellow, blue, white	BS970-605-A37 (hardened and tempered).
Blue, yellow, blue, yellow	
Blue, yellow, brown, green	BS970-665-M17 (as rolled or forged and bright bars).
Blue, yellow, brown, red	
Blue, yellow, brown, white	BS2056 - En 58A (cold drawn).
Blue, yellow, brown, yellow	
Blue, yellow, green, brown	
Blue, yellow, green, red	
Blue, yellow, green, white	
Blue, yellow, green, yellow	
Blue, yellow, red, brown	
Blue, yellow, red, green	BS970-735-A50 (as rolled or forged).
Blue, yellow, red, white	
Blue, yellow, red, yellow	
Blue, yellow, white, brown	
Blue, yellow, white, green	BS970-080-M30 (as rolled or forged).
Blue, yellow, white, red	
Blue, yellow, white, yellow	HR202 (softened and descaled).
Brown, black, blue, brown	
Brown, black, blue, green	BS970-503-A37 (as rolled).
Brown, black, blue, red	BS970-503-A42 (as rolled).
Brown, black, blue, white	BS970-785-M19 (as rolled).
Brown, black, blue, yellow	BS970-150-M19 (as rolled or forged).
Brown, black, brown, green	L158 (as rolled), BS970-150-M28-Q.
Brown, black, brown, red	BS970-605-M30-R.
Brown, black, brown, white	BS970-606-M36-R.
Brown, black, brown, yellow	BS970-608-M38-R.
Brown, black, green, brown	BS970-240-M07 (cold drawn), BS1470-NS4-M, BS1475-NG4-M.

Brown, black, green, red	L158-T42, BS970-709-M40 (as rolled).
Brown, black, green, white	BS970-708-M40 (as rolled).
Brown, black, green, yellow	BS970-708-A37 (as rolled), BS1470-NS4-H3.
Brown, black, red, brown	L158-T4.
Brown, black, red, green	
Brown, black, red, white	
Brown, black, red, yellow	
Brown, black, white, brown	
Brown, black, white, green	BS970-905-M39 (as rolled).
Brown, black, white, red	BS970-080-M50 (as rolled or forged).
Brown, black, white, yellow	BS970-080-M50 (cold drawn from normalised).
Brown, black, yellow, brown	HR202 (solution treated).
Brown, black, yellow, green	
Brown, black, yellow, red	
Brown, black, yellow, white	
Brown, blue, black, green	BS970-080-M40 (cold drawn from hot rolled), BS2873-C101-0.
Brown, blue, black, red	BS970-080-A35 (as rolled or forged).
Brown, blue, black, white	BS970-080-A37 (as rolled or forged).
Brown, blue, black, yellow	BS970-080-A40 (as rolled or forged).
Brown, blue, brown, black	BS970-530-M40-R.
Brown, blue, brown, green	BS970-530-A32 (hardened and tempered), BS2873-C102-H.
Brown, blue, brown, red	L159-T6, BS970-530-A36 (hardened and tempered).
Brown, blue, brown, white	BS970-530-A40 (hardened and tempered).
Brown, blue, brown, yellow	BS970-709-M40-R, BS2873-C103.
Brown, blue, green, brown	BS2873-C106.
Brown, blue, green, red	BS970-708-A42 (as rolled).
Brown, blue, green, white	
Brown, blue, green, yellow	L159-T62.
Brown, blue, red, brown	
Brown, blue, red, green	BS2873-C108-H.
Brown, blue, red, white	
Brown, blue, red, yellow	BS970-534-A99 (as rolled).
Brown, blue, white, brown	BS2873-cz101-0.
Brown, blue, white, green	
Brown, blue, white, red	BS970-080-A47 (as rolled or forged).
Brown, blue, white, yellow	BS970-080-A52 (PART 1 - as rolled or forged), BS1475-HG9-M.
Brown, blue, yellow, brown	TA22, BS1470-SIA-M.
Brown, blue, yellow, green	BS2873-CZ101-1/2H.
Brown, blue, yellow, red	
Brown, blue, yellow, white	
Brown, green, black, green	HR11 (forging stock).
Brown, green, black, red	BS1554-En 56A (drawn).
Brown, green, black, white	BS1554-EN 56B (drawn), BS2873-CZ101-H.
Brown, green, black, yellow	BS970-212-M36 (as rolled or forged), BS1554-En 56C drawn).
Brown, green, blue, green	L168-T6511 (3L.100, Section 5), BS1470-NS4-H6.
Brown, green, blue, red	L168-T6510 (3L.100, Section 5), BS970-150-M28. (as rolled or forged), BS2873-CZ102-0.
Brown, green, blue, white	
Brown, green, blue, yellow	BS970-150-M36 (as rolled or forged).
Brown, green, brown, black	BS970-708-M40-R.

Brown, green, brown, blue	bs970-708-a37 (hardened and tempered).
Brown, green, brown, green	BS970-240-M07 (hot rolled), BS1474-HE9-TE, BS2873-CZ102-1/2H.
Brown, green, brown, red	QQ-S-766C-301 sheet (full hard).
Brown, green, brown, white	BS970-708-142 (hardened and tempered).
Brown, green, brown, yellow	TA21.
Brown, green, red, brown	L168-T6510 (3L.100, Section 6), BS2873-CZ102-H.
Brown, green, red, green	L168-T6511 (3L.100, Section 6), BS1471-HT102-H4.
Brown, green, red, white	
Brown, green, red, yellow	
Brown, green, white, brown	
Brown, green, white, green	BS2873-CZ103-0.
Brown, green, white, red	BS1449-En 44D (hot rolled or normalised).
Brown, green, white, yellow	
Brown, green, yellow, brown	
Brown, green, yellow, green	
Brown, green, yellow, red	
Brown, green, yellow, white	BS1449-HS20, BS2873-CZ103-1/2H.
Brown, red, black, green	BS970-212-M36 (cold drawn from hot rolled), BS2873CZ103-H.
Brown, red, black, red	
Brown, red, black, white	BS1449-CS30.
Brown, red, black, yellow	BS970-212-A37 (as rolled or forged), BS2873-CZ106-0.
Brown, red, blue, green	BS970-216-M36 (as rolled or forged), BS1449-CS40.
Brown, red, blue, red	BS1449-En 2D.
Brown, red, blue, white	BS970-120-M36 (as rolled or forged), BS2873-CZ106-H.
Brown, red, blue, yellow	
Brown, red, brown, green	TA11.
Brown, red, brown, red	DTD5100.
Brown, red, brown, white	
Brown, red, brown, yellow	BS970-635-M31-S, BS1449-CS50.
Brown, red, green, brown	BS970-635-M31 (as rolled).
Brown, red, green, red	BS2873-CZ107-0, Q-A-200/8D-T6511 (as supplied).
Brown, red, green, white	BS1449-HS40.
Brown, red, green, yellow	BS1449-CS60.
Brown, red, white, brown	BS3602-HFS-23.
Brown, red, white, green	BS970-080-A62 (as rolled or forged), BS2873-CZ107-1/2H.
Brown, red, white, red	BS1449-En 5, BS3602-HFS-27.
Brown, red, white, yellow	BS970-080-A67 (PART 1 - as rolled or forged), BS3602-HFS-35.
Brown, red, yellow, brown	BS1449-CS70, BS2873-CZ107-H.
Brown, red, yellow, green	
Brown, red, yellow, red	
Brown, red, yellow, white	
Brown, white, black, green	BS970-212-A42 (as rolled or forged), BS2873-CZ107-EH, BS3603-HFS-27-LT30.
Brown, white, black, red	BS3603-HFS-27-LT50.
Brown, white, black, white	BS3603-HFS-503-LT100.
Brown, white, black, yellow	BS1449-CS80 (annealed).
Brown, white, blue, brown	BS970-695-A32 (as rolled).
Brown, white, blue, green	BS970-605-A37 (as rolled).
Brown, white, blue, red	BS970-605-M30 (as rolled), BS2873-CZ108-0.
Brown, white, blue, white	DTD5056 (wire).
Brown, white, blue, yellow	BS970-606-M36 (as rolled).
Brown, white, brown, blue	BS970-826-M31-T.

Brown, white, brown, green	BS970-826-M40-U, BS1449-CS90.
Brown, white, brown, red	BS970-830-M31-T, BS2873-CZ108-EH.
Brown, white, brown, white	BS970-070-M20 (as rolled or normalised).
Brown, white, brown, yellow	
Brown, white, green, brown	BS970-826-M40 (as rolled).
Brown, white, green, red	
Brown, white, green, white	
Brown, white, green, yellow	BS970-830-M31 (as rolled), BS1449-CS100.
Brown, white, red, green	BS2873-CZ119-0.
Brown, white, red, white	
Brown, white, red, yellow	BS970-722-M24 (as rolled).
Brown, white, yellow, brown	BS1449-HS12B, BS2873-CZ119-1/2H.
Brown, white, yellow, green	
Brown, white, yellow, red	
Brown, white, yellow, white	
Brown, yellow, black, green	BS2873-CZ119-H, BS3604-HF-620.
Brown, yellow, black, red	
Brown, yellow, black, white	BS3604-HF-621, BS970-526-M60 (as rolled).
Brown, yellow, black, yellow	
Brown, yellow, blue, brown	BS970-530-A30 (as rolled).
Brown, yellow, blue, green	BS970-530-A32 (as rolled), BS1449-HS12C.
Brown, yellow, blue, red	BS970-530-A36 (as rolled), BS2873-CB101-W, BS3604-HF-622/27.
Brown, yellow, blue, white	BS970-530-A40 (as rolled).
Brown, yellow, blue, yellow	BS2873-CB101-W(H), BS3604-HF-622/35
Brown, yellow, brown, green	BS3604-HF-625.
Brown, yellow, brown, red	BS1449-En 2, BS2873-CB101.
Brown, yellow, brown, white	
Brown, yellow, brown, yellow	BS2873-NS103-0.
Brown, yellow, green, red	BS1449-HS22A.
Brown, yellow, green, white	
Brown, yellow, green, yellow	BS1449-HS12A.
Brown, yellow, red, brown	BS970-897-M39 (as rolled).
Brown, yellow, red, green	BS2873-NS103-1/2H, BS3604-HF-660.
Brown, yellow, red, white	BS970-905-M31 (as rolled).
Brown, yellow, red, yellow	BS1449-HS17B.
Brown, yellow, white, green	BS1449-HS17A, BS1474-HE30-0.
Brown, yellow, white, red	BS2873-NS103-H.
Brown, yellow, white, yellow	
Green, black, blue, green	BS2873-NS104-0.
Green, black, blue, red	HR40 (annealed bar and section for machining), BS1471-TIC-H8.
Green, black, blue, white	HR40 (forging stock).
Green, black, blue, yellow	HR53 (annealed bar and section for machining).
Green, black, brown, green	
Green, black, brown, red	HR51 (annealed bar and section for machining). BS2873-NS104-1/2H.
Green, black, brown, white	HR51 (forging stock).
Green, black, brown, yellow	TA12.
Green, black, green, blue	BS970-045-M10 (as rolled or forged and bright bars), BS-1449-En 42E (as cold rolled).
Green, black, green, brown	BS1449-En 42E (as rolled or normalised).
Green, black, green, red	HR52 (annealed bar and section for machining). BS1449-En 42F (as cold rolled), BS1471-TIB-H4.

Green, black, green, white	BS970-210-M15 (as rolled or forged and bright bars), BS2873-NS104-H.
Green, black, green, yellow	HR52 (forging stock), BS1449-En 42F (hot rolled or normalised), BS1475-NG4-H8.
Green, black, red, green	
Green, black, red, white	TA16.
Green, black, red, yellow	BS2873-NS105-0.
Green, black, white, green	
Green, black, white, red	HR53 (forging stock), BS2873-NS105-1/2H.
Green, black, white, yellow	TA19.
Green, black, yellow, green	L114 (annealed).
Green, black, yellow, red	L114 (solution treated).
Green, black, yellow, white	TA8.
Green, blue, black, green	BS970-431-S29 (softened).
Green, blue, black, red	BS2873-NS105-H.
Green, blue, black, white	
Green, blue, black, yellow	
Green, blue, brown, green	L167-T6, TA7, BS2873-NS106-0.
Green, blue, brown, red	
Green, blue, brown, white	
Green, blue, brown, yellow	BS2873-NS106-H.
Green, blue, green, black	BS1449-En 42G (as cold rolled).
Green, blue, green, brown	BS970-665-M23 (as rolled or forged and bright bars), BS1449-En 42G (hot rolled or normalised).
Green, blue, green, red	BS970-665-A22 (as rolled or forged and bright bars), BS1449-En 42J (as cold rolled).
Green, blue, green, white	BS970-665-A24 (as rolled or forged and bright bars), BS2873-NS106-1/2H
Green, blue, green, yellow	BS970-640-A35 (as rolled), BS1449-En 42J (hot rolled or normalised).
Green, blue, red, green	TA26, BS2873-NS107-0.
Green, blue, red, white	
Green, blue, red, yellow	L167-T62.
Green, blue, white, green	
Green, blue, white, red	AIR9160-30CD12 (hardened and tempered - 1080/1270 MPa).
Green, blue, white, yellow	BS2873-NS107-1/2H.
Green, blue, yellow, green	
Green, blue, yellow, red	AIR9160-30CD12 (hardened and tempered - 930/1080 MPa).
Green, blue, yellow, white	BS4300/5-TF.
Green, brown, black, red	BS2873-NS107-H.
Green, brown, black, white	BS1449-CS12C.
Green, brown, black, yellow	BS2873-NS108-0.
Green, brown, blue, red	T76.
Green, brown, blue, white	
Green, brown, blue, yellow	L166-T42.
Green, brown, green, black	BS970-640-A35 (hardened and tempered), BS1449-En 43G (as cold rolled).
Green, brown, green, red	L166 (as rolled), BS1449-En 43G (hot rolled or normalised), BS2873-NS108-1/2H.
Green, brown, green, white	BS970-130-M15 (as rolled or forged and bright bars).
Green, brown, green, yellow	BS970-214-M15 (as rolled or forged and bright bars), BS1449-En 43J (as cold rolled).

Green, brown, red, green	TA3, BS1449-En 2D/A, BS2873-NS108-H.
Green, brown, red, white	BS1449-HS23A.
Green, brown, red, yellow	S132 (fully heat treated - not nitrided).
Green, brown, white, green	DTD5212 (bars for forging).
Green, brown, white, red	BS2873-NS109-0.
Green, brown, white, yellow	TA4.
Green, brown, yellow, green	L166-T4.
Green, brown, yellow, red	
Green, brown, yellow, white	BS2873-NS109-1/2H.
Green, red, black, red	BS2873-NS109-H, DTD5212 (bars for machining).
Green, red, black, white	
Green, red, black, yellow	
Green, red, blue, red	BS2873-PB101-0.
Green, red, blue, white	BS1449-HS23B.
Green, red, blue, yellow	BS970-070-M55 (cold drawn from normalised).
Green, red, brown, red	BS3602-CDS-23.
Green, red, brown, white	BS970-080-M46 (cold drawn from hot rolled), BS2873-PB101-1/2H.
Green, red, brown, yellow	BS970-0700-M55-R, BS1449-HR6C, BS1449-HRP6C, BS1449-HR17C, BS1449-HRP17C.
Green, red, green, black	BS970-523-A14 (as rolled or forged and bright bars), BS1449-En 43J (hot rolled or normalised).
Green, red, green, blue	BS970-527-A19 (as rolled or forged and bright bars), BS1449-En 44D (as cold rolled).
Green, red, green, red	BS970-040-A04 (as rolled or forged), BS2873-PB101-H.
Green, red, green, white	BS970-635-M15 (as rolled or forged and bright bars).
Green, red, green, yellow	BS970-637-M17 (as rolled or forged and bright bars).
Green, red, white, green	BS2873-PB101-EH.
Green, red, white, red	BS1449-En 14A, BS3602-CDS-27.
Green, red, white, yellow	BS970-070-M55 (as rolled or forged), BS3602-CDS-35.
Green, red, yellow, green	BS1449-HR6B, BS1449-HRP6B, BS1449-HR17B, BS1449-HRP17B, BS2873-PB103-0, DTD202 (normalised).
Green, red, yellow, red	BS2871-CZ127-M.
Green, red, yellow, white	BS970-070-M55-S, BS2873-PB103-1/2H.
Green, white, black, red	
Green, white, black, white	HR201 (softened and descaled), HR401 (cold worked and softened).
Green, white, black, yellow	BS970-816-M40 (as rolled), BS1449-CS80 (hardened and tempered), BS2873-PB103-H.
Green, white, blue, red	BS3676-NA18 (cold worked and precipitated).
Green, white, blue, white	BS2873-PB103-EH.
Green, white, blue, yellow	BS3076-NA18 (cold worked, solution treated and precipitated).
Green, white, brown, red	
Green, white, brown, white	BS2871-CZ127-0.
Green, white, brown, yellow	BS970-080-M50-T, BS4109-C102-H.
Green, white, green, black	BS970-815-M17 (as rolled or forged and bright bars), BS1449-En 44E (as cold rolled).
Green, white, green, blue	BS970-820-M17 (as rolled or forged and bright bars).
Green, white, green, brown	BS970-822-M17 (as rolled or forged and bright bars).
Green, white, green, red	BS970-805-M17 (as rolled or forged and bright bars). BS1449-HR17/1
Green, white, green, white	BS970-050-A2017 (as rolled or forged), BS4109-C102-0.

Green, white, green, yellow	BS970-050-A2017 (as rolled or forged and bright bars), BS1408-C (Range 3), BS3072-NA13 (cold rolled and annealed).
Green, white, red, white	
Green, white, red, yellow	
Green, white, yellow, green	BS1449-HS100, BS3603-CDS-27-LT30, DTD5192 (softened).
Green, white, yellow, red	BS3076-NA18 (hot worked and precipitated), BS3603-CDS-27-LT50, BS4109-C101-H.
Green, white, yellow, white	BS3603-CDS-503-LT100.
Green, yellow, black, red	BS3604-CD-620, BS4109-C103-0.
Green, yellow, black, white	BS3076-NA18 (hot worked, solution treated and precipitated), BS3604-CD621.
Green, yellow, black, yellow	BS4109-C101-0.
Green, yellow, blue, red	BS970-070-M55 (normalised), BS1449-HR6A, BS1449-HRP6A, BS1449-HRI7A, BS1449-HRP17A, BS3604-CD-622/27, BS4109-C103-H,
Green, yellow, blue, white	BS970-070-M55-T, BS1449-NHR23.
Green, yellow, blue, yellow	BS1472-HF16-M, BS3604-CD62/35.
Green, yellow, brown, green	BS1449-En 2D/B.
Green, yellow, brown, red	BS970-060-A57 (as rolled or forged), BS3604-CD-625.
Green, yellow, brown, white	TA23.
Green, yellow, brown, yellow	
Green, yellow, green, black	BS970-805-M25 (as rolled or forged and bright bars), BS1449-En 44E (hot rolled or normalised).
Green, yellow, green, brown	BS970-530-A30 (hardened and tempered).
Green, yellow, green, red	BS1470-NS8-M.
Green, yellow, green, white	BS1449-HR7A, BS1449-HRP7A.
Green, yellow, green, yellow	DTD5091 (soft).
Green, yellow, red, white	BS970-080-A57 (as rolled or forged), BS1449-HS80, BS3604-CD-660.
Green, yellow, red, yellow	
Green, yellow, green, red	BS970-060-A62 (as rolled or forged), BS1449-HS22C.
Green, yellow, white, yellow	BS1449-HR7B, BS1449-HRP7B
Red, black, blue, red	
Red, black, blue, white	BS970-060-A67 (as rolled or forged), BS1554-En 58E (softened), BS3601-ERW-410.
Red, black, blue, yellow	BS1554-En 58F (softened).
Red, black, brown, red	S201.
Red, black, brown, white	BS970-060-A72 (as rolled or forged), BS3601-BW-320.
Red, black, brown, yellow	BS970-070-A72 (PART 1 - as rolled or forged), BS3601-ERW-360
Red, black, green, red	BS970-080-A72 (as rolled or forged).
Red, black, green, white	BS970-945-A40 (as rolled), BS3601-ERW-320.
Red, black, green, yellow	BS970-060-A78 (as rolled or forged), BS1449-CS12B.
Red, black, red, brown	BS970-640-M40 (as rolled).
Red, black, red, white	BS3839-1/2H.
Red, black, red, yellow	
Red, black, white, red	BS970-070-A78 (PART 1 - as rolled or forged).
Red, black, white, yellow	BS970-080-A78 (as rolled or forged), BS3601-SAW-410.

Red, black, yellow, red	BS1449-En 2C.
Red, black, yellow, white	BS970-060-A83 (as rolled or forged).
Red, blue, black, red	BS1554-En 56A (softened).
Red, blue, black, white	BS970-080-A83 (as rolled or forged), BS1449-CS12A, BS1554-En 56B (softened).
Red, blue, black, yellow	TA18, TA25, BS3601-S-410, BS1554-En 56C (softened).
Red, blue, brown, white	BS970-050-A86 (as rolled or forged), BS1449-HS22B.
Red, blue, brown, yellow	BS970-060-A86 (as rolled or forged), BS3601-S-320.
Red, blue, green, red	
Red, blue, green, white	BS970-080-A86 (as rolled or forged), BS3601-S-360.
Red, blue, green, yellow	BS970-060-A96 (PART 1 - as rolled or forged), BS1449-HR8B, BS1449-HRP8B.
Red, blue, red, green	BS970-832-M13 (as rolled or forged and bright bars).
Red, blue, red, white	
Red, blue, red, yellow	
Red, blue, white, red	TA14, TA15.
Red, blue, white, yellow	BS970-060-A99 (as rolled or forged), BS1449-HS17C.
Red, blue, yellow, red	BS970-120-M19 (as rolled or forged).
Red, blue, yellow, white	BS970-150-M19-P.
Red, brown, black, white	BS970-120-M28 (as rolled or forged), BS3839-H.
Red, brown, black, yellow	BS970-150-M28-S.
Red, brown, blue, red	BS1554-En 58G (softened).
Red, brown, blue, white	BS970-120-M36 (normalised), BS1449-HR8C, BS1449-HRP8C, BS1554-En 58H (softened).
Red, brown, blue, yellow	BS970-120-M19 (cold drawn from hot rolled), BS1449-HS90, BS1554-En 58J (softened).
Red, brown, green, red	DTD5222.
Red, brown, green, white	BS970-150-M36 (normalised).
Red, brown, green, yellow	TA29, TA32, TA35.
Red, brown, red, black	BS970-659-M15 (as rolled or forged).
Red, brown, red, blue	BS970-835-M15 (as rolled or forged).
Red, brown, red, green	BS1449-En 42F (cold rolled and annealed).
Red, brown, red, white	BS1449-En 42F (hardened and tempered).
Red, brown, red, yellow	BS970-897-M39 (suitable for nitriding-85 tonf/in2), BS1449-En 2A/1.
Red, brown, white, red	S202, BS1449-HS23C.
Red, brown, white, yellow	HRI (forging stock), BS1449-NHR25.
Red, brown, yellow, red	BS970-120-M28 (normalised).
Red, brown, yellow, white	
Red, green, black, red	BS1554-En 56D (softened).
Red, green, black, white	BS1554-En 57 (softened).
Red, green, black, yellow	BS970-216-M28 (as rolled or forged), BS1554-En 58A (softened), BS1824-NS107 (temper 3).
Red, green, blue, white	BS970-216-M28-P.
Red, green, blue, yellow	BS970-212-M36-P.
Red, green, brown, white	BS1824-NS107 (temper 2).
Red, green, brown, yellow	BS970-216-M36-Q.
Red, green, red, black	BS970-905-M31-R.
Red, green, red, blue	BS970-905-M39-R.
Red, brown, red, brown	BS970-070-A72 (PART 5 - as rolled or forged), BS1449-En 2C/1.

Red, green, red, white	BS1449-En 2C/2.
Red, green, red, yellow	BS1471-NT8-0.
Red, green, white, red	S203, BS1449-NHR15.
Red, green, white, yellow	TA45.
Red, green, yellow, red	BS970-225-M36 (as rolled or forged).
Red, green, yellow, white	BS970-212-M44 (as rolled or forged), BS1449-HR5C, BS1449-HRP5C, BS1449-HR16C, BS1449-HRP16C.
Red, white, black, red	BS15540EN 58B (softened).
Red, white, black, white	
Red, white, black, yellow	BS1824-NS107 (temper 1 - extra hard), BS1554-En 58C (softened).
Red, white, blue, white	BS1824-NS107 (temper 4).
Red, white, blue, yellow	BS970-216-M28-Q.
Red, white, brown, white	
Red, white, brown, yellow	TA46, BS970-216-M36-P, BS1449-NHR24.
Red, white, green, white	
Red, white, green, yellow	BS1824-NS107 (temper 5 - soft), BS4360-43C.
Red, white, red, blue	BS1449-En 2D/1.
Red, white, red, white	BS970-040-A22 (as rolled or forged), BS1449-En 21A.
Red, white, red, yellow	BS1449-En 43G (cold rolled and annealed).
Red, white, yellow, red	BS970-225-M36-Q, BS1449HR5A, BS1449-HRP5A, BS1449-HR16A, BS1449-HRP16A.
Red, white, yellow, white	
Red, yellow, black, red	BS1554-En 58D (softened).
Red, yellow, black, white	TA49.
Red, yellow, black, yellow	
Red, yellow, blue, white	BS970-216-M28 (cold drawn from hot rolled).
Red, yellow, blue, yellow	
Red, yellow, brown, white	TA52, TA53.
Red, yellow, brown, yellow	BS1449-HR5B, BS1449-HRP5B, BS1449-HR16B, BS1449-HRP16B, BS1471-NT8-H2.
Red, yellow, green, white	BS970-120-M19-P, BS1449-HR16/1, BS1449-HRP16/1.
Red, yellow, green, yellow	BS1449-En 2C/B.
Red, yellow, red, black	BS970-080-A52 (PART 5 - as rolled or forged).
Red, yellow, red, blue	BS1449-En 43G (hardened and tempered).
Red, yellow, red, brown	BS1449-En 43J (cold rolled and annealed).
Red, yellow, red, green	BS970-080-M50 (normalised), BS1449-En 43J (hardened and tempered).
Red, yellow, red, white	BS970-080-M50-R, BS1449-En 42E (cold rolled and annealed), BS1449-HR7C, BS1449-HRP7C.
Red, yellow, red, yellow	BS970-040-A10 (as rolled or forged), BS1449-En 42E (hardened and tempered).
Red, yellow, white, yellow	
White, black, blue, white	TA38
White, black, blue, yellow	TA39
White, black, brown, white	BS970-150-M36-T.
White, black, brown, yellow	BS1554-En 58C (drawn).
White, black, green, white	
White, black, green, yellow	BS970-120-M19 (normalised).

White, black, red, white	TA54
White, black, red, yellow	BS970-120-M28-Q.
White, black, white, yellow	
White, black, yellow, white	BS970-212-M44-Q.
White, blue, black, white	BS1554-En 56A (hardened and tempered).
White, blue, black, yellow	HR1 (solution treated bar and section for machining), BS1449-CS22A, BS1554-En 56B (hardened and tempered).
White, blue, brown, white	
White, blue, brown, yellow	BS970-225-M44 (as rolled or forged), BS1554-En 58D (drawn).
White, blue, green, white	
White, blue, green, yellow	
White, blue, red, white	
White, blue, red, yellow	BS1449-HS70
White, blue, white, blue	BS1449-En 42G (cold rolled and annealed).
White, blue, white, brown	BS1449-En 42G (hardened and tempered).
White, blue, white, green	BS1449-En 42J (cold rolled and annealed).
White, blue, white, red	BS970-060-A96 (PART 5 - as rolled or forged), BS1449-En 42J (hardened and tempered).
White, blue, white, yellow	BS1449-En 44D (cold rolled and annealed).
White, blue, yellow, white	BS970-225-M36 (cold drawn from hot rolled), dtd5152.
White, brown, black, yellow	
White, brown, blue, white	BS1554-En 56C (hardened and tempered).
White, brown, blue, yellow	BS970-212-M44-R, BS1554-En 56D (hardened and tempered).
White, brown, green, white	DTD5056 (rod).
White, brown, green, yellow	BS1449-NHR22.
White, brown, red, white	BS970-225-M44-R.
White, brown, red, yellow	TA40.
White, brown, white, blue	BS1449-En 44D (hardened and tempered).
White, brown, white, brown	BS1449-En 44E (cold rolled and annealed).
White, brown, white, green	BS1449-En-44E (hardened and tempered).
White, brown, white, red	BS970-250-A53 (as rolled or forged), BS1449-En 56A (softened), BS2056-En 56A (softened).
White, brown, white, yellow	BS970-250-A58 (as rolled or forged), BS1449-En 56A (hardened and tempered).
White, brown, yellow, white	BS1400-L85.
White, green, black, yellow	BS970-216-M36 (cold drawn from hot rolled).
White, green, blue, white	BS1554-En 57 (hardened and tempered).
White, green, blue, yellow	TA26.
White, green, brown, white	BS1554-En 58E (drawn).
White, green, brown, yellow	BS1554-En 58F (drawn).
White, green, red, white	BS1449-HS30.
White, green, red, yellow	BS970-225-M36-R, BS1449-NHR21.

White, green, white, blue	BS1449-En 56B (softened), BS2056-En 56B (softened).
White, green, white, brown	BS1449-En 56B (hardened and tempered).
White, green, white, green	BS1449-En 56C (softened), BS2056-En 56C (softened).
White, green, white, red	BS1449-En 56C (hardened and tempered).
White, green, white, yellow	BS1400-LB4, BS1440-En 56D (softened), BS2056-En 56D (softened).
White, green, yellow, white	BS970-120-M36 (cold drawn from hor rolled). BS1449-CS22B.
White, red, black, yellow	HR2 (solution treated bar and section for machining).
White, red, blue, white	BS1554-En 57 (drawn).
White, red, blue, yellow	BS970-120-M19-Q, BS1554-En 58A (drawn).
White, red, brown, white	BS1554-En 58G (drawn).
White, red, brown, yellow	BS970-212-M44-S, BS1554-En 58H (drawn).
White, red, green, yellow	BS970-120-M28-R.
White, red, white, blue	BS1449-En 56D (hardened and tempered).
White, red, white, brown	BS1449-En 57 (softened), BS2056-En 57 (softened).
White, red, white, green	BS1449-En 57 (hardened and tempered).
White, red, white, yellow	BS1449-En 58A (cold rolled).
White, red, yellow, white	HR504.
White, yellow, black, yellow	
White, yellow, blue, white	BS1554-En 58B (drawn).
White, yellow, blue, yellow	
White, yellow, brown, white	BS1554-En 58J (drawn).
White, yellow, brown, yellow	DTD5086 (wire-cold drawn).
White, yellow, green, yellow	BS1449-HS50.
White, yellow, red, yellow	BS1449-CS22C.
White, yellow, white, blue	BS1449-En 58B (softened).
White, yellow, white, brown	BS1449-En 58B (cold rolled).
White, yellow, white, green	BS1449-En 58C (softened).
White, yellow, white, red	BS1449-En 58C (cold rolled).
White, yellow, white, yellow	BS970-080-M30 (normalised), BS1449-En 58D (softened).
Yellow, black, blue, yellow	BS1470-SIC-M, DTD5086 (rod-solution annealed), DTD5142.
Yellow, black, brown, yellow	S204, BS1824-NS104 (temper 2).
Yellow, black, green, yellow	BS1824-NS104 (temper 3), DTD5076 (annealed cold reduced and solution treated).
Yellow, black, red, yellow	BS1824-NS104 (temper 4), DTD5076 (annealed cold reduced and finally heat treated).
Yellow, black, white, yellow	L113 (annealed), HR54 (heat treated bars for machining), BS1824-NS104 (temper 5 - soft).
Yellow, blue, brown, yellow	DTD5076 (annealed and cold reduced).
Yellow, blue, green, yellow	HR54 (forging stock), BS1449-HS60.
Yellow, blue, red, yellow	
Yellow, blue, white, yellow	S111D.
Yellow, blue, yellow, red	BS970-431-S29 (hardened and tempered, and condition), BS1449-En 56R.
Yellow, brown, green, yellow	TA50.
Yellow, brown, red, yellow	TA41.
Yellow, brown, white, yellow	
Yellow, brown, yellow, black	BS1449-En 56T.
Yellow, brown, yellow, green	BS1449-En 56V.
Yellow, green, red, yellow	TA43.
Yellow, green, white, yellow	
Yellow, red, white, yellow	TA47.
Yellow, red, yellow, brown	BS970-945-M38-R.
Yellow, white, yellow, green	BS970-816-M40-S.
Yellow, white, yellow, red	BS970-640-M40-R.

Black, blue, black, blue, black	BS970-321-S12 (as rolled).
Black, blue, brown, blue, black	BS970-606-M36-S.
Black, blue, green, blue, black	BS970-321-S12 (softened).
Black, blue, red, blue, black	BS970-321-S12 (cold drawn)
Black, blue, white, blue, black	BS970-503-H37 (as rolled).
Black, blue, yellow, blue, black	BS970-606-M36-T.
Black, brown, black, brown, black	BS970-503-H37 (heat treated).
Black, brown, blue, brown black	BS970-503-H42 (as rolled).
Black, brown, green, brown, black	BS970-503-H42 (heat treated).
Black, brown, red, brown, black	BS970-530-H30 (as rolled).
Black, brown, white, brown, black	BS970-530-H32 (as rolled).
Black, brown, yellow, brown, black	BS970-530-H30 (heat treated).
Black, green, black, green, black	BS970-530-H32 (heat treated).
Black, green, blue, green, black	BS970-530-H36 (as rolled).
Black, green, brown, green, black	BS970-530-H36 (heat treated).
Black, green, red, green, black	
Black, green, white, green, black	BS970-321-S20 (as rolled)
Black, green, yellow, green, black	BS970-530-H40 (as rolled).
Black, red, black, red, black	BS970-321-S20 (softened).
Black, red, blue, red, black	BS970-530-H40 (heat treated).
Black, red, brown, red, black	BS970-523-M15 (as rolled or forged and bright bars).
Black, red, green, red, black	BS970-527-M20 (as rolled or forged and bright bars).
Black, red, white, red, black	BS970-635-H15 (as rolled or forged and bright bars).
Black, red, yellow, red, black	BS970-635-A14 (as rolled or forged and bright bars).
Black, white, black, white, black	BS970-655-H13 (as rolled or forged and bright bars).
Black, white, blue, white, black	BS970-655-M13 (as rolled or forged and bright bars).
Black, white, brown, white, black	BS970-659-A15 (as rolled or forged and bright bars).
Black, white, green, white, black	BS970-659-H15 (as rolled or forged and bright bars).
Black, white, red, white, black	BS970-665-A17 (as rolled or forged and bright bars).
Black, white, yellow, white, black	BS970-665-H17 (as rolled or forged and bright bars).
Black, yellow, black, yellow, black	BS970-321-S20 (cold drawn).
Black, yellow, blue, yellow, black	BS970-070-M20 (cold drawn from hot rolled).
Black, yellow, brown, yellow, black	
Black, yellow, green, yellow, black	BS970-637-A16 (as rolled or forged and bright bars).
Black, yellow, red, yellow, black	BS970-637-H17 (as rolled or forged and bright bars).
Black, yellow, white, yellow, black	BS970-655-A12 (as rolled or forged and bright bars).
Blue, black, blue, black, blue	S150 (bars and billets for forging - softened).
Blue, black, brown, black, blue	BS970-401-S45 (as rolled and stress relieved).
Blue, black, green, black, blue	S150 (bright and black bars for machining).
Blue, black, red, black, blue	S151 (bars and billets for forging - softened).
Blue, black, white, black, blue	BS970-403-S17 (softened).
Blue, black, yellow, black, blue	S151 (bright and black, bars for machining).
Blue, brown, black, brown, blue	S152 (bars and billets for forging - softened).
Blue, brown, blue, brown, blue	BS970-410-S21-P.
Blue, brown, green, brown, blue	BS970-410-S21 (softened).
Blue, brown, red, brown, blue	S152 (bright and black, bars for machining).
Blue, brown, white, brown, blue	S153 (bars and billets for forging - softened).
Blue, brown, yellow, brown, blue	BS970-420-S29-R.
Blue, green, black, green, blue	BS970-416-S29-R.
Blue, green, blue, green, blue	S153 (bright and black bars for machining)
Blue, green, brown, green, blue	S154 (bars and billets for forging - softened).
Blue, green, red, green, blue	BS970-416-S29-S.
Blue, green, white, green, blue	BS970-420-S29-S.
Blue, green, yellow, green, blue	S154 (bright and black, bars for machining).
Blue, red, black, red, blue	BS970-416-S37-R.
Blue, red, blue, red, blue	S154 (bars for machining - normalised and softened).

Blue, red, brown, red, blue	S155 (forging stock - softened).
Blue, red, green, red, blue	S156 (bright and black, bars for machining).
Blue, red, white, red, blue	S156 (forging stock - softened).
Blue, red, yellow, red, blue	BS970-416-S37-S.
Blue, white, black, white, blue	BS970-420-S45-R.
Blue, white, blue, white, blue	BS970-420-S37 (softened).
Blue, white, brown, white, blue	BS970-420-S45-S.
Blue, white, green, white, blue	BS970-420-S45 (softened).
Blue, white, red, white, blue	BS970-430-S15 (softened).
Blue, white, yellow, white, blue	BS970-443-S65 (as rolled and stress relieved).
Blue, yellow, black, yellow, blue	S157 (forging stock - softened).
Blue, yellow, blue, yellow, blue	S157 (bright and black, bars for machining).
Blue, yellow, brown, yellow, blue	BS970-302-S25 (as rolled).
Blue, yellow, green, yellow, blue	BS970-420-S29 (softened).
Blue, yellow, red, yellow, blue	BS970-420-S37-R.
Blue, yellow, white, yellow, blue	BS970-420-S37-S.
Brown, black, blue, black, brown	BS970-347-S17 (softened).
Brown, black, brown, black, brown	BS970-347-S17 (as rolled).
Brown, black, green, black, brown	BS970-349-S52 (as rolled and stress relieved).
Brown, black, red, black, brown	BS970-349-S54 (as rolled and stress relieved).
Brown, black, white, black, brown	BS970-352-S54 (as rolled and stress relieved).
Brown, black, yellow, black, brown	BS970-352-S52 (as rolled and stress relieved).
Brown, blue, black, blue, brown	BS970-302-S25 (softened).
Brown, blue, brown, blue, brown	BS970-302-S25 (cold drawn).
Brown, blue, green, blue, brown	AIR 9160B-15CDV6 (annealed).
Brown, blue, red, blue, brown	BS970-303-S21 (as rolled).
Brown, blue, white, blue, brown	BS970-303-S41 (cold drawn).
Brown, blue, yellow, blue, brown	BS970-303-S21 (cold drawn).
Brown, green, black, green, brown	BS970-304-S15 (cold drawn).
Brown, green, blue, green, brown	BS970-304-S12 (as rolled).
Brown, green, brown, green, brown	BS970-310-S24 (as rolled).
Brown, green, red, green, brown	QQ-S-764B-303 SE-A (cold finished).
Brown, green, white, green, brown	BS970-315-S16 (as rolled).
Brown, green, yellow, green, brown	BS970-310-S24 (softened).
Brown, red, black, red, brown	BS970-316-S12 (as rolled).
Brown, red, blue, red, brown	BS970-315-S16 (softened).
Brown, red, brown, red, brown	BS970-316-S12 (softened).
Brown, red, green, red, brown	BS970-316-S16 (as rolled).
Brown, red, white, red, brown	BS970-316-S16 (cold drawn).
Brown, red, yellow, red, brown	BS970-316-S16 (softened).
Brown, white, black, white, brown	BS970-326-S36 (softened).
Brown, white, blue, white, brown	BS970-325-S21 (cold drawn).
Brown, white, brown, white, brown	BS970-326-S36 (cold drawn).
Brown, white, green, white, brown	BS970-331-S40 (as rolled or softened).
Brown, white, red, white, brown	BS970-331-S42 (as rolled or softened).
Brown, white, yellow, white, brown	BS970-381-S34 (as rolled and stress relieved).
Brown, yellow, black, yellow, brown	BS970-317-S12 (softened).
Brown, yellow, blue, yellow, brown	BS970-317-S12 (as rolled).
Brown, yellow, brown, yellow, brown	BS970-317-S16 (as rolled).
Brown, yellow, green, yellow, brown	BS970-317-S16 (softened).
Brown, yellow, red, yellow, brown	BS970-320-S17 (as rolled).
Brown, yellow, white, yellow, brown	BS970-320-S17 (softened).
Green, black, blue, black, green	BS970-665-A19 (as rolled or forged and bright bars).
Green, black, brown, black, green	BS970-665-H20 (as rolled or forged and bright bars).

Green, black, green, black, green	
Green, black, red, black, green	
Green, black, white, black, green	BS970-665-H23 (as rolled or forged and bright bars).
Green, black, yellow, black, green	BS970-665-M20 (as rolled or forged and bright bars).
Green, blue, black, blue, green	AIR 9160B-35NC6 (annealed), MIL-T-8504 (annealed).
Green, blue, brown, blue, green	BS970-805-A17 (as rolled or forged and bright bars).
Green, blue, green, blue, green	BS970-805-A115 (as rolled or forged and bright bars).
Green, blue, red, blue, green	BS970-805-H17 (as rolled or forged and bright bars).
Green, blue, white, blue, green	BS970-805-H20 (as rolled or forged and bright bars).
Green, blue, yellow, blue, green	BS970-805-A20 (as rolled or forged and bright bars).
Green, brown, black, brown, green	BS970-805-A22 (as rolled or forged and bright bars).
Green, brown, blue, brown, green	BS970-805-H22 (as rolled or forged and bright bars).
Green, brown, green, brown, green	QQ-S-763-TYPE 440C-A (annealed).
Green, brown, red, brown, green	BS970-805-M22 (as rolled or forged and bright bars).
Green, brown, white, brown, green	AIR9160C-25CDS4S (hardened and tempered - 880/1080 MPa.)
Green, brown, yellow, brown green	BS970-805-A24 (as rolled or forged and bright bars).
Green, red, black, red, green	BS970-815-A16 (as rolled or forged and bright bars).
Green, red, blue, red, green	BS970-815-H17 (as rolled or forged and bright bars).
Green, red, brown, red, green	BS970-820-A16 (as rolled or forged and bright bars).
Green, red, green, red, green	BS970-805-H25 (as rolled or forged and bright bars).
Green, red, white, red, green	BS970-822-A17 (as rolled or forged and bright bars).
Green, red, yellow, red, green	BS970-820-H17 (as rolled or forged and bright bars).
Green, white, black, white, green	BS970-527-A60 (as rolled or forged).
Green, white, blue, white, green	BS970-527-H60 (as rolled or forged).
Green, white, brown, white, green	BS970-805-A60 (as rolled or forged).
Green, white, green, white, green	BS970-250-A61 (as rolled or forged).
Green, white, red, white, green	BS970-805-H60 (as rolled or forged).
Green, white, yellow, white, green	BS970-925-A60 (as rolled or forged).
Green, yellow, black, yellow, green	BS970-832-H13 (as rolled or forged and bright bars).
Green, yellow, blue, yellow, green	BS970-835-A15 (as rolled or forged and bright bars).
Green, yellow, brown, yellow, green	BS970-835-H15 (as rolled or forged and bright bars).
Green, yellow, green, yellow, green	BS970-822-H17 (as rolled or forged and bright bars).
Green, yellow, red, yellow, green	BS970-080-A67 (PART 5 - as rolled or forged).
Green, yellow, white, yellow, green	BS970-080-A67 (PART 5 - as rolled or forged).
Red, black, blue, black, red	BS970-503-M40-S.
Red, black, brown, black, red	BS970-441-S49 (solution).
Red, black, green, black, red	BS970-897-M39-Z.
Red, black, red, black, red	BS970-503-M40-R.
Red, black, white, black, red	BS970-823-M30 (as rolled).
Red, black, yellow, black, red	BS970-416-S41-R.
Red, blue, black, blue, red	BS970-441-S29-T.
Red, blue, brown, blue, red	BS970-823-M30-U.
Red, blue, green, blue, red	BS970-823-M30-V.
Red, blue, red, blue, red	BS970823-M30-T.
Red, blue, white, blue, red	BS970-823-M30-X.
Red, blue, yellow, blue, red	BS970-823-M30-W.
Red, brown, black, brown, red	BS970-441-S49 (hardened and tempered).
Red, brown, blue, brown, red	BS970-608-H37 (as rolled).
Red, brown, green, brown, red	BS970-608-H37 (heat treated).
Red, brown, red, brown, red	BS970-823-M30-Z.
Red, brown, white, brown, red	BS970-708-H37 (heat treated).
Red, brown, yellow, brown, red	BS970-708-H37 (as rolled).
Red, green, black, green, red	BS970-708-H42 (heat treated).
Red, green, blue, green, red	BS970-441-S29 (hardened and tempered).
Red, green, brown, green, red	BS970-640-H35 (as rolled).
Red, green, red, green, red	BS970-708-H42 (as rolled).
Red, green, white, green, red	BS970-304-S12 (softened), BS1449-304-S12 (softened).

Red, green, yellow, green, red	BS970-416-S21-P.
Red, white, black, white, red	BS416-S41-P.
Red, white, blue, white, red	BS970-605-H32 (as rolled).
Red, white, brown, white, red	BS970-605-H32 (heat treated).
Red, white, green, white, red	BS970-605-H37 (as rolled).
Red, white, red, white, red	BS970970-535-A99 (as rolled).
Red, white, yellow, white, red	BS970-605-H37 (heat treated).
Red, yellow, black, yellow, red	BS970-441-S49-T.
Red, yellow, blue, yellow, red	BS970-640-H35 (heat treated).
Red, yellow, brown, yellow, red	BS970-304-S15 (softened).
Red, yellow, green, yellow, red	BS970-303-S21 (softened).
Red, yellow, red, yellow, red	BS970-325-S21 (softened).
Red, yellow, white, yellow, red	BS970-341-S29 (softened).
White, black, blue, black, white	AIR9160B-15CDV6 (hardened and tempered - 980/1130 MPa.)
White, black, brown, black, white	AIR9160B-15CDV6 (hardened and tempered - 1030/1180 MPa.)
White, black, green, black, white	QQ-A-250/4E (2024-T351), BS970-015-A03 (as rolled or forged.
White, black, red, black, white	AIR9160-30 NCD16 (annealed), MIL-T6736-HT150, QQ-A-225/6D (2024-T351).
White, black, white, black, white	MIL-S-6758A (condition A and B - forged or rolled).
White, black, yellow, black, white	BS970-030-A04 (as rolled or forged).
White, blue, black, blue, white	MIL-S-6758A (condition C- annealed).
White, blue, brown, blue, white	MIL-S-7720A (condition C -hot rolled or forged), QQ-A-200/3D (2024-T351).
White, blue, green, blue, white	AIR9160B-35NC6 (hardened and tempered - 880/1080 MPa), AMS5572C.
White, blue, red, blue, white	AIR9160B-35NC6 (hardened and tempered - 1030/1180 MPa).
White, blue, white, blue, white	QQ-A-250/5F (2024-T351), BS970-050-A04 (as rolled or forged).
White, blue, yellow, blue, white	MIL-S-7720A (condition B - cold finished).
White, brown, black, brown, white	QQ-A-250/11E (6061-0).
White, brown, blue, brown, white	MIL-S-6758A (condition F - hardened and tempered).
White, brown, green, brown, white	MIL-T-6736-HT125, BS970-045-A10 (as rolled or forged).
White, brown, red, brown, white	
White, brown, white, brown, white	AIR9160C-Z100 CD17 (annealed).
White, brown, yellow, brown, white	
White, green, black, green, white	AMS5643 (17/4 PH).
White, green, blue, green, white	
White, green, brown, green, white	QQ-A-250/4E-T3 (as supplied), BS970-060-A10 (as rolled or forged).
White, green, red, green, white	MIL-T-6736B (condition N - normalised).
White, green, white, green, white	MIL-S-7720A (condition A - annealed).
White, green, yellow, green, white	BS970-050-A12 (as rolled or forged).
White, red, black, red, white	
White, red, blue, red, white	MIL-T-6736B (condition A - annealed), BS970-040-A15 (as rolled or forged).
White, red, brown, red, white	QQ-A-250/11E - T4 (as supplied), BS970-050-A15 (as rolled or forged).
White, red, green, red, white	
White, red, white, red, white	QQ-A-250/4E-0 (as supplied), BS970-060-A12 (as rolled or forged).
White, red, yellow, red, white	
White, yellow, black, yellow, white	QQ-A-225/9D (7075-T351), BS970-080-A15 (as rolled or forged).
White, yellow, blue, yellow, white	
White, yellow, brown, yellow, white	QQ-A-250/11E-T6 (as supplied), BS970-040-A17 (as rolled or forged).

White, yellow, green, yellow, White	BS970-050-A17 (as rolled or forged).
White, yellow, red, yellow, white	AIR9160C-35CD4 (annealed).
White, yellow, white, yellow, white	MIL-T-6736B-HT180, BS970-060-A15 (as rolled or forged).
Yellow, black, blue, black, yellow	BS970-080-A17 (as rolled or forged).
Yellow, black, brown, black, yellow	BS970-040-A20 (as rolled or forged).
Yellow, black, green, black, yellow	BS970-060-A20 (as rolled or forged).
Yellow, black, red, black, yellow	BS970-080-A20 (as rolled or forged).
Yellow, black, white, black, yellow	BS970-050-A22 (as rolled or forged).
Yellow, black, yellow, black, yellow	BS970-060-A17 (as rolled or forged).
Yellow, blue, black, blue, yellow	BS970-080-A22 (as rolled or forged).
Yellow, blue, brown, blue, yellow	BS970-060-A25 (as rolled or forged).
Yellow, blue, green, blue, yellow	BS970-080-A25 (as rolled or forged).
Yellow, blue, red, blue, yellow	BS970-070-M26 (as rolled or forged).
Yellow, blue, white, blue, yellow	BS970-060-A27 (as rolled or forged).
Yellow, blue, yellow, blue, yellow	BS970-060-A22 (as rolled or forged).
Yellow, brown, black, brown, yellow	BS970-060-A30 (as rolled or forged).
Yellow, brown, blue, brown, yellow	BS970-070-M26 (normalised)
Yellow, brown, green, brown, yellow	BS970-070-M26-P.
Yellow, brown, red, brown, yellow	BS970-080-M30 (cold drawn from hot rolled).
Yellow, brown, white, brown, yellow	BS970-060-A32 (as rolled or forged).
Yellow, brown, yellow, brown, yellow	
Yellow, green, black, green, yellow	BS970-080-A36 (normalised).
Yellow, green, blue, green, yellow	BS970-070-M26-Q.
Yellow, green, brown, green, yellow	BS970-080-M36 (cold drawn from hot rolled).
Yellow, green, red, green, yellow	BS970-060-A40 (as rolled or forged).
Yellow, green, white, green, yellow	BS970-060-A47 (as rolled or forged).
Yellow, green, yellow, green, yellow	BS970-060-A35 (as rolled or forged).
Yellow, red, black, red, yellow	BS970-060-A37 (as rolled or forged).
Yellow, red, blue, red, yellow	BS970-080-M36-Q.
Yellow, red, brown, red, yellow	BS970-060-A42 (as rolled or forged).
Yellow, red, green, red, yellow	BS970-080-M46 (normalised)
Yellow, red, white, red, yellow	BS970-080-M46-R.
Yellow, red, yellow, red, yellow	BS970-070-M26 (cold drawn from hot rolled).
Yellow, white, black, white, yellow	BS970-080-M36 (as rolled or forged).
Yellow, white, blue, white, yellow	BS970-080-M36-R.
Yellow, white, brown, white, yellow	BS970-060-M52 (as rolled or forged).
Yellow, white, green, white, yellow	BS970-080-M46-Q.
Yellow, white, red, white, yellow	BS970-080-M46-S.
Yellow, white, yellow, white, yellow	BS970-080-M46 (as rolled or forged).
Green, black, green, brown, green	BS970-304-S15 (as rolled).
Yellow, green, yellow, red, yellow	BS970-303-S41 (softened).

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CHAPTER : 12

IDENTIFICATION OF MARKINGS ON METALLIC MATERIALS

INTRODUCTION

This chapter gives guidance on the determination of type and positioning of markings on metallic materials, for the purpose of identification during manufacture. This chapter should be read in conjunction with chapter, which gives information on standard colour schemes and which gives information on the processes for identification marking of aircraft parts.

British Civil Airworthiness Requirements specifies that materials used in parts affected by airworthiness requirements shall comply with one of the following specifications:

a. British Standard Aerospace Series Specifications.
b. DTD Specifications.
c. Specifications approved by the CAA. or DGCA.
d. Specifications prepared for a material in accordance with BCAR, Chapter D4-1 for large aeroplane, by an Organisation approved for design where the material is to be used in a part designed within the terms of the design approval.

British Standards Aerospace Series and DTD Specifications make provision for the identification. Manufacturers' Specifications [as in paragraph (d)] normally refer to the inspectional clauses of the relevant BS or DTD Specifications and, consequently, similar provision for identification is made.

METHOD OF MARKING

Material should be identified as early as possible in their manufacture.
The markings most appropriate for materials such as bar and casting are -

a. metallic stamp markings,
b. markings produced by the die or mould used in shaping the material, and
c. marking by rubber stamp, hand roller or printing machine.

Whichever method of marking is employed, damage to the material must be avoided and particular care should be taken when marking stressed parts of materials.
The markings most appropriate for parts and semi-finished materials as -

a. acid etching,
b. electro-chemical methods,
c. vibratory percussion,
d. grit blasting, and
e. deposition of iron-copper selenite.

Incised markings are not recommended for -

a. stressed parts where the impressions may act as stress raisers and originate cracks,
b. materials and parts of thin section,
c. material or parts of such hardness, surface condition or shape that it is impracticable to apply a well defined marking, and
d. material ordered to exact sizes where no provision is made for the subsequent removal of the portion containing the incised markings.

NOTE

Electro-engraving of parts is prohibited and metallic stamp and vibratory percussion methods must not be used at highly stressed locations. If it is necessary to mark a part in a stressed region, etching or electro-chemical methods should be employed.

When metallic stamp marking is used, and method is preferred for stock or random sizes of material, the marks have to be confined to minimum area in a suitable position.

When marking with ink, enamel or paint is permitted, the marking medium has to meet the following criteria:

a. It has to be permanent, except for 'non-immersion' markings used with some aluminium-based materials, where the marking is designed to disappear during solution treatment.
b. It has to have no corrosive or adverse effect on the material and be compatible with any material or substance with which it may subsequently be in contact.

NOTE

For stainless steels, the marking medium has to be free from organic compounds to obviate the possibility of carbon 'pick-up'.

c. It has to remain legible when any protective process is applied to the material.

Where material is ordered to sizes which do not permit the identification markings being removed during production of a part, the purchase may state expressly in his order that the material is to be used in the size as delivered and must not bear any incised markings. In such circumstances the material may be identified by -

a. the pieces of material being bundled or parcelled and the marks required being stamped on a metal label securely attached to each bundle or parcel,
b. marking with paint, enamel or ink , or
c. one of the etching or electrochemical methods.

IDENTIFICATION OF METALLIC MATERIALS TO APPROVED SPECIFICATIONS

The Procedure Specifications in the British Standards Aerospace Series, i.e. HC.100, HR.100, L.100, L.500, S.100, S.500, T.100, contain identification marking clauses which are applicable to all BS Aerospace Series and DTD Specifications for iron, nickel, copper and refractory base alloy castings, wrought iron resisting alloys, wrought aluminium and aluminium alloys, aluminium base and magnesium base ingots and casting wrought magnesium alloys, wrought steels and wrought titanium and titanium alloys. New issues of approved specifications will include references to the identification clauses of the relevant specification.

The identification marking of metallic materials other than those covered in paragraph above is governed by the individual Approved Specification.

The identification marking should consist of the specification reference, the inspection stamp (except as indicated in paragraph below on identification of material forms) and such other markings as are necessary to enable the following details to be established:

a. Manufacturer.
b. Cast number (where cast or cast/heat treatment batching is required by the Specification).
c. Batch number.
d. Test report number.

The identification mark of the inspector and the manufacturer's trade or identification mark may be combined in one symbol. Correlation between the relevant approved certificate and test report may conveniently be secured by marking the material with the test report number. Additional markings such as those agreed by the supplier and purchaser and stated on the order or drawing may also be applied.

IDENTIFICATION OF MATERIAL FORMS

The identification markings which are generally application to various forms of material, ingots, castings, bars, sheets, etc., are given in this paragraph.

Ingots

Each ingots should be stamped with the marks indicated above, except that the inspection stamp may be omitted if the manufacturer's name or trade mark is cast on each ingot and the relevant inspection records are signed by the inspector accepting the ingots.

Castings, Forgings and Stampings

Each casting, forging and stamping which is large enough to be individually marked should bear the marks described in above and such other markings as many be stated on the order.

Marks, such as the part number and the manufacturer's name, may be incorporated in the die or mould used in shaping the part. Marks not so applied should be added by means of stamps unless some other method of marking is specified. All stamp markings must be placed where they have the least detrimental effect on the part; such position usually being indicated on the drawing.

Where forgings, stampings and precision casting approximate closely to the finished parts, the method of identification should follow the requirements for the marking of the finished parts, as shown on the drawing. Wherever practicable, compressor and turbine blade forgings should be individually identified, and this is of particular importance where the blade forgings are of similar shape and size and made from closely associated alloys, e.g. the alloys of the Nimonic series. Segregation and identification of stock, 'uses' and forgings for blades throughout the various production and heat treatment stages is necessary.

Billets and Bars

Each billet and bar, the diameter or width across the flats of which is greater than 19 mm (0.75 inch), should be stamped at one end with the markings detailed in paragraph 3.2.

Sheets and Strips

Each sheet and each coil or strip wider than 19 mm (0.75 inch) should be stamped with the markings .

Sections

Each extruded and rolled section, the major sectional dimension of which exceeds 19 mm (0.75 inch), should be stamped at one extreme end with the markings.

Wire

Each coil or bundle of wire should bear a metal label stamped with the markings and such additional markings as may be required by the relevant specification (which may also require colour identification).

Tubes

Each tube, the diameter of which exceeds 19 mm (0.75 inch), should be stamped at one end with the markings and with any additional markings required by the relevant specification.

Items not Requiring Individual Identification

As an alternative to individual identification, and provided that the material the same cast or batch:

a. ingots, small castings, forgings, stampings, and bars, the diameter or width across flats of which does not exceed 6.5 mm (0.25 inch);
b. sheet and flat strips, the width of which does not exceed 19 mm (0.75 inch);
c. sections, the major sectional dimensions of which do not exceed 19 mm (0.75 inch);
d. tubes, the diameter of which does not exceed 25 mm (1 inch), or in the case of light alloy and steel tubes does not exceed 19 mm (0.75 inch).

Should be either wired together or packed in parcels, as appropriate, and metal label, stamped with the markings , should be attached to each bundle or parcel.

ALUMINIUM-BASED MATERIALS

The identification marking requirements for aluminium-based materials are prescribed in British Standards L.100, and castings, extruded bars sections and sections rolled from strip, wire and tubes should, unless otherwise specified, be so identified.

Ingots

Ingots which have a sufficient clean and smooth face to enable full legibility to be secured may at the discretion of the appropriately authorised person, be rubber stamped with the specifications reference, preferably at each end of the ingot. The letters and figures should be not less than 13 mm (0.5 inch) high and the ink used should comply with standards given before in this chapter with regard to ink uses.

Sheet and Strip in Coil Form

In addition to the identification markings detailed before, sheet and strip may be required to be 'all-over' marked by the specification reference may be omitted. 'All-over' marking should be carried out in accordance with the relevant clauses of BS L.100 and as detailed in before, unless otherwise agreed between the manufacturer and the purchaser and stated on the order.

Each sheet and each strip in coil form, the width of which is 152 mm (6 inch) or greater, should be marked in green ink with the Specification reference and the manufacturer's symbol in figures and letters 13 mm (0.5 inch) high. The lines of markings should be at a pitch of 100 mm (4 inch). The markings should be arranged in accordance with (a) or (b).

a. The specification reference and the manufacturer's symbol should appear alternately and should be repeated at intervals of approximately 100 mm (4 inch) along each line of marking; the marks being so disposed that the Specification reference in one line is above the manufacture symbol in the line immediately below it.
b. The specification reference and manufacture's symbol should appear on alternate lines, the marks in each line being repeated with a gap of approximately 25 mm (1 inch) between them.

Each sheet and each strip in coil form, the width of which does not exceed 152 mm (6 inch) (but not less than 50 mm (2 inch) wide, should be marked as in para (a) or (b) above at intervals of 100 mm (4 inch) approximately along the centre line.

At the option of the manufacturer each sheet and strip in coil form, the width of which does not exceed 50 mm (2 in) wide, can be 'all-over' marked, individually identified as detailed in before, or if from the same batch, bundled together with the required marks stamped on a metal label attached to each bundle.

Sheet and strip in coil form of material 26 s.w.g. and thinner, in the heat treatment condition stipulated by the specification and wide enough to be 'all-over' marked, may be hand marked in green ink along two lines only.

Plate and Extrusions

Plate, not included in the current issue of BS L.100, should of rolling (not readily apparent with pieces cut to size) and the result of non-destructive testing. The user may require appropriate indications to be marked on each plate; such additional markings should be agreed between the purchaser and manufacturer and stated on the drawing or order.

Extrusions and plate which have been stretched in accordance with the specification other conditions should be marked with the letters CS in circle. Bars and sections should be marked alongside the specification reference. The marks should be made either by rubber stamp (blue or black ink) or by metal stamps, at the discretion of the material manufacturer.

Forgings

Forgings should unless otherwise specified, be finally marked as required by BS L.100. Where individual markings are required, L.100 specifies that the drawing for the forgings should state the position at which the identification marks are to be applied; this is particularly important for forgings in high strength alloys.

NOTE

The method of applying the identification markings should be confirmed where it is not indicated on the drawing.

Annealed, Not Aged, and as-Rolled Material

Material released in than the heat treatment condition stipulated by the specification should be marked in red by means of a transfer paint or ink markings with the appropriate term to denote its condition and Approved Certificates covering such material should be clearly annotated "annealed", "not aged", etc., as appropriate.

For extruded bars, sections and tubing, the red markings should be applied near one end off each length but, where lengths greater than 5 m (15 ft.) are supplied, ; the markings should be applied at each end of each length.

For plate, the red marking should be placed near the specification reference or, where 'all-over' marking is required by the order, repeated at intervals midway between the lines of 'all-over' marking.

Material which is to be bundled and labelled should bear the appropriate wording stamped on the attachment label.

The following terms are to be used, as appropriate :

a. ***AS ROLLED***. To denote 'as-rolled' material.
b. ***ANNEALED***. To denote material in the softened condition.
c. ***NOT AGED***. To denote material solution treated but which requires precipitation treatment.

The method of applying the red markings is left to the discretion of the manufacturer but the medium used should comply with the standards given before.

MAGNESIUM-BASED MATERIALS

Cast products should, unless otherwise specified, be identified in accordance with the requirements of BS L.101. Wrought products should be identified as required to BS L.500. In general, the guidance given in previous paragraph is applicable and the marking should be applied before chromate treatment.

TITANIUM-BASED MATERIALS

Titanium-based materials should be finally marked inn accordance with BS TA.100 and order requirements, . It is preferable not to use metallic stamping unless otherwise indicate on the order; billets, bars, sheet, etc., may be identified by rubber stamp markings. Where the cross-section is insufficient to enable full legibility to be secured, bars, rods, etc., from the same cast or batch and of the same nominal size may be worked together and the marks required may be stamped on a metal label attached to each bundle.

FERROUS MATERIALS

Steel ingots and wrought products should, unless otherwise specified, be identified in accordance with the relevant procedure specifications, i.e. BS S.100, S.500 and T.100; the identification marking requirements for steel castings are given in the relevant specifications.

NOTE

Leaded steels should be identified with a distinguishing mark "L", "LED" or "LEADED" and the associated Approved Certificate should be appropriately endorsed.

IDENTIFICATION OF METALLIC MATERIALS TO OTHER THAN APPROVED SPECIFICATIONS

Parts for general supplies (i.e. uncontrolled items as specified in Section A, Chapter A3-3 of British Civil Airworthiness requirements) may be made from materials for which identification marking requirement are not specified. In such cases the appropriate person employed by the materials manufacturer should be guided by the terms of the order, but it is preferable that some of marking be carried out by the manufacturer to correlate the material with its accompanying release documentation. It is essential, however, that the material is rendered identifiable after delivery to prevent any possible confusion with other material held by the purchaser.

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CHAPTER : 13
BOLTS AND SCREWS OF BRITISH MANUFACTURE
(IDENTIFICATIONMARKING)

13.1 INTRODUCTION

This chapter gives guidance on the identification of bolts and screws complying with British Standards 'A' Series of Aircraft Materials and Components and the Society of British Aerospace Companies 'AS' series of specification. The chapter does not include information on the 'AGS' series since these have been entirely superseded by other standards. Information on the manufacture and testing of bolts and screws will be found in British Standards A100 and A101m entitled ''General Requirements for Bolts and Nuts of Tensile Strength not exceeding 180000 lbf/in^2 (125 bar)'', and ''General Requirements for Titanium Bolts'', respectively.

The identification of bolts and screws located on aircraft may not always be an easy task since not all are marked to show the standard to which they conform. This chapter sets out to show the features from which positive identification may be made, but it should be understood that items exist, which although identical in appearance, may not be interchangeable. It is also important to understand the direction of stress in a particular bolt since a 'shear' bolt must not be used to replace a 'tension' bolt. If any doubt exists as to the identity of a particular item the appropriate Parts Catalogue should be consulted; replacement of an incorrect part may lead to failure in service.

It will be found that a number of Specifications are either obsolete or obsolescent, in some instances due to standardisation of a countersunk head of 100^0 included angle. The replacements are indicated in the tables.

A list of the abbreviations used in the chapter is given in at the end of this chapter.

13.2 BRITISH STANDARDS

This paragraph is concerned with the identification of bolts and screws complying with the British Standards 'Aircraft' (A) series. For ease of reference the paragraph has been divided in to two section, paragraph 13.2.1 dealing with bolts and screws having either British Association (BA) or British Standard Fine (BSF) threads, and paragraph 13.2.2 dealing with bolts and screws having Unified threads.

13.2.1 Bolts and Screws with BA or BSF Threads

In this series, BSF threads are used on bolts of ¼-inch diameter and larger; smaller bolts and all screws have BA threads, except that grub screws are also supplied in ¼-inch BSF. BA sizes larger than 2 BA are not specified. Table 13.1 gives a list of the relevant Standards, superseding Standards and identification data appropriate to the series, and Figure 13.1 illustrates the types of head used. To find the Standard number of a given item proceed as follows:-

Identify the head from Figure 13.1, for example '(ℓ)'. Reference to Table 1 shows that '(ℓ)' refers to an A61 bolt. If the illustration applies to more than one specification, further information contained in the table, such as the type of finish, should enable the identification to be completed.

In some instances, e.g. A31 to A56 in Table 13.1, identification can only be effected from the finish applied (mechanical testing apart), or by the labelling on packages.

Code Systems for Bolts

The code system used for the identification of the bolts listed in Table 13.1 consists of the standard number followed by the part number of the particular bolt. The part number consists of a number indicating the nominal length of the plain portion of the shank in tenths of an inch, followed by a letter indicating the nominal diameter (Table 13.2). Example : The complete part reference number for a 3/8 inch A57 bolt of length L = 3.1 inch is A57 31J.

i. All bolts to British Standards A25, A26, A30, A57, A59, A60, and A61 of 1/4 inch nominal diameter and over are marked with the appropriate British Standard on the upper face of the head. Additionally, bolts of 7/16 inch nominal size and larger have the appropriate part number applied to the upper face of the head. Parcels of bolts have the number of the relevant British Standard and the appropriate part number clearly stated on the labels.
ii. The positions at which the plain length is measured on hexagon bolts and the overall lengths on various types of screws are indicated in Figure 13.2. It should be noted that with BA and BSF bolts, the plain portion of the shank includes the thread 'run-out'. A 'washer face' [e.g. Figure 13.1 (b)] on the under surface of a bolt head is not included in the plain length of the shank.

Code System for Screw (A31 to A46)

The code system used for the identification of the screw listed in Table 13.1 consists of the British Standard number followed by the part number of the particular screw. The part number consists of a number indicating the nominal length of the screw (in thirty-seconds of an inch) when measured as described below (see also Figure 13.2) preceded by a letter indicating the nominal diameter (Table 13.2). Example: The complete part referencing number for a 2 BA A41 countersunk head aluminium alloy screw 1/2 inch long, is A41 C16.

TABLE 13.1
BA AND BSF BOLTS AND SCREWS

Stan-dard No.	Description	Mate-rial	Finish	Head (Fig. 1)	Remarks	Thread	Normal Size Range
A17	Hex. hd. bolt	Al Al	anodic	e or f	obsolescent	BA/BSF	6BA to 1 in BSF
A25	Hex. hd. bolt	HTS	cad	a,b,c or d	replaces A15Y	BA/BSF	6 BA to 1 in BSF
A26	Hex. hd. bolt	CRS	nat	a	replaces A15Z	BA/BSF	6BA to 1 in BSF
A28	Hex. hd. bolt	Al Al	anodic	g or h	obsolescent	BA/BSF	6 BA to 1 in BSF
A30	Hex. hd. c/t bolt	HTS	cad	i or j	cad h & t	BA/BSF	6 BA to 1 in BSF
A31	Cheese hd. screw	LTS	cad	o	replaces AGS 247	BA	12 BA to 2 BA
A32	Round hd. screw	LTS	cad	n	replaces AGS 245	BA	10 BA to 2 BA
A33	90° csk. hd. screw	LTS	cad	q	replaces AGS 249	BA	12 BA to 2 BA
A34	Raised csk. hd. screw	LTS	cad	p		BA	10 BA to 2 BA
A35	Cheese hd. screw	CRS	nat	o	replaces AGS 896	BA	12 BA to 2 BA
A36	Round hd. screw	CRS	nat	n	replaces AGS 967	BA	10 BA to 2 BA
A37	90° csk. hd. screw	CRS	nat	q	replaces AGS 968	BA	12 BA to 2 BA
A38	Raised csk. hd. screw	CRS	nat	p		BA	10 BA to 2 BA
A39	Cheese hd. screw	Al Al	anodic	o		BA	12 BA to 2 BA
A40	Round hd. screw	Al Al	anodic	n	replaces AGS 564	BA	10 BA to 2 BA
A41	90° csk. hd. screw	Al Al	anodic	q		BA	12 BA to 2 BA
A42	Raised csk. hd. screw	Al Al	anodic	p		BA	10 BA to 2 BA
A43	Cheese hd. screw	Brass	tinned	o	replaces AGS 246	BA	12 BA to 2 BA
A44	Round hd. screw	Brass	tinned	n	replaces AGS 244	BA	10 BA to 2 BA
A45	90°csk. hd. screw	Brass	tinned	q	replaces AGS 248	BA	12 BA to 2 BA
A46	Raised csk. hd. screw	Brass	tinned	p		BA	10 BA to 2 BA
A55	Grub screw	FCS	cad	none		BA/BSF	6 BA to ¼ BSF
A56	Grub screw	CRS	nat	none		BA/BSF	6 BA to ¼ BSF
A57	Hex. hd. shear bolt	HTS	cad	k	cad h & t only	BSF	¼ to $\frac{3}{4}$ in BSF
A59	Hex. hd. c/t bolt	HTS	cad	i		BA /BSF	6 BA to 1 in BSF
A60	Hex. hd. shear bolt	HTS	cad	k		BSF	¼ to $\frac{3}{4}$ in BSF
A61	Hex. hd. bolt	Al Al	anodic	l or m	replaces A28	BA/BSF	6 BA to 1 in BSF

TABLE 13.2
DIAMETER CODE LETTERS

Code	Size	Code	Size
A	6 BA	P	$\frac{9}{16}$ in BSF
B	4 BA	Q	$\frac{5}{8}$ in BSF
C	2 BA	S	$\frac{3}{4}$ in BSF
E	¼ in BSF	U	$\frac{7}{8}$ in BSF
G	$\frac{5}{16}$ in BSF	W	1 in BSF
J	$\frac{3}{8}$ in BSF	X	12 BA
L	$\frac{7}{16}$ in BSF	Y	10 BA
N	½ in BSF	Z	8 BA

i. ***Cheese and Round Heads***

The nominal length is the distance measured from the surface of the head to the extreme end of the shank, including any chamfer or radius.

ii. ***Countersunk Heads***

The nominal length is the distance measured from the upper surface of the head to the extreme end of the shank, including any chamfer or radius.

iii. ***Raised Countersunk Heads***

The nominal length is the distance measured from the upper surface of the head (excluding the raised portion) to the extreme end of the shank, including any chamfer or radius.

Code System for Grub Screws Complying with A55-A56

The code system used for these screws consists of the British Standard number followed by the part number of the particular screw. The part number consists of a number indicating the overall length of the screw in sixteenths of an inch, preceded by a letter indicating the nominal diameter. Example: The complete part referencing number for a 1/4 inch diameter A55 screw, ½-inch long, would be A55 8.

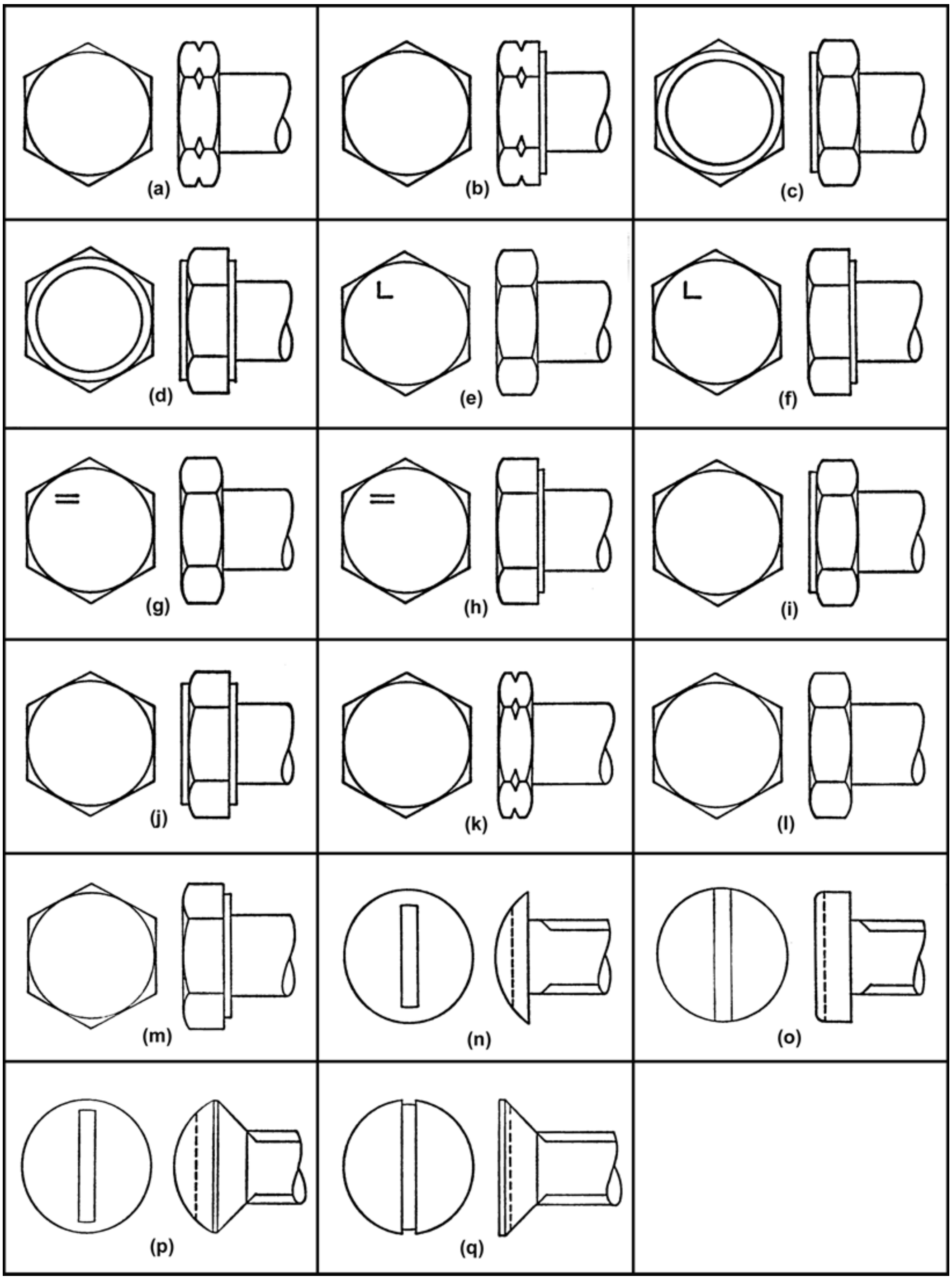


Fig. 13.1, Identification of British Standards BA/BSF Bolts and Screws.

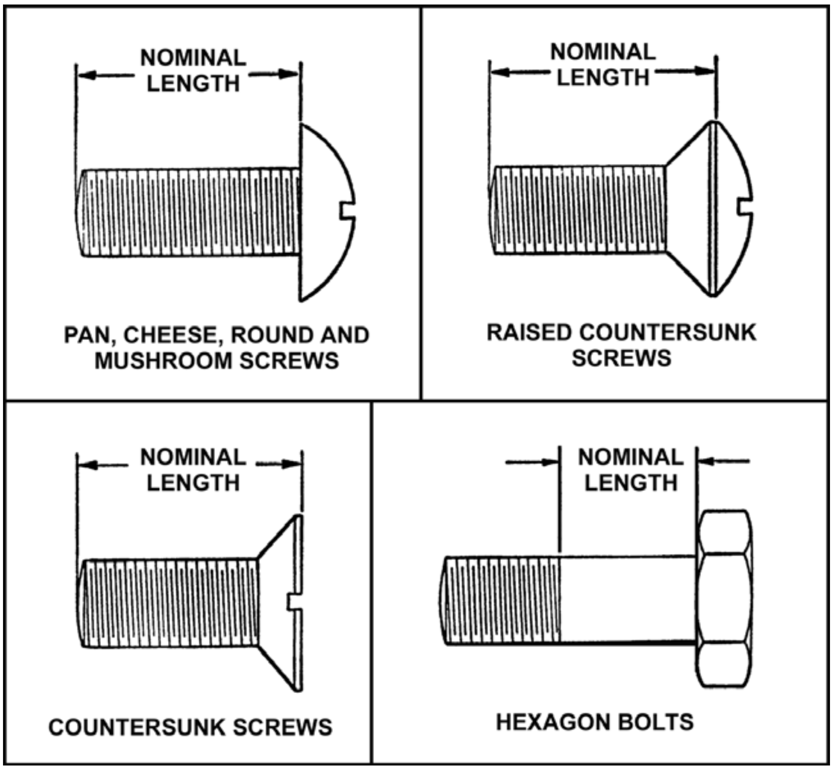


Fig. 13.2, Length of BA/BSF Bolts and all Screws.

13.2.2 Bolts and Screws Having Unified Threads

Table 13.3 gives a list of current and obsolescent bolts and screws in the Unified range. Figure 13.3 illustrates the type of head used in this range and also shows the general 'Unified' symbols, including (h) the cylindrical extension (dog point) sometimes used on parts not having hexagon shaped heads. It will be noticed that there are several shapes of hexagon head; these are alternative methods of manufacture and do not necessarily provide a means of identification, although A108 and A111 bolts, which have close tolerance shanks, have a cylindrical extension on top of the head and shear bolts always have thin heads. Bolts and screws of similar shape may be further identified by the material; aluminium alloy is dyed green, high tensile steel is cadmium plated and corrosion resistant steel or brass are normally uncoated. When the British Standard number is not marked on the bolt head, identification should be made as follows:-

Identify the head from Figure 13.3, for example (g). Reference to Table 13.3 shows that the bolt could be an A113, A114 or A170. Complete identification is possible in this example from the type of finish; in other instances it may be derived from further information, such as diameter or thread length, contained in Table 13.3.

Code System for Unified Bolts and Screws.

The code system used for the identification of the bolts and screws listed in Table 13.3 consists of the Standard number followed by the part number of the particular bolt. The diameter code shown in Table 13.4 is used on all parts but the measurement of length varies with different Standards as follows:-

i. All bolts from A102 to A212 inclusive, normal length in tenths of an inch followed by the diameter, e.g. an A102, 10-32 UNF bolt with plain length of one inch = A102-10D.

   NOTE : Hexagon and mushroom head bolts are also supplied in lengths of 0.05 inch in some specifications, e.g. an A170-1/2D bolt has a plain length of 0.05 inch.

ii. All screws from A204 to A221 inclusive, diameter followed by length in thirty seconds of an inch, e.g. a4-40 UNC A217 screw 1 inch long = A217-A32.

iii All bolts from A226 to A232 inclusive, diameter followed by nominal length in sixteenths of an inch, e.g. a1/4 inch UNJF A229 bolt with plain length one inch = A229-e16.

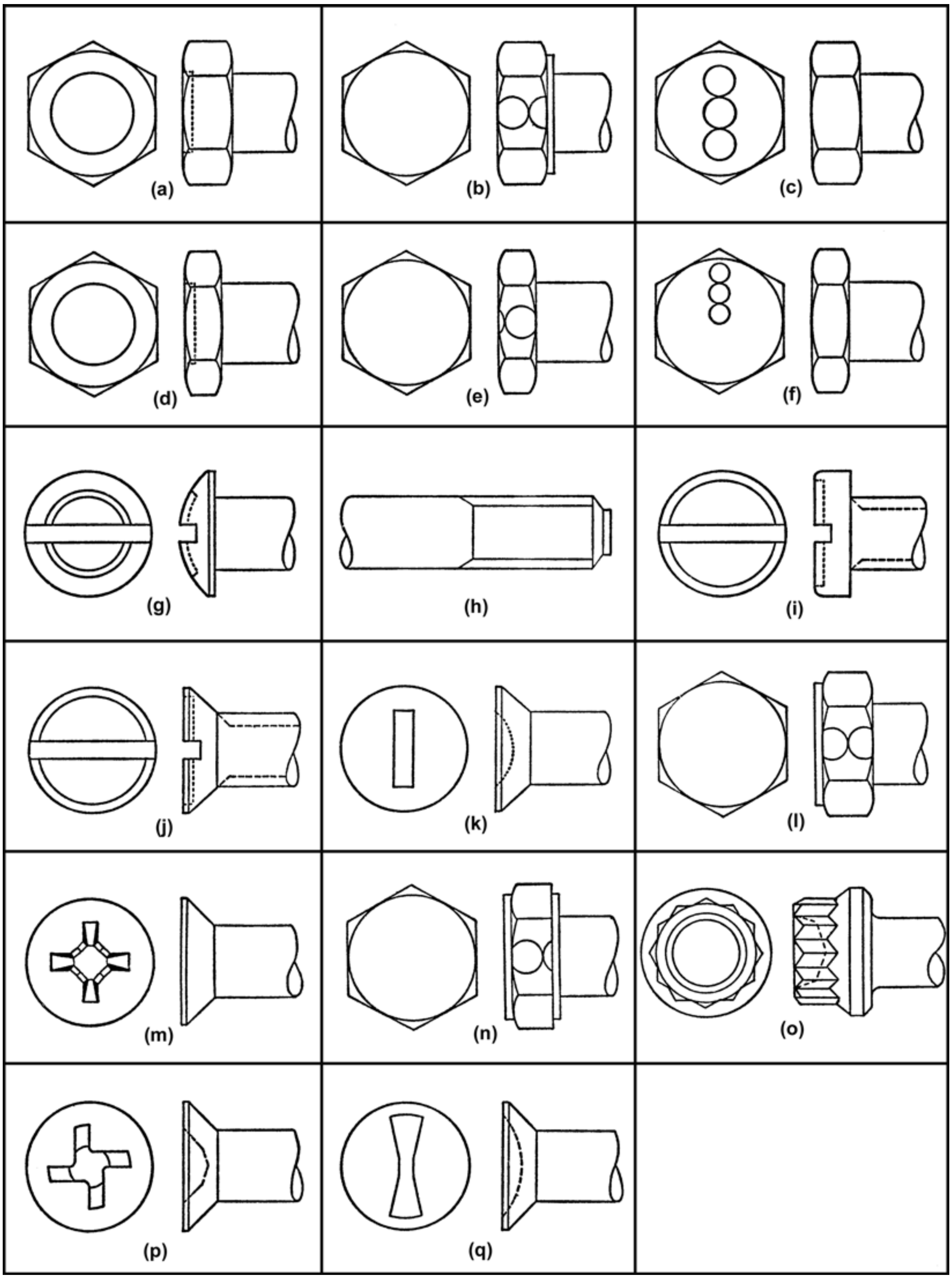
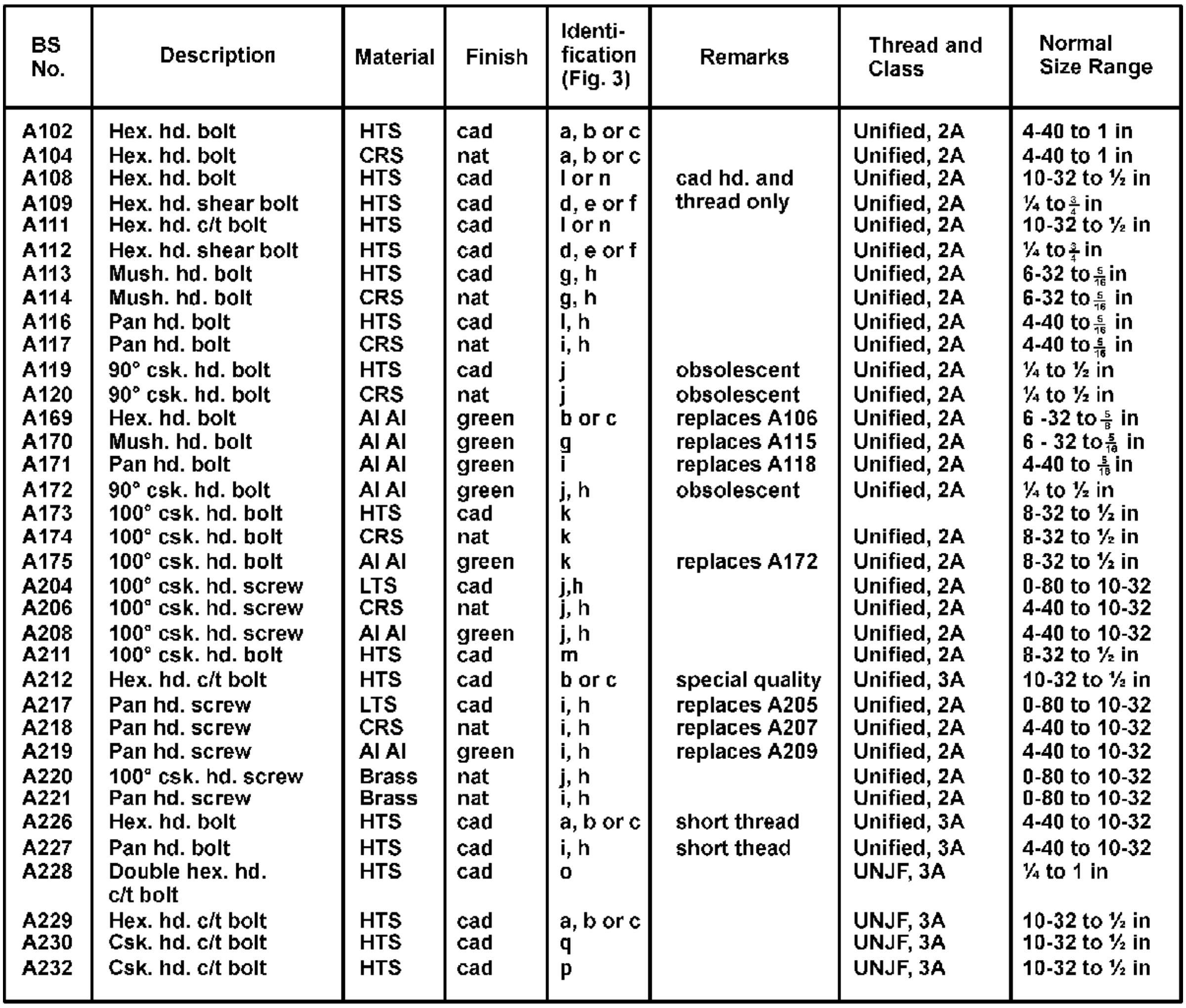


Fig. 13.3, Identification of British Standards Unified Bolts and Screws.

TABLE 13.3
UNIFIED BOLTS AND SCREWS



BS No.	Description	Material	Finish	Identi-fication (Fig. 3)	Remarks	Thread and Class	Normal Size Range
A102	Hex. hd. bolt	HTS	cad	a, b or c		Unified, 2A	4-40 to 1 in
A104	Hex. hd. bolt	CRS	nat	a, b or c		Unified, 2A	4-40 to 1 in
A108	Hex. hd. bolt	HTS	cad	l or n	cad hd. and	Unified, 2A	10-32 to ½ in
A109	Hex. hd. shear bolt	HTS	cad	d, e or f	thread only	Unified, 2A	¼ to $\frac{3}{4}$ in
A111	Hex. hd. c/t bolt	HTS	cad	l or n		Unified, 2A	10-32 to ½ in
A112	Hex. hd. shear bolt	HTS	cad	d, e or f		Unified, 2A	¼ to $\frac{3}{4}$ in
A113	Mush. hd. bolt	HTS	cad	g, h		Unified, 2A	6-32 to $\frac{5}{16}$ in
A114	Mush. hd. bolt	CRS	nat	g, h		Unified, 2A	6-32 to $\frac{5}{16}$ in
A116	Pan hd. bolt	HTS	cad	l, h		Unified, 2A	4-40 to $\frac{5}{16}$ in
A117	Pan hd. bolt	CRS	nat	i, h		Unified, 2A	4-40 to $\frac{5}{16}$ in
A119	90° csk. hd. bolt	HTS	cad	j	obsolescent	Unified, 2A	¼ to ½ in
A120	90° csk. hd. bolt	CRS	nat	j	obsolescent	Unified, 2A	¼ to ½ in
A169	Hex. hd. bolt	Al Al	green	b or c	replaces A106	Unified, 2A	6 -32 to $\frac{5}{8}$ in
A170	Mush. hd. bolt	Al Al	green	g	replaces A115	Unified, 2A	6 - 32 to $\frac{5}{16}$ in
A171	Pan hd. bolt	Al Al	green	i	replaces A118	Unified, 2A	4-40 to $\frac{5}{16}$ in
A172	90° csk. hd. bolt	Al Al	green	j, h	obsolescent	Unified, 2A	¼ to ½ in
A173	100° csk. hd. bolt	HTS	cad	k			8-32 to ½ in
A174	100° csk. hd. bolt	CRS	nat	k		Unified, 2A	8-32 to ½ in
A175	100° csk. hd. bolt	Al Al	green	k	replaces A172	Unified, 2A	8-32 to ½ in
A204	100° csk. hd. screw	LTS	cad	j,h		Unified, 2A	0-80 to 10-32
A206	100° csk. hd. screw	CRS	nat	j, h		Unified, 2A	4-40 to 10-32
A208	100° csk. hd. screw	Al Al	green	j, h		Unified, 2A	4-40 to 10-32
A211	100° csk. hd. bolt	HTS	cad	m		Unified, 2A	8-32 to ½ in
A212	Hex. hd. c/t bolt	HTS	cad	b or c	special quality	Unified, 3A	10-32 to ½ in
A217	Pan hd. screw	LTS	cad	i, h	replaces A205	Unified, 2A	0-80 to 10-32
A218	Pan hd. screw	CRS	nat	i, h	replaces A207	Unified, 2A	4-40 to 10-32
A219	Pan hd. screw	Al Al	green	i, h	replaces A209	Unified, 2A	4-40 to 10-32
A220	100° csk. hd. screw	Brass	nat	j, h		Unified, 2A	0-80 to 10-32
A221	Pan hd. screw	Brass	nat	i, h		Unified, 2A	0-80 to 10-32
A226	Hex. hd. bolt	HTS	cad	a, b or c	short thread	Unified, 3A	4-40 to 10-32
A227	Pan hd. bolt	HTS	cad	i, h	short thead	Unified, 3A	4-40 to 10-32
A228	Double hex. hd. c/t bolt	HTS	cad	o		UNJF, 3A	¼ to 1 in
A229	Hex. hd. c/t bolt	HTS	cad	a, b or c		UNJF, 3A	10-32 to ½ in
A230	Csk. hd. c/t bolt	HTS	cad	q		UNJF, 3A	10-32 to ½ in
A232	Csk. hd. c/t bolt	HTS	cad	p		UNJF, 3A	10-32 to ½ in

Extent of Marking

The marking actually applied to a bolt depend on the particular specification and whether marking is practical. Adding the code 'A217-Z32' to the head of a 2-64 UNF pan head screw (head diameter 0.0155 to 0.167 in), for example, would be very difficult, and having raised characters on a countersunk head bolt would, in certain circumstances, defeat the object of using that shape of head.

i. 'Unified' Marking

Most bolts, and screws 4-40 UNC and larger, are marked with a symbol to show that they have 'Unified' threads. The markings consist of continuous circles (hexagon headed bolts only), a recessed head or shank dog point, and are illustrated in Figure 13.3.

NOTE

At some future date, to be agreed, the 'Unified' marking of screws will be discontinued and identification of these items will be solely from the label on the package.

ii. Code Marking

Most hexagon head bolts 10-32 UNF and larger are marked with the full code, i.e. Standard plus size code, but pan and mushroom head bolts may only be marked with the bolt length and countersunk head bolts are not usually marked at all. The code is not applied to screws, or bolts smaller than 10-32 UNF.

TABLE 13.4
DIAMETER CODE LETTERS

Code	Size	Code	Size
Y	0 - 80 UNF	J	$\frac{3}{8}$ in UNF (UNJF)
Z	2 - 64 UNF	L	$\frac{7}{16}$ in UNF (UNJF)
A	4 - 40 UNC	N	$\frac{1}{2}$ in UNF (UNJF)
B	6 - 32 UNC	P	$\frac{9}{16}$ in UNF (UNJF)
C	8 - 32 UNC	Q	$\frac{5}{8}$ in UNF (UNJF)
D	10 - 32 UNF (UNJF)	S	$\frac{3}{4}$ in UNF (UNJF)
E	¼ IN UNF (UNJF)	U	$\frac{7}{8}$ in UNF (UNJF)
G	$\frac{5}{16}$ in UNF (UNJF)	W	1 in UNF (UNJF)

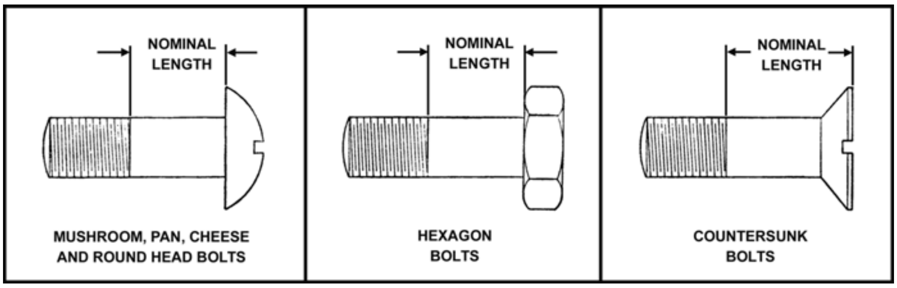


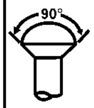
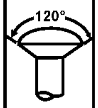
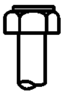
Fig. 13.4, Length of BS unified Bolts

13.3 'AS' BOLTS AND SCREWS

This paragraph is concerned with the identification of bolts and screws complying with the Society of British Aerospace Companies ‘AS’ series of specification. The specification provide a range of bolts and screws in sizes and head shapes not found in British Standards specification. Bolts manufactured from special materials (e.g. heat resistant steel) and having Unified threads are also included.

Table 13.5 shows the AS specification for bolts and screws with BA/BSF threads, together with complete identification details.

TABLE 13.5
‘AS’ NUMBERS OF BA/BSF BOLTS AND SCREWS

Head	Round 	Mush-room 	Raised Counter-sunk (90°) 	Counter-sunk (90°) 	Raised Counter-sunk (120°) 	Counter-sunk (120°) 	hexagon 	Material	Finish
Bolts with screwdriver slot or hexagonal head	1247+	1249+	1245+	1243+				Al Al	Anodic
	4565	4566	4564	4563				Al Al	Blue
	1246	1248	1244+	1242			4569$^{+}_{+}$	HTS	Cad.
	2922	2923	2921	2920				SS	Nat.
							2504$^{+}_{+}$	HTS	Cad h & t
Bolts with phillips recess	3078*+ 4597**	3079*+ 4598**	3295**	3294**	3296**	3297**		HTS	Cad.
Screws with Phillips recess	2991	2992	2994	2993	2995	2996		Mild Steel	Cad.

* 1 dot on head

**2 dots on head

\+ obsolescent

$^{+}_{+}$ 2 BA only

Table 13.6 shows the AS specification for 'round head' bolts with a locking flat and Unified threads. These bolts are manufactured from high tensile steel and are cadmium plated.

TABLE 13.6
'AS' NUMBERS OF ROUND HEAD BOLTS WITH FLAT (UNIFIED)

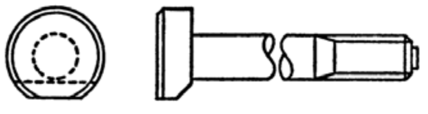
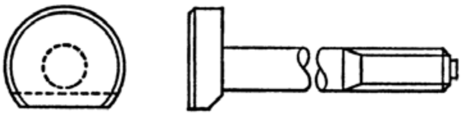
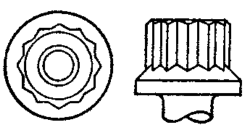
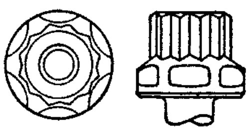
 Small head				 Large head			
10 - 32 UNF	¼ UNF	$\frac{5}{16}$ UNF	$\frac{3}{8}$ UNF	10 - 32 UNF	¼ UNF	$\frac{5}{16}$ UNF	$\frac{3}{8}$ UNF
6760 to 6804	6895 to 6939	7033 to 7077	7171 to 7215	6850 to 6894	6985 to 7032	7123 to 7170	7264 to 7308

Table 13.7 shows the AS specifications for double hexagon head bolts manufactured from heat resistant steel and having UNS of UNJF threads. Requirements for protective treatment vary between specifications, some bolts being silver plated while others have a natural finish.

TABLE 13.7
'AS' SPECIFICATIONS

			HEADS SHAPE	
Thread	Type	Material		
UNS Threads (10-32 to $\frac{3}{8}$ - 24 UNS - 3A)	Plain	DTD 5066	13000 - 13399	17000 - 17399
		DTD 5026	13400 - 13799	17400 - 17799
		DTD 5077	13800 - 14199	17800 - 18199
	Externally Relieved Body	DTD 5066	14500 - 14899	18200 - 18599
		DTD 5026	14900 - 15299	18600 - 18999
		DTD 5077	15300 - 15699	19000 - 19399
	Close Tolerance Shank	DTD 5066	19400 - 19799	
		DTD 5026	19800 - 20199	
		DTD 5077	20200 - 20599	
UNJF Threads	Plain (8 - 36 to $\frac{3}{8}$ - 24 UNJF)	DTD 5066	20800 - 21299	
		DTD 5026	21300 - 21799	
		DTD 5077	21800 - 22299	
	Close Tolerance Shank (10 - 32 to $\frac{3}{8}$ - 24 UNJF)	DTD 5066	22400 - 22799	
		DTD 5026	22900 - 23299	
		DTD 5077	23400 - 23799	

NOTE

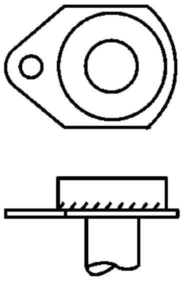
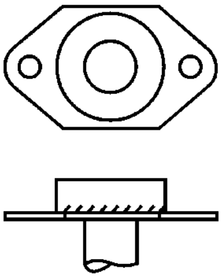
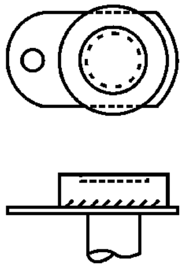
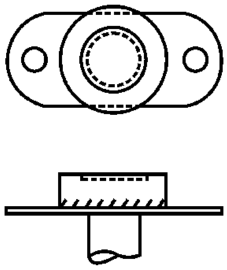
The UNS bolts listed in the table have reduced diameter threads for use in high temperature applications and should be fitted with nuts complying with specifications AS20620 to AS 20639.

For purposes of standardisation a further series of heat resistant bolts with UNJF threads is being introduced to replace those with UNS threads. Details of the AS numbers allocated to these bolts are not, as yet, available, but the method of identification will be the same as described for the bolts in Table 13.7.

Table 13.8 shows the AS specifications for anchor bolts manufactured from weldable steel.

ASI and AS2 are specifications for titanium bolts having Unified threads, with hexagon and 100^0 countersunk heads respectively. Both specifications are obsolescent but the bolts may be recognised by the material finish and the marking 'AS1' or 'AS2' on the head, as appropriate.

TABLE 13.8
'AS' NUMBERS OF ANCHOR BOLTS

BA/BSF		Unified	
			
4752	4753	6735	6736
Weldable bolt is AS 4754		Weldable bolt is AS 6737	

Identification Marking

AS1, AS2 and all the bolts listed in Table 13.7 are marked with the AS specification to which they conform. Other AS bolts are unmarked except for the 'Unified' symbol which is applied to anchor bolts (recessed head) and the round head bolts shown in Table 13.6 (shank dog point).

Code System

Although a large number of AS bolts and screws are not marked in any way, codes are necessary for ordering and storage purposes.

The code system used for the identification of the bolts and screws listed in Table 13.5 and 13.8, and for ASI and AS2 bolts, is the same as that used for British Standards bolts, i.e. AS number followed by a number indicating length in tenths of an inch and a letter indicating diameter (Tables 13.2 or 13.4 as appropriate). The length is measured in the same way as for British Standard parts.

NOTE

AS 2504 and 4569 bolts are only manufactured in 2 BA; the diameter code is therefore not required.

Reference to Table 13.6 shows that a batch of AS numbers is allocated to each diameter of bolt in this series. A separate number within each batch is reserved for a particular length of bolt so that a code system is unnecessary; any particular AS number in this series applies only to a bolt of specified length and diameter. The plain length is graduated in steps of 0.05 inch from 0.05 inch to 0.9 inch, and steps of 0.1 inch thereafter up to 3.4 inch. A 10-32 UNF bolt 1.2 inch long and having a small head will therefore be AS 6780

The bolts shown in Table 13.7 also have a batch of AS numbers allocated to each diameter but in this case the range of available lengths varies between specifications. The length of the bolt is taken as the whole length of the shank, including the thread in sixteenths of an inch up to 2 inches long, and eighths thereafter, each particular size having a unique reference number. It should be noted that this series of bolts has a threaded length greater than that normally found on aircraft fasteners. A minimum length of plain portion is also maintained, so that the thread length in the shorter bolts is reduced below the normal for the particular diameter.

13.4 FUTURE TRENDS

Because of the importance of reducing weight in the construction of an aircraft, designers are constantly seeking means of using higher strength or lighter alloys for structural purposes. This trend applies particularly to fasteners and it is apparent that the use of smaller diameter bolts and miniature anchor nuts will become more widespread. It will be accompanied by the use of threads of UNJF from.

In the field of light alloys, specifications for titanium bolts are being prepared and will probably be drawn up in accordance with existing American practice, within the framework of British Standard A101, entitled ''General Requirements for Titanium Bolts''

Because of the vast experience gained, particularly in America, in the use of both standard and miniature components, it has been internationally agreed to use Unified inch threads on fasteners. However, with the introduction of metric dimensions in other fields, it is probable that a metric thread series will eventually be accepted.

As far as identification features are concerned it appears likely that the system used for recent specifications will continue; bolts in the AS series will be marked with a number which will be unique for a particular diameter and length, and bolts in the BS series will use the code at present applied to bolts with UNJ threads.

NOTE

There is no symbol used to differentiate between threads of standard unified or UNJ form.

13.5 ABBREVIATIONS

The following is an alphabetical list of abbreviations used in this Leaflet:-

AGS	Aircraft General Standards
AS	Aircraft Standards
Al Al	Aluminium alloy
BA	British Association
blue	dyed blue over anodic film
BSF	British Standards Fine
cad.	cadmium plated all over
cad. h & t	cadmium plated head and thread only
csk.	countersunk
c/t	close tolerance
CRS	corrosion resisting steel
FCS	free-cutting steel
green	dyed green over anodic film
hd.	head
hex.	hexagon
HTS	high tensile steel
LTS	low tensile steel
mush.	mushroom
nat.	natural finish
SS	stainless steel
UNC	Unified coarse thread
UNF	Unified fine thread
UNS	Unified special thread
UNJF	Unified fatigue-resistant fine thread

■■■

CHAPTER : 14
IDENTIFICATION MARKING
NUTS OF BRITISH MANUFACTURE

INTRODUCTION

This chapter gives guidance on the identification of nuts complying with British Standards 'A' Series of Aircraft Materials and Components, with AGS Specifications and with certain specifications in the Society of British Aerospace Companies 'AS' Series.

Failure of a fastener through the use of an incorrect nut could cause malfunction and, in certain circumstances, lead to the jamming of controls. It is most important, therefore, that engineers and inspectors should be acquainted with the features by which any particular type of nut may be identified. A nut may have the correct type of thread but it may be unsuitable for some other reasons such as material, temperature classification or length of thread; it is also possible to fit a nut of incorrect size, e.g. a 10-32 UNF nut may fit an 8-32 UNC screw. These dangers may be minimised by constant vigilance during servicing operations.

For the benefit of engineers engaged on the maintenance of older types of aircraft, information on obsolescent Standards is also included in this chapter, together with details of replacement Standards.

Information on the identification of bolts and screw of British manufacture is given in chapter before..

A list of abbreviations and terms used in this chapter is given at the end.

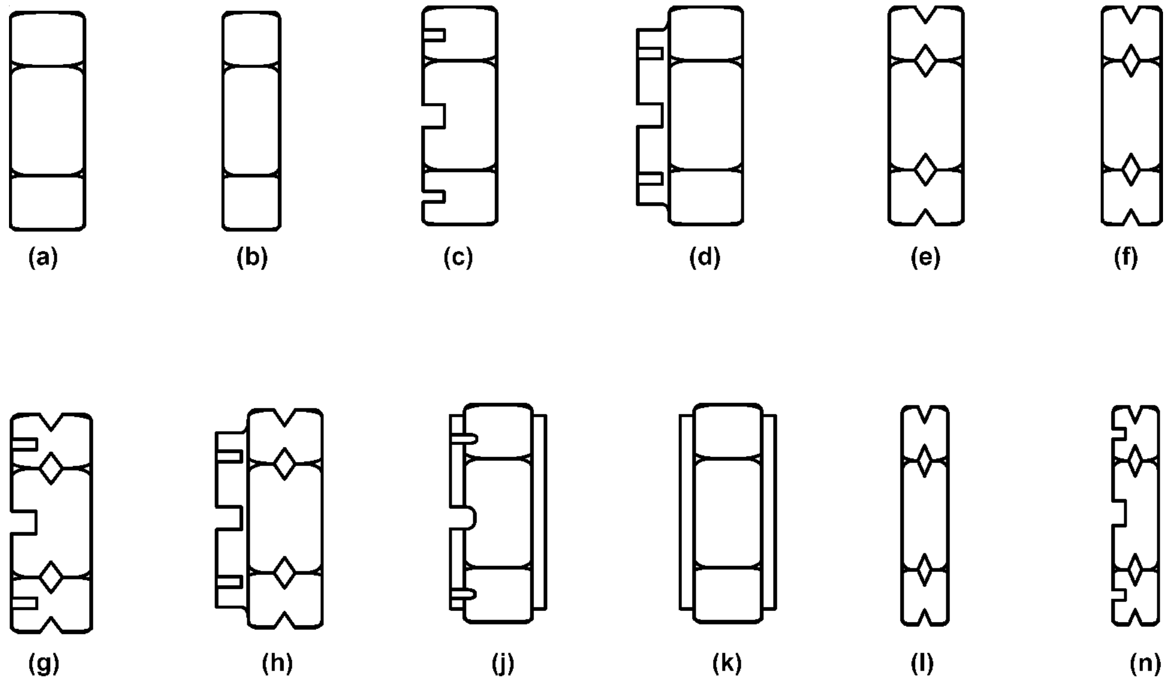
BRITISH STANDARDS NUTS HAVING BA OR BSF THREADS

Table 14.1 gives a list of relevant Standards and superseding Standards. Identification details are included in the table and the different nuts included in this range are illustrated in Figure 14.1.

TABLE 14.1
BA AND BSF HEXAGON NUTS

BS No.	Types (para. 2.2)	Material	Finish	Remarks	Identi-fication (Fig. 1)*	Size Range
A14	P and T	Brass	cad or natural	obsolescent	a or b	(i) 10 BA to 0 BA (ii) 4 BA to 1¼ BSF
A24	P, T, S and C	HTSS	natural	replaces A16 Z	e, f, g or h	6 BA to 1 in BSF
A27	P, T, S and C	HTS	cadmium	replaces A16 Y	e, f, g or h**	6 BA to 1 in BSF
A29	P and S	Al Al	anodic	replaces A18	j or k	6 BA to 1 in BSF
A47	P	LTS	cadmium	order as A27 in	a	12 BA to2 BA
A48	T	LTS	cadmium	2, 4 and 6 BA	b	8 BA to 2 BA
A49	P	SS	natural		a	12 BA to 2 BA
A50	T	SS	natural		b	8 BA to 2 BA
A51	P	Al Al	anodic		a	12 BA to 2 BA
A52	T	Al Al	anodic		b	8 BA to 2 BA
A53	P	Brass	tinned	replaces A14 P	a	12 BA to 2 BA
A54	T	Brass	tinned	replaces A14 T, 2 and 4 BA	b	8 BA to 2 BA
A58	T or TS	HTS	cadmium	shear nut	l or n	¼ to $\frac{3}{4}$ in BSF

* The BS number is marked on all nuts larger than $\frac{3}{4}$ inch BSF.
** a, b, c or d in sizes below ¼ inch BSF.



NOTE : Shear nuts (l) and (n) are 0 - 2 in thick in all sizes.

Fig. 14.1, Identification Features BA/BSF Nuts.

Identification

Identification of a particular nut may be effected from its shape and anti-corrosive treatment; in addition, all nuts larger than 3/8 inch BSF are marked with the British Standards number, and parcels of nuts are labelled with the complete part number.

Code System for Nuts

The code system used for the identification of the nuts listed in Table 14.1 (with the exception of A14) consists of the Standards number followed by a letter indicating the size of the thread (Table 14.2), followed by a letter indicating the type of nut, i.e. P (ordinary nut), S (slotted nut), c (castle nut), and T (thin nut). These type letters are not, however, applied to the nuts. For example, the complete part referencing number used on the drawing, or when ordering 7/16 inch ordinary A27 nuts is A27LP, but the corresponding marking of the nuts will be A27L.

TABLE 14.2
DIAMETER CODE LETTERS

Code	Size	Code	Size
A	6 BA	P	$\frac{9}{16}$ in BSF
B	4 BA	Q	$\frac{5}{8}$in BSF
C	2 BA	S	$\frac{3}{4}$in BSF
E	¼ in BSF	U	$\frac{7}{8}$in BSF
G	$\frac{5}{16}$ in BSF	W	1 in BSF
J	$\frac{3}{8}$ in BSF	X	12 BA
L	$\frac{7}{16}$ in BSF	Y	10 BA
N	$\frac{1}{2}$ in BSF	Z	8 BA

Where nuts have a left-hand thread the letter 'L' is added to the part number, thus the above example with a left-hand thread would have the part number A27LPL. The letter 'L' is marked on of the hexagonal surfaces of the nut.

Code System for BS A14 Brass Nuts

In the obsolescent British Standard A14 two ranges of nuts are covered, viz. O BA plain and 4 BA to 1.1/4 inch BSF thin.

i. In the former (which is superseded by A53) the diameter is indicated by the BA number, and the part number consists of the Standard number followed by the diameter number and the letter 'B'. For example, the complete part reference number used on the drawing or when ordering 4 BA plain nuts, is A14 4B.

ii. In the second range the 4 and 2 BA nuts are superseded by British Standard A54, but the coding system is similar to that in Table 14.3, with the exceptions that 'X' and 'Y' are used to denote 1.1/3 inch BSF and 1.1/4 inch BSF nuts respectively, and the letter 'B' is substituted for the usual letter 'T'. For example, a 1/4 inch thin nut has a reference number A14 EB.

iii. Both ranges include nuts with left-hand threads .

BRITISH STANDARDS NUTS HAVING UNIFIED THREADS

Table 14.3 gives a list of the relevant Standards and superseding Standards for ordinary hexagon nuts and Table 4 gives the Standards applicable to stiff nuts of various types. The nut are illustrated in Figures 14.2 and 14.3 respectively.

TABLE 14.3
UNIFIED HEXAGON NUTS

BS No.	Type (para. 3.2)	Material	Finish	Remarks	Identification (Fig. 2)*	Size Range
A 103	P, T, S or C	HTS	cad		a, b, c or d	4 - 40 UNC to 1 in UNF
A 105	P, T, S, or C	CRS	natural	marked with 'Z'	a, b, c or d	4 - 40 UNC to 1 in UNF
A 107	P or S	Al Al	green		a or c	4 - 40 UNC to 1 in UNF
A 110	T or TS	HTS	cad	shear nut	e or f	¼ to $\frac{3}{4}$ in UNF
A 222	P	LTS	cad		a	0- 80 and 2 - 64 UNF
A 223	T	LTS	cad		b	0 - 80 and 2 - 64 UNF
A 224	P	Brass	tinned		a	0 - 80 and 2 - 64 UNF
A 225	T	Brass	tinned		b	0 - 80 and 2 - 64 UNF

*** The BS number is marked on all nuts larger than $\frac{3}{8}$ inch UNF.**

IDENTIFICATION

Nuts with Unified threads may be identified by their shape, type of finish and thread size. Additionally, all nuts other than anchor nuts, 8-32 UNC and larger, are marked with the 'Unified' symbol of continuous circles. The identification of smaller nuts may be more difficult, for example, an A222, 2-64 UNF nut is similar to an A47, 8 BA nut, and it may be necessary to try the nut on a bolt of known thread to achieve positive identification.

Nuts listed in Table 14.3, larger than 3/8 inch diameter, are marked with the British Standard number. Stiff nuts 1/4 inch UNF and larger which are manufactured from corrosion resisting steel, are marked with the letter 'Z' either on one flat or on the base plate; when the nut is also silver plated, the letter 'X' is added to or replaces the 'Z'.

Brass anchor nuts are marked with the letter 'B' and all hexagon brass stiff nuts have a washer face (Figure 14.3).

NOTE

The shape of the friction element on a stiff nut should not be taken as an identification feature. These are usually patented devices and depend on the design favoured by the particular manufacturer. Nut specifications normally only quote the maximum dimensions of the friction element and the frictional unscrewing torque required.

TABLE 14.4
UNIFIED STIFFNUTS

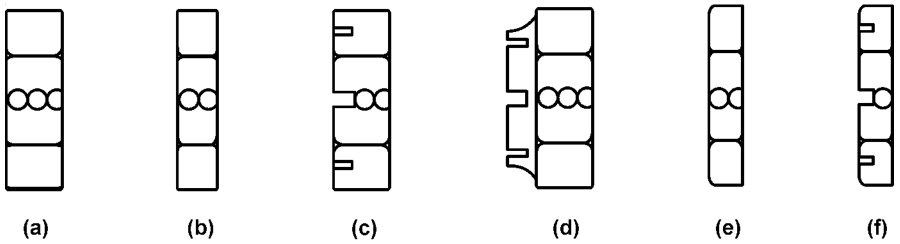
Basic Type		Attach-ment plate material	Temperature Classification, Nut Material and Coating				
			- 75°C to + 125°C		- 75°C to + 200°C		- 75°C to + 425°C
			Al Al†	Brass or Bronze††	Steel*	CRS**	
			Anodised	Tinned	Cad plated		Silver Plated
Hexagon	Ordinary thin cap		A 129 A 130 A 214	A 131 A 132 —	A 125 A 126 A 213	A 127 A 128 —	A 180 A 181 —
Clinch			A 124	A 123	A 122	—	—
Single lug fixed anchor	ordinary thin		A 161 A 162	A 163 A 164	A 157 A 158	A 159 A 160	A 200 A 201
Double lug fixed anchor	ordinary thin cap		A 140 A 141 A 216	A 142 A 143 —	A 136 A 137 A 215	A 138 A 139 —	A 186 A 187 —
Double lug floating anchor	ordinary thin	Al Al	A 153 A 154	— —	A 151 A 152	— —	— —
	ordinary thin	Brass	— —	A 155 A 156	— —	— —	— —
	ordinary thin	Steel	— —	— —	A 147 A 148	— —	— —
	ordinary thin	CRS	— —	— —	— —	A 149 A 150	A 192 A 193
Strip	ordinary thin		A 167 A 168	— —	A 165 A 166	— —	— —

* Nut body is made from S 92, S 112, S 113, S 114 or S 117 depending on the size of the nut. Base plate is made from S 510 or S 511 and attachment plate from S 511 or L 72.

** Nut body is made from S 80, base plate and attachment plate from S 521.

† Nut body is made from L 65, base plate and attachment plate from L 72.

†† Nut body is made from B 11, BS 249, BS 250, BS 251 or BS 369. Base plate and attachment plate are made from BS 267 or BS 409.



NOTE : Sheat nuts (e) and (f) are 0.2 in thick in all sizes

Fig.14.2, Unified Nuts.

Code System

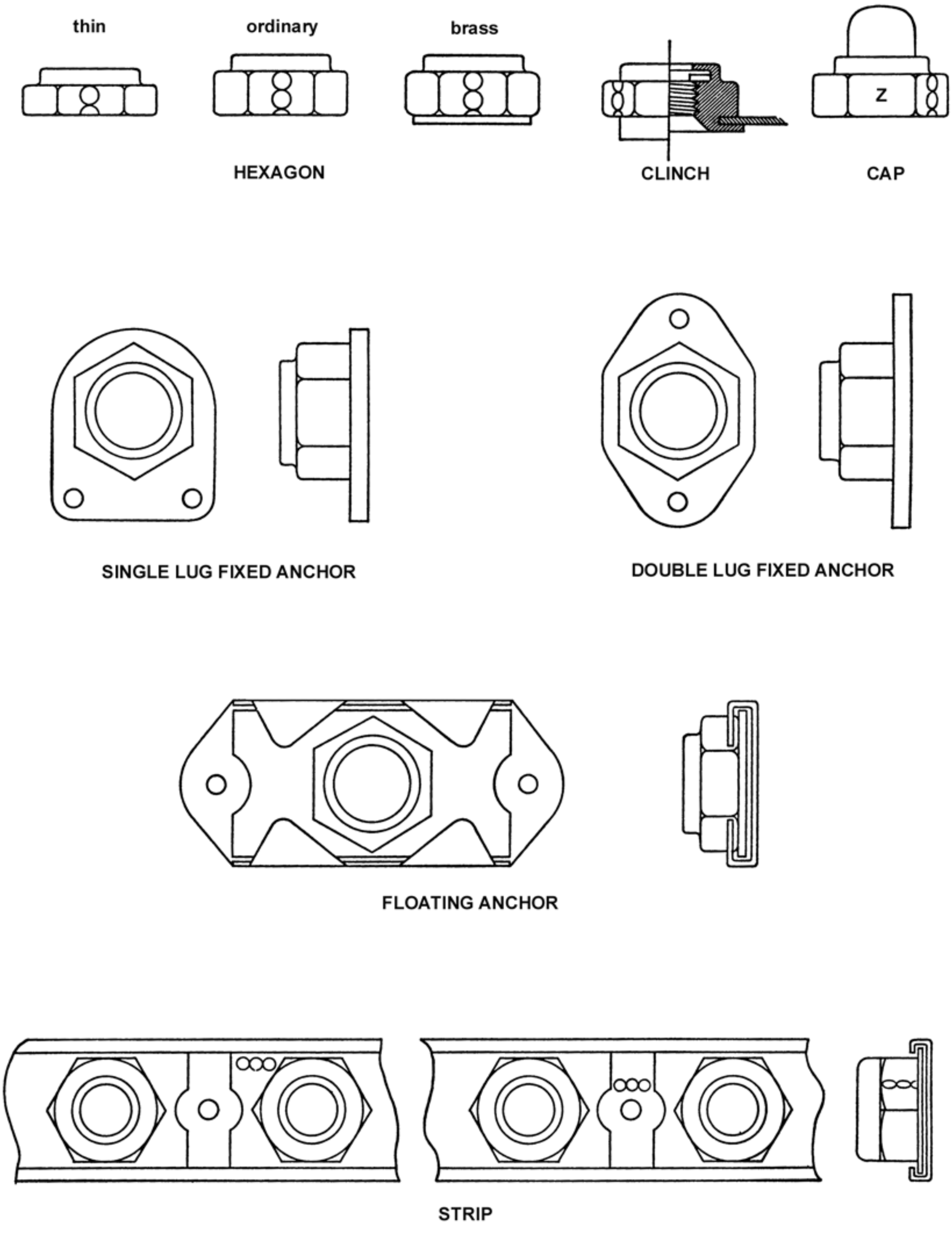
The code system used for the identification of nuts having Unified threads consists of the British Standard number followed by a letter indicating the size of thread (Table 14.5), followed, when appropriate, by a letter indicating the type of nut, i.e. P (ordinary nut), S (slotted nut), C (castellated nut) and T (thin nut). These letters are not, however, applied to the nut. For example, the complete part number used on drawings or when ordering a 7/16 inch UNF ordinary A 107 nut is A107 nut is A107 LP but the nut is only marked 'A 107'. Where stiff nuts are concerned the part number is not marked on nuts of any size, but over 3/8 inch diameter a letter indicating thread size is applied.

Clinch Nuts, A122 to A124

A similar coding system to that described in paragraph 3.2 is used, followed by a number indicating the length of spigot required. A choice of three spigot length is specified of each size of nut, depending on the thickness of material through which the nut is to be clinched.

Stiff nuts

As mentioned in paragraph above, hexagon, clinch and strip stiff nuts are marked with a 'Unified' symbol to show the type of thread used. Anchor nuts (fixed or floating) are not so marked as the shape of the base plates is considered to be adequate for recognition purposes; there are much smaller and less angular than those fitted to similar stiff nuts with a BA of BSF threads in the AGS range of specifications. In the Unified stiff nuts the base plate is integral with the nut body, but the nut portion of an AGS stiff nut is retained inside a cage.



NOTE : The nut body of any anchor stiffnut may be either hexagonal or round.

Fig. 14.3, Identification Features, Unified Stiffnuts.

When it is necessary to differentiate on the drawing or order between metallic and nonmetallic friction element stiff nuts in the steel and corrosion-resisting steel (-75^{0}C to +200^{0}C) ranges, the suffix '/66' or '/77' respectively is added to the part reference. For example, the complete part reference for a 1/4 inch UNF steel nut with a metallic friction element is A125 E/77. A part reference with out such a suffix indicates that either type of nut may be used.

Stiff nuts complying with British Standards A 180, A 181, A 186, A 187, A 192, A193, A200 and A201 may be supplied unplated for use in that condition, or for subsequent plating by the user for applications where plating other than silver is required. When ordering such nuts, '/UP' should be added to the reference number. For example, a 16 inch UNF corrosion-resisting Steel, thin double-lug, floating anchor nut unplated, is A 193 G/UP.

Left-Hand Threads

Left-Hand threads in nuts are indicated by the use of the suffix letter 'L'. Thus the reference number for a 4-40 UNC ordinary brass nut complying with BS A210 would be A210 APL, i.e. the Standard number + the diameter letter + the nut type + left-hand thread. The letter 'L' is also applied to one of the hexagon faces of the nut. There is no provision made for left-hand threads in the specifications relating to stiff nuts.

TABLE 14.5
DIAMETER CODE LETTERS
UNIFIED THREADS

Code	Size	Code	Size
Y	0 - 80 UNF	J	$\frac{3}{8}$in UNF
Z	2 - 64 UNF	L	$\frac{7}{16}$ in UNF
A	4 - 40 UNC	N	$\frac{1}{2}$ in UNF
B	6 - 32 UNC	P	$\frac{9}{16}$ in UNF
C	8 - 32 UNC	Q	$\frac{5}{8}$ in UNF
D	10 - 32 UNF	S	$\frac{3}{4}$ in UNF
E	¼ in UNF	U	$\frac{7}{8}$ in UNF
G	$\frac{5}{16}$ in UNF	W	1 in UNF

'AS' NUTS
Double hexagon Stiff nuts

A range of double-hexagon stiff nuts manufactured from heat resistant steel and having UNJF threads, is provided in the SBAC, AS series 20623 to 20630, representing thread sizes 8-36 UNJF to 9/1618 UNJF. These nuts are specified for use on the AS series of heat resistant bolts with UNJF threads, and may be identified from the AS number marked on the extended washer portion of the nut. They are illustrated in Figure 14.4.

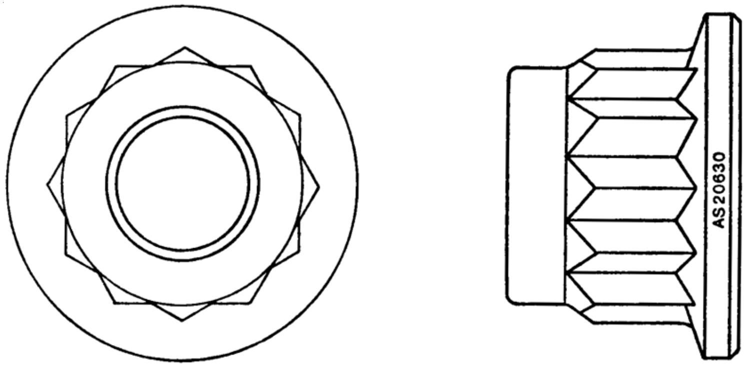


Fig. 14.4, 'AS' Double Hexagon Stiffnuts.

Ordinary and Anchor Stiff nuts

A Series of AS specifications for lightweight hexagon and anchor stiff nuts has been produced in the range AS 8600 to 8661 (see Table 14.6). These nuts are manufactured from high tensile steel and are considerably lighter than conventional nuts; all are now manufactured with UNJ threads.

No markings are applied to the nuts but they are quite different from either the BS or AGS stiff nuts and may be identified purely from their shape (see Figure 14.5). For storage and ordering purposes the nuts are identified by the AS number, followed by a size code letter as shown in Table 14.5. A further code is necessary for ordering strip nuts, and this consists of a number representing the distance between nut centres in eighths of an inch, followed by an additional number representing the number of nuts required in a strip. A 10-32 UNF strip nut with 0.75 inch nut spacing and having 10 mm nuts would therefore be, AS 8612/D/6/10.

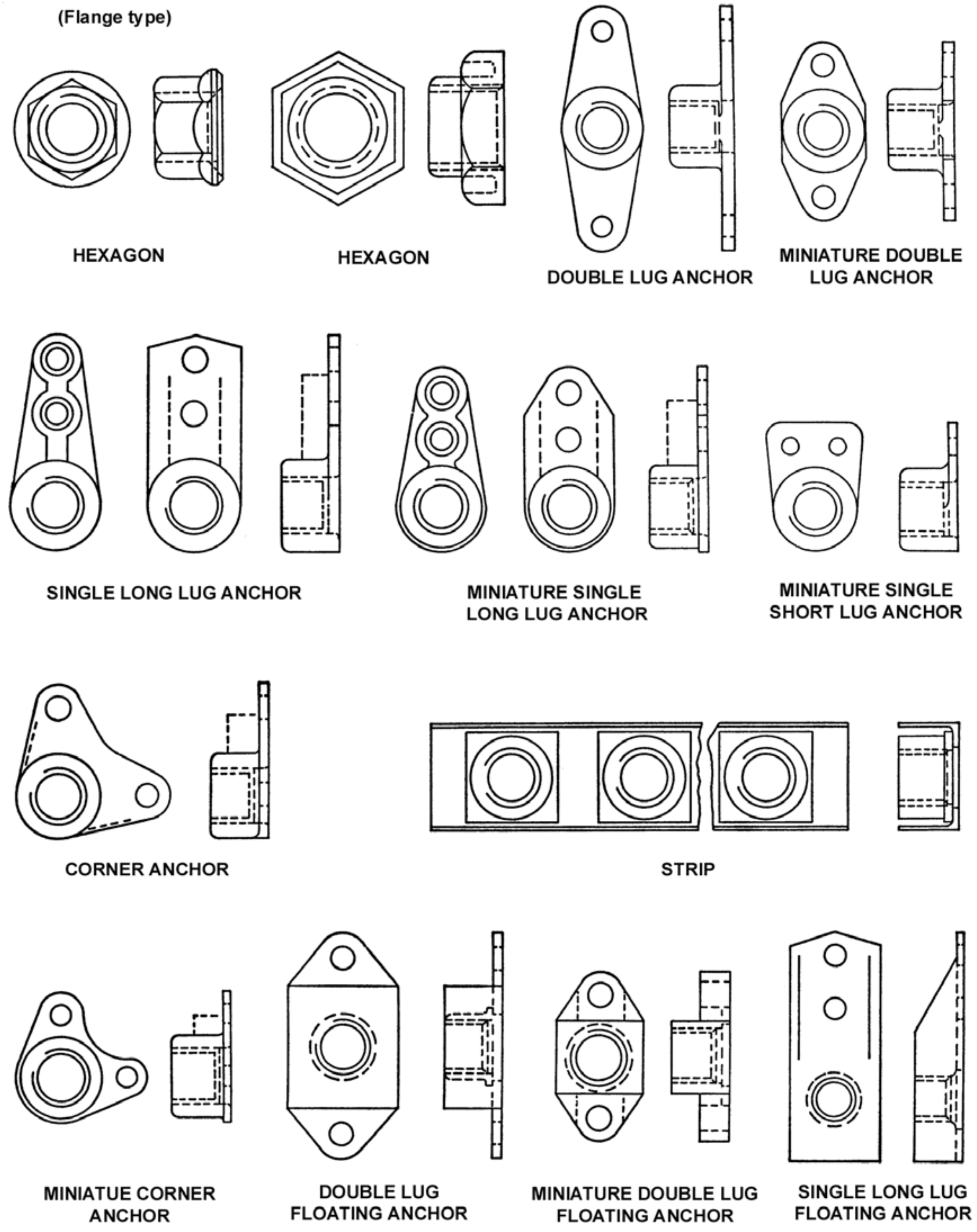
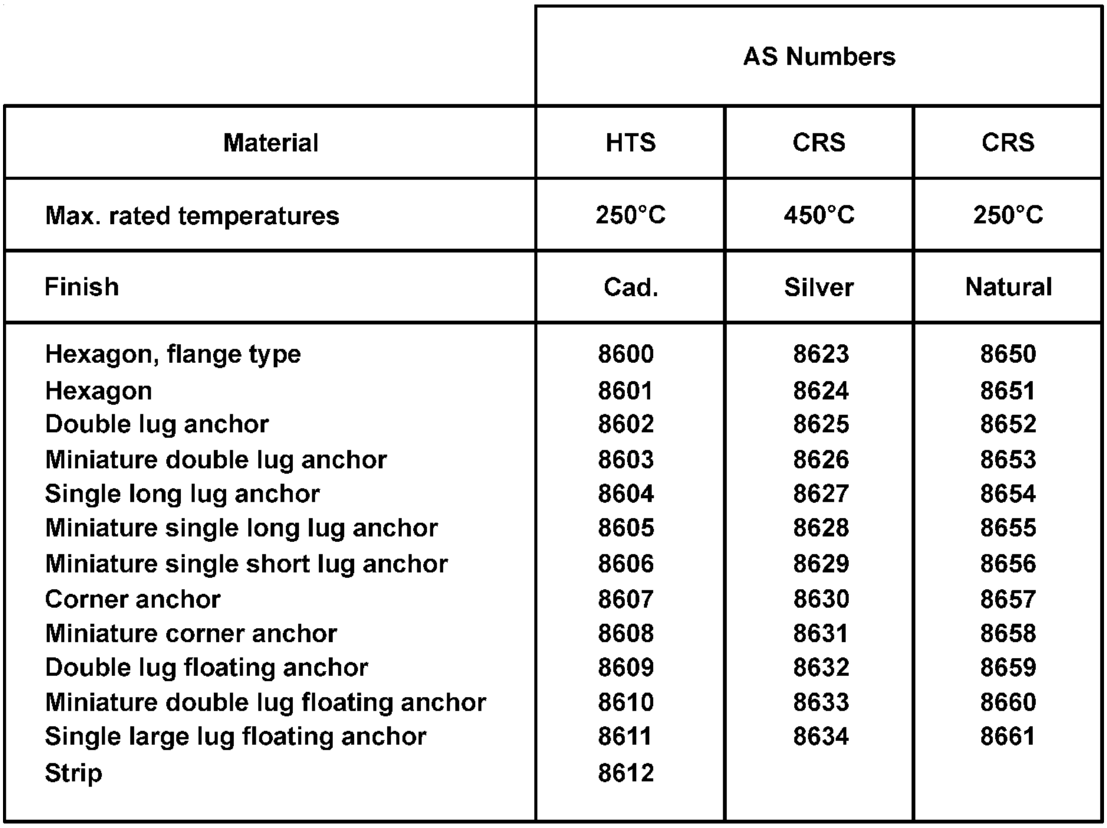


Fig. 14.5, Typical 'AS' Lightweight Stiffnuts.

As with the BS and AGS stiff nuts, the shape of the friction device is optional, the specification merely stating the maximum or minimum limits as appropriate. A further stipulation with this series of nuts is the maximum permissible weight per 100 units (and weight per inch for strip nut channels).

TABLE 14.6
'AS' LIGHTWEIGHT STIFF NUTS

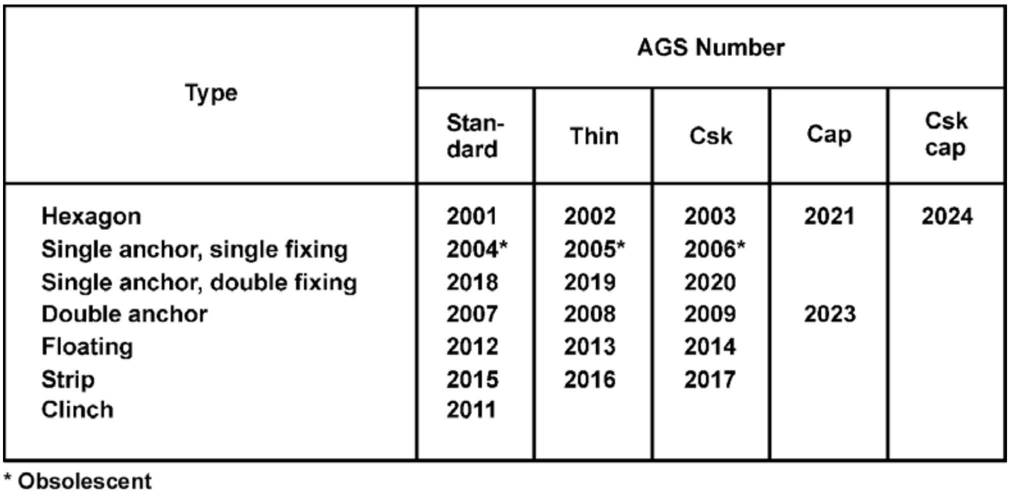


	AS Numbers		
Material	HTS	CRS	CRS
Max. rated temperatures	250°C	450°C	250°C
Finish	Cad.	Silver	Natural
Hexagon, flange type	8600	8623	8650
Hexagon	8601	8624	8651
Double lug anchor	8602	8625	8652
Miniature double lug anchor	8603	8626	8653
Single long lug anchor	8604	8627	8654
Miniature single long lug anchor	8605	8628	8655
Miniature single short lug anchor	8606	8629	8656
Corner anchor	8607	8630	8657
Miniature corner anchor	8608	8631	8658
Double lug floating anchor	8609	8632	8659
Miniature double lug floating anchor	8610	8633	8660
Single large lug floating anchor	8611	8634	8661
Strip	8612		

Stiff nuts

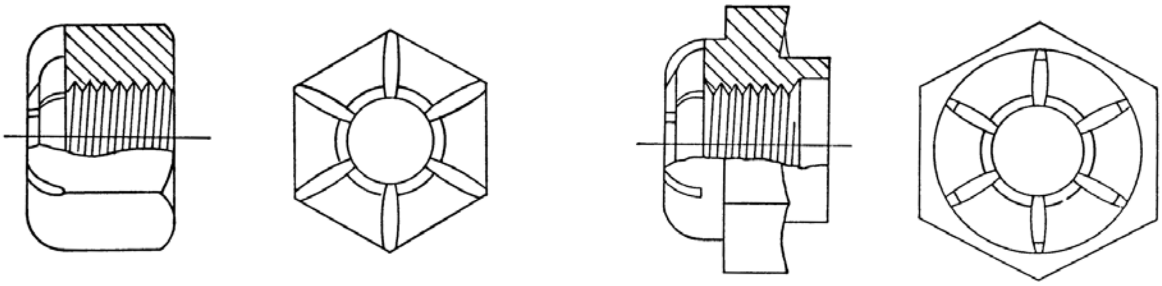
Table 14.7 gives a list of the relevant AGS numbers for the various types of stiff nuts in this series; the nuts are illustrated in Figure 14.6 to show the differences from British Standards stiff nuts AGS stiff nuts have BA or BSF threads

TABLE 14.7
AGS STIFF NUTS



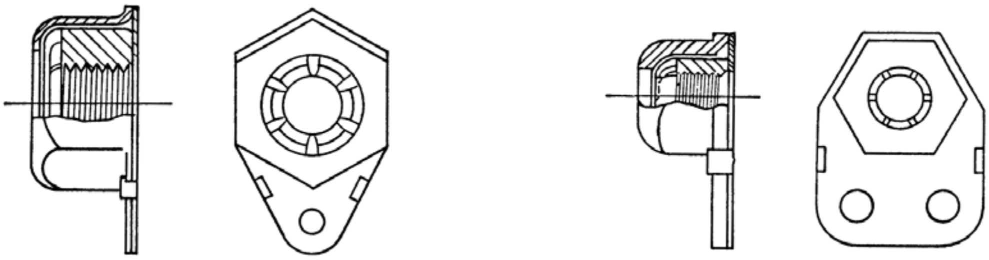
Type	AGS Number				
	Standard	Thin	Csk	Cap	Csk cap
Hexagon	2001	2002	2003	2021	2024
Single anchor, single fixing	2004*	2005*	2006*		
Single anchor, double fixing	2018	2019	2020		
Double anchor	2007	2008	2009	2023	
Floating	2012	2013	2014		
Strip	2015	2016	2017		
Clinch	2011				

* Obsolescent



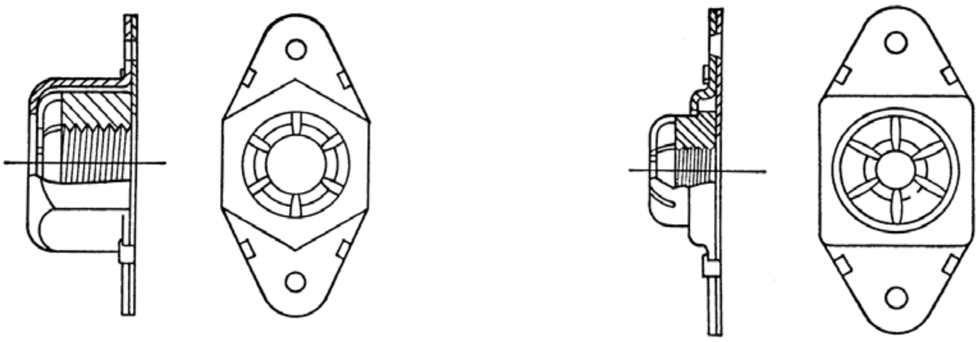
HEXAGON NUT

CLINCH NUT



SINGLE LUG ANCHOR NUT WITH SINGLE RIVET FIXING

SINGLE LUG ANCHOR NUT WITH DOUBLE RIVET FIXING



DOUBLE LUG ANCHOR NUT

FLOATING ANCHOR NUT

Fig.14.6, Typical AGS Stiffnuts.

Code Systems

The part referencing system consists of the AGS number, followed by a letter indicating the thread size, followed by a number indicating the material Floating anchor nuts are referenced with two material numbers, the first for the attachment plate and the second for the nut. The complete part number for a 5/16 inch BSF countersunk floating anchor nut with mild steel base plate and light alloy nut would be, AGS 2014/G/13. The diameter code letters are the same as those shown in Table 14.2 and the material code is as follows:-

1 Mild steel, cad. plated
2. CRS or monel, cad. plated
3. Light Alloy, anodised and dyed blue
4. Brass or bronze, electro-tinned.

TABLE 14.8
WING NUTS

Code	Size	Code	Size
A	6 BA (AGS 113 only)	D	$\frac{11}{32}$ in BSF (AGS 120 only)
B	4 BA (AGS 113 only)	E	$\frac{3}{8}$ in BSF (AGS 120 only)
C	2 BA (AGS 113 only)	F	$\frac{13}{32}$ in BSF (AGS 120 only)
A	¼ in BSF (AGS 120 only)	G	$\frac{7}{16}$ in BSF (AGS 120 only)
B	$\frac{9}{32}$ in BSF (AGS 120 only)	H	$\frac{1}{2}$ in BSF (AGS 120 only)
C	$\frac{5}{16}$ in BSF (AGS 120 only)		

AGS NUTS - VARIOUS

Wing Nuts AGS 113 AGS 120 (Brass Cadmium Coated)

AGS 113 relates only to BA sizes, whilst 120 relates only to BSF sizes. The coding system for these nuts consists of the AGS number followed by a letter indicating the size of thread (Table 88). Example: A¼- inch BSF brass wing nut would be AGS 120/A.

Wing Nuts AGS 3413

These are cadmium coated brass wing nuts with Unified threads in the sizes 4-40 UNC to ½- inch UNF. The coding system consists of the AGS number followed by a letter indicating the thread size (Table 14.5).

BSP Union Lock Nuts, AGS 207 (Mild steel, cad. plated), AGS 224 (Brass cad. plated) and AGS 957 (Al anodised)

The coding system used for these nuts consists of the AGS number (which indicates the type of material), followed by a letter indicating the thread size. The letters A to E are used, representing the sizes 1/8 inch BSP to 5/8 inch BSP in steps of 1/8 inch BSP brass lock nut would therefore be AGS 224/D.

Thin Nuts BSP and Whitworth Form, AGS 1148 (Al anodised)

The coding system used for these nuts consists of the AGs number, followed by a letter indicating the thread size (Table 14.9). ***Example:*** A 1/2 inch BSP nut would be AGS 1148/D.

TABLE 14.9
THIN NUTS

Code	Size	Code	Size
A	$\frac{1}{8}$ in BSP	F	$\frac{3}{4}$ in BSP
B	$\frac{1}{4}$ in BSP	G	$\frac{7}{8}$ in BSP
BB	19 t.p.i. Whit. Form 0.60 o/d	H	1.0 in BSP
C	$\frac{3}{8}$ in BSP	J	$1\frac{1}{4}$ in BSP
CC	14 t.p.i. Whit. Form 0.75 o/d	K	$1\frac{1}{2}$ in BSP
D	$\frac{1}{2}$ in BSP	L	$1\frac{3}{4}$ in BSP
E	$\frac{5}{8}$ in BSP	M	2.0 in BSP

Union Nuts AGS 1187 (Al Anodised), AGS 1216 (Mild Steel, Cadmium treated) and AGS 1217 (Brass, cadmium treated)

The coding system used for these nuts consists of the AGS number, followed by a letter indicating the thread size (Table 9). Example: 1/4 inch BSP union nut made of brass would be AGS 1217/B.

L.T. Union Lock Nut, AGS 1710 (Brass, tinned)

This nut is made in one size only, i.e. 1/2 inch × 26 t.p.i. Whitworth form.

FUTURE TRENDS

The need for saving weight on aircraft structures has led to the widespread use of lightweight fasteners of all types, particularly of self-locking nuts and anchor nuts. The use of lightweight and miniature stiff nuts was pioneered in the United States and although these nuts are readily available in this country, very few of British design are, as yet, manufactured in Great Britain

Aircraft manufacturers are tending to make greater use of the UNJ thread form because of its high resistance to fatigue. All future specifications for aircraft fasteners are expected to stipulate this thread and some existing specifications for nuts contain a clause requiring the thread to be of UNJ form after a specified date. Nuts with UNJ threads are fully interchangeable with nuts having standard Unified threads of the same class, the only difference being a slight increase in the minor diameter to accommodate the increased root radius of the external thread.

In view of the general acceptance of metric dimensions in other fields, it seems likely that the metric thread of UNJ form will eventually be used internationally and result in further specifications for nuts in both the AS and BS series. It is expected that fasteners having metric threads will be identified by marking with the letter 'M'.

ABBREVIATIONS AND TERMS USED

AGS	Aircraft General Standards
Al	Aluminium Alloy.
AS	Aircraft Standards of the SBAC.
Attachment Plate	The formed sheet metal plate of a floating anchor nut which is riveted to the structure. It retains the nut body and base plate, allowing a specified amount of movement in relation to the structure.
BA	British Association
Base Plate	The plate, normal to the axis of the nut, which forms the riveting lugs of a fixed anchor nut. In a floating anchor nut it remains the nut body in the attachment plate.
BS	British standard.
BSF	British standard fine.
BSP	British standard pipe.
Cap Nut	A stiff nut, the threaded bore of which is sealed by a metal cap to prevent the leakage of fluid.
Clinch Nut	A self retaining nut having a spigot at the bearing face which is spread to hold the nut in position.
Fixed Anchor Nut	A stiff nut which is rigidly attached to the structure.
Floating Anchor Nut	A stiff nut which has a limited amount of movement in a plane normal to the axis of the nut for purposes of alignment. Friction Element
HTS	High tensile steel.
HTSS	High tensile stainless steel.
LTS	Low tensile steel.
MTS	Medium tensile steel.
Nut Body	The portion of a stiff nut containing the screw thread.
SS	Stainless steel.
Stiff nut	A nut body surmounted by a device which imposes friction between the nut and the thread on which it is mounted so that no other form of locking is required.

Strip Nuts	A row of stiff nuts mounted on a common attachment plate in the form of a continuous strip.
t.p.i.	Thread per inch.
UNC	Unified Coarse thread.
UNF	Unified fine thread.
UNJ	Unified thread with increased root radius for added fatigue resistance. Ranges of fine threads (UNJF) and coarse threads are provided in this series.
UNS	Threads of basically Unified form but differing slightly from the standard Unified series.
Whit.	Whitworth.

■■■

CHAPTER : 15
STANDARD FASTENERS OF AMERICAN MANUFACTURE

INTRODUCTION

This chapter gives guidance on the identification and coding of bolts, nuts, screws and washers which are manufactured to American National Standards and are used for general aircraft assembly. Many other types of American fasteners are used on aircraft, particularly in the field of lightweight, self-locking nuts and bolts, and these are approved for use by the relevant manufacturer or Airworthiness Authority; these fasteners will not necessarily be marked or identified in accordance with the national standards, but will comply with information published by the particular manufacturer.

SPECIFICATIONS

Standard aircraft fasteners in America are manufactured in accordance with Government, Military and Civil Specifications. The following series of specifications cover the materials, processes, and component drawings for all standard fasteners:-

Federal Specifications

Society of Automotive Engineers Specifications (SAE)

Aeronautical Materials Division of SAE Specifications (AMS)

Air Force\Navy Specifications (AN)

Military Standards (MIL and MS)

National Aerospace Standards (NAS)

These specifications provide for a range of fasteners with Unified threads in the UNC, UNF and UNJF series . However, whereas for British aircraft, fasteners are manufactured in a selected range of Unified threads, American fasteners are, in some instances, supplied with both UNC and UNF threads. Extreme care is necessary when matching up nuts with screws or bolt in these series. If not properly identified, then thread gauges must be used to check the thread. Visual comparison of small threads is not recommended.

The various standards are dealt with separately in this chapter, and it should be noted that an AN series has to a large extent been replaced by MS and NAS components.

AN FASTENERS

These specifications are in two series. The early series has numbers from 3 to 9000, with the fasteners occupying a range from 3 to 1000; these fasteners are of comparatively low strength, and are manufactured in steel or aluminium alloy. The steel parts are generally manufactured from low-alloy steel, and if non-corrosion-resistant, are cadmium plated, whilst the aluminium parts are anodised. The later series parts have six figure numbers commencing with 1,000,000, are of more recent design and are generally manufactured from higher-strength materials

AIRCRAFT BOLTS

Most, but not all, aircraft bolts are designed and fabricated according to government standards with the following specifications :

1. AN, Air Force/Navy
2. NAS, National Aerospace Standards
3. MS, Military Standards.

General - Purpose Bolts

The hex-head aircraft bolt (AN-3 through AN-20) is an all - purpose structural bolt used for general applications involving tension or shear loads where a light-drive fit is permissible (0.006-inch clearance for a 5/8-inch hole, and other sizes in proportion). They are fabricated from SAE 2330 nickel steel and are cadmium plated.

Alloy steel bolts smaller than No. 10-32 (3/16-inch diameter, AN-3) and aluminum alloy bolts smaller than 1/4-inch diameter are not used in primary structures. Aluminum alloy bolts and nuts are not used where they will be repeatedly removed for purposes of maintenance and inspection.

The AN 73-AN81 (MS20073-MS20074) drilled-head bolt is similar to the standard hex-bolt, but has a deeper head that is drilled to receive wire for safetying. The AN 3-AN 20 and the AN-73, AN-81 series bolts are interchangeable, for all practical purposes, from the standpoint of tension and shear strengths.

AN3-AN20 AIRFRAME BOLTS

Application

These bolts may be used for either tensile or shear loads.

Material

Cadmium plated nickel alloy steel : No letter designation - Head marked with cross or asterisk.

Corrosion resistant steel (CRES) : C - Head marked with single dash.

Aluminum alloy (2024-T4) : DD-Head marked with two dashes.

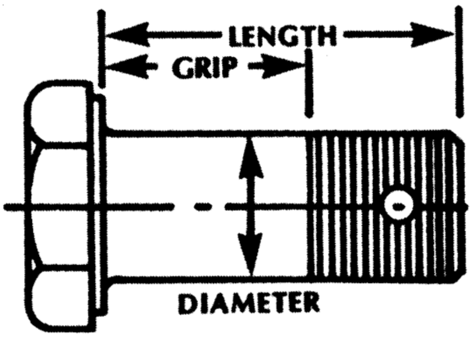


Fig.15.1 AN3 - AN20 Airframe Bolts.

Diameter

The AN number denotes the diameter of the shank in 1/16-inch increments :
Example 3 = 3/16".

Length

The dash number denotes the length in eighths of an inch up through 7/8. For lengths greater than one inch, the first digit is the number of inches and the second digit is the number of eighths.

Example

12 = 1 inch + 2/8 or 1-1/4 inch long.

Thread

Class 3NF

Safety Provisions

1. This bolt was originally designed to be used with a castle nut and cotter pin wherein the shank is drilled for the pin.
2. If a self-locking nut is to be used, the shank should be undrilled. This is designated by the letter A following the dash number.

   Example AN4-6A.
3. If the bolt is used in a blind hole and safetied with wire through the head, the head is drilled and designated by the letter H used in place of the dash.

TABLE 15.1 NUT AND COTTER PIN SIZES

AN Number	Diameter	Plain Nut AN Number	Castle Nut AN Number	Cotter Pin MS Number
AN3	3/16	AN315-3R	AN310-3	MS24665-132
AN4	1/4	AN315-4R	AN310-4	MS24665-132
AN5	5/16	AN315-5R	AN310-5	MS24665-132
AN6	3/8	AN315-6R	AN310-6	MS24665-283
AN7	7/16	AN315-7R	AN310-7	MS24665-283
AN8	1/2	AN315-8R	AN310-8	MS24665-283

AN21-AN36 CLEVIS BOLTS

Application

These bolts are used for shear loads only.

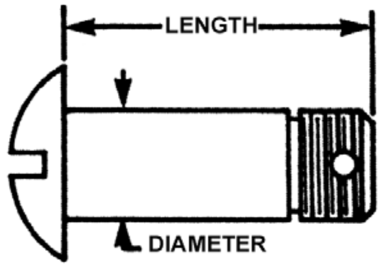


Fig.15.2 AN21 - AN36 Clevis Bolts

Material

Nickel steel alloy, SAE 2330.

Diameter

AN21 - AN23 - the second digit denotes the fine thread machine screw size.

Example

21 is 6-40, 22 is 8-36; 23 is 10-32.
AN 24-AN36- the second digit denotes the diameter in 1/16th-inch increments.

Example

AN25 has a diameter of 5/16th -inch.

Length

The dash number indicates the length in 1/16th-inch increments.

Example

9 = 9/16-inch, -26/16 or 1-5/8 inches long.

Thread

Class 3NF

Safety Provisions

This bolt is designed to be used with a shear castle nut, safetied with a cotter pin. In the event a self-locking nut is used, the bolt should not be drilled. This is designated by the letter A following the dash number.

Example

AN 24-16A.

TABLE 15.2, NUT AND COTTER PIN SIZES
To Use With Each Clevis Bolt Size

AN Number	Diameter & Threads Per Inch	Self-Locking Nut	Castle Shear Nut	Cotter Pin
AN21	6 - 40	- - - - - - - - - - -	AN320 - 1	MS24665 - 3
AN22	8 - 36	- - - - - - - - - - -	AN320 - 2	MS24665 - 132
AN23	10 - 32	MS20364 - 1032	AN320 - 3	MS24665 - 132
AN24	1/4 - 28	MS20364 - 428	AN320 - 4	MS24665 - 132

TABLE 15.3, DASH NUMBER - NOMINAL LENGTH

-8	1/2	-14	7/8	-20	1 - 1/4
-9	9/16	-15	15/16	-21	1-5/16
-10	5/8	-16	1	-22	1-3/8
-11	11/16	-17	1-1/16	-23	1-7/16
-12	3/4	-18	1-1/8	-24	1-1/2
-13	13/16	-19	1-3/16	-25	1-9/16

Clevis Bolt & Eye Bolt

Aircraft bolts are fabricated from cadmium - or zinc-plated corrosion-resistant steel, unplated corrosion-resistant steel, and anodized aluminum alloys. Most bolts used in aircraft structures are either general-purpose, AN bolts, or NAS internal-wrenching or close-tolerance bolts, or MS bolts. In certain cases, aircraft manufacturers make bolts of different dimensions or greater strength than the standard types. Such bolts are made for a particular application, and it is of extreme importance to use like bolts in replacement. Special bolts are usually identified by the letter "S" stamped on the head.

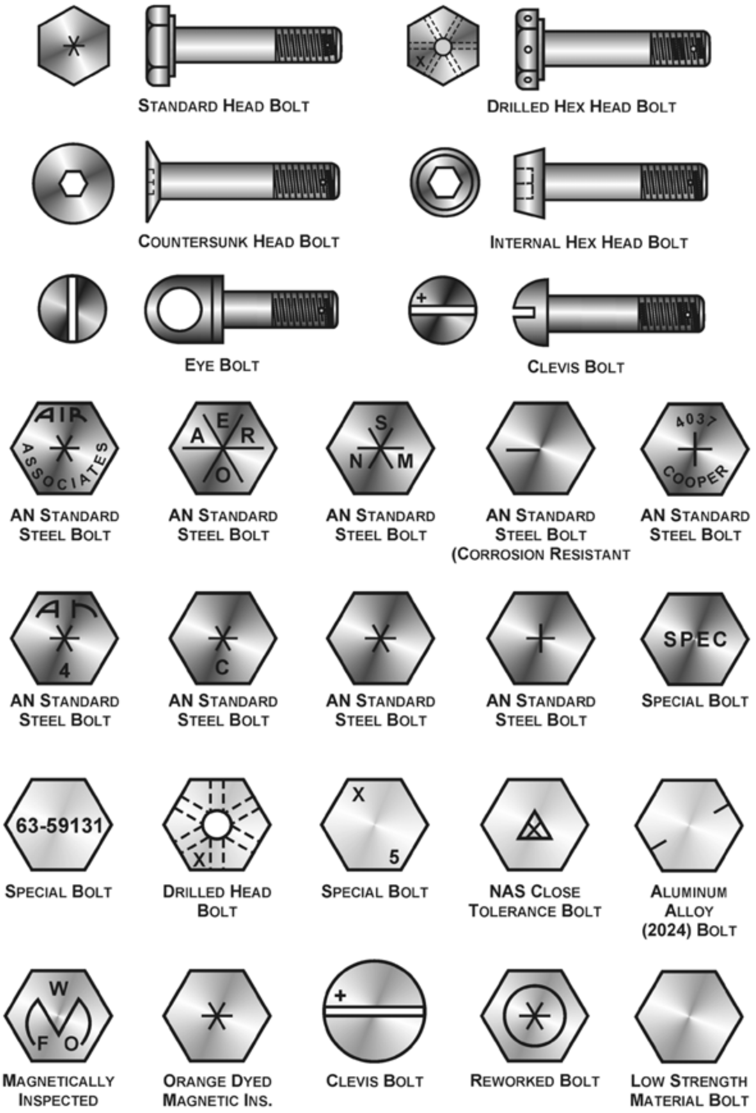


Fig.15.3, Aircraft Bolt Identification.

AN bolts come in three head styles - hex-head, clevis, and eyebolt (See figure 15.3). NAS bolts are available in hex-head, internal-wrenching, and countersunk head styles. MS bolts come in hex-head and internal-wrenching styles.

LOCK BOLT TYPE

Jo-Bolt

Jo-bolt is a trade name for an internally threaded three-piece rivet. The Jo-bolt consists of three parts - a threaded steel alloy bolt, a threaded steel nut, and an expandable stainless steel sleeve. The parts are factory preassembled. As the Jo-bolt is installed, the bolt is turned while the nut is held. This causes the sleeve to expand over the end of the nut, forming the blind head and clamping against the work. When driving is complete, a portion of the bolt breaks off. The high-shear and tensile strength of the Jo-bolt makes it suitable for use in cases of high stresses where some of the other blind fasteners would not be practical. Jo-bolts are often a part of the permanent structure of late-model aircraft. They are used in areas which are not often subjected to replacement or servicing. (Because it is a three-part fastener, it should not be used where any part, in becoming loose, could be drawn into the engine air intake). Other advantages of using Jo-bolts are their excellent resistance to vibration, weight saving, and fast installation by one person.

Presently, Jo-bolts are available in four diameters : The 200 series, approximately 3/16 - inch in diameter; the 260 series, approximately ¼-inch in diameter; the 312 series, approximately 5/16 - inch in diameter; and the 375 series, approximately 3/8 - inch in diameter. Jo-bolts are available in three head styles which are : F (flush), P (hex-head), and FA (flush millable).

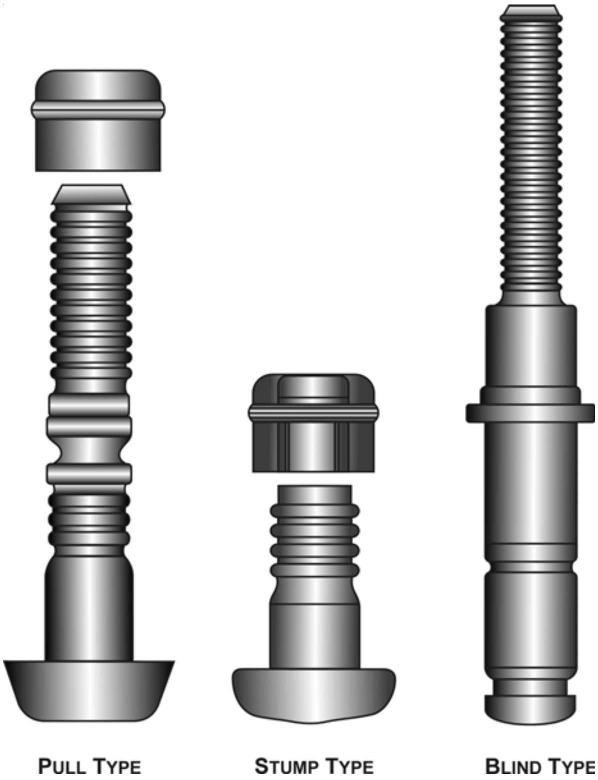


Fig.15.4, Lockbolt types.

Lockbolts

The lockbolt combines the features of a high-strength bolt and rivet, but it has advantages over both. The lockbolt is generally used in wing-splice fittings, landing-gear fittings, fuel-cell fittings, longerons, beams, skin-splice plates, and other major structural attachments. It is more easily and quickly installed than the conventional rivet or bolt and eliminates the use of lockwashers, cotter pins, and special nuts. Like the rivet, the lockbolt requires a pneumatic hammer or "pull gun" for installation; when installed, it is rigidly and permanently locked in place. Three types of lockbolts are commonly used, the pull type, the stump type, and the blind type. (See figure 15.4).

Pull type

Pull-type lockbolts are used mainly in aircraft primary and secondary structures. They are installed very rapidly and have approximately one-half the weight of equivalent AN steel bolts and nuts. A special pneumatic "pull gun" is required to install this type of lockbolt. Installation can be accomplished by one person since bucking is not required.

Stump type

Stump-type lockbolts, although they do not have the extended stem with pull grooves, are companion fasteners to pull-type lockbolts. They are used primarily where clearance will not permit installation of the pull-type lockbolt. A standard pneumatic riveting hammer (with a hammer set attached for swaging the collar into the pin-locking grooves) and a bucking bar are tools necessary for the installation of stump-type lockbolts.

Blind type

Blind-type lockbolts come as complete units or assemblies. They have exceptional strength and sheet pull-together characteristics. Blind lockbolts are used where only one side of the work is accessible and, generally, where it is difficult to drive a conventional rivet. This type of lockbolt is installed in the same manner as the pull-type lockbolt.

Common features

common features of the three types of lockbolts are the annular locking grooves on the pin and the locking collar which is swaged into the pin's lock grooves to lock the pin in tension. The pins of the pull - and blind - type lockbolts are extended for pull installation. The extension is provided with pulling grooves and a tension breakoff groove.

LOCKBOLT NUMBERING SYSTEM

Numbering System

The numbering systems for the various types of lockbolts are explained by the following breakouts (see figure 15.5)

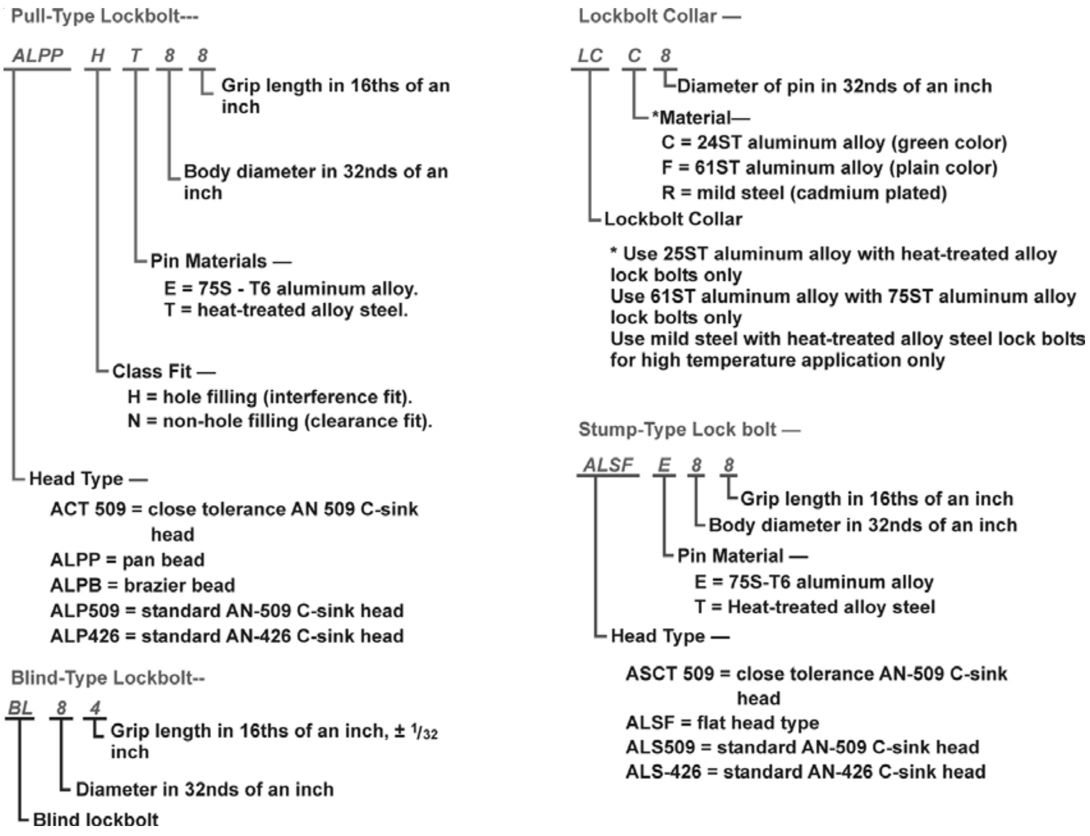


Fig.15.5, Lockbolt numbering system.

AIRCRAFT NUTS

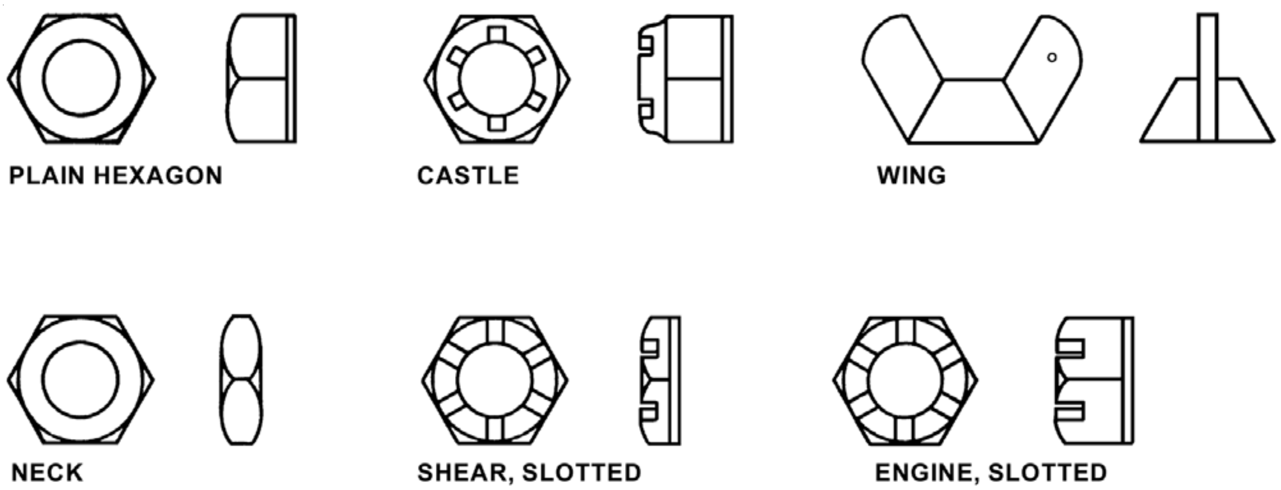


Fig. 15.6, Early Series AN Nuts.

Aircraft nuts are manufactured in a variety of shapes and sizes, made of alloy steel, stainless steel, aluminum alloys or titanium. No identification marks or letters appear on nuts. They can be identified only by the characteristic metallic luster or by color of the aluminum, brass, or the insert, when the nut is of the self-locking type. They can be further identified by their construction.

Like aircraft bolts, most aircraft nuts are designed and fabricated in accordance with AN, NAS, and MS standards and specifications.

Aircraft nuts can be divided into two general groups; non-self-locking and self-locking nuts. Non-self-locking nuts (Fig. 15.7) must be safetied by external locking devices, such as cotter pins, safety wire, or locknuts. Self-locking nuts contain the locking feature as an integral part. Self-locking nuts can be further subdivided into low temperature (250° F or less) Fig. 15.8 and high temperature (more than 250° F) Fig. 15.9.

Non-Self Locking Nuts

Most of the familiar nuts (plain, castle, castellated shear, plain hex, light hex, and plain check) are the non-self-locking type (Fig. 15.7).

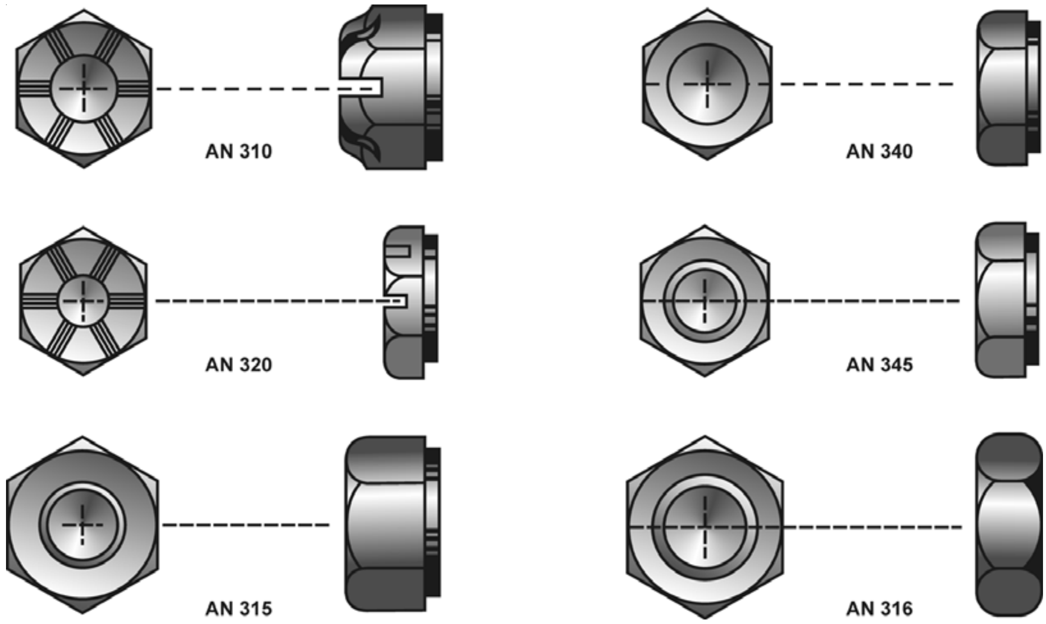


Fig.15.7, Nonself-locking, castellated, and plain nuts.

The castle nut, AN 310, is used with drilled-shank AN hex head bolts, clevis bolts, eyebolts, drilled head bolts, or studs. It is fairly rugged and can withstand large-tension loads. Slots (castellations) in the nut are designed to accommodate a cotter pin or lock wire for safety. The AN310 castellated, cadmium-plated steel nut is by far the most commonly used airframe nut.

The castellated shear nut, AN320, is designed for use with devices (such as drilled clevis bolts and threaded taper pins) that are normally subjected to shearing stress only. Like the castle nut, it is castellated for safetying. Note, however, that the nut is not as deep or as strong as the castle nut; also notice that the castellations are not as deep as those in the castle nut.

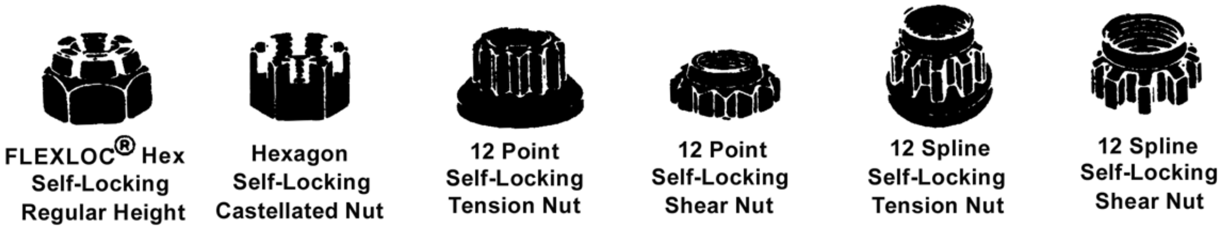


Fig.15.8, High-temperature (more than 250°F) self-locking nuts.

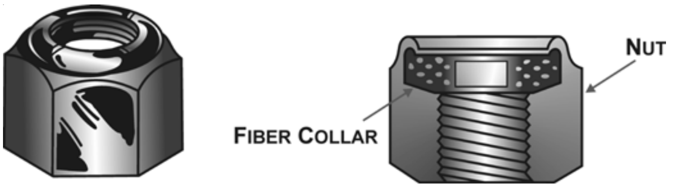
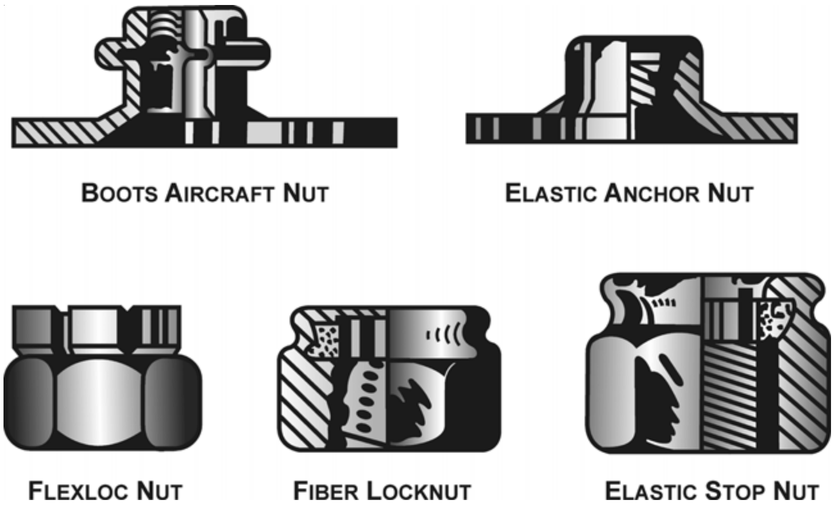


Fig. 15.9, Low-temperature (250°F or less) self-locking nut (elastic stop nut, AN 365, MS20365)

Self-Locking Nuts

As their name implies, self-locking nuts need no auxiliary means of safetying but have a safetying feature included as an integral part of their construction. Many types of self-locking nuts have been designed and their use has become quite widespread. Common applications are : (1) Attachment of antifriction bearings and control pulleys; (2) Attachment of accessories, anchor nuts around inspection holes and small tank installation openings; and (3) Attachment of rocker box covers and exhaust stacks. Self-locking nuts are acceptable for use on certificated aircraft subject to the restrictions of the manufacturer.



BOOTS AIRCRAFT NUT ELASTIC ANCHOR NUT

FLEXLOC NUT FIBER LOCKNUT ELASTIC STOP NUT

Fig. 15.10, Self-locking nuts

Self-locking nuts are used on aircraft to provide tight connections which will not shake loose under severe vibration. Do not use self-locking nuts at joints which subject either the nut or bolt to rotation. They may be used with antifriction bearings and control pulleys, provided the inner race of the bearing is clamped to the supporting structure by the nut and bolt. Plates must be attached to the structure in a positive manner to eliminate rotation or misalignment when tightening the bolts or screws.

The two general types of self-locking nuts currently in use are the all-metal type and the fiber-lock type. For the sake of simplicity, only three typical kinds of self-locking nuts are considered in this handbook : The Boots self-locking and the stainless steel self-locking nuts, representing the all metal types; and the elastic stop nut, representing the fiber-insert type.

Boots Self-Locking Nut

The Boots self-locking nut is of one-piece, all metal construction, designed to hold tight in spite of severe vibration. Note in Figure 15.10 that it has two sections and is essentially two nuts in one, a locking nut and a load-carrying nut. The two sections are connected with a spring which is an integral part of the nut. The spring keeps the locking and load-carrying sections such a distance apart that the two sets of threads are out-or-phase ; that is, so spaced that a bolt which has been screwed through the load-carrying section must push the locking section outward against the force of the spring to engage the threads of the locking section properly.

Thus, the spring, through the medium of the locking section, exerts a constant locking force on the bolt in the same direction as a force that would tighten the nut. In this nut, the load-carrying section has the thread strength of a standard nut of comparable size, while the locking section presses against the threads of the bolt and locks the nut firmly in position. Only a wrench applied to the nut will loosen it. The nut can be removed and reused without impairing its efficiency.

Boots self-locking nuts are made with three different spring styles and in various shapes and sizes. The wing type, which is the most common, ranges in size for No. 6 up to ¼ - inch, the Rol-top ranges from ¼ - inch to 9/16 inch, and the bellows type ranges in size from No. 8 up to 3/8 inch. Wing-type nuts are made of anodized aluminum alloy, cadmium plated carbon steel, or stainless steel. The Rol-top nut is cadmium-plated steel, and the bellows type is made of aluminum alloy only.

Stainless Steel Self-Locking Nut

The stainless steel self-locking nut may be spun on and off with the fingers, as its locking action takes place only when the nut is seated against a solid surface and tightened. The nut consists of two parts; a case with a beveled locking shoulder and key, and a threaded insert with a locking shoulder and slotted keyway. Until the nut is tightened it spins on the bolt easily, because the threaded insert is the proper size for the bolt. However, when the nut is seated against a solid surface and tightened, the locking shoulder of the insert is pulled downward and wedged against the locking shoulder of the case. This action compresses the threaded insert and causes it to clench the bolt tightly. The cross-sectional view in figure 15.11 shows how the key of the case fits into the slotted keyway of the insert so that when the case is turned the threaded insert is turned with it. Note that the slot is wider than the key. This permits the slot to be narrowed and the insert to be compressed when the nut is tightened.

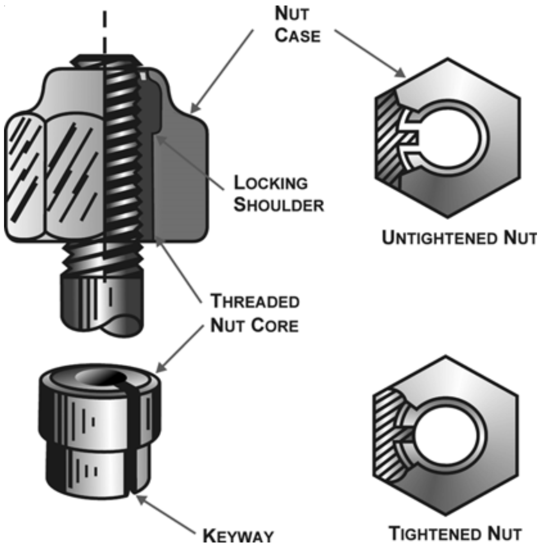


Fig. 15.11, Stainless steel self-locking nut.

Elastic Stop Nut

The elastic stop nut is a standard nut with the height increased to accommodate a fiber-locking collar. This fiber collar is very tough and durable and is unaffected by immersion in hot or cold water or ordinary solvents such as ether, carbon tetrachloride, oils, and gasoline. It will not damage bolt threads or plating.

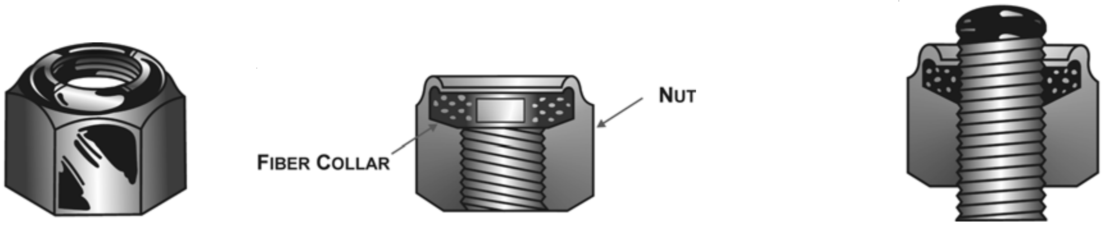


Fig. 15.12, Elastic stop nut.

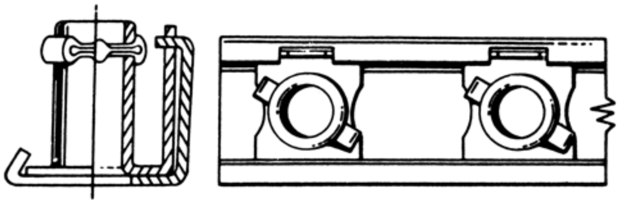
As shown in figure 15.12, the fiber-locking collar is not threaded and its inside diameter is smaller than the largest diameter of the threaded portion or the outside diameter of a corresponding bolt. When the nut is screwed onto a bolt, it acts as an ordinary nut until the bolt reaches the fiber collar. When the bolt is screwed into the fiber collar, however, friction (or drag) causes the fiber to be pushed upward. This creates a heavy downward pressure on the load-carrying part and automatically throws the load-carrying sides of the nut and bolt threads into positive contact. After the bolt has been forced all the way through the fiber collar, the downward pressure remains constant. This pressure locks and holds the nut securely in place even under severe vibration.

Nearly all elastic stop nuts are steel or aluminum alloy. However, such nuts are available in practically any kind of metal. Aluminum alloy elastic stop nuts are supplied with an anodized finish. Steel nuts are cadmium plated.

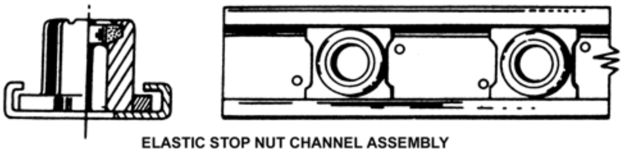
Normally elastic stop nuts can be used many times with complete safety and without detriment to their locking efficiency. When reusing elastic stop nuts, be sure the fiber has not lost its locking friction or become brittle. If a nut can be turned with the fingers, replace it.

After the nut has been tightened, make sure the rounded or chamfered end of the bolts, studs, or screws extends at least the full round or chamfer through the nut. Flat end bolts, studs, or screws should extend at least 1/32 inch through the nut. Bolts of 5/16 inch diameter and over with cotter pin holes may be used with self-locking nuts, but only if free from burrs around the holes. Bolts with damaged threads and rough ends are not acceptable. Do not tap the fiber-locking insert. The self-locking action of the elastic stop nut is the result of having the bolt threads impress themselves into the untapped fiber.

Do not install elastic stop nuts in places where the temperature is higher than 250° F., because the effectiveness of the self-locking action is reduced beyond this point. Self-locking nuts may be used on aircraft engines and accessories when their use is specified by the engine manufacturer.



BOOTS AIRCRAFT CHANNEL ASSEMBLY



ELASTIC STOP NUT CHANNEL ASSEMBLY

Fig. 15.13, Self-locking nut bases.

Self-locking nut bases are made in a number of forms and materials for riveting and welding to aircraft structure or parts. (See figures 15.13.) Certain applications require the installation of self-locking nuts in channels, an arrangement which permits the attachment of many nuts with only a few rivets. These channels are tack-like bases with regularly spaced nuts which are either removable or nonremovable. The removable type carries a floating nut, which can be snapped in or out of the channel, thus making possible the easy removal of damaged nuts. Nuts such as the clinch-type and spline-type which depends on friction for their anchorage are not acceptable for use in aircraft structures.

Self-Locking Nuts to 250°F

The elastic stop nut is essentially a standard hex nut that in-corporates a fiber or nylon insert (Fig. 15.14). The inside diameter of the red insert is deliberately smaller than the major diameter of the matching bolt. The nut spins freely on the bolt until the bolt threads enter the locking insert, where they impress, but do not cut, mating threads in the insert. This compression forces a metal-to-metal contact between the top flanks of the nut threads and the bottom flanks of the bolt threads. This friction hold plus the compression hold of the insert essentially "locks" the nut anywhere on the bolt.

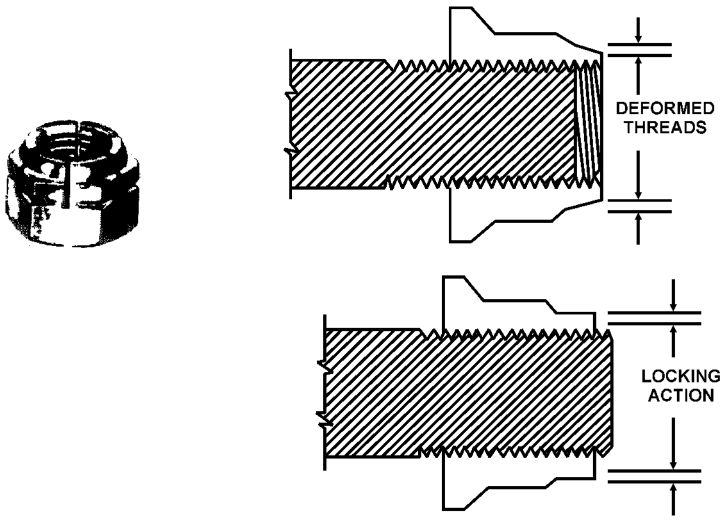


Fig. 15.14, The Boot's self-locking, all-metal nut.

After the nut has been tightened, the rounded or chamfered end of bolts, studs, or screws should extend at least the full round or chamfer through the nut. Flat-end bolts, studs, or screws should extend at least 1/32" through the nut. When fiber-type self-locking nuts are reused, the fiber should be carefully checked to be sure that it has not lost its locking friction or become brittle. Locknuts should not be reused if they can be run up to a finger-tight position. Bolts 5/16" diameter and larger, with cotter pin holes, can be used with self-locking nuts, but only if they are free from burrs around the holes. Bolts with damaged threads and rough ends are not acceptable.

Self-locking nuts should not be used at joints that subject either the nut or the bolt to rotation. They can be used with antifriction bearings and control pulleys, provided that the inner face of the bearing is clamped to the supporting structure by the nut and bolt.

High-Temperature Self-Locking Nuts

All-metal locknuts are constructed with either the threads in the locking insert out-of-phase with the load-carrying section (Fig.15.14) or with a saw-cut insert with a pinched-in thread in the locking section. The locking action of the all-metal nut depends upon the resiliency of the metal when the locking section and load-carrying section are engaged by screw threads.

D. TYPES OF NUTS

Self-locking nut bases are made in a number of forms and materials for riveting and welding to aircraft structure or parts (Fig. 15.14). Certain applications require the installation of self-locking nuts in channels, an arrangement that permits the attachment of many nuts with only a few rivets. These channels are track-like bases with regularly spaced nuts that are either removable or nonremovable. The removable type carries a floating nut that can be snapped in or out of the channel, thus making possible the easy removal of damaged nuts. Clinch and spline nuts, which depend on friction for their anchorage, are not acceptable for use in aircraft structures.

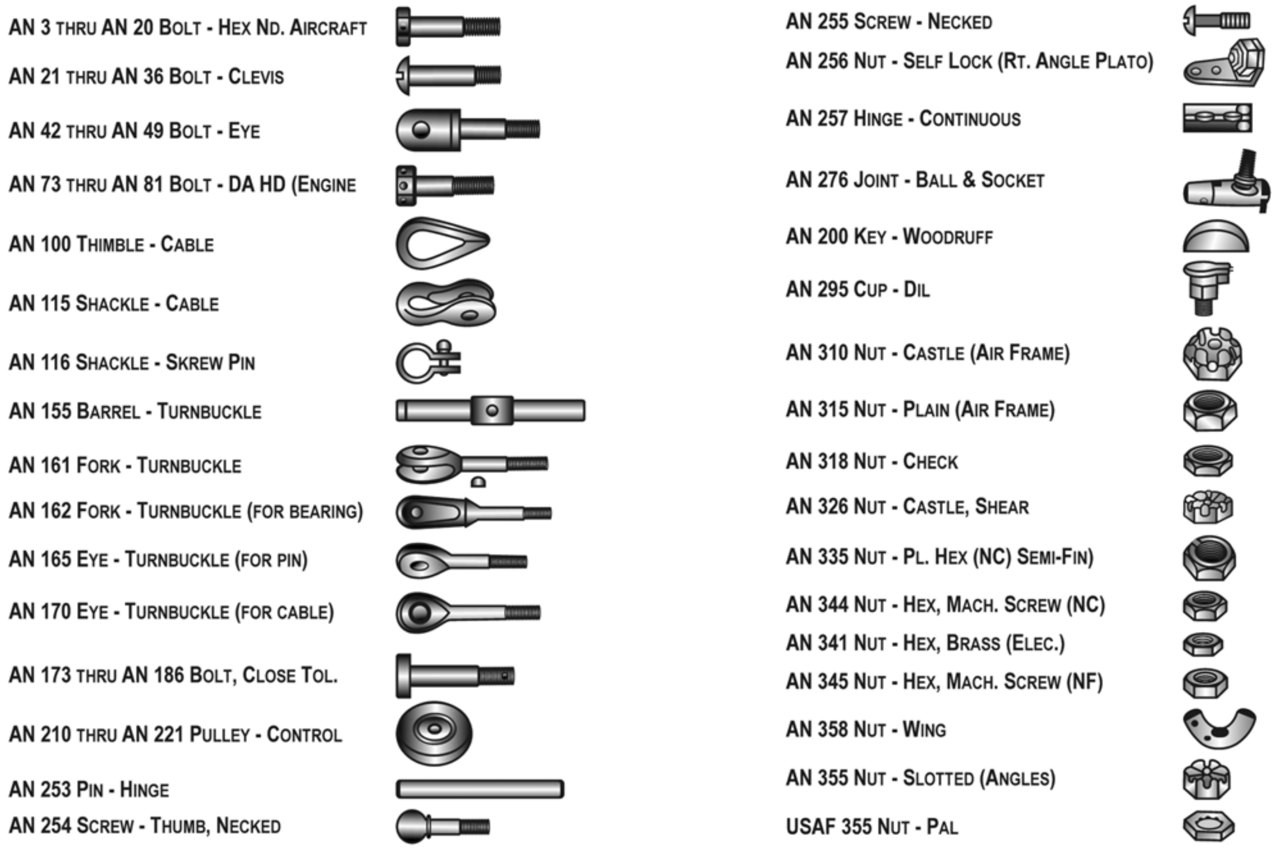


Fig. 15.15, Types of Nuts.

Various types of anchor nuts (Fig. 15.16) are available for riveting to the structure for application as removable panels.

Sheet spring nuts, sometimes called speed nuts, are used with standard and sheet-metal self-tapping screws in nonstructural locations. They find various used in supporting line clamps conduit clamps, electrical equipment access doors, etc., and are available in several types. Speed nuts are made from spring steel and are arched prior to tightening. This arched spring lock prevents the screw from working loose. These nuts should be used only where originally used in fabrication of the aircraft (Fig. 15.15).

Fig. 15.16, Various types of anchor nuts.

ii. Castle Nuts

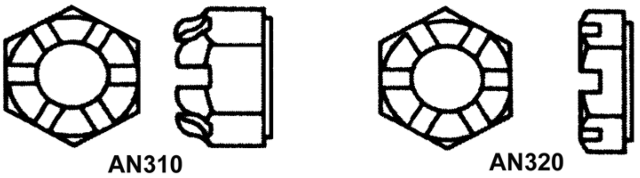


Fig.15.17, AN310 Castle Nut

Application

These nuts are used for tension loads on drilled-shank bolts and are safetied with a cotter pin

Material

Cadmium plated alloy steel : No letter designation.
Aluminium alloy (2024 - T4) : D in place of dash
Corrosion resistant steel : C in place of dash.

Size

These nuts all have National Fine threads and the dash number denotes the diameter of the bolt they fit, in 1/16ths of an inch.

Example

AN310C12 = corrosion resistant steel castle nut to fit a 3/4 - 16 bolt.

Thread

Class 3NF.

Table 15.4, CASTLE NUTS

DASH NUMBER	DIAMETER & THREAD	COTTER PINS USED WITH AN310 & AN320
-3	No. 10-32	AN380-2-2
-4	1/4-28	AN380-2-2
-5	5/16-24	AN380-2-2
-6	3/8-24	AN380-3-3
-7	7/16-20	AN380-3-3
-8	1/2-20	AN380-3-3
-9	9/16-18	AN380-4-4
-10	5/8-18	AN380-4-4
-12	3/4-16	AN380-4-5

AN320 SHEAR CASTLE NUT

Application

These nuts are used on drilled shank clevis bolts for shear loads, and safetied with a cotter pin.

Material

Cadmium plated alloy steel : No letter designation
Aluminum alloy (2024 - T4) : D in place of dash
Corrosion resistant steel : C in place of dash

Size

The size is indicated by the dash number. -1 fits a 6 -40 machine screw, -2 fits an 8 - 36 screw. Other dash numbers indicate the diameter in sixteenths of an inch of the fine thread bolt the nut fits.

Example

AN320 -6 fits a 3/8" clevis bolt (AN26).

Thread

Class 3NF.

MS21078 TWO LUG ANCHOR NUT

MILITARY NUMBERS	THREAD SIZE
MS21078-06	6-32
-08	8-32
-3	10-32
-4	1/4-28
-5	5/16-24

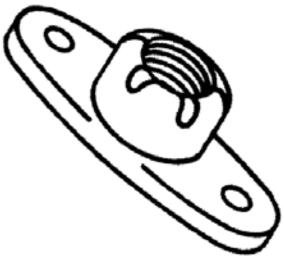


Fig.15.18

MS21080 ONE LUG ANCHOR NUT

MILITARY NUMBERS	THREAD SIZE
MS21080-06	6-32
-08	8-32
-3	10-32
-4	1/4-28

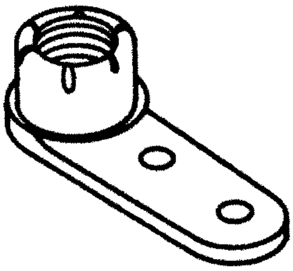


Fig.15.19

MS21081 CORNER ANCHOR NUT

MILITARY NUMBERS	THREAD SIZE
MS21081-06	6-32
-08	8-32
-3	10-32

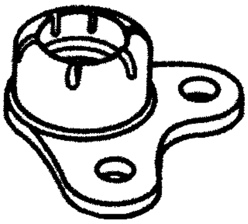


Fig.15.20

AN315-316 PLAIN AND CHECK NUTS

DASH NUMBER	DIAMETER & SIZE
-3	No. 10-32
-4	1/4-28
-5	5/16-24
-6	3/8-24

Add "L: after dash for left-hand thread.

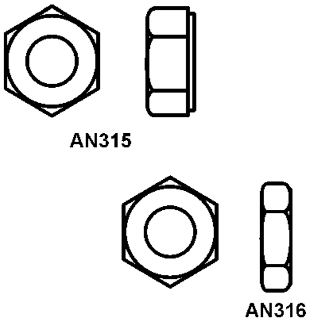


Fig.15.21

MS20341 ELECTRICAL NUT

PART NUMBER	THREAD SIZE
MS20341-6	6 - 32
MS20341-8	8 - 32
MS20341-10	10 - 32

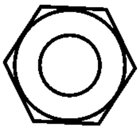


Fig.15.22

NAF213790 BRASS MANIFOLD NUT

PART NUMBER	"AC" NUMBER	SIZE & THREAD
NAF213790-4 NAF213790-5	AC36A6203-4 AC36A6203-5	1/4-28 5/16-24

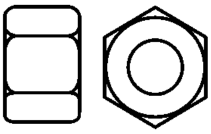


Fig.15.23

HIGH TEMPERATURE SELF-LOCKING NUT

MILITARY NUMBER	THREAD SIZE
AN363C-832	8-32
AN363C-1032	10-32
AN363C-428	1/4-28
AN363C-524	5/16-24
AN363C-624	3/8-24

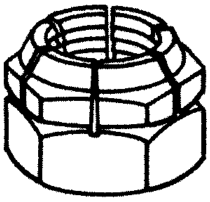


Fig.15.24

MS20364 THIN SELF-LOCKING NUT

MILITARY NUMBER	THREAD SIZE
MS20364-632	6-32
MS20364-832	8-32
MS20364-1032	10-32
MS20364-428	1/4-28
MS20364-524	5/16-24
MS20364-624	3/8-24

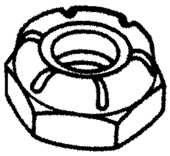


Fig.15.25

PART NUMBER	OLD "AC" PART NO.	SIZE & THREAD
MS27151-6	AC356-832	8-32
-7	-1032	10-32
-13	-428	1/4-28
-16	-524	5/16-24
-19	-624	3/8-24
-21	-720	7/16-20
-24	-820	1/2-20

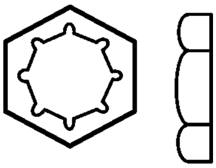


Fig.15.26

MS20365 SELF-LOCKING NUT

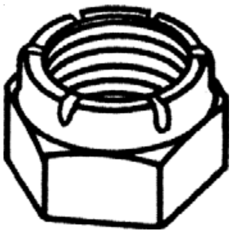


Fig. 15.27

Material

cadmium plated alloy steel : No. letter designation
Aluminum alloy (2024 - T4) : D in place of dash
Brass : B in place of dash

Size

These nuts are available in both National Fine and National Coarse threads. The size and number of threads is denoted by the dash number.

Other dash numbers denote the diameter in sixteenth-inch increments and the number of threads per inch :

Example

AN365C428 = High temperature self-locking nut, 1/4 - inch diameter, with 28 threads per inch.

AN365B632 - Low temperature regular hex self-locking nut made of brass that fits a 6 - 32 machine screw.

Coding

The nuts listed in Table 15.5 are coded according to the type and size of thread, by a dash number placed after the AN number. Those nuts which are intended for use with AN bolts have the same code as the bolts, i.e. a number indicating thread diameter in sixteenths of an inch, and No.6, No.8 and No.10 threads being -1, -2 and -3, respectively. Those nuts intended for use with machine screws (AN 340 and 345) are coded according to the code for screws. The code represents the thread number (-0 to -10) or the diameter in sixteenths of an inch (-416, -516, etc.) designation (-640, -832, etc.) or thread diameter in fraction sizes (-4 = 1/4 in, -5 = 5/16 in, etc.). Material is indicated by a letter placed in the code instead of the dash ; C = corrosion-resistant steel, DD = aluminium alloy, machine-screws nuts, D = other aluminium alloy nuts, B = brass, and the absence of a letter indicates a non-corrosion-resistant steel nut. With AN 315 and 316 nuts, 'L' or 'R' is added after the code to indicate left - or right-hand threads. Examples of this coding are ; AN 350B4 is a brass wing nut to fit a 1/4 in bolt, and AN 316-6L is a steel check nut to fit a 3/8 in bolt with a left-hand thread.

TABLE 15.5, EARLY SERIES AN NUTS

AN Number	Type	Material	Process	Nominal Range of Thread Sizes	Thread
310	Nut, castle	Steel CRS Al. alloy	Cad. plated Nil Anodised	No. 10 to 1¼ in	UNF
315	Nut, plain	Steel CRS Al. alloy	Cad. plated Nil Anodised	No. 6 to 1¼ in (also left-hand thread)	UNF
316	Nut, check	Steel	Cad. plated	¼ to 1 in (also left-hand thread)	UNF
320	Nut, castle, shear	Steel CRS Al. alloy	Cad. plated Nil Anodised	No. 6 to 1 ¼ in	UNF
340	Nut, machine screw, hexagon	Steel CRS Brass Al. alloy	Cad. plated Nil Nil Anodised	No. 2 to ¼ in No. 2 to ¼ in No. 2 to No. 6 No. 6 to $\frac{3}{8}$ in	UNC
345	Nut, machine screw, hexagon	Steel CRS Brass Al. alloy	Cad. plated Nil Nil Anodised	No. 0 to ¼ in No. 0 to ¼ in No. 0 to No. 10 No. 10 to ¼ in	UNF
350	Nut, wing	Steel Brass	Cad. plated Nil	NO. 6 to ½ in	UNF
355	Nut, engine, slotted	Steel	Cad. plated	No. 10 to $\frac{3}{4}$ in	UNF
360	Nut, engine, plain	Steel	Cad. plated	No. 10 to $\frac{3}{4}$ in	UNF

PINS

The main types of pins used in aircraft structures are the roll pin, clevis pin, cotter pin, and taper pin. Pins are used in shear applications and for safetying.

Roll Pin

Roll pins are often used to provide a pivot for a joint where the pin is not likely to be removed. A roll pin is made of flat spring steel that is rolled into a cylinder but the two ends are not joined. This allows the pin to compress when it is pressed into a hole and create a spring action that holds the pin tight against the edge of the hole. To remove a roll pin, it must be driven from a hole with a proper size pin punch. (Fig. 15.28)

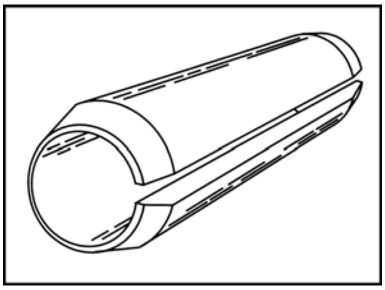


Fig.15.28, MS16562 spring steel rollpins are often used in the movable joints of aircraft seats.

Clevis Pin

Clevis, or flat-head, pins are used for hinge pins in some aircraft control systems. They are made of cadmium-plated steel and have grip lengths in 1/16 inch increments. When installing a clevis pin place the head in the up position, place a plain washer over the opposite end, and insert a cotter pin through the hole to lock the pin in place (Fig. 15.29)

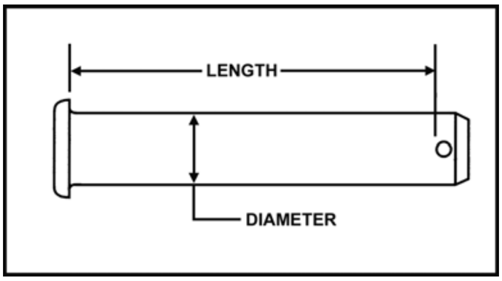


Fig.15.29, AN392 through AN406 (MS20392) clevis pin are often found in control cable systems.

Cotter Pins

Castellated nuts are locked onto drilled bolts by passing a cotter pin through the hole and nut castellations and then spreading the ends of the cotter pin. They are made of either cadmium-plated carbon steel or corrosion-resistant steel.

There are two methods of securing cotter pins that are generally acceptable. In the preferred method, one leg of the cotter pin is bent up over the end of the bolt, and the other leg is bent down over one of the flats of the nut. With the second method, the cotter pin is rotated 90 degrees and the legs wrapped around the castellations. It is important to note that nuts should never be overtorqued to make the hole in the bolt align with the castellations. If the castellations in the nut fail to align with the drilled bolt hole, add washers under the nut until a cotter pin can be inserted.

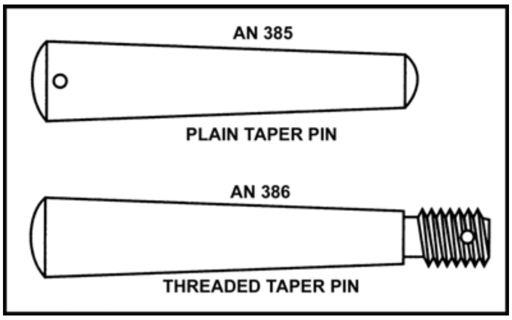


Fig. 15.30, Taper pins produce a tight fit in a reamed hole for applications loaded in shear.

Taper Pin

Both the plain and threaded taper pin are used in aircraft structures to make a joint that is designed to carry shear loads. This type of pin does not allow any loose motion or play. The AN385 plain taper pin is forced into a hole that has been reamed with a Morse standard taper pin reamer and is held in place by friction. It can be safetied by passing safety wire around the shaft and through a hole drilled in its larte end. An 386 taper pin is similar to the AN 385 except that its small-end is threaded to accept either a self-locking shear nut (AN 364) or a shear castle nut (AN320) (Fig. 15.30)

AIRCRAFT WASHERS

Aircraft washers used in airframe repair are plain, lock, or special washers.

Plain Washers

The plain washer, AN960 (Fig. 15.31), is used under hex nuts. It provides a smooth bearing surface and acts as a shim in obtaining correct grip length for a bolt and nut assembly. It is used to adjust the position of castellated nuts with respect to drilled cotter pin holes in bolts. Plain washers should be used under lock washers to prevent damage to the surface material.

Lock Washers

Lock washers (AN-935 and AN-936) can be used with machine screws or bolts whenever the self-clocking or castellated nut is not applicable. They are not to be used as fastenings to primary or secondary structures, or where subject to frequent removal or corrosive conditions.

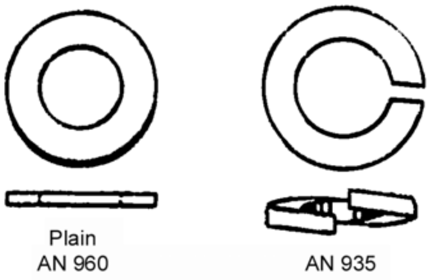
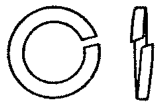
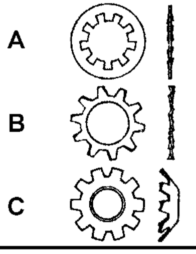
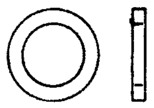


Fig.15.31, Plain and lock washers

Early Series AN Washers

AN standards include three types of washers, and, although these have been replace in later aircraft designs by MS washers, they may still be found on some older types of aircraft and are included for reference. These washers are listed and illustrated in Table 15.6.

TABLE 15.6, EARLY SERIES AN WASHERS

AN Number	Type	Shape	Material	Process	Material Code
935	Washer, lock spring		Steel Bronze CRS	Cadmium plated NIl	Nil B C
936	Washer, shake-proof		Steel Bronze	Cadmium plated Tinned	Nil B
960	Washer, plain		Steel CRS Brass Al. alloy Al. alloy	Cadmium plated Nil Nil Nil Anodised	Nil C B D PD

Coding

Washers are identified by the AN number, a dash number to indicate size, and letters to indicate material and finish.

a. Size

The size of a washer is related to the size of bolt it is designed to fit, and the dash number is in accordance with the code.

b. Material

Material is indicated in the code by adding the letters shown in Table 15.6.

c. Thickness

AN 935 and 960 washers may be available in light or regular thickness, the light washer being indicated by an 'L' at the end of the code. Actual thicknesses should be obtained from the AN Standard.

d. Examples

i. AN 936A416B is a style A regular shakeproof washer designed to fit a 1/4 in bolt and is made of bronze.
ii. AN 960 C-616L is a light plain washer in corrosion-resistant steel, for a 3/8 in bolt.

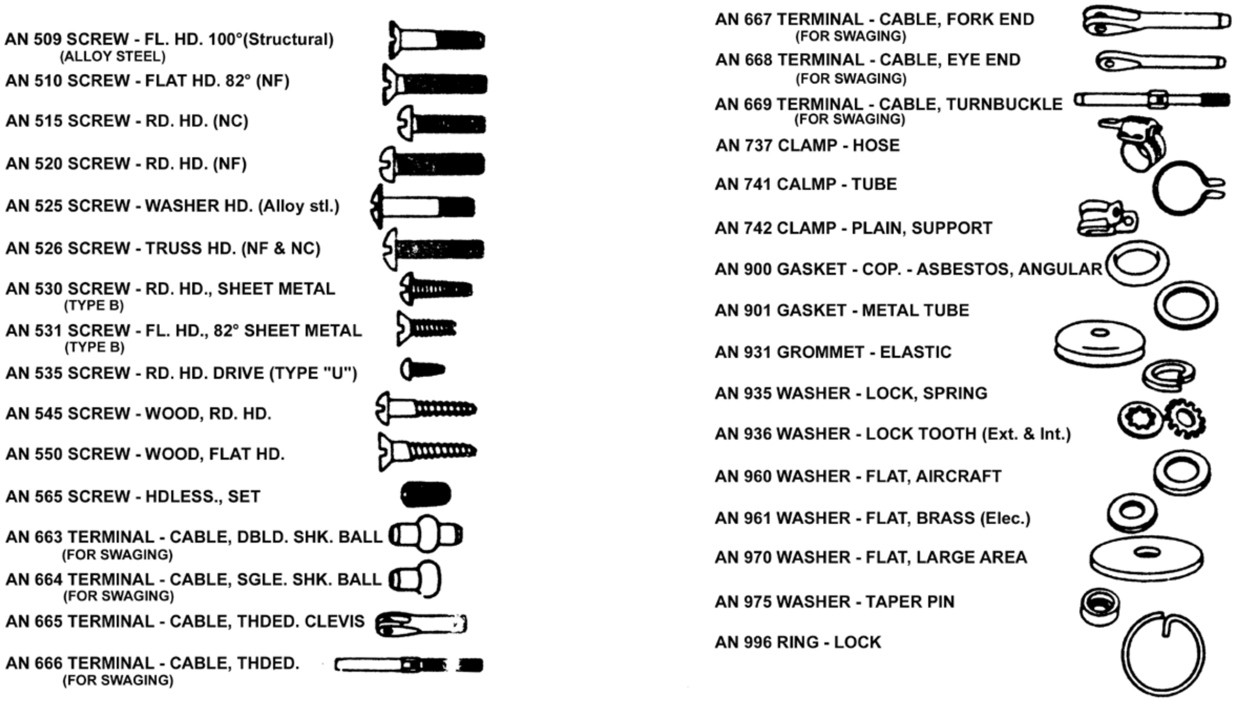


Fig. 15.32, Aircraft Washers.

INSTALLATION OF NUTS AND BOLTS

Bolt and Hole Sizes

Slight clearances in boltholes are permissible wherever bolts are used in tension and are not subject to reversal of load. A few of the applications in which clearance of holes may be permitted are in pulley brackets, conduit boxes, lining trim, and miscellaneous supports and brackets.

Boltholes are to be normal to the surface involved to provide full bearing surface for the bolthead and nut and must not be oversized or elongated. A bolt in such a hole will carry none of its shear load until parts have yielded or deformed enough to allow the bearing surface of the oversized hole to contact the bolt. In this respect, remember that bolts do not become swaged to fill up the holes as do rivets.

In cases of oversized or elongated holes in critical members, obtain advice from the aircraft or engine manufacturer before drilling or reaming the hole to take the next larger bolt. Usually, such factors as edge distance, clearance, or load factor must be considered. Oversized or elongated holes in noncritical members can usually be drilled or reamed to the next larger size.

Many boltholes, particularly those in primary connecting elements, have close tolerances. Generally, it is permissible to use the first lettered drill size larger than the normal bolt diameter, except where the AN hexagon bolts are used in light-drive fit (reamed) applications and where NAS close-tolerance bolts or AN clevis bolts are used.

Light-drive fits for bolts (specified on the repair drawings as .0015 - inch maximum clearance between bolt and hole) are required in places where bolts are used in repair, or where they are placed in the original structure.

The fit of holes and bolts cannot be defined in terms of shaft and hole diameters; it is defined in terms of the friction between bolts and hole when sliding the bolt into place. A tight-drive fit, for example, is one in which a sharp blow of a 12- or 14-ounce hammer is required to move the bolt. A bolt that requires a hard blow and sounds tight is considered to fit tool tightly. A light-drive fit is one in which a bolt will move when a hammer handle is held against its head and pressed by the weight of the body.

Installation Practices

Examine the markings on the bolthead to determine that each bolt is of the correct material. It is of extreme importance to use like bolts in replacement. In every case, refer to the applicable Maintenance Instructions Manual and Illustrated Parts Breakdown.

Be sure that washers are used under both the heads of bolts and nuts unless their omission is specified. A washer guards against mechanical damage to the material being bolted and prevents corrosion of the structural members. An aluminum alloy washer should be used under the head and nut of a steel bolt securing aluminum alloy or magnesium alloy members. Any corrosion that occurs then attacks the washer rather than the members. Steel washers should be used when joining steel members with steel bolts.

Whenever possible, the bolt should be placed with the head on top or in the forward position. This positioning tends to prevent the bolt from slipping out if the nut is accidently lost.

Be certain that the bolt grip length is correct. Grip length is the length of the unthreaded portion of the bolt shank. Generally speaking, the grip length should equal the thickness of the material being bolted together. However, bolts of slightly greater grip length may be used if washers are placed under the nut or the bolthead. In the case of plate nuts, add shims under the plate.

Safetying of Bolts and Nuts

It is very important that all bolts or nuts, except the self-locking type, be safetied after installation. This prevents them from loosening in flight due to vibration.

MS20073 - MS20074 DRILLED HEAD BOLTS

Application

Primarily in high stress areas where the bolt is screwed into a blind hole and safetied with lock wire. An example of the use of this bolt is to attach a propeller to a flanged shaft.

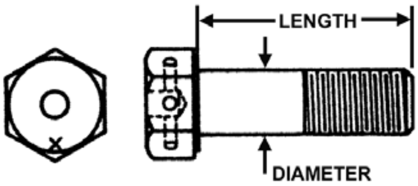


Fig. 15.33, MS20073 - MS20074 Drilled Head Bolts.

Materials

-03 through - 12
MS20073 has from 10-32 to 3/4-16 threads
MS20074 has from 10-24 to 3/4-10 threads

Length

The dash number denotes the length in eighths of an inch up through 7/8-inch. For lengths greater than one inch, the first digit is the number of inches and the second digit is the number of eighths.
Example : MS20073-7-7 is 3/8-inch diameter, 7/8-inch long.
MS20073-5-33 is 5/16-inch diameter, 3-3/8 inches long.

Thread

The MS20073 has a national fine thread and is designed to be used with nuts or screwed into a steel part. MS20074 is national course threaded and is principally used in aluminum or magnesium castings.

Safety provisions

All of these bolts have their drilled hole for safety wire with no hole in the shank for a cotter pin.

AN173-AN186 CLOSE TOLERANCE BOLT

Application

Any time a bolted joint is subject to pounding loads or if bolts and rivets are used in the same joint, the bolts should fit the hole with a tight fit. These bolts are ground to a tolerance of +0.0005" and are protected form rust by greasing instead of plating.

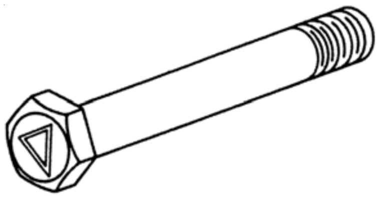


Fig.15.34, AN173 - AB186 Close Tolerance Bolt

Material

SAE 2330 nickel alloy steal.

Diameter

The last digit in the AN number denotes the diameter in sixteenth-inch increments added to the basic 17.
Ex. AN176 is 6/16 - of 3/8-inch diameter, AN182 is 12/16 - or 3/4 - inch diameter.

Length

The dash number denotes the length in eights of an inch. Bolts longer than one inch use two digits - the first indicating the number of inches, and the second, the number of eighths of an inch.

Example

AN175-22 = 5/16 diameter close tolerance bolt 2 –1/4 *inches long.*

Thread

Thread is NF.

Safety provision

The standard bolt is drilled for a cotter pin, but if it is desired that the shank be undrilled so a self-locking nut may be used, the letter A is added to the end of the number : AN174-12A. If it is desired that the head be drilled to accept safety wire, the letter H is inserted in place of the dash.

Example

AN173H4A.

Early Series AN Bolts

Table 15.1 gives a list of the early series AN Bolts, and Fig.15.35, shows the types of heads and the identification marking used to indicate the material from which the parts are made.

TABLE 15.7, EARLY SERIES AN BOLTS

AN Number	Type	Material	Process	Nominal Range of Thread Sizes	Thread
3 - 20	Bolt, hexagon head	Steel	Cad. plated	No. 10 to 1¼ in	UNF
		CRS*	Nil		
		Al. alloy	Anodised		
21 - 36	Bolt, clevis	Steel	Cad. plated	No. 6 to 1 in	UNF
42 - 49	Bolt, eye	Steel	Cad. plated	No. 10 to $\frac{9}{16}$ in	UNF
73 - 81	Bolt, hexagon, drilled head	Steel	Cad. plated	No. 10 to $\frac{3}{4}$ in	UNF or UNC
173 - 186	Bolt, close-tolerance	Steel	Cad. plated thread and head	No. 10 to 1 in	UNF
		CRS*	Nil		
		Al. alloy	Anodised		

* CRS = Corrosion-resistant steel.

All of the bolts listed in Table 15.7 may be identified as to type by reference to the head marking or position of the locking wire holes. Diameter may be identified by experience, or by measurement and reference to the specification. Other dimensions such as grip length, head size and thread length, must be obtained from the specification.

Coding

For identification purposes the AN number is used to indicate the type of bolt and its diameter, and a code is used to indicate the material, length and thread (where these vary) and the position of the locking wire or cotter pin (split pin) hole.

a. Diameter

The last figure or last two figures of the AN number indicate the diameter of the thread. 1 = No. 6, 2 = No. 8, 3 = No. 10, and 4 = 1/4 in, and subsequent numbers indicate the diameter in 1/16 in increments ; above 5/8 in the available sizes are in 1/8 in steps, but are still coded in sixteenths. Thus an AN 4 is a hexagon head bolt with 1/4 in thread, an AN 14 is a hexagon head bolt with a 7/8 in (14/16) thread and an AN 182 is a close-tolerance bolt with a 3/4 in (12/16) thread (the numbering in this case starting at 173). An exception to this is the eye bolt, where different diameter pin holes affect the coding ; AN 42 is No.10, AN 43 is 1/4 in, AN 44 is 5/16 in with a 1/4 in diameter pin hole, and AN 45 is 5/16 in with a 5/16 in diameter pin hole.

b. Length

The length of a bolt as quoted in the specifications, is the overall length from under the head to the end of the shank (L in Fig. 15.35), but the length is generally regarded as from under the head to the first full thread (excluding the chamfer) and is quoted in 1/8 in increments as a 'dash' number. The last figure of the dash number represents eights of an inch, and the first figure of the dash number represents inches. Thus an AN 4 - 12 is a 1/4 in hexagon - head bolt 1 1/4 in (i.e. 1 2/8) long, and an AN 12 - 24 is a 3/4 in hexagon-head bolt 2 1/2 in long. The total lengths quoted in the specifications for these bolts, is actually 1 9/32 in and 2 21/32 in, respectively. Clevis bolts (AN 21 to 36) do not follow this coding, but the length is indicated in 1/16 in increments by the dash number ; thus an AN 29-9 is 9/16 in long.

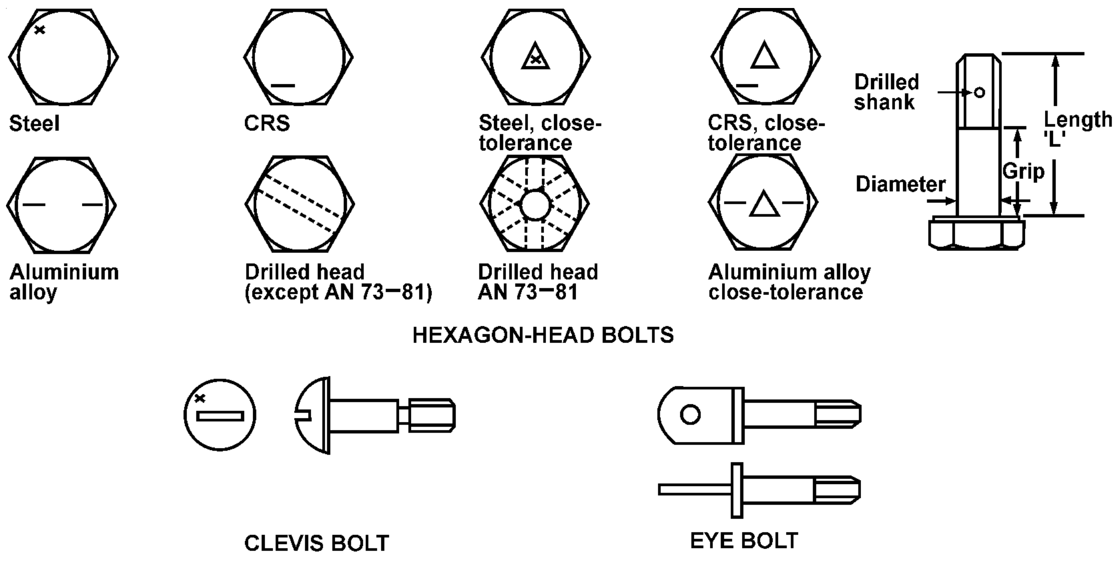


Fig. 15.35, Early Series AN Bolts.

c. Position of Drilled Hole.

Bolts are normally supplied with a hole drilled in the threaded part of he shank, but different arrangements may be obtained by use of the following code :-

Drilled shank = normal coding, e.g. AN 24 - 15.

Undrilled shank = A added after dash number, e.g. AN 24 - 15 A

Drilled head only = H added before dash number (replacing the dash sign) and A added after dash number, e.g. AN 6H10A.

Drilled head and shank = H added before dash number, e.g. AN 6 H 10.

d. Material

The standard coding applies to a non-corrosion-resistant, cadmium-plated steel bolt. Where the bolt is supplied in other materials, letters are placed after the AN number as follows :-

C = corrosion-resistant steel (CRS)
DD = aluminium alloy, e.g. AN 6 DD 10.

e. Thread

Where the bolt is supplied with either UNF or UNC threads, a UNC thread is indicated by placing an 'A' in place of the dash, e.g. AN 74A6.

AIRCRAFT SCREWS

Screws are the most commonly used threaded fastening devices on aircraft. They differ from bolts in as much as they are generally made of lower strength materials. They can be installed with a loose-fitting thread, and the head shapes are made to engage a screwdriver or wrench. Some screws have a clearly defined grip or unthreaded portion while others are threaded along their entire length.

Several types of structural screws differ from the standard structural bolts only in head style. The material in them is the same, and a definite grip length is provided. The AN525 washer-head screw and the NAS220 through NAS227 series are such screws.

Commonly used screws are classified in three groups : (1) Structural screws which have the same strength as equal size bolts; (2) machine screws, which include the majority of types used for general repair; and (3) self-tapping screws, which are used for attaching lighter parts. A fourth group, drive screws, are not actually screws but nails. They are driven into metal parts with a mallet or hammer and their heads are not slotted or recessed.

STRUCTURAL SCREWS

Structural screws are made of alloy steel, are properly heat treated, and can be used as structural bolts. These screws are found in the NAS204 through NAS235 and AN509 and AN525 series. They have a definite grip and the same shear strength as a bolt of the same size. Shank tolerances are similar to AN hex-head bolts, and the threads are National Fine. Structural screws are available with round, brazier, or countersunk heads. The recessed head screws are driven by either a Phillips or a Reed and Prince screwdriver.

The AN509 (100°) flathead screw is used in countersunk holes where a flush surface is necessary.

The AN525 washer-head structural screw is used where raised heads are not objectionable. The washer-head screw provides a large contact area.

DRIVE SCREWS

Drive screws, AN535, correspond to the Parker-Kalon U-type. They are plain-head self-tapping screws used as capscrews for attaching nameplates in castings and for sealing drain holes in corrosion proofing tubular structures. They are not intended to be removed after installation.

Early Series AN Machine Screws

Screws differ from bolts in being made from a lower strength material, having a looser fit (class 2A thread instead of class 3A) and having a slotted or a cruciform-recessed head, for rotation by a suitably-shaped screwdriver. The thread is usually continued up to the head, but the shank of 'structural' screws (i.e. AN 509 and 525) has a plain potion and may be used in locations where shear loading is present. Some screw heads are marked to indicate the material from which they are made, and these markings are listed in Table 15.8. The markings, head shape and material will enable identification of a particular screw to be made. Table 15.8 lists the AN machine screws, and Fig. 2 illustrates the various head shapes. It should be noted that some of these screws are obsolescent, and may not be available in the full range of sizes.

TABLE 15.8, EARLY SERIES AN MACHINE SCREWS

AN Number	Type	Material	Process	Head Marking*	Nominal Range of Thread Sizes	Thread
500	Screw, fillister head	Steel	Cad. plated		No. 2 to $\frac{3}{8}$ in	UNC
		CRS	Nil			
		Brass	Nil			
501	Screw, fillister head	Steel	Cad. plated		No. 0 to $\frac{3}{8}$ in	UNF
		CRS	Nil			
		Brass	Nil			
502	Screw, fillister head (drilled)	Steel	Cad. plated	X X	No. 10 to $\frac{5}{16}$ in	UNF
503	Screw, fillister head (drilled)	Steel	Cad. plated	X X	No. 6 to $\frac{5}{16}$ in	UNC
505	Screw, flat 82°	Steel	Cad. plated	- -	No. 2 to $\frac{3}{8}$ in	UNC
		CRS	Nil			
		Brass	Nil			
		Al. alloy	Anodised			
507	Screw, flat 100°	Steel	Cad. plated		NO. 6 to ¼ in	UNC and UNF
		CRS	Nil	- -		
		Brass	Black oxide			
		Brass	Nil			
		Al. alloy	Anodised			
509	Screw, flat 100° structural	Steel	Cad. plated	X X	No. 8 to $\frac{5}{16}$ in	UNF
		Al. alloy	Anodised			
		Bronze	Cad. plated	= =		
		Bronze	Nil	= =		
510	Screw, flat 82°	Steel	Cad. plated		No. 5 to ¼ in	UNF
		CRS	Nil	- -		
		Brass	Nil			
		Al. alloy	Anodised			
515	Screw, round head	Steel	Cad. plated		No. 5 to $\frac{3}{8}$ in	UNC
		CRS	Nil	- -		
		Brass	Nil			
		Al. alloy	Anodised			
520	Screw, round head	Steel	Cad. plated		No. 5 to ¼ in	UNF
		CRS	Nil	- -		
		Brass	Nil			
		Al. alloy	Anodised			
525	Screw, washer head	Steel	Cad. plated		No. 8 to ¼ in	No. 8 UNC & UNF No. 10 UNF ¼ in UnF
526	Screw, truss head	Steel	Cad. plated		No. 6 to ¼ in	UNF and UNC
		CRS	Nil	- -		
		Al. alloy	Anodised			

* Only one symbol may be found on some screw heads

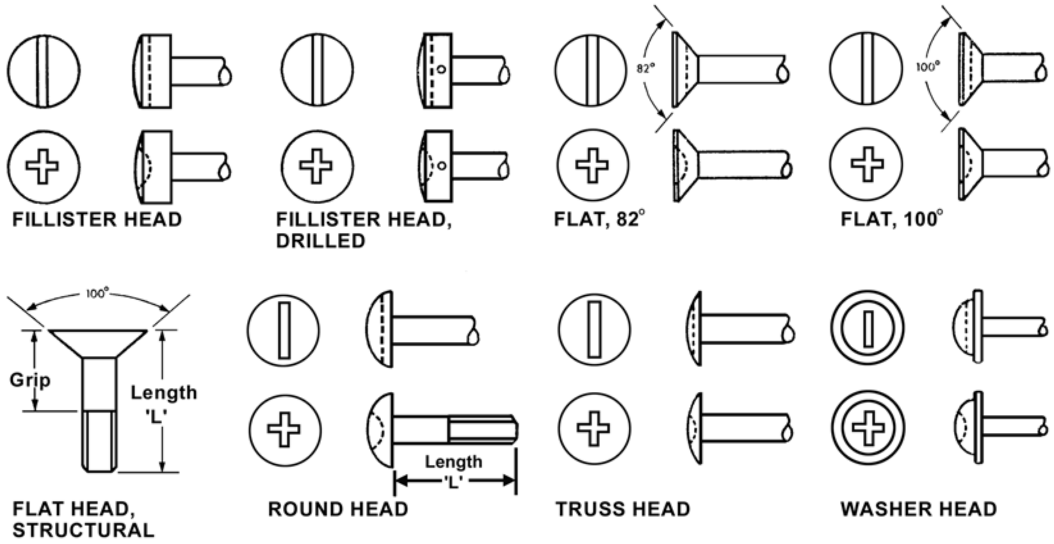


Fig.15.36, Early Series AN Screws.

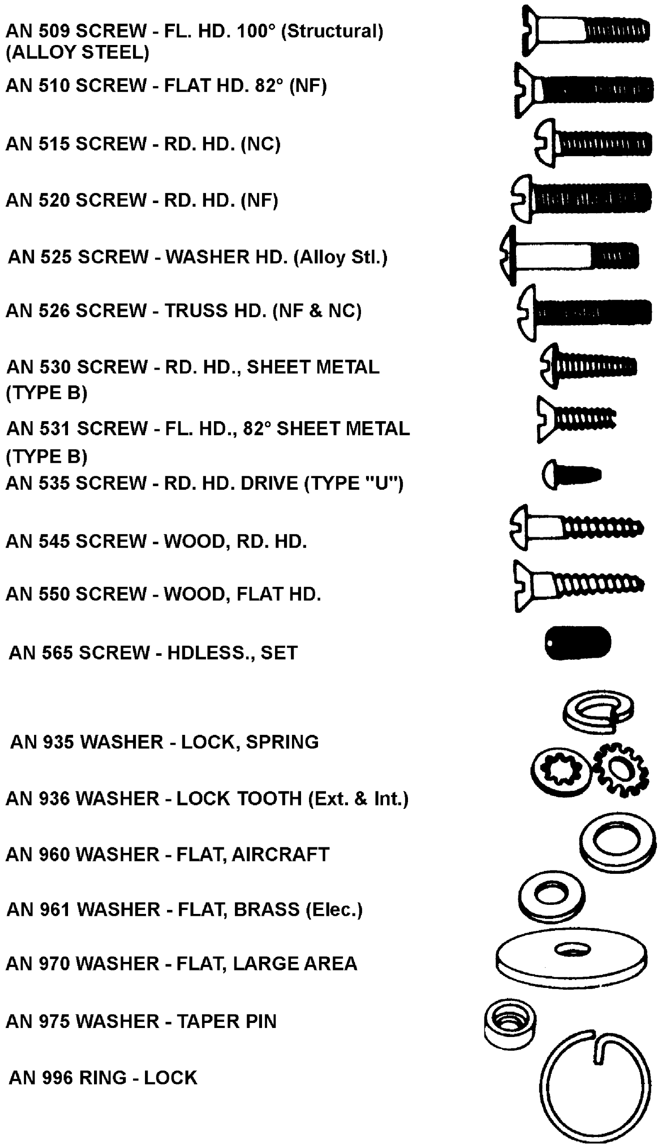


Fig.15.37, Aircraft Screws and Washers

Coding

Screws are coded by the AN number, to indicate the type (e.g. round head), letters to indicate material (and in some cases the shape of the screwdriver recess), and two dash numbers indicating diameter and length. In addition, some are coded to indicate whether the head is drilled or not.

a. Diameter

The coding for the diameter depends on whether the screw is available with only fine or coarse threads, or with either type of threads. Diameter is indicated by the first dash number.

i. Screws available with only one type of thread are coded by the thread number or diameter in sixteenths of an inch. For example, No. 4 (UNC or UNF) = -4, No. 10 (UNC or UNF) = - 10, 1/4 in (UNC or UNF) = -416, 5/16 in (UNC or UNF) = -516, etc.

ii. Screws available with both coarse and fine threads (AN 525 and AN 526) are coded by the thread number or diameter in sixteenths of an inch, followed by the number of threads per inch. For example, No. 6-32 (UNC) = -632, No. 8-36 (UNF) = -836, 1/4 - 28 (UNF) = -428, etc.

iii. AN 525 screws are available in only one coarse thread size (No.8) and this is coded - 832. The remaining sizes are coded in accordance with (i).

b. Length

The second dash number indicates the length (L in Fig. 15.37) of a screw in sixteenths of an inch. AN 509 screws are an exception to this rule, the actual length of the screw being 1/32 in longer than the size indicated by the code.

c. Material

Material is indicated by a letter (or letters) placed after the AN number as follows :-

Steel = no letter

CRS = C

Brass (unplated), AN 507 = UB, and other screws = B

Brass (black oxide), AN 507 = B

Aluminium alloy, AN 507, 509 and 526 = DD, and other screws = D

Bronze (cad. plated), AN 509 = P

Bronze (unplated), AN 509 = Z

d. Head Recess

Where a screwdriver slot is required the basic code only is used. Where a cruciform recess is required, 'R' is added instead of the second dash.

e. Drilled Head

AN 500 and 501 screws are provided with a plain or drilled heads. The letter A before the first dash number indicates a screw with a drilled head.

f. Examples of Coding

i. An AN 500A6 -32 is a fillister head screw with a locking wire hole. It is made of cadmium-plated steel, has a No.6 (UNC) thread, has a slotted head and is 2 in long.

ii. An AN 507C832R8 is a 100° flat head screw in corrosion-resistant steel. It has a No.8-32 (UNC) thread, has a cruciform recessed head and is 1/2 in long.

iii. An AN 509DD416-20 is a 100° flat head, structural screw in aluminium alloy. It has a 1/4 in (UNF) thread, has a slotted head and is 9/32 in long.

TURNLOCK FASTENERS

Turnlock fasteners are used to secure inspection plates, doors, cowlings, and other removable panels on aircraft. The most desirable feature of these fasteners is that they permit quick and easy removal of access panels for inspection and servicing purposes. Turnlock fasteners are manufactured and supplied by a number of manufacturers under various trade names. Some of the most commonly used are the Dzus, Airloc, and Camloc.

Dzus Fasteners

Cowling and other inspection access doors that must be opened frequently can be held with dzus fasteners that require only a quarter of a turn to lock or unlock. With a Dzus fastener a hard spring-steel wire is riveted across an opening on a fixed part of a fuselage, and a stud is mounted on the removable panel with a metal grommet. When the panel is closed, a slot in the stud straddles the spring. Turning the stud a quarter of a turn pulls the spring up into the slanted slot and locks it as the spring passes over the hump in the slot. (Fig. 15.38)

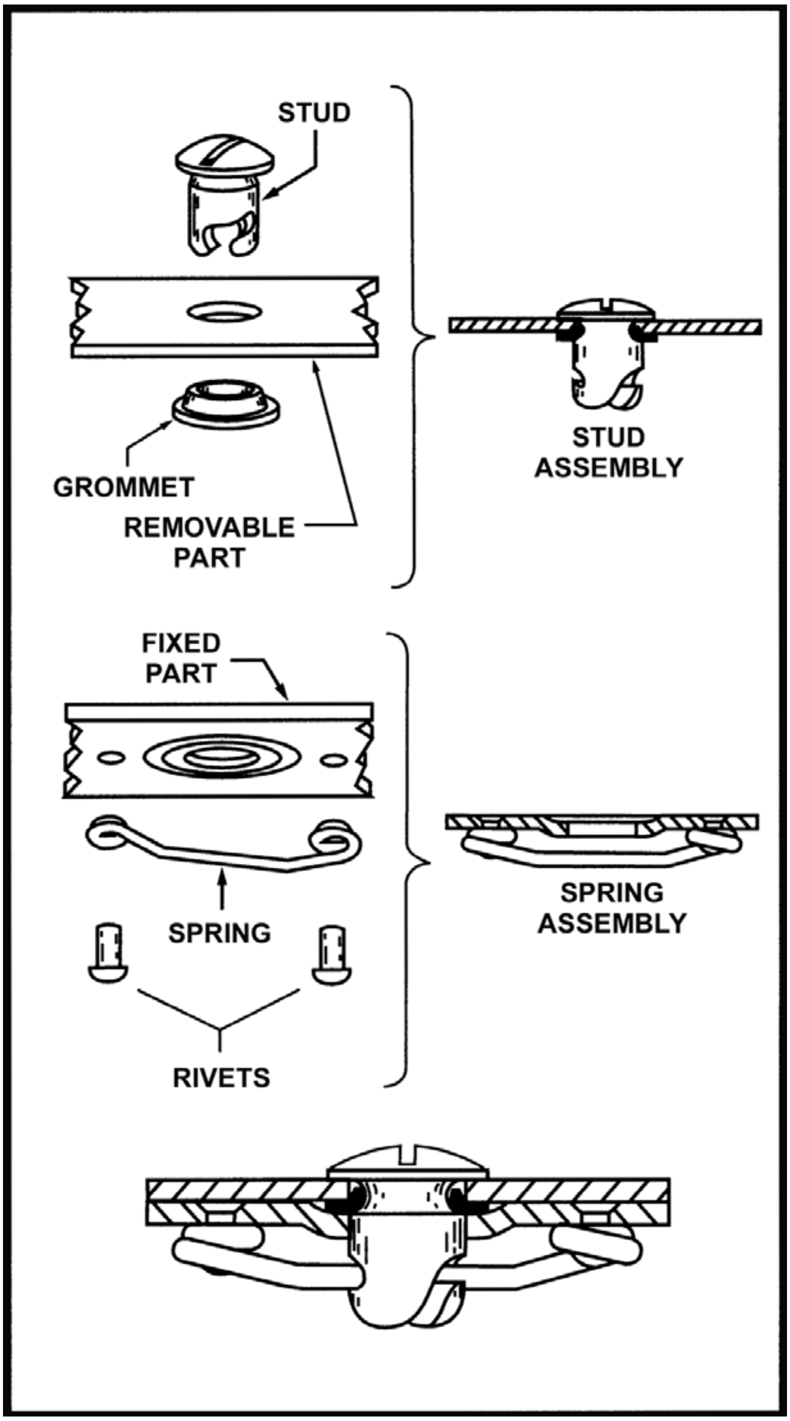


Fig.15.38, With a standard Dzus fastener, a slotted stud engages a spring mounted to the fuselage. As the stud is turned onequarter turn, the spring locks the fastener in place.

When something is fastened with Dzus fasteners, care must be taken that the stud in every fastener straddles each of the springs rather than passing beside them. In order to be sure that all of the fasteners are properly locked, the slots should all be lined up. Furthermore, when a Dzus fastener is fastened, a distinct click is heard when the spring drops over the hump into the locked position. To aid in assuring that no stud misses the spring, special receptacle-type fasteners are available that guide the stud over the spring. (Fig. 15.39).

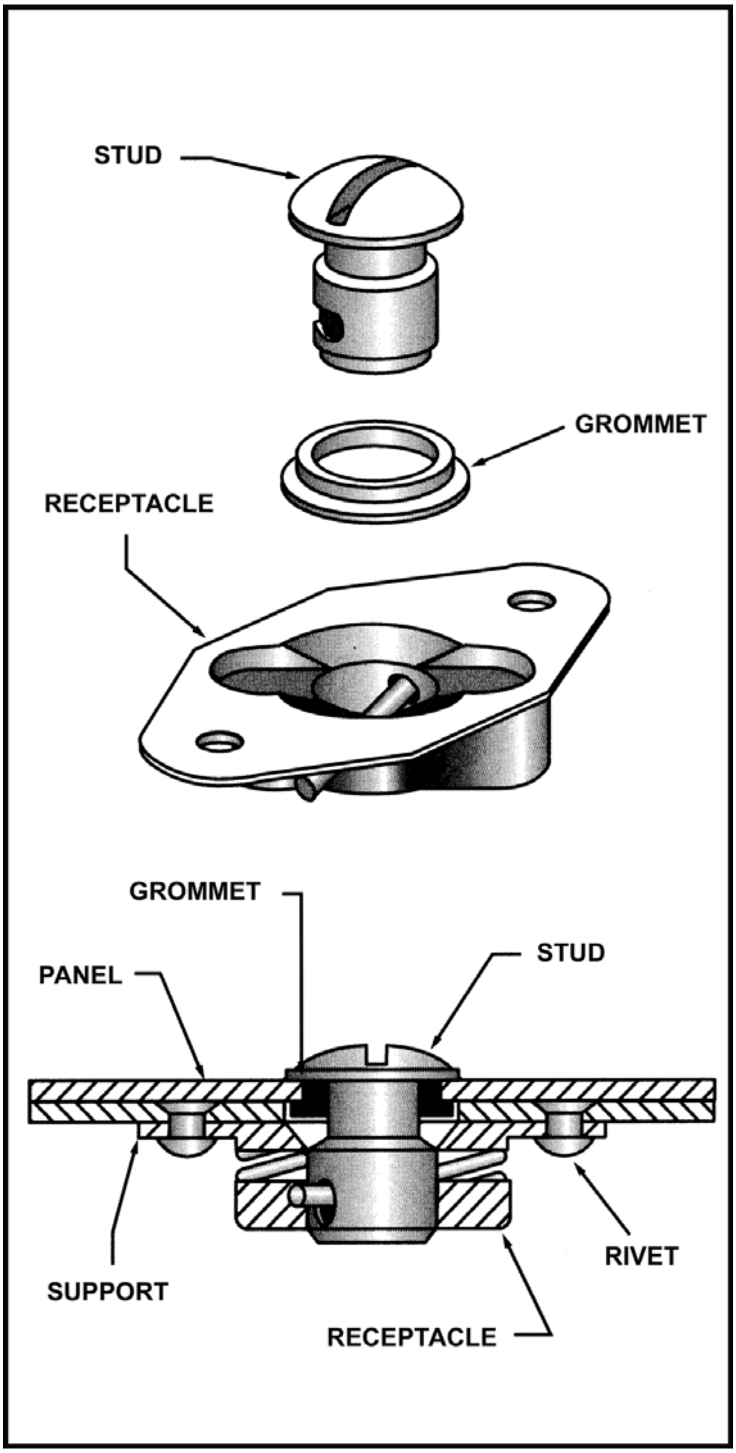


Fig.15.39, The receptacle of a receptacle-type Dzus fastener guides the stud to the exact location it needs to be prior to engaging the spring.

Airloc Fastener

An Airloc fastener consists of a steel stud and crosspin in a removable cowling or door and a sheet sprig-steel receptacle in the stationary member. To lock this type of fastener, the stud slips into the receptacle and is rotated a quarter of a turn. The pin drops into an indetation in the receptacle spring and hods the fastener locked. (Fig. 15.40).

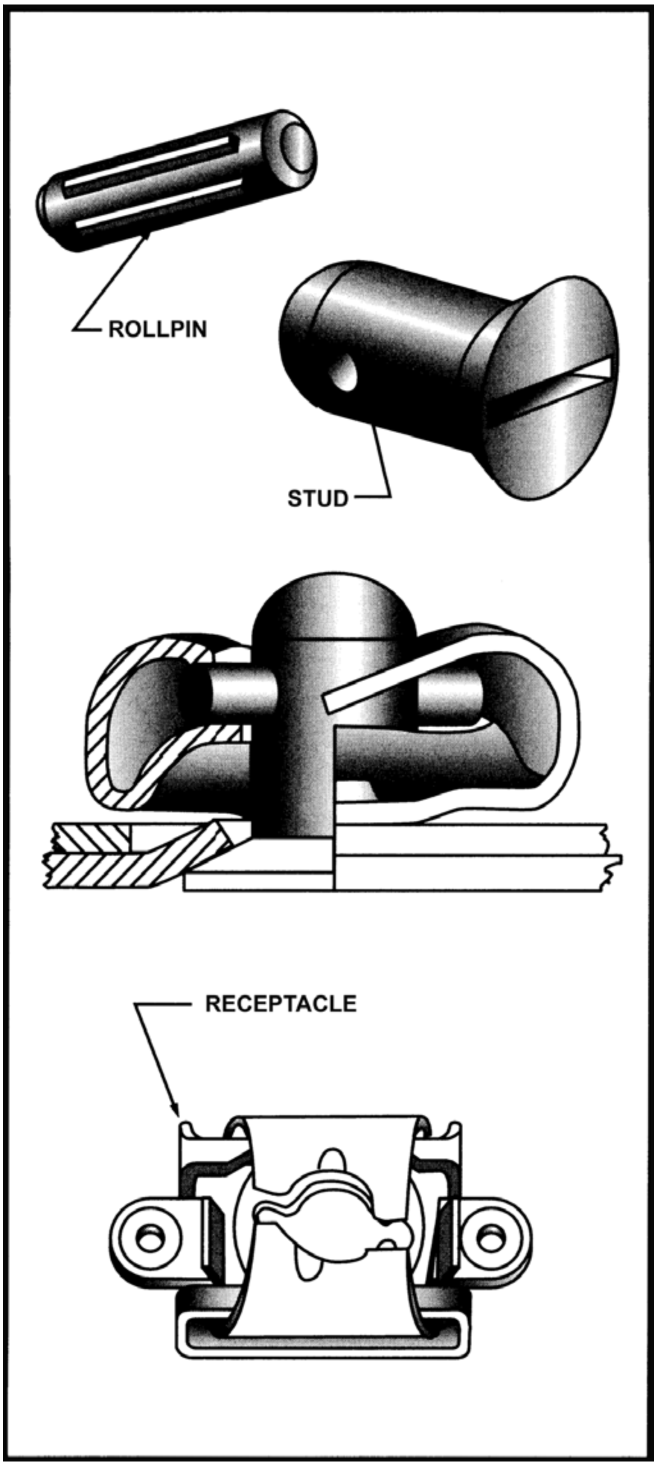


Fig.15.40, Airloc cowling fasteners are similar to Dzus fasteners and are used in many of the same applications

Camlock Fastener

The stud assembly of a Camlock fastener consists of a housing containing a spring and a stud with a steel pin. This assembly is held onto the removable portion of the cowling or access door with a metal grommet. The stud fits into a pressed steel receptacle, and a quarter of a turn locks the steel pin in a groove in the bottom of the receptacle (Fig. 15.41).

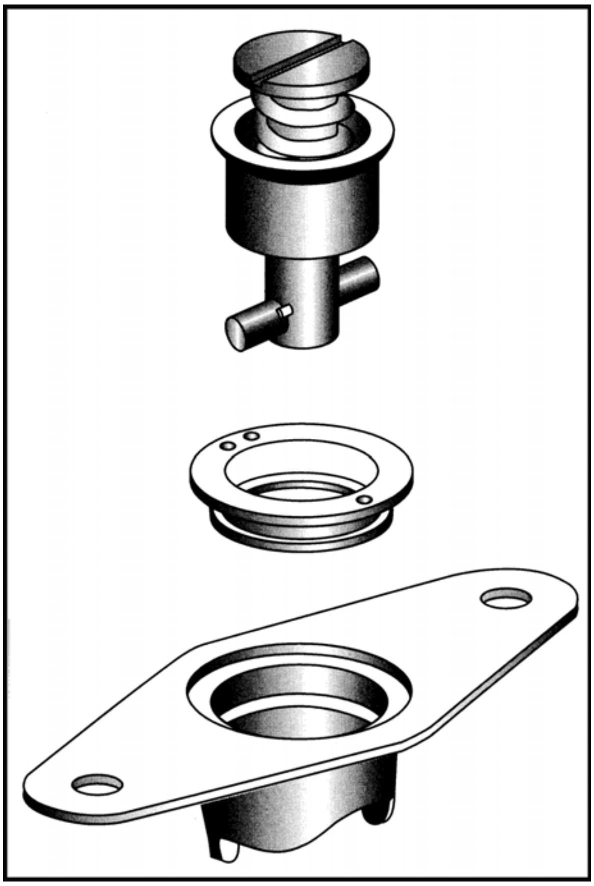


Fig.15.41, With a Camlock cowling fastener the stud assembly can be inserted into the receptacle when the pin is aligned with the slot in the slot in the receptacle.

SCREWS

Late Series AN Fasteners

These fasteners are all marked to show the material from which they are made. When ordering a particular fastener, the part number should be taken from the tables in the appropriate specification, since the size cannot be determined from a standard coding. Tables 15.9, 15.10 and 15.11 list the various bolts, screws and nuts which are currently available in this series of specifications, and give the range of numbers allocated to each type.

Late series AN bolts are listed in Table 15.9 and are available in sizes 10 - 32, 1/4 - 28, 5/16 - 24, 3/8 - 24, 7/16 - 20, 1/2 - 20, 9/16 - 18, 5/8 - 18 and 3/4 - 16.

TABLE 15.9, LATE SERIES AN BOLTS

AN Number	Type	Material	Identification
101001 - 101900	Bolt, hexagon head	Alloy steel (AMS 6322) cadmium plated	
101901 - 102800	Bolt, hexagon head, drilled shank		
102801 - 103700	Bolt, hexagon head, drilled head (1 hole)		
103701 - 104600	Bolt, hexagon head, drilled head (6 hole)		
104601 - 105500	Bolt, hexagon head	Corrosion-resistant steel (AMS 7472)	
105501 - 106400	Bolt, hexagon head, drilled shank		
106401 - 107300	Bolt, hexagon head, drilled head (1 hole)		
107301 - 108200	Bolt, hexagon head, drilled head (6 holes)		

Late series AN screws are listed in Table 15.10, and are available in the sizes shown.

Late series AN nuts are listed in Table 15.11 and are available in the sizes shown.
A plain washer is also available in the late series AN specifications. This is a plain steel washer of cadmium plated steel (AMS 6350), made to fit bolts in sizes No.10 to 1 in, and given a number in the range 122576 to 122600. The washers are rubber stamped with the mark 'E 23'.

MS FASTENERS

A wide variety of fasteners is available in the MS range. All of these fasteners are marked to show the material from which they are made or the MS specification to which they conform ; in addition, most fasteners are marked with the manufacturer's identification. Bolts and screws are marked on their heads, and nuts are marked either on the flat (hexagon nuts) or on the top face (other types). To assist in identification, Fig. 15.42 illustrates the various types of bolt and screw heads in this series, and these are referred to in the appropriate Tables. Nuts are similar to those illustrated in Table 15.11.

TABLE 15.10, LATE SERIES AN SCREWS

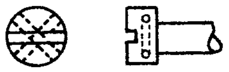
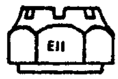
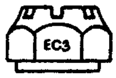
AN Number	Type	Material	Sizes	Identification
116901 - 116912	Screw, oval fillister	Carbon steel (AMS 5061) cadmium plated	4 - 40	
116913 - 116924	Screw, oval fillister, drilled		4 - 40	
116925 - 116960	Screw, oval fillister		6 - 32	
116961 - 117000	Screw, oval fillister, drilled		6 - 32	
117001 - 117040	Screw, oval fillister		8 - 32	
117041 - 117080	Screw, oval fillister, drilled		8 - 32	
115401 - 115600	Screw, flat fillister	Alloy steel (AMS 6322) cadmium plated	UNF No. 10 to $\frac{3}{8}$ in	
115601 - 115800	Screw, flat fillister, drilled shank			
115801 - 116150	Screw, flat fillister, drilled head		No. 10 UNF ¼ to $\frac{3}{8}$ in UNF ¼ to $\frac{3}{8}$ in UNC	

TABLE 15.11, LATE SERIES AN NUTS

AN Number	Type	Material	Sizes	Identification
121501 - 121525	Nut, hexagon, plain	Alloy steel (AMS 6322) cadmium plated	No. 10 to 1 in UNF	
121551 - 121575	Nut, hexagon, castle			
121526 - 121550	Nut, hexagon, plain	Corrosion-resistant steel (AMS 7472)		
121576 - 121600	Nut, hexagon, castle			
150401 - 150425	Nut, hexagon, check	Alloy steel (AMS 6320) cadmium plated	No. 10 to $\frac{3}{4}$ in UNF	
150426 - 150450	Nut, hexagon, shear, slotted			

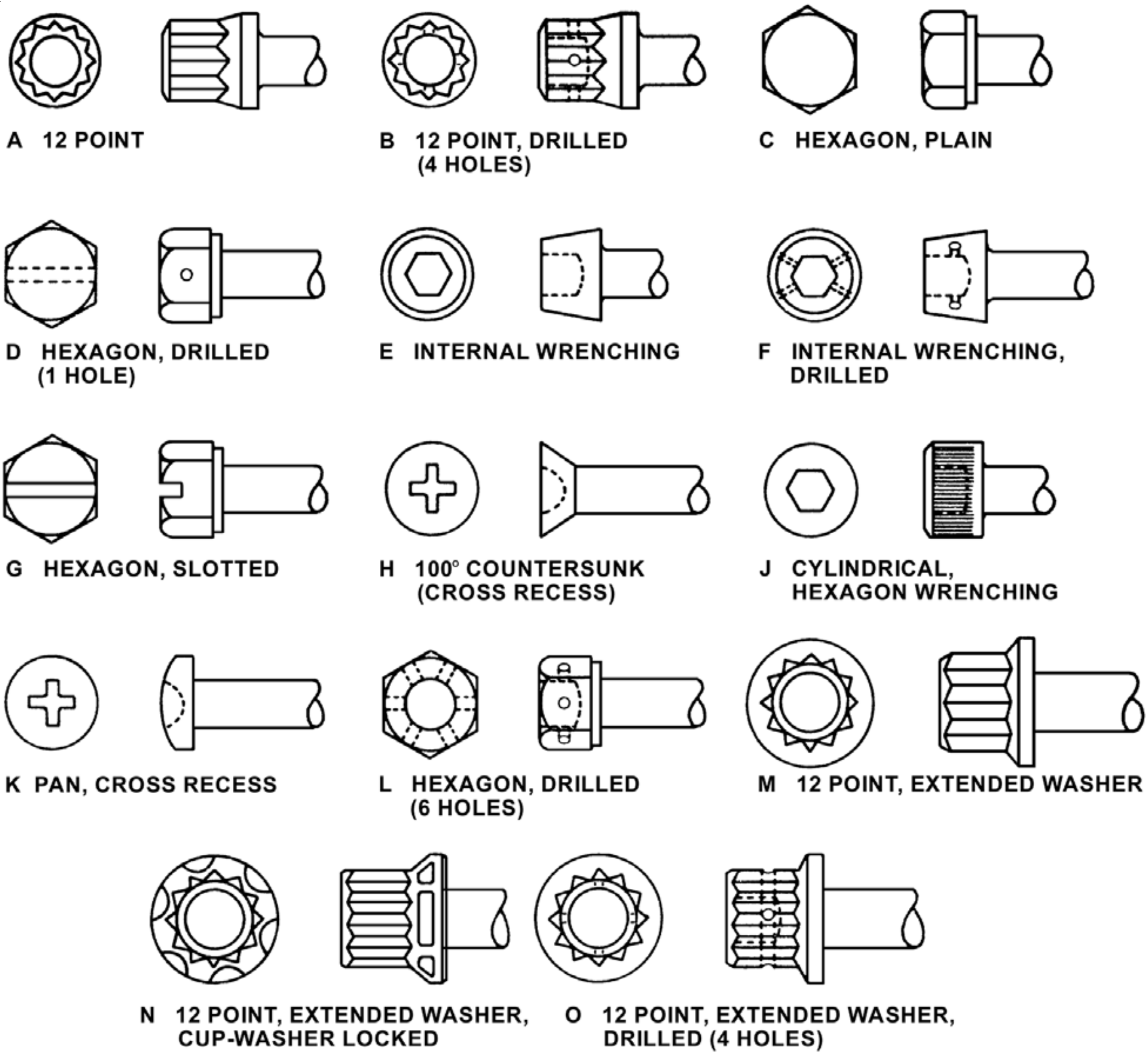


Fig.15.42, MS Bolts And Screws

MS Bolts

Table 15.12 lists a wide range of bolts and screws in the MS series. It should be noted, however, that the term 'bolt' is applied to the whole range of sizes in which a particular item is supplied. In the specifications, an item with a No. 8 or smaller thread is generally termed a 'screw', regardless of the fact that it is identical inshape and material to a larger item, which is termed a 'bolt'. However, in some cases the term 'bolt' is also applied to an item with a No. 8 thread.

Coding

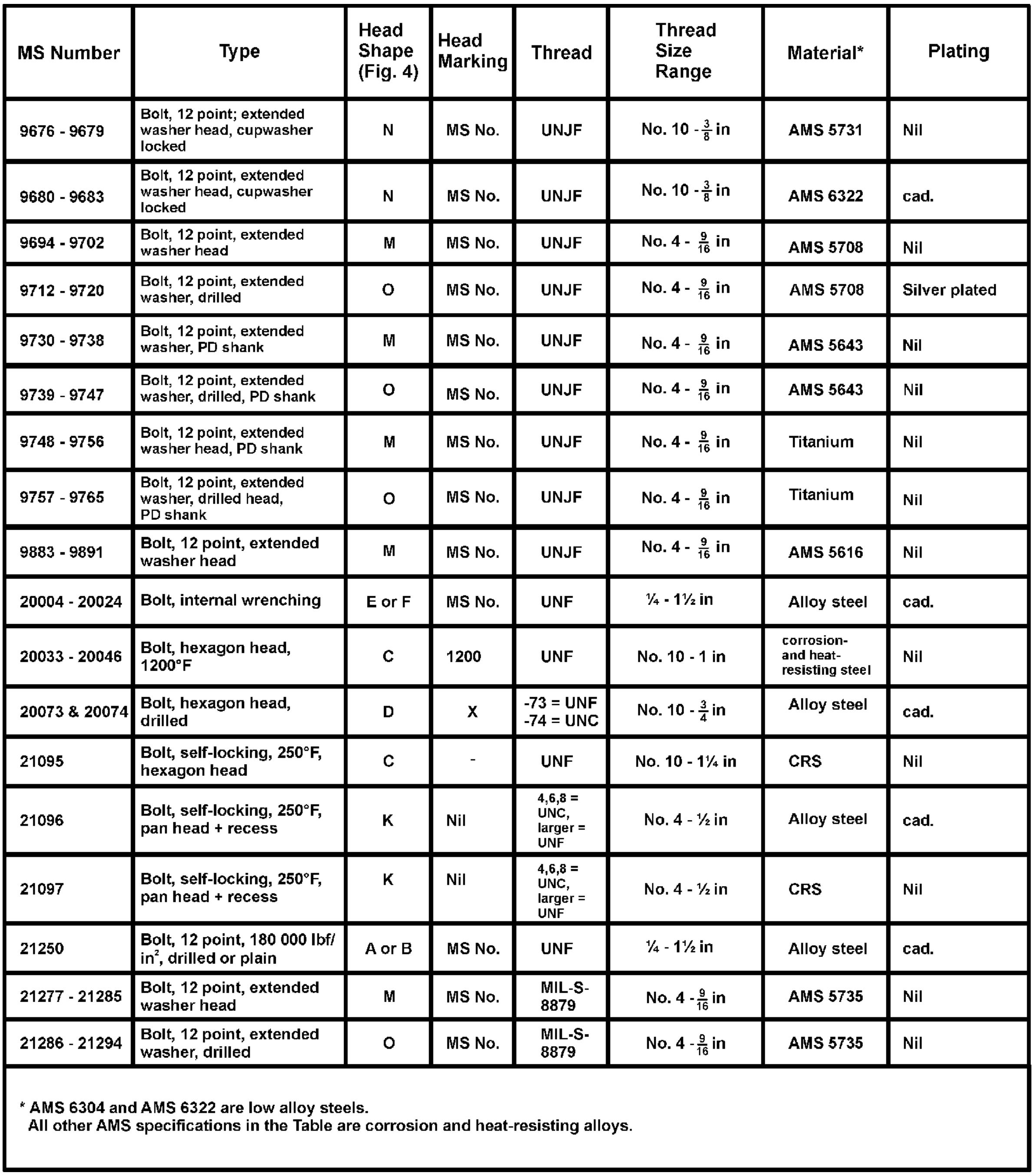
For most of the items listed in Table 15.12, the MS number relates to an item of a particular diameter, and a table provide in the specification details the range of lengths available in that size. Length is indicated by a dash number, nut the length indicated by a particular dash number varies with the diameter, so that the complete part number of a particular item can only be determined by reference to the specifications.

With bolts in the ranges MS 20004 to 20024 and MS 20033 to 20046, the thread size is indicated by the part number as outlined, and the length is indicated by a dash number, which represents grip length in sixteenths of an inch.

TABLE 15.12, MS BOLTS AND SCREWS

MS Number	Type	Head Shape (Fig. 4)	Head Marking	Thread	Thread Size Range	Material*	Plating
9033 - 9038	Bolt, 12 point, heat resistant	A	EH 19	UNF	No. 10 - ½ in	AMS 5735	Nil
9060 - 9066	Bolt, 12 point, drilled, extended washer head	O	EH 19	UNF	No. 10 - ½ in	AMS 5735	Nil
9088 - 9094	Bolt, 12 point, drilled head	B	E 11	UNF	No. 10 - $\frac{9}{16}$ in	AMS 6322	Cad.
9110 - 9113	Bolt, 12 point, extended washer head	M	MS No.	UNF	No. 10 - $\frac{3}{8}$ in	AMS 5731	Nil
9146 - 9152	Bolt, 12 point	A	E 11	UNF	No. 10 - $\frac{9}{16}$ in	AMS 6322	Cad.
9157 - 9163	Bolt, 12 point	A	E 11	UNF	No. 10 - $\frac{9}{16}$ in	AMS 6322	Black oxide
9169 - 9175	Bolt, 12 point, drilled head	B	E 11	UNF	No. 10 - $\frac{9}{16}$ in	AMS 6322	Black oxide
9177 and 9178	Screw, 12 point, extended washer head	N	EH 19	UNF	No. 6 & No. 8	AMS 5735	Nil
9183 and 9184	Screw, 12 point, drilled head	B	E 11	UNF	No. 6 & No. 8	AMS 6322	Cad.
9185 and 9186	Screw, 12 point	A	E 11	UNF	No. 6 & No. 8	AMS 6322	Cad.
9189 and 9190	Screw, 12 point	A	E 11	UNF	No. 6 & No. 8	AMS 6322	Black oxide
9191 and 9192	Screw, 12 point, drilled head	B	E 11	UNF	No. 6 & No. 8	AMS 6322	Black oxide
9206 - 9214	Bolt, 12 point extended washer head	M	MS No.	UNJF	No. 6 - $\frac{9}{16}$ in	AMS 6304	Diffused nickel cadmium
9215 - 9222	Bolt, 12 point, extended washer, drilled head	O	MS No.	UNJF	No. 6 - ½ in	AMS 6304	Diffused nickel cadmium
9224	Bolt, 12 point, heat resistant	A	EH 19	UNF	$\frac{9}{16}$ in	AMS 5735	Nil
9281 - 9291	Bolt, hexagon head	C	MS No.	UNF	No. 4 - $\frac{3}{4}$ in	AMS 6322	Black oxide
9292 - 9302	Bolt, hexagon head, drilled	D	MS No.	UNF	No. 4 - $\frac{3}{4}$ in	AMS 6322	Black oxide
9438 - 9448	Bolt, hexagon head, drilled	D	MS No.	UNJF	No. 6 - $\frac{3}{4}$ in	AMS 6304	Diffused nickel cadmium
9449 - 9459	Bolt, hexagon head	C	MS No.	UNJF	No. 6 - $\frac{3}{4}$ in	AMS 6304	Diffused nickel cadmium
9487 - 9497	Bolt, hexagon head	C	MS No.	UNJF	No. 8 - $\frac{3}{4}$ in	AMS 5731	Nil
9498 - 9508	Bolt, hexagon head, drilled	D	MS No.	UNJF	No. 6 - $\frac{3}{4}$ in	AMS 5731	Nil
9516 - 9526	Screw, hexagon head	C	MS No.	UNJF	No. 4 - $\frac{3}{4}$ in	AMS 6322	Cad.
9527 - 9537	Screw, hexagon head, drilled	D	MS No.	UNJF	No. 4 - $\frac{3}{4}$ in	AMS 6322	Cad.
9554 - 9562	Bolt, 12 point, extended washer head, PD shank	M	MS No.	UNJF	No. 6 - $\frac{9}{16}$ in	AMS 5731	Nil
9563 - 9571	Bolt, 12 point, ext. washer, drilled head, PD shank	O	MS No.	UNJF	No. 6 - $\frac{9}{16}$ in	AMS 5731	Nil
9572 - 9580	Bolt, 12 point, extended washer head	M	MS No.	UNJF	No. 6 - $\frac{9}{16}$ in	AMS 5731	Silver plated
9583 - 9591	Bolt, hexagon head, drilled	L	MS No.	UNJF	No. 10 - $\frac{3}{4}$ in	AMS 5731	Nil

TABLE 15.12, (continued)



MS Number	Type	Head Shape (Fig. 4)	Head Marking	Thread	Thread Size Range	Material*	Plating
9676 - 9679	Bolt, 12 point; extended washer head, cupwasher locked	N	MS No.	UNJF	No. 10 - $\frac{3}{8}$ in	AMS 5731	Nil
9680 - 9683	Bolt, 12 point, extended washer head, cupwasher locked	N	MS No.	UNJF	No. 10 - $\frac{3}{8}$ in	AMS 6322	cad.
9694 - 9702	Bolt, 12 point, extended washer head	M	MS No.	UNJF	No. 4 - $\frac{9}{16}$ in	AMS 5708	Nil
9712 - 9720	Bolt, 12 point, extended washer, drilled	O	MS No.	UNJF	No. 4 - $\frac{9}{16}$ in	AMS 5708	Silver plated
9730 - 9738	Bolt, 12 point, extended washer, PD shank	M	MS No.	UNJF	No. 4 - $\frac{9}{16}$ in	AMS 5643	Nil
9739 - 9747	Bolt, 12 point, extended washer, drilled, PD shank	O	MS No.	UNJF	No. 4 - $\frac{9}{16}$ in	AMS 5643	Nil
9748 - 9756	Bolt, 12 point, extended washer head, PD shank	M	MS No.	UNJF	No. 4 - $\frac{9}{16}$ in	Titanium	Nil
9757 - 9765	Bolt, 12 point, extended washer, drilled head, PD shank	O	MS No.	UNJF	No. 4 - $\frac{9}{16}$ in	Titanium	Nil
9883 - 9891	Bolt, 12 point, extended washer head	M	MS No.	UNJF	No. 4 - $\frac{9}{16}$ in	AMS 5616	Nil
20004 - 20024	Bolt, internal wrenching	E or F	MS No.	UNF	¼ - 1½ in	Alloy steel	cad.
20033 - 20046	Bolt, hexagon head, 1200°F	C	1200	UNF	No. 10 - 1 in	corrosion- and heat-resisting steel	Nil
20073 & 20074	Bolt, hexagon head, drilled	D	X	-73 = UNF -74 = UNC	No. 10 - $\frac{3}{4}$ in	Alloy steel	cad.
21095	Bolt, self-locking, 250°F, hexagon head	C	-	UNF	No. 10 - 1¼ in	CRS	Nil
21096	Bolt, self-locking, 250°F, pan head + recess	K	Nil	4,6,8 = UNC, larger = UNF	No. 4 - ½ in	Alloy steel	cad.
21097	Bolt, self-locking, 250°F, pan head + recess	K	Nil	4,6,8 = UNC, larger = UNF	No. 4 - ½ in	CRS	Nil
21250	Bolt, 12 point, 180 000 lbf/ in^2, drilled or plain	A or B	MS No.	UNF	¼ - 1½ in	Alloy steel	cad.
21277 - 21285	Bolt, 12 point, extended washer head	M	MS No.	MIL-S-8879	No. 4 - $\frac{9}{16}$ in	AMS 5735	Nil
21286 - 21294	Bolt, 12 point, extended washer, drilled	O	MS No.	MIL-S-8879	No. 4 - $\frac{9}{16}$ in	AMS 5735	Nil

* AMS 6304 and AMS 6322 are low alloy steels.
All other AMS specifications in the Table are corrosion and heat-resisting alloys.

With bolts in the MS 21250 series, the dash number indicates both diameter and length. The first two figure as indicate diameter in sixteenths of an inch, and the last two figures indicate grip length in sixteenths of an inch.

With the MS 20004 to 20024, and MS 21250, bolts, an H in place of the dash indicates a drilled-head bolt.

MS Screws

Table 15.13 lists a variety of the screws covered by MS specifications, and shows the features by which these screws may be partially identified.

Because the individual specifications vary, the screws listed in Table 15.13 should be fully identified by reference to the particular specification.

TABLE 15.13 MS SCREWS

MS Number	Type	Head Shape (Fig. 4)	Head Marking	Thread	Thread Size Range	Material	Plating
9122 and 9123	Screw, hex. head, slotted	G	E 11	UNF	No. 10 and ¼ in	AMS 6322	Cadmium
21262	Screw, cyl. head, 160 KSI int. wren. 250°F	J	⠿	4,6,8 = UNC larger = UNF	No. 4 - ⅝ in	Alloy steel	Cadmium
21295	Screw, cyl. head, 160 KSI int. wren. 250°F	J	⠿	4,6,8 = UNC Larger = UNF	No. 4 - ⅝ in	CRS	Nil
24693	Screw, flat 100° + recess	H	—	UNC 2A UNF 2A	No. 6 - ⅜ in	CRS	Nil
24694	Screw, flat 100° + recess	H	—	UNC 3A UNF 3A	No. 6 - $\frac{9}{16}$ in	CRS	Nil
27039	Screw, pan head, + recess, structural	K	$\frac{B}{C}$	8 = UNC Larger = UNF	No. 8 - ½ in	Bronze Alloy steel CRS	Nil Cadmium Nil
35297	Screw, cap, hex. head	C	⅄	UNC 2A	¼ - 1¼ in	Carbon steel	Cad. or zinc
35299	Screw, cap, hex. head	C	⅄	UNC 2A	¼ - 1¼ in	Carbon steel	Phosphate
35307	Screw, cap, hex. head	C	∟	UNC 2A	¼ - 1¼ in	CRS	Nil
35308	Screw, cap, hex. head	C	∟	UNF 2A	¼ - 1¼ in	CRS	Nil
51095	Screw, cap, hex. head, drilled	D	⅄	UNC 2A	¼ - 1 in	Carbon steel	Cadmium
51096	Screw, cap, hex. head, drilled	D	⅄	UNF 2A	¼ - 1 in	Carbon steel	Cadmium
51099	Screw, cap, hex. head, drilled	D	∟	UNC 2A	¼ - 1 in	CRS	Nil
51100	Screw, cap, hex. head, drilled	D	∟	UNF 2A	¼ - 1 in	CRS	Nil
51105	Screw, cap, hex. head, drilled	D	⅄	UNC 2A	¼ - 1 in	Carbon steel	Cadmium
51106	Screw, cap, hex. head, drilled	D	⅄	UNF 2A	¼ - 1 in	Carbon steel	Cadmium
51107	Screw, cap, hex. head, drilled shank	C	✱	UNC 2A	¼ - 1 in	Alloy steel	Phosphate
51108	Screw, cap, hex. head, drilled shank	C	✱	UNF 2A	¼ - 1 in	Alloy steel	Phosphate
51109	Screw, cap, hex. head, drilled shank	C	∟	UNC 2A	¼ - 1 in	CRS	Nil
51110	Screw, cap, hex. head, drilled shank	C	∟	UNF 2A	¼ - 1 in	CRS	Nil
90726	Screw, cap, hex. head	C	⅄	UNF 2A	¼ - 1½ in	Carbon steel	Cadmium
90727	Screw, cap, hex. head	C	✱	UNF 2A	¼ - 1½ in	Alloy steel	Cadmium
90728	Screw, cap, hex. head	C	✱	UNC 2A	¼ - 1½ in	Alloy steel	Cadmium

MS Nuts

The non-self-locking nuts to MS specifications are listed in Table 15.14. These nuts are similar in appearance to those shown in Table 15.11, but all are marked with the appropriate MS part number for identification purposes.

Coding

Nuts are coded by the MS number plus a dash number indicating thread size -04 is No. 4, -06 is No. 6, -08 is No. 8, -09 is No. 10, -10 is 1/4 in, -11 is 5/16 in, -12 is 3/8 in, -13 is 7/16 in, -14 is 1/2 in, -15 is 9/16 in, -16 is 5/8 in, -17 is 3/4 in, -18 is 7/8 in and -19 is 1 in.

MS Washers

Two ranges of washers are covered in the MS series. MS 35338 is a cadmium-plated, steel, spring washer, and replaces the AN 935 regular spring washer. MS 35333 and 35335 are lock washers in cadmium-plated steel and bronze, which replace the AN 936 style A and style B shakeproof washers, respectively. All of these washers are ordered by the MS number, followed by dash number indicating the size of bolt the washer is designed to fit. The dash number applicable to a particular washer should be obtained from the tables providing the specification.

TABLE 15.14, MS NON-SELF-LOCKING NUTS

MS Number	Type	Thread	Size Range	Material	Plating
9356	Nut, plain, hexagon	No. 4, 6 and 8 nuts have UNC thread. Larger size nuts have UNF thread.	No. 4 - 1 in	AMS 5735	Nil
9357	Nut, plain, hexagon		No. 4 - 1 in		Silver
9358	Nut, castle		No. 10 - 1 in		Nil
9359	Nut, castle		No. 10 - 1 in		Silver
9360	Nut, plain, hexagon, drilled		No. 10 - 1 in		Silver
9361	Nut, plain, hexagon, check		No. 10 - 1 in		Nil
9362	Nut, plain, hexagon, check		No. 10 - 1 in		Silver
9363	Nut, hexagon, slotted, shear		No. 10 - 1 in		Nil
9364	Nut, hexagon, slotted, shear		No.10 - 1 in		Silver

NAS FASTENERS

NAS Specifications provide a wide range of fasteners, with a variety of head shapes and wrenching recesses (Fig. 15.43). The range of bolts and screws includes both self-locking and non-locking versions, and many varieties are also available with oversize shanks for repair work. A few washers and nuts are also included in the NAS specifications, but these items are generally supplied under manufacturers' specifications and are not included in this Chapter.

All NAS bolts and screws are marked for identification purposes, but the extent of the marking depends on the size of the head and on the requirements of the particular specification. Many components are marked in accordance with NAS 1347, which provides for four types of identification. Type I is the material code and is the same as that shown in Fig. 1 for AN bolts ; Type II is the basic part number, i.e. the NAS number; Type III is the basic part number and a material code letter; Type IV is the complete part number, including basic part number, material code, figures for diameter and length, and a letter for type of finish. These markings are shown in Table 15.15. It should be noted, however, that in the smaller sizes a shortened version of the code may be permitted by the specification. On fasteners with a Tri-Wing recess the marking also includes a figure, inside a circle, which indicates the size of the recess in accordance with NAS 4000. Oversize bolts are also marked with an 'X' or 'Y'.

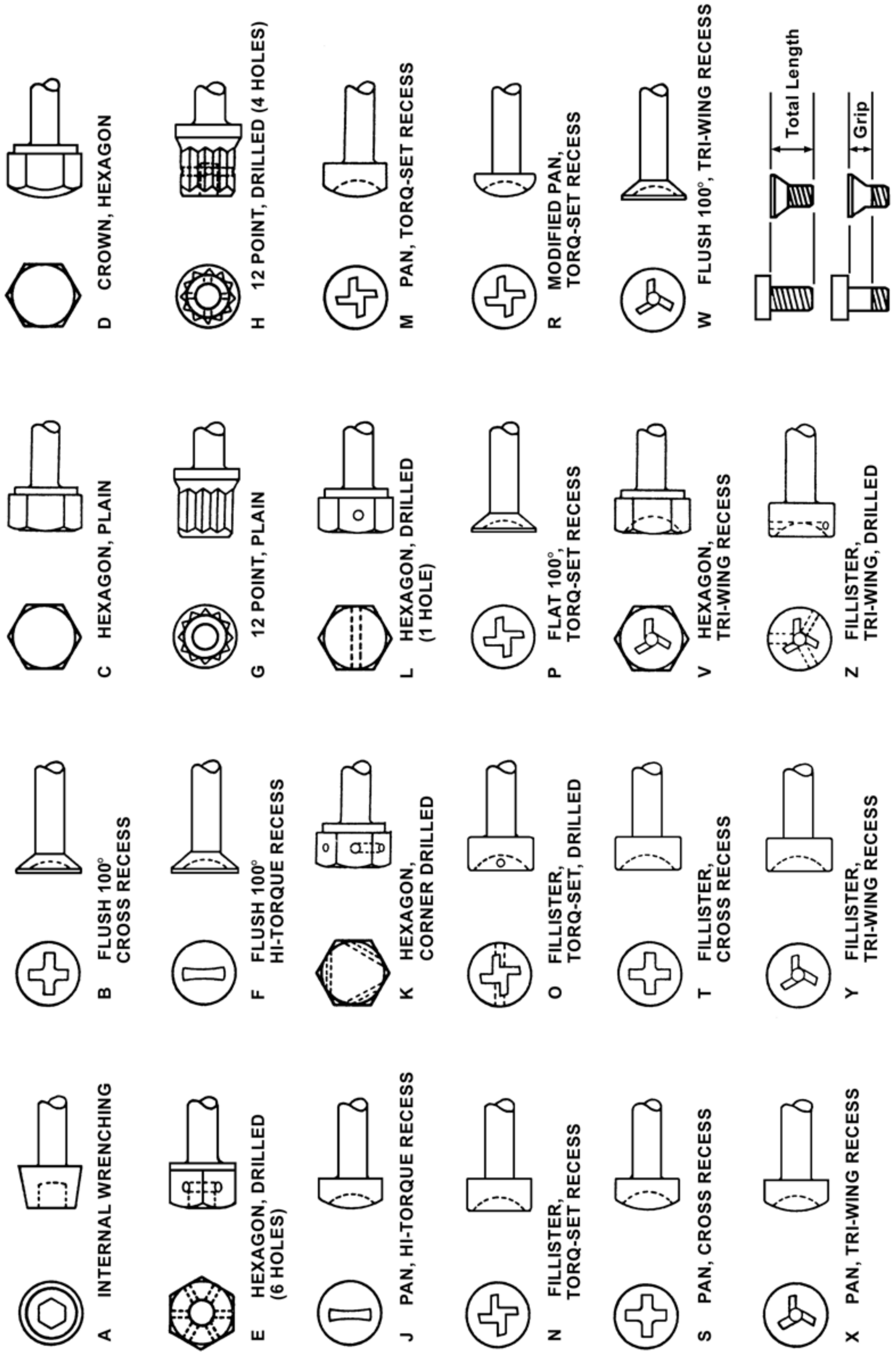


Fig. 15.43, NAS Bolts and Screws

Note

Provision is also made for including the manufacturer's identification mark on the head.

Coding

The bolts and screws listed in Table 15.15, are coded according to their type, diameter, length, type of plating and material. Where a component is made in more than one material, an alloy steel part is given the basic part number ; similarly, where applicable, the basic part number implies that the part is not drilled for locking purposes.

Diameter

Most bolts and screws are coded according to thread size in a similar way to AN and MS parts; however, there are some exceptions.

a. BAS 1261 to 1265 and NAS 1266 to 1270 are available in sizes 9/16 - 18, 5/8 - 18, 3/4 - 16, 7/8 - 14, and 1 - 12; they are coded in numerical order and indicated by an 'A' in Table 15.11.

b. For bolts and screws which are given a range of numbers [except as detailed in (d)], the last figure or two figures indicates the size as follows :-

   NAS xxx0 = 4 - 40, xxx1 = 6 - 32, xxx2 = 8 - 32, xxx3 = 10 - 32, xxx4 = 1/4 - 28, xxx5 = 5/16 - 24, xxx6 = 3/8 - 24, xxx7 = 7/16 - 20, xxx8 = 1/2 - 20, xxx9 = 9/16 - 18, xx10 = 5/8 - 18, xx12 = 3/4 - 16, xx14 = 7/8 - 14, xx16 = 1 - 12, xx18 = 1 1/8 - 12, xx20 = 1 1/4 - 12.

   The threads are usually UNC, UNF, UNJC or UNJF, but some bolts and screws are also available with American National threads, and these are coded separately. Those parts which comply with the Unified standard are indicated by a 'B' in Table 15.15.

c. For bolts and screws which are given a single NAS number, the diameter is given by the first dash number as follows:-

   NAS xxxx - 02 = 2 - 56, xxxx - 04 = 4 - 40, xxxx - 06 = 6 - 32, xxxx - 08 = 8 - 32, xxxx - 3 = 10 - 32, xxxx - 4 = 1/4 - 28, and so on, in steps of 1/16 in, following the sizes given in (b). Parts following this code are marked 'C' in Table 15.15.

d. NAS 1271 to 1280 are available in sizes from 1/4 to 1 in, and are coded in numerical order.

Length

The length is indicated by the second dash number for parts with the 'C' diameter code, or the first dash number for all other parts. The length dash-number indicates the total length of a part with a full thread or the grip length of a part with a shorter thread (see Fig. 15.43), in sixteenths of an inch; exceptions are NAS 563 to 572, for which the length dash number represents thirty-seconds of an inch, and NAS 428, for which the dash number represents eighths of an inch as detailed in paragraph for AN parts.

TABLE 15.15, NAS BOLTS AND SCREWS

NAS No.	Type	Head (Fig.5)	Size Range	Material	Coding				Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
144–158	Bolt, internal wrenching	A	No.1 – 1¼in	Alloy steel	B	A = drilled shank DH = drilled head Nil = undrilled			NAS No.
333–340	Bolt, flush 100°, close-tolerance	B	No.10 – $\frac{5}{8}$ in	Alloy steel	B	A = undrilled shank P = Phillips recess Nil = hex. socket C = cad. plated shank	–	See Specification for Length Code	NAS No. + △
428	Bolt, crown hex. head	D	No.10 – $\frac{3}{8}$ in	Alloy steel	C	H = drilled head K = slotted shank	–	–	NAS 1347 Type IV
464	Bolt, shear, close-tolerance	C	No.10 – 1 in	Alloy steel	C	P = cad. shank	A = undrilled shank		NAS No. + △
501	Bolt, hex. head, non-magnetic	C	No.10 – 1¼ in	CRS	C	A = undrilled shank H = drilled head	–	–	NAS No. + –
560	Screw, 100°, non-magnetic, structural	B	No.8 – $\frac{9}{16}$ in	CRS	C	C = low strength H = high temp. X = high strength	K = Phillips recess P = cad.plated	–	NAS No. +C, H or X
563–572	Bolt, full threaded, fully identified	E	No.10 – ¾ in	Alloy steel	B	–	–	–	NAS No. + dash no.
583–590	Bolt, 100°, close-tolerance, 160,000 lbf/in , Hi-Torque	F	No.10– $\frac{5}{8}$ in	Alloy steel	B	–	–	–	NAS 1347 Type IV
624–644	Bolt, 12 point, 180,000 lbf/in	G or H	¼ – 1½ in	Alloy steel	B	H = drilled head	–	–	NAS No.
653–658	Bolt, hex. head, short thread, close-tolerance	C	No.10 – ½ in	Titanium	B	V = titanium	–	D = drilled shank	NAS No. + dash no. + material
663–668	Bolt, 100°, close-tolerance long thread	F	No.10 – ½ in	Titanium	B	V = titanium	–	HT = Hi-Torque	NAS 1347 Type IV
673–678	Bolt, hex. head, close-tolerance	C or K	No.10 – ½ in	Titanium	B	V = titanium	–	D = drilled shank H = drilled head	NAS No. + dash no. + material
1003–1020	Bolt, hex. head, non-magnetic, heat-resistant	C or L	No.10 – 1¼ in	CRS	B	–	–	A = undrilled H = drilled head Nil = drilled shank	NAS No. + dash no.
1083–1088	Bolt, 100°, close-tolerance, short thread	F	No.10 – ½ in	Titanium	B	V = 6AL-4V alloy T = 4AL-4MN alloy		Nil = Phillips HT = Hi-Torque	NAS 1347 Type IV

TABLE 15.15, NAS BOLTS AND SCREWS - CONTINUED

NAS No.	Type	Head (Fig. 5)	Size Range	Material		Coding			Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
1100	Screw, pan head, full thread, Torq-Set	M	No.0 — $\frac{3}{8}$ in	Alloy steel Titanium CRS	C	C = CRS 140 000 psi E = CRS 160 000 psi V = titanium	–	B = black plating P = type II plating W = type I plating	NAS No. + dash no. + material
1101	Screw, flat fillister, full thread, Torq-Set	N or O	No.0 — $\frac{3}{8}$ in	As 1100	C	As 1100	H = drilled head	As 1100	NAS No. + dash no. + material
1102	Screw, 100°, full thread, Torq-Set	P	No.2 — $\frac{3}{8}$ in	As 1100	C	As 1100	–	As 1100	NAS No. + dash no. + material
1103 – 1120	Bolt, shear, hex. head modified, short thread	C	No.10 — 1½ in	Alloy steel	C	As 1100	–	As 1100 D = drilled	NAS No. + dash no. + material
1121 – 1128	Screw, flat fillister, close-tolerance, short thread	N or O	No.6 — ½ in	As 1100	B	As 1100	–	H = drilled head P and W as 1100	NAS No. + dash no. + material
1131 – 1138	Screw, pan head, close-tolerance, short thread	M	No.6 — ½ in	As 1100	B	C = CRS V and T as 1083	–	P and W as 1100	NAS No. + dash no. + material
1141 – 1148	Screw, pan head (mod), close-tolerance, short thread	R	No.6 — ½ in	As 1100	B	As 1100	–	P and W as 1100	NAS No. + dash no. + material
1151 – 1158	Screw, 100°, close-tolerance, short thread	P	No.6 — ½ in	As 1100	B	As 1131	–	D = Drilled shank P and W as 1100	NAS No. + dash no. + material
1161 – 1168	Screw, 100°, shear, self-locking	P	No.6 — ½ in	Alloy steel CRS	B	E as 1100	–	P and W as 1100 + locking code	NAS No. + dash no. + material + circle of dots
1171 – 1178	Screw, pan, shear, self-locking	M	No.6 — ½ in	Alloy steel CRS	B	E as 1100	–	P and W as 1100 + locking code	NAS No. + dash no. + material + circle of dots
1181 – 1188	Screw, flat fillister, shear, self-locking	N	No.6 — ½ in	Alloy steel CRS	B	C and E as 1100	–	P and W as 1100 + locking code	NAS No. + dash no. + material + circle of dots

TABLE 15.15, NAS BOLTS AND SCREWS - CONTINUED

NAS No.	Type	Head (Fig. 5)	Size Range	Material	Coding				Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
1189	Screw, 100°, full thread, self-locking, 250° F	B or P	No.2 — $\frac{3}{8}$ in	Alloy steel CRS	C	C as 1100	P = Phillips recess T = Torq-Set recess	W as 1100 + locking code	NAS No. + dash no. + circle of dots
1190	Screw, pan head, full thread, self-locking	M or S	No.2 — $\frac{3}{8}$ in	Alloy steel CRS	C	C and E as 1100	P = Phillips recess T = Torq-Set recess	H = type II plating W = type I plating + locking code	NAS No. + dash no. + circle of dots
1191	Screw, flat fillister, full thread, self-locking, 250° F	N or T	No.2 — $\frac{3}{8}$ in	Alloy steel CRS	C	C and E as 1100	P = Phillips recess T = Torq-Set recess	H and W as 1190 + locking code	NAS No. + dash no. + circle of dots
1202 — 1210	Bolt, 100°, close-tolerance, 160,000 lbf/in², short thread	B	No.8 — $\frac{5}{8}$ in	Alloy steel	B		—	D = drilled shank W as 1190	NAS 1347 Type IV
1216	Bolt, pan head, full thread, Hi-Torque	J	No.4 — $\frac{3}{8}$ in	Alloy steel CRS	C	—	CR = CRS 125,000 lbf /in² C = CRS 140,000 lbf /in²	B = black plating P = type II plating	NAS 1347 Type IV
1217	Bolt, pan head, short thread, Hi-Torque	J	No.8 — $\frac{3}{8}$ in	Alloy steel CRS	C	—	C and CR as 1216	B and P as 1216	NAS 1347 Type IV
1218	Bolt, pan head, long thread, Hi-Torque	J	No.4 — $\frac{3}{8}$ in	Alloy steel CRS	C	—	C and CR as 1216	B and P as 1216	NAS 1347 Type IV
1219	Bolt, 100°, full thread, Hi-Torque	F	No.4 — $\frac{3}{8}$ in	Alloy steel CRS	C	—	C and CR as 1216	B and P as 1216	NAS 1347 Type IV
1220	Bolt, 100°, short thread, Hi-Torque	F	No.8 — $\frac{3}{8}$ in	Alloy steel CRS	C	—	C and CR as 1216	B and P as 1216	NAS 1347 Type IV
1221	Bolt, 100°, long thread, Hi-Torque	F	No.4 — $\frac{3}{8}$ in	Alloy steel CRS	C	—	C and CR as 1216	B and P as 1216	NAS 1347 Type IV
1223 — 1235	Bolt, hex. head, close-tolerance, self-locking	C	No.10 — 1¼ in	Alloy steel CRS	B	C = CRS	—	W as 1190 + locking code	NAS 1347 Type IV + circle of dots
1243 1250	Bolt, 100°, close-tolerance, short thread, Hi-Torque, 0.0156 in oversize, 160,000 lbf/in² (a)	F	No.10 — $\frac{5}{8}$ in	Alloy steel	B	—	—	—	NAS 1347 Type IV
1253 — 1260	Bolt, 100°, close-tolerance, short thread, Hi-Torque, 0.0312 in oversize, 160,000 lbf/in² (a)	F	No.10 — $\frac{5}{8}$ in	Alloy steel	B		—	—	NAS 1347 Type IV

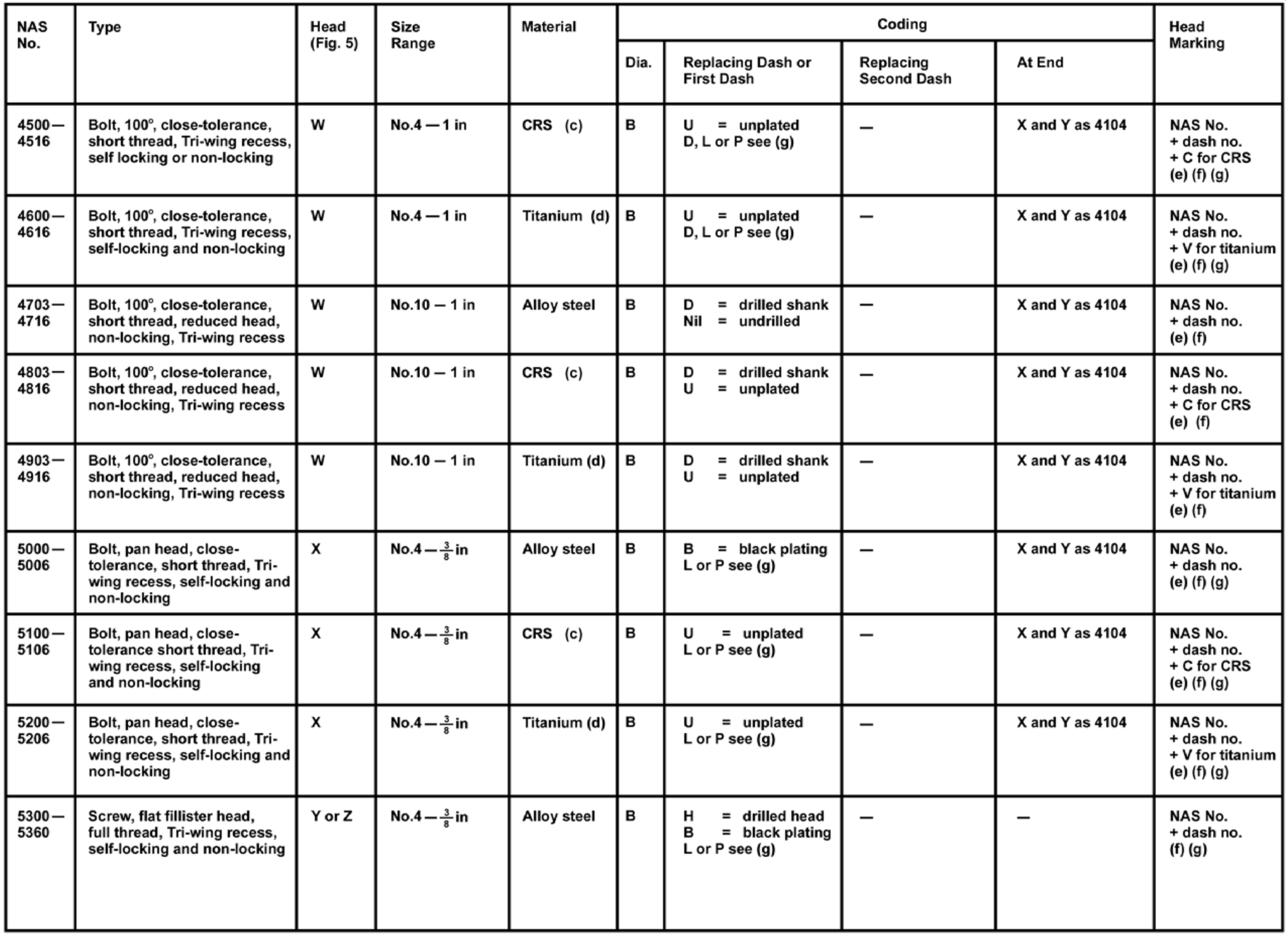
TABLE 15.15, NAS BOLTS AND SCREWS - CONTINUED

NAS No.	Type	Head (Fig. 5)	Size Range	Material	Coding				Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
1261 — 1265	Bolt, hex. head, close-tolerance, short thread	C	$\frac{9}{16}$ — 1 in	Titanium	A	—	—	D = drilled shank	NAS 1347 Type IV
1266 — 1270	Bolt, hex. head, close-tolerance	C	$\frac{9}{16}$ — 1 in	Titanium	A	—		D = drilled shank	NAS 1347 Type IV
1271 — 1280	Bolt, 12 point	G or H	$\frac{1}{4}$ — 1 in	Titanium	D	H = drilled head	—		NAS 1347 Type IV
1303 — 1320	Bolt, hex. head, close-tolerance, 160,000 lbf/in^2	C or K	No.10 — $1\frac{1}{4}$ in	Alloy steel	B	—	—	D = drilled shank H = drilled head W = type I plating	NAS No. + dash no.
1503 — 1510	Bolt, 100°, close-tolerance, short thread, Hi-Torque, 160,000 lbf/in^2	F	No.10 — $\frac{5}{8}$ in	Alloy steel	B	—	—	W = type I plating	NAS No. + dash no.
1578	Bolt, pan head, shear, 1200°F	J or M	No.10 — $\frac{1}{2}$ in	C and HR steel (U—212)	C	—	T = Torq-Set recess H = Hi-Torque recess	—	NAS 1347 Type II
1579	Bolt, pan head, full thread, 1200°F	J or M	No.10 — $\frac{3}{8}$ in	C and HR steel (U—212)	C	—	T and H as 1578	—	NAS 1347 Type II
1580	Bolt, tension, 100°, 1200° F	F or P	No.10 — $\frac{5}{8}$ in	C and HR steel (U—212)	C	—	T and H as 1578	—	NAS 1347 Type II
1581	Bolt, shear, 100° reduced, 1200° F	F or P	No.10 — $\frac{5}{8}$ in	C and HR steel (U—212)	C	—	T and H as 1578	—	NAS 1347 Type II
1582	Bolt, 100°, full thread, 1200° F	F or P	No.10 — $\frac{3}{8}$ in	C and HR steel (U—212)	C	—	T and H as 1578	—	NAS 1347 Type II
1586	Bolt, tension, 12 point, 1200° F, external wrenching	G or H	$\frac{1}{4}$—$1\frac{1}{4}$ in	C and HR steel (U—212)	C	—	H = drilled head	—	NAS 1347 Type II
1588	Bolt, shear, hex. head, 1200° F	C	No.10 — 1 in	C and HR steel (U—212)	C	—	—	—	NAS 1347 Type II

TABLE 15.15, NAS BOLTS AND SCREWS - CONTINUED

NAS No.	Type	Head (Fig. 5)	Size Range	Material	Coding				Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
1603 — 1610	Bolt, 100°, close-tolerance, 0.0312 in oversize, 160,000 lbf/in² (b)	F or P	No.10 — $\frac{5}{8}$ in	Alloy steel	B	—	—	R = Phillips recess Nil = Hi-Torque	NAS 1347 Type IV
1620 — 1628	Screw, 100°, short thread, Torq-Set recess	P	No.4 — $\frac{1}{2}$ in	Alloy steel CRS Titanium	B	C, E and V as 1100	—	D = drilled shank P = type II plating	NAS 1347 Type IV
1630 — 1634	Screw, pan head, short thread Torq-Set	M	No.4 — $\frac{1}{2}$ in	Alloy steel CRS Titanium	B	C, E and V as 1100	—	D = drilled shank P = type II plating	NAS 1347 Type IV
1703 — 1710	Bolt, 100°, close-tolerance, 0.0156 in oversize, 160,000 lbf/in² (b)	B or F	No.10 — $\frac{5}{8}$ in	Alloy steel	B	—	—	R = Phillips recess Nil = Hi-Torque	NAS 1347 Type IV
2803 — 2810	Bolt, 100°, close-tolerance, 180,000 lbf/in², Torq-Set	P	No.10 — $\frac{5}{8}$ in	Alloy steel	B	—	—	—	NAS No. + dash no.
2903 — 2920	Bolt, shear, hex. head, 0.0156 in oversize (b)	C or K	No.10 — $1\frac{1}{4}$ in	Alloy steel	B	E = short thread	—	D = drilled shank H = drilled head W = type I plating	NAS No. + dash no.
3003 — 3020	Bolt, shear, hex. head, long or short thread, 0.0312 in oversize (b)	C or K	No.10 — $1\frac{1}{4}$ in	Alloy steel	B	E = short thread	—	D = drilled shank H = drilled head W = type I plating	NAS No. + dash no.
4104 — 4116	Bolt, 100°, close-tolerance, long thread, Tri-wing recess, self-locking and non-locking	W	$\frac{1}{4}$ — 1 in	Alloy steel	B	B = black plating D, L or P see (g)	—	X = 0.0156 in oversize Y = 0.0312 in oversize	NAS No. + dash no. (e) (f) (g)
4204 — 4216	Bolt, 100°, close-tolerance, long thread, Tri-wing recess, self-locking and non-locking	W	$\frac{1}{4}$ — 1 in	CRS (c)	B	U = unplated D, L or P see (g)	—	X and Y as 4104	NAS No. + dash no. (e) (f) (g)
4304 — 4316	Bolt, 100°, long thread, Tri-wing recess, self-locking and non-locking	W	$\frac{1}{4}$ — 1 in	Titanium (d)	B	U = unplated D, L or P see (g)	—	X and Y as 4104	NAS No. + dash no. (e) (f) (g)
4400 — 4416	Bolt, 100°, short thread, Tri-wing recess, self-locking and non-locking	W	No.4 — 1 in	Alloy steel	B	B = black plating D, L or P see (g)	—	X and Y as 4104	NAS No. + dash no. (e) (f) (g)

TABLE 15.15, NAS BOLTS AND SCREWS - CONTINUED



NAS No.	Type	Head (Fig. 5)	Size Range	Material	Coding				Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
4500—4516	Bolt, 100°, close-tolerance, short thread, Tri-wing recess, self locking or non-locking	W	No.4 — 1 in	CRS (c)	B	U = unplated D, L or P see (g)	—	X and Y as 4104	NAS No. + dash no. + C for CRS (e) (f) (g)
4600—4616	Bolt, 100°, close-tolerance, short thread, Tri-wing recess, self-locking and non-locking	W	No.4 — 1 in	Titanium (d)	B	U = unplated D, L or P see (g)	—	X and Y as 4104	NAS No. + dash no. + V for titanium (e) (f) (g)
4703—4716	Bolt, 100°, close-tolerance, short thread, reduced head, non-locking, Tri-wing recess	W	No.10 — 1 in	Alloy steel	B	D = drilled shank Nil = undrilled	—	X and Y as 4104	NAS No. + dash no. (e) (f)
4803—4816	Bolt, 100°, close-tolerance, short thread, reduced head, non-locking, Tri-wing recess	W	No.10 — 1 in	CRS (c)	B	D = drilled shank U = unplated	—	X and Y as 4104	NAS No. + dash no. + C for CRS (e) (f)
4903—4916	Bolt, 100°, close-tolerance, short thread, reduced head, non-locking, Tri-wing recess	W	No.10 — 1 in	Titanium (d)	B	D = drilled shank U = unplated	—	X and Y as 4104	NAS No. + dash no. + V for titanium (e) (f)
5000—5006	Bolt, pan head, close-tolerance, short thread, Tri-wing recess, self-locking and non-locking	X	No.4 — $\frac{3}{8}$ in	Alloy steel	B	B = black plating L or P see (g)	—	X and Y as 4104	NAS No. + dash no. (e) (f) (g)
5100—5106	Bolt, pan head, close-tolerance short thread, Tri-wing recess, self-locking and non-locking	X	No.4 — $\frac{3}{8}$ in	CRS (c)	B	U = unplated L or P see (g)	—	X and Y as 4104	NAS No. + dash no. + C for CRS (e) (f) (g)
5200—5206	Bolt, pan head, close-tolerance, short thread, Tri-wing recess, self-locking and non-locking	X	No.4 — $\frac{3}{8}$ in	Titanium (d)	B	U = unplated L or P see (g)	—	X and Y as 4104	NAS No. + dash no. + V for titanium (e) (f) (g)
5300—5360	Screw, flat fillister head, full thread, Tri-wing recess, self-locking and non-locking	Y or Z	No.4 — $\frac{3}{8}$ in	Alloy steel	B	H = drilled head B = black plating L or P see (g)	—	—	NAS No. + dash no. (f) (g)

TABLE 15.15, NAS BOLTS AND SCREWS - CONTINUED

NAS No.	Type	Head (Fig. 5)	Size Range	Material	Coding				Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
5400 — 5406	Screw, flat fillister head, full thread, Tri-wing recess, self-locking and non-locking	Y or Z	No.4 — $\frac{3}{8}$ in	CRS (c)	B	H = drilled head U = unplated L or P see (g)	–	–	NAS No. + dash no. + C for CRS (f) (g)
5500 — 5506	Screw, flat fillister head, full thread, Tri-wing recess, self-locking and non-locking	Y or Z	No.4 — $\frac{3}{8}$ in	Titanium (d)	B	H = drilled head U = unplated L or P see (g)	–	–	NAS No. + dash no. + V for titanium (f) (g)
5600 — 5606	Screw, 100°, full thread, Tri-wing recess, self-locking and non-locking	W	No.4 — $\frac{3}{8}$ in	Alloy steel	B	B = black plating L or P see (g)	–	–	NAS No. + dash no. (f) (g)
5700 — 5706	Screw, 100°, full thread, Tri-wing recess, self-locking and non-locking	W	No.4 — $\frac{3}{8}$ in	CRS (c)	B	B = black plating U = unplated L or P see (g)	–	–	NAS No. + dash no. + C for CRS (f) (g)
5800 — 5806	Screw, 100°, full thread, Tri-wing recess, self-locking and non-locking	W	No.4 — $\frac{3}{8}$ in	Titanium (d)	B	U = unplated L or P see (g)	–	–	NAS No. + dash no. + V for titanium (f) (g)
6000 — 6003	Screw, hex. head, full thread, Tri-wing recess	V	No.4 to No.10	CRS (c)	B	U = unplated	–	–	NAS No. + dash no. + C for CRS (f)
6100 — 6103	Screw, hex. head, full thread, Tri-wing recess	V	No.4 to No.10	Titanium (d)	B	U = unplated	–	–	NAS No. + dash no. + V for titanium
6203 — 6220	Bolt, hex. head, short thread, close-tolerance, self-locking and non-locking	C or K	No.10 — $1\frac{1}{4}$ in	Alloy steel	B	D, L or P see (g)	–	X or Y as 4104 D = drilled shank H = drilled head	NAS No. + dash no. (e) (g)
6303 — 6320	Bolt, hex. head, short thread, close-tolerance, self-locking or non-locking	C or K	No.10 — $1\frac{1}{4}$ in	CRS (c)	B	U = unplated L or P see (g)	–	X or Y as 4104 D = drilled shank H = drilled head	NAS No. + dash no. (e) (g)
6403 — 6420	Bolt, hex. head, short thread, close-tolerance, self-locking and non-locking	C or K	No.10 — $1\frac{1}{4}$ in	Titanium (d)	B	U = unplated L or P see (g)	–	X or Y as 4104 D = drilled shank H = drilled head	NAS No. + dash no. (e) (g)

TABLE 15.15 , NAS BOLTS AND SCREWS - CONTINUED

NAS No.	Type	Head (Fig. 5)	Size Range	Material	Coding				Head Marking
					Dia.	Replacing Dash or First Dash	Replacing Second Dash	At End	
6604 6620	Bolt, hex. head, long thread, close-tolerance, self-locking and non-locking	C or K	¼—1¼ in	Alloy steel	B	D = drilled shank H = drilled head L or P see (g)	—	X or Y as 4104	NAS No. + dash no. (e) (g)
6704 — 6720	Bolt, hex. head, long thread, close-tolerance, self-locking and non-locking	C or K	¼—1¼ in	CRS (c)	B	D = drilled shank H = drilled head U = unplated L or P see (g)	—	X or Y as 4104	NAS No. + dash no. (e) (g)
6804 — 6820	Bolt, hex. head, long thread, close-tolerance, self-locking and non-locking	C or K	¼—1¼ in	Titanium (d)	B	D = drilled shank H = drilled head U = unplated L or P see (g)	—	X or Y as 4104	NAS No. + dash no. (e) (g)

NOTES :
(a) For repair work only, replacing NAS 1503 to 1510.

(b) For repair work only.

(c) Cadmium plated CRS bolts have green dye or paint on the end of the shank.

(d) Cadmium plated titanium bolts have red dye or paint on the end of the shank.

(e) Oversize bolts are marked with 'X' or 'Y' (see code).

(f) Heads are also marked with an encircled number, to indicate the size of the Tri-wing recess, in accordance with NAS 4000.

(g) Method of locking, included in code and marked on head, is as follows:
D = drilled shank. L = locking element is optional. P = patch type locking element.

Plating

Alloy-steel bolts and screws are normally cadmium plated in accordance with QQ-P-416 Type II Class 3. If a different plating is used, or if CRS or titanium parts are plated, the following code may be used :-

W = QQ-P-416 Type I Class 3 plating.
B = Blackened Type II plating.
H = CRS with Type II plating.
P = CRS or titanium with Type II plating.
U = Unplated.
A = Aluminium coating to NAS 4006.

Type of Locking

Unless otherwise noted in Table 15, the type of locking is indicated as follows :

D = Drilled shank.
H = Drilled head.
L = Nylon strip locking element.
N = Nylon button or pellet locking element.
LK = KEL-F strip locking element.
NK= KEL-F pellet locking element
K = KEL-F locking element, type optional.

Note

The lack of a letter for a self-locking bolt indicates that the type of locking element is unimportant.

Type of Recess

Where a choice of wrenching recesses is available, the following code is used to indicate the type required :

T = Torque - set.
H = Hi-Torque
P or R = Phillips (cruciform).

Note

The type of recess indicated by the lack of a code letter is shown in Table 15.15.

Type of material

The NAS fasteners listed in Table 15.15 are manufactured from alloy steel, corrosion-resistant steel (CRS), corrosion-and heat-resistant (C and HR) steel, and titanium alloy. Except in the case of titanium alloy, which is sometimes indicated by a 'V' (see Table 15.15), the type of material is not specified unless the fastener is made in more than one material. The basic code applies to alloy steel, and the following code indicates other materials :-

CR = corrosion-resistant steel, 125,000 lbf/in^2
C = corrosion-resistant steel, 140,000 lbf/in^2
E = corrosion-resistant steel, 160,000 lbf/in^2
V = titanium alloy.

Examples of coding

a.	NAS 564-15	is full-threaded bolt in cadmium-plated alloy steel, with 1/4 - 28 thread, and length of 15/32 in.
b.	NAS 1146E12P	is a screw with a modified pan head, close-tolerance shank and Torque-Set recess, made from CRS (160,000 lbf/in^2), with Type II plating. It has a 3/8 - 24 thread and a 3/4 in grip length.
c.	NAS 1189-3T8L	is a self-locking screw with a 100° countersunk head and full thread. It has a 10-32 thread, is 1/2 in long, and is in alloy steel with Type II plating. It has a strip-type nylon locking element and a Torque-Set recess.
d.	NAS 6804D10X	is a hexagon head, close-tolerance bolt in titanium alloy, with a long thread, It has a 1/4-28 thread and 5/8 in grip length, and a drilled shank which is 0.0156 in oversize.

■■■

CHAPTER : 16
SOLID RIVETS

INTRODUCTION

This chapter gives guidance on the various types of solid rivets used in aircraft structures. It includes tables of the principal types of British and American rivets and gives guidance on the heat treatment of aluminium alloy rivets.

GENERAL

Rivets are designed to be strong in shear and should not be subjected to excessive tension loads. The two main groups of solid rivets are those with protruding heads, mostly used in the interiors of aircraft, and those with countersunk heads which are used on exterior surfaces where a flush finish is required. If protruding rivets are used externally they are usually of the mushroom (Figures 16.1 and 16.2) or universal (Figure 16.3) head types.

British and American rivets are not manufactured to identical specifications nor from identical materials but, since American rivets are not always available, it is often necessary to repair American-built aircraft using British rivets. Unless there are specific instructions to the contrary the information given in paragraph 5 may be used as a guide in choosing British substitutes for American rivets. When American rivets are available, all protruding-head rivets in American-built aircraft may be replaced by universal head rivets which have now been adopted as the standard for protruding-head rivets in that country.

NOTE

Deviations from the original repair scheme approved for an aircraft type, e.g. use of rivets of a different material, may only be made if written authority is obtained from an approved design organisation. The possibility of electro-chemical reaction between rivets and the surrounding material must always be considered.

Both British and American rivets are identified by head or shank end markings except where a material is easily identified by its natural colour or weight. Certain British rivets are also coloured all over to enable them to be more readily distinguished.

NOTE

Identification colouring requirements for British aluminium or aluminium alloy rivets are contained in Specification DTD 913.

Some aircraft manufacturers specify rivets made to the standards of their own companies, and may also use a different colour identification for standard rivets.

BRITISH SOLID RIVETS

Standards for British rivets are issued by the Society of British Aerospace Companies (AS series) and the British Standards Institute (SP series).

Rivets are identified by a Standard number and a part number. The Standard number identifies the head shape, material and finish, and the part number indicates the size in terms of shank diameter (thirty-seconds of an inch or millimetres 10) and length (in sixteenths of an inch or millimetres). For example, an AS162 rivet 1/8 inch diameter and 1/2 inch long would be AS162-408 and an SP160 rivet 4 mm in diameter and 16 mm long would be SP 160-40-16.

NOTE

'AS' close tolerance rivets are supplied in length graduations of 1/32 inch. The part number system remains the same, however, and odd 1/32 inches in length are shown by the addition of '5' after the normal part number.

Materials

The materials used for the manufacture of British rivets comply with DTD or British Standards (BS) Specifications, the actual material being quoted in the relevant tables. Rivets now manufactured from BS L86 were, until September 1961, manufactured from BS L69. Where the rivets require heat treatment, i.e. all BS L37 rivets, this is also indicated in the tables by the symbols and the procedures explained in the topic of Heat Treatment.

'AS' Rivets

Table 16.1 gives a list of the solid rivets which conform to the Aircraft Standards of the Society of British Aerospace Companies; these rivets are made in a range of sizes from 1/16 inch diameter and from 1/8 inch to 2 inches long except that copper rivets to AS 469 are only made in diameters up to 1/4 inch. Figure 16.1 illustrates the AS solid rivets and indicates the method of measuring the length ‘L’. It will be seen from the Table that most of these rivets are obsolescent and have been replaced by rivets conforming to SP Standards.

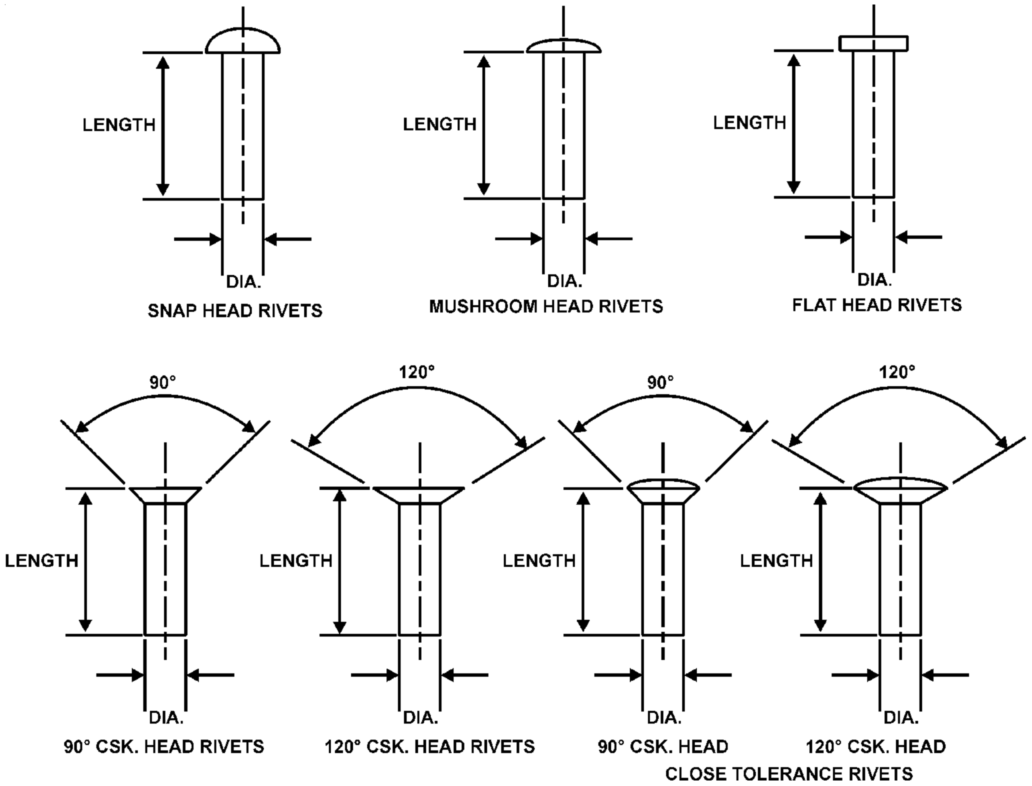


Fig. 16.1, 'AS' Rivets.

TABLE 16.1

AIRCRAFT STANDARD NUMBER	MATERIAL	MATERIAI SPECIFICATION	HEAD TYPE	FINISH	IDENTIFICATION MARK ON END OF SHANK	REMARKS
AS 155*	aluminium	L 36	snap	black anodic	A	superseded by SP 77
AS 156*	aluminium alloy	L 37††	snap	natural	D	superseded by SP 78
AS 157*	aluminium alloy	L 58	snap	green anodic	X	superseded by SP 79
AS 455*	mild steel	BS 1109	snap	cadmium		superseded by SP 76
AS 457*	monel	DTD 204	snap	natural	M	superseded by SP 81
AS 458*	tungum	DTD 367	snap	cadmium		
AS 459	copper		snap	natural		non-magnetic
AS 2227*	aluminium alloy	L 86	snap	violet anodic	S	superseded by SP 80
AS 4694*	monel	DTD 204	snap	cadmium	M	superseded by SP 82
AS 158*	aluminium alloy	L 37††	mushroom	natural	D	superseded by SP 83
AS 159*	aluminium alloy	L 58	mushroom	green anodic	X	superseded by SP 84
AS 2228*	aluminium alloy	L 86	mushroom	violet anodic	S	superseded by SP 85
AS 160*	aluminium	L 36	90°csk.	black anodic	A	
AS 161*	aluminium alloy	L 37††	90°csk.	natural	D	

TABLE 16.1 - CONTINUED

AIRCRAFT STANDARD NUMBER	MATERIAL	MATERIAI SPECI-FICATION	HEAD TYPE	FINISH	IDENTI-FICATION MARK ON END OF SHANK	REMARKS
AS 162*	aluminium alloy	L 58	90°csk.	green anodic	X	
AS 460	mild steel	BS 1109	90°csk.	cadmium		magnetic
AS 462	monel	DTD 204	90°csk.	natural	M	
AS 466*	tungum	DTD 367	90°csk.	cadmium		
AS 467	copper		90°csk.	natural		non-magnetic
AS 2229*	aluminium alloy	L 86	90°csk.	violet anodic	S	
AS 4695	monel	DTD 204	90°csk.	cadmium		
AS 4645	aluminium alloy	L 86	90°csk.	violet anodic	S	shank $\frac{1}{64}$ in. oversize, "R" on head
AS 4646	aluminium alloy	L 37††	90°csk.	plain anodic	D	
AS 163*	aluminium	L 36	120°csk.	black anodic	A	
AS 164*	aluminium alloy	L 37††	120°csk.	natural	D	
AS 165*	aluminium alloy	L 58	120°csk.	green anodic	X	
AS 463	mild steel	BS 1109	120° csk.	cadmium		magnetic
AS 465	monel	DTD 204	120° csk.	natural	M	
AS 468*	tungum	DTD 367	120° csk.	cadmium		
AS 2230*	aluminium alloy	L 86	120° csk.	violet anodic	S	
AS 4696	monel	DTD 204	120° csk.	cadmium	M	
AS 4647	aluminium alloy	L 86	120° csk.	violet anodic	S	shank $\frac{1}{64}$ in. oversize, "R" on head
AS 4648	aluminium alloy	L 37††	120° csk.	plain anodic	D	
AS 469	copper		flat	natural		non-magnetic
AS 2918	aluminium alloy	L 37††	90° raised csk.	natural		close tolerance
AS 3362	aluminium alloy	L 86	90° raised csk.	violet anodic		close tolerance
AS 2919	aluminium alloy	L 37††	120° raised csk.	natural		close tolerance
AS 3363	aluminium alloy	L 86	120° raised csk.	violet anodic		close tolerance

* Obsolescent

†† Require heat treatment before driving.

‘SP’ Inch Size Rivets

Table 16.2 give a list of the solid rivets which conform to the British Standards Institute Aerospace Standards for rivets in inch sizes. These rivets are made in a range of size from 1/16 inch to 3/8 inch in diameter and from 1/8 inch to 3 inches long, and are illustrated in Figure 16.2.

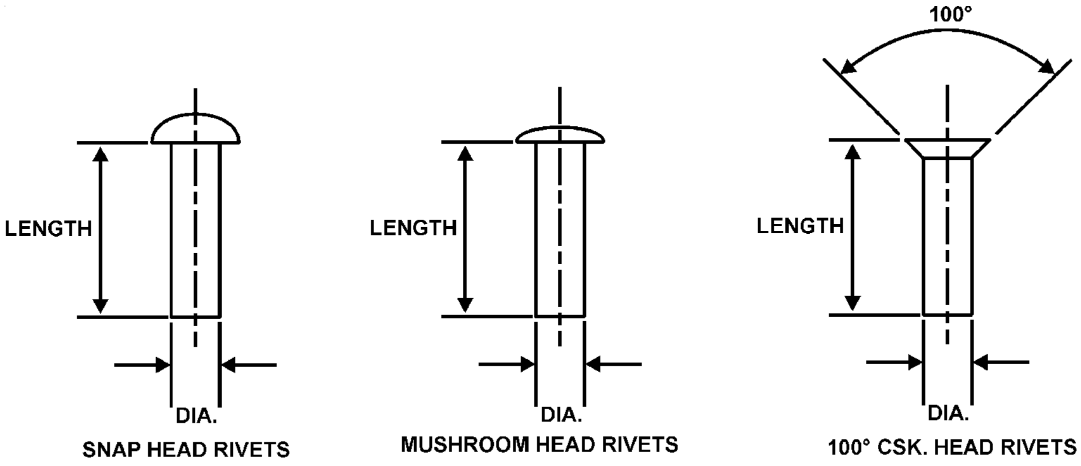


Fig. 16.2, 'SP' Inch Size Rivets.

TABLE 16.2

BRITISH STANDARD NUMBER	MATERIAL	MATERIAL SPECIFI-CATION	HEAD TYPE	FINSIH	IDENTIFI-CATION MARK**	REMARKS
SP 68	aluminium	L 36	100° csk.	black anodic	I*	
SP 69	aluminium alloy	L 37††	100° csk.	natural	7	
SP 70	aluminium alloy	L 58	100° csk.	green anodic	8	
SP 71	aluminium alloy	L 86	100° csk.	violet anodic	O†	
SP 76	steel	BS 1109	snap	cadmium		magnetic, superseding AS 455
SP 77	aluminium	L 36	snap	black anodic	I	superseding AS 155
SP 78	aluminium alloy	L 37††	snap	natural	7	superseding AS 156
SP 79	aluminium alloy	L 58	snap	green anodic	8	superseding AS 157
SP 80	aluminium alloy	L 86	snap	violet anodic	O	superseding AS 2227
SP 81	monel	DTD 204	snap	natural	M	superseding AS 457
SP 82	monel	DTD 204	snap	cadmium	M	non-magnetic, superseding AS 4694
SP 83	aluminium alloy	L 37††	mushroom	natural	7	superseding AS 158
SP 84	aluminium alloy	L 58	mushroom	green anodic	8	superseding AS 159
SP 85	aluminium alloy	L 86	mushroom	violet anodic	O	superseding AS 2228
SP 86	steel	BS 1109	100°csk.	cadmium		magnetic
SP 87	monel	DTD 204	100°csk.	natural	M	non-magnetic
SP 88	monel	DTD 204	100°csk.	cadmium	M	non-magnetic

* SP 68 rivets, prior to Amendment No. 1 to the Standard, published in September, 1959, bore no identification marks.

† SP 71 rivets, prior to Amendment No. 1 to the Standard, published in September, 1959, bore the identification mark '9' to signify manufacture from L 69 material.

†† Require heat treatment before use.

** May be on head or shank end, depending on rivet size.

‘SP’ Metric Size Rivets

Table 16.3 gives a list of rivets which conform to the British Standards Institute Aerospace Standards for rivets in metric sizes. These are confined, at present, to universal head and 100° countersunk truncated radiused head rivets in diameters of 2.4 to 9.6 mm and lengths of 4 to 60 mm. The identification marks listed in the table are applied the matric size rivets shank end only.

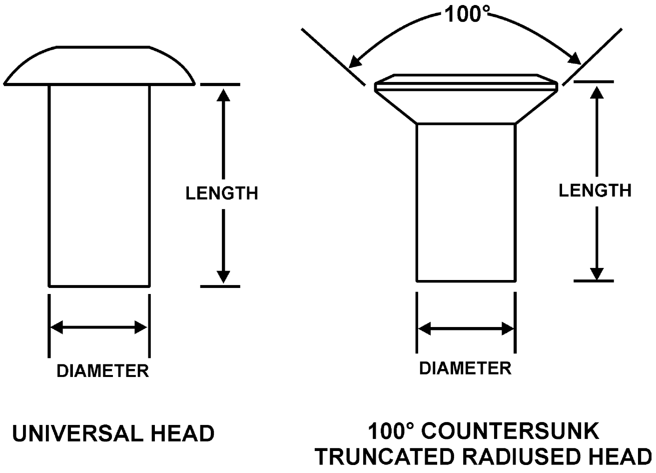


Fig. 16.3, 'SP' Metric Size Rivets.

TABLE 16.3

BRITISH STANDARD NUMBER	MATERIAL		HEAD TYPE	FINISH	IDENTIFICATION
	TYPE	SPECIFICATION			
SP 142	al. alloy	L 86	100° csk.†	violet anodic	indented dot
SP 157	al. alloy	L 86	universal	violet anodic	indented dot
SP 158	monel	DTD 204	universal	natural	two indented dots
SP 159	monel	DTD 204	universal	cadmium	nil
SP 160	al. alloy	L 58	universal	green anodic	raised cross
SP 161	al. alloy	L 58	universal	plain anodic	raised cross
SP 162	al. alloy	L 37††	universal	natural	raised broken line and centre point
SP 163	al. alloy	L 86	universal	plain anodic	indented dot

† 100° countersunk, truncated radiused head.
†† Required heat treatment before driving.

AMERICAN SOLID RIVETS

American rivets in general use are listed in Table 16.4, together with the means of identification which, since all the aluminium alloy rivets are anodised, is by means of head alloy anodic head markings rather than colour. The code used for the classification of American rivets is similar to that used for British rivets and is best illustrated by an example such as MS 20470 AD 5-12, which has the following meaning:

i. MS Signifies Military Standard
ii. 20470 is a code for the head shape and basic material (aluminium universal head in this instance).
iii. AD is a code for the rivet material (2117 aluminium alloy in this instance, see next paragraph.
iv. 5 is the diameter in thirty seconds of an inch
v. 12 is the length in sixteenths of an inch.

American wrought aluminium and aluminium alloys are identified by a four digit index system. The first digit indicates the main alloying element, the second indicates modifications to the original alloy and the last two indicate the aluminium purity or the specific alloy. These numbers are followed by a letter indicating the temper condition. Table 16.5 shows the aluminium and aluminium alloys used in the manufacture of rivets and the condition in which they are normally supplied to the user. Further information on temper designations is contained in next page under heading "American Temper Designations".

TABLE 16.4

RIVET AND MATERIAL CODE	MATERIAL	MATERIAL SPECIFICATION	HEAD TYPE	IDENTIFICATION MARK ON HEAD	REMARKS
MS 20426A	aluminium	1100	100° csk.	nil	supersedes AN 426 A
MS 20426B	aluminium alloy	5056	100° csk.	raised cross	supersedes AN 426B
MS 20426AD	aluminium alloy	2117	100° csk.	dimple	supersedes AN 426AD
MS 20426DD	aluminium alloy	2024[††]	100° csk.	raised double dash	supersedes AN 426DD
MS 20426D	aluminium alloy	2017[††]	100° csk.	raised dot	supersedes AN 426D
MS 20427	carbon steel	QQ-W-409 or QQ-S-633	100° csk.	recessed triangle	supersedes AN 427
MS 20427F	corrosion resistant steel	QQ-W-423	100° csk.	recessed dash	supersedes AN 427F
MS 20427M	monel	QQ-N-281	100° csk.	nil	supersedes AN 427M
MS 20427C	copper	QQ-W-341	100° csk.	nil	supersedes AN 427C
MS 20470A	aluminium	1100	universal	nil	supersedes AN 470A
MS 20470B	aluminium alloy	5056	universal	raised cross	supersedes AN 470 B
MS 20470AD	aluminium alloy	2117	universal	dimple	supersedes AN 470AD
MS 2047ODD	aluminium alloy	2024[††]	universal	raised double dash	supersedes AN 470DD
MS 20470D	aluminium alloy	2017[††]	universal	raised dot	supersedes AN 470 D
MS 20613 P/Z	carbon steel	QQ-S-633	universal	recessed triangle	supersedes MS 20435
MS 20613 C	corrosion resistant steel	QQ-W-423	universal	nil	supersedes MS 20435
MS 20615 M	monel	QQ-N-281	universal	double dimple	supersedes MS 20435
MS 20615CU	copper	QQ-W-341	universal	nil	supersedes MS 20435

NOTE : For MS 20613 rivets the letter P is added to indicate cadmium plated carbon steel and the letter Z to indicate zinc plated carbon steel.

[††] Require heat treatment before use.

TABLE 16.5

SPECIFICATIONS OF ALUMINIUM / ALLOY	CONDITION IN WHICH NORMALLY SUPPLIED
1100	— F as fabricated
2017	— T4 solution heat-treated
2024	— T4 solution heat-treated
2117	— T4 solution heat-treated
5056	— H32 strain hardened and then stabilised

MS Standards provide for two types of rivets, i.e. the universal head which is standard for protruding head rivets, and the 100° countersunk head which is standard for all flush head rivets.

American Temper Designations

American aluminium alloy rivets are given a temper designation to signify their condition. Non heat-treatable alloys such as 5056 have attained their maximum strength by working and are driven in the ‘as received’ condition. Of the heat-treatable alloys, 2117 does not benefit from further heat treatment and is driven in the ‘as received’ condition, 2024 must be solution treated before use and it is recommended that 2017 rivets of 3/8 inch diameter and larger are also solution treated to prevent cracking. Heat-treatable alloy rivets are supplied in the T4 condition (solution treated by the rivet manufacturer); when solution treated by the user before driving the final temper is T31 and when driven ‘as received’ the final temper is T3.

AN470 - Universal Headed
AN430 - Round Headed

Material	Head Marking	AN Material Code	AN425 78° Counter-Sunk Head	AN426 100° Counter-Sunk Head MS20426*	AN427 100° Counter-Sunk Head MS20427	AN430 Round Head MS20470*	AN435 Round Head MS20613* MS20615	AN441 Flat Head	AN442 Flat Head MS20470*	AN455 Brazier Head MS20470	AN456 Brazier Head MS20470	AN470 Universal Head MS20470*	Heat Treat Before Using	Shear Strength P.S.I.	Bearing Strength P.S.I.
1100	Plain	A	X	X		X			X	X	X	X	No	10000	25000
2117T	Recessed Dot	AD	X	X		X			X	X	X	X	No	30000	100000
2017T	Raised Dot	D	X	X		X			X	X	X	X	Yes	34000	113000
2017T-HD	Raised Dot	D	X	X		X			X	X	X	X	No	38000	120000
2024T	Raised Double Dash	DD	X	X		X			X	X	X	X	Yes	41000	130000
5056T	Raised Cross	B		X		X			X	X	X	X	No	27000	90000
7075-T73	Three Raised Dashes		X	X		X			X	X	X	X	No		
Carbon Steel	Recessed Triangle				X		X MS20613*	X					No	35000	90000
Corrosion Resistant Steel	Recessed Dash	F			X		X MS20613*						No	65000	90000
Copper	Plain	C			X		X	X					No	23000	
Monel	Plain	M			X			X					No	49000	
Monel (Nickel-Copper Alloy)	Recessed Double Dots	C					X MS20615*						No	49000	
Brass	Plain						X MS20615*						No		
Titanium	Recessed Large and Dmall Dot			MS20426				X					No	95000	

* New specifications are for Design purposes

Fig.16.4, Rivet Identification Chart

SELECTION OF RIVETS

The following paragraphs give general guidance on the factors which must be considered when rivets of either British or American manufacture are specified for a particular application.

The rivet material must be compatible with the material in which it is to be used, for reasons of strength and resistance to corrosion. L 58 (or 5056) rivets must be used in magnesium structures, monel rivets in titanium and stainless steel, and aluminium or copper rivets in parts of similar or nonmetallic materials in non-structural applications. The type of aluminium alloy rivets to be used for a particular repair depends on the strength of the alloy with which it is used. Table 16.6 indicates the shear strengths of various rivet materials. Rivets of less shear strength than those specified in a Repair Manual drawing should not be used without the approval of the manufacturer. L 37 (or 2024) rivets require heat treatment before use and if they are to be replaced by L 86 (or 2117) rivets through lack of treatment facilities, the number of rivets must be increased to provide the same shear strength. Cadmium plated rivets should not be used in areas where temperatures of 250°C or more are likely to be encountered.

The shear strength of the rivets used is not the only factor which determines the strength of a riveted joint. Generally, if the thickness of the sheets is less than half the diameter of the rivets used, failure of the joint will depend on the bearing stress rather than on the shear stress in the rivets.

The diameters and types of rivets to be used in repairs are normally specified either in the Repair Manual or in the repair scheme, but in the absence of specific instructions, 3/32 inch rivets should be used for 24 and 22 s.w.g. material, 1/8 inch rivets for 20 and 18 s.w.g. material and 5/32 inch for 16 s.w.g. If rivets of reduced diameter have to be substituted during repair work, the total number of rivets must be increased to provide equivalent cross-sectional area. Where 22 s.w.g. and thinner material is concerned, an there are no specific instructions regarding repair after a riveting failure, the substitution of mushroom head rivets for snap head rivets should be considered.

NOTE

Shear strength of a rivet is proportional to its cross-sectional area and not its diameter. Thus four rivets 1/16th inch diameter must be used to replace one rivet 1/8 inch diameter.

Where a large diameter rivet is used with thin sheet metal, the pressure required to close the rivet generally causes an undesirable bulging of the sheet around the rivet head. A diameter/thickness ratio not exceeding 3 is satisfactory for protruding head rivets but for countersunk rivets this ratio should not exceed 1.5.

When British rivets have to be used in American-built aircraft, rivets of the material with the nearest equivalent shear strength to the material of the original American rivets should be selected. If, as occurs in some instances, the available British rivets have lower shear strengths than the American rivets, either the total number of rivets should be increased or rivets of larger diameter should be used to make the strength of the joint in bearing and shear not less than it was originally. However, it should be borne in mind that an increase in the size of the rivets does not necessarily increase the strength of a joint; indeed, if the rivet sizes are increased beyond a certain amount, a reduction in strength will result.

TABLE 16.6

AMERICAN RIVET MATERIALS			BRITISH RIVET MATERIALS		
Material Specification	Tensile Strength lb/in^2	Shear Strength lb/in^2	Material Specification	Tensile Strength lb/in^2	Shear Strength lb/in^2
5056 - H32 2117 - T4 2017 - T4 2024 - T4	38000 38000 55000 62000	24000 26000 33000 37000	L 58 L 86 L 37 L 37	35500 38000 56000 56000	28500 29500 36000 36000

To ensure correct seating, countersunk head rivets should always be installed in dimples or countersunk holes of the same angle as the rivet head. Rivets with countersunk heads of 70° or 82° included angle are often used in positions where sealing is of primary importance, such as in integral fuel tanks, and when these rivets require replacement care is necessary to ensure that rivets with the correct angle heads are selected.

HEAT TREATMENT

Rivets which require heat treatment prior to driving should be treated in accordance with the requirements of the relevant specification.

Generally the most satisfactory way of heating rivets is to immerse them in a salt bath, although muffle furnaces of the circulating hot air type are used. The rivets should be placed in wire baskets or perforated containers and immersed in the salts for 15 minutes, then quenched in water at a temperature of not more than 40°C. The time between removal from the bath and quenching must be not more than 10 seconds to achieve satisfactory properties. The temperature of the bath must be 495 ± 5° C (maximum 496°C for 2024 rivets) and if the maximum is exceeded at any time the rivets should be rejected. Rivets which have been heated in a salt bath must be thoroughly washed after quenching to remove all traces of salt.

BS L37 rivets commence to age harden immediately after quenching and should normally be used within 2 hours of treatment (a period of 20 minutes is specified for 2024 rivets). Age hardening can be delayed by storing the rivets at a low temperature immediately after quenching. At a temperature of 0°C to -5°C they will keep satisfactorily for 45 hours and at a temperature of -15°C to 20°C for 150 hours, but must be used within 2 hours of removal from cold storage.

If the treated rivets have not been used within the prescribed time after solution treatment they may be retreated up to a maximum of three times. Further heat treatments would increase the grain size and result in low strength even after ageing.

Precautions must be taken to prevent the accidental use of aged rivets. A satisfactory method of ensuring this is to use the rivets from trays or boxes which are coloured to indicate the periods during which the rivets may be used. Thus a suitable colour code might permit only rivets from green trays to be used during the first two hours of a working day, after which only rivets from blue trays should be used for the next two hours and so on. American 2024 rivets could be controlled in a similar manner but the elapsed time should not exceed 20 minutes.

■■■

CHAPTER : 17
HOLLOW RIVETS AND SPECIAL FASTENERS

INTRODUCTION

This chapter gives general information on the various types of hollow rivets used in aircraft structures. It lists the principal types of British and American tubular, hollow and self-sealing rivets and also includes information on other types of fasteners which are widely used as replacement for nuts and bolts.

GENERAL

Hollow rivets may be broadly classified into two main group, those which are closed by drawing a mandrel through the bore and those which are closed by hammering. The first group are known as ‘blind’ rivet, because they may be installed when only one side of the rivet hole is accessible.

It is most important that the correct tools are used, with the types of rivets mentioned in this chapter a variety of tools being available for each type of rivet. Power tools are normally used by aircraft manufactures, but hand tools are often used with the smaller rivet sizes for repair work.

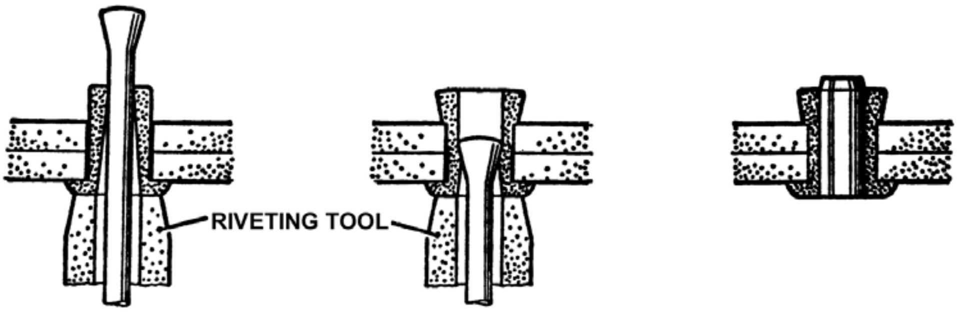
Blind rivets may only be used to replace solid rivets when this is permitted by the repair scheme. In the absence of specific instructions it is important to ensure that the rivet is either of the same material as the original solid rivet or, if dissimilar, has the minimum potential difference with the material being riveted, otherwise there may be a risk of corrosion . The blind rivet must also possess equivalent shear strength and this may be achieved by plugging the rivet bore.

BLIND RIVETS

The blind rivets discussed in this paragraph are all closed by pulling a mandrel through the bore. In some cases the mandrel also plugs the rivet, but in others a separate sealing pin must be driven in after the rivet has been closed.

Chobert Rivets

Chobert rivets are manufactured with either snap or countersunk heads and are normally supplied in tubes for ease of assembly on the mandrel. The action of closing a Chobert rivet is shown in Figure 17.1, initial movement of the mandrel down the tapered bore forming the head and subsequent movement expanding the shank to fill the rivet hole. Sealing pins are an interference fit in the rivet bore and, apart from increasing shear strength, will prevent the ingress of moisture.



RIVET THREADED ON MANDREL AND INSERTED IN HOLE

BROACHING ACTION: MANDREL EXPANDING RIVET SHANK

RIVET PLUGGED BY SEALING PIN

Fig.17.1, Closing Chobert Rivets

The Chobert rivets which have been given AGS numbers by the Society of British Aerospace Companies are shown in Table 17.1, but many other types are suitable for use on aircraft, full detail of materials, size an grip length being quoted in the manufacture’s literature. For ordering purpose Chobert rivets may be identified by either the AGS number or a four figure code number assigned to it by the manufacture. This is followed by a further four figures indicating the size of the rivet. The first two figures of the size code indicate the diameter and the second two the length (both in thirty seconds of an inch), expect that if the AGS number is being quoted a zero in the diameter code is disregarded. As an example, a steel snap head rivet, $\frac{5}{32}$ inch diameter and $\frac{3}{8}\left(\frac{12}{32}\right)$ inch long , would be known by the manufacturer as 1201-0512, but the same rivet could also be ordered as AGS 2040\512.

NOTE
The length referred to for ordering purposes is the length of the rivet as supplied (i.e. shank length of snap head rivets and total length of countersunk rivets) and not the thickness to be riveted (i.e. grip)

The size code used for sealing pins fitted to snap head rivets is the same as the code used for the rivet itself, but if a sealing pin is to be fitted to a countersunk rivet the preceding length should be quoted. For example, a sealing pin for an AGS 2045\512 rivet (snap head) would be AGS 2047\512 but sealing pin for an AGS 2068/512 rivet (countersunk 100°) would be AGS 2047/510.

TABLE 17.1
CHOBERT RIVETS

AGS Number	Maker's Code	Head Type	Material Spec.	Anti-corrosive treatment	Identification
2040	1201	snap	DTD 720	cad. plated	magnetic
2045	1211	snap	L86	anodised	dyed violet
2041	1203	120° countersunk	DTD 720	cad. plated	magnetic
2046	1213	120° countersunk	L86	anodised	dyed violet
2067	1204	100° countersunk	DTD 720	cad. plated	magnetic
2042	1281	sealing pin	DTD 904	cad. plated	magnetic
2047	1282	sealing pin	L64	anodised	plain

A range of Chobert rivets with oversize shanks is also available and a may be used for repair work on aircraft. This is an advantage when rivets have been removed, since the increase in diameter is of the order 0.015 to 0.020 inches, depending on rivet size, so that repositioning of holes or re-stressing of joints is unnecessary.

Avdel Rivets
These rivets are similar to Chobert rivets, but each is fitted with its own stem (mandrel), the component parts being referred to; as the body and stem respectively. The stem is pulled into the body to close the rivet and, at a predetermined load, breaks proud of the manufactured head, leaving part of the stem inside the body in the form of a plug. Excess stem material may be nipped off and milled flush with the rivet head when required, e.g. on external surfaces, but stainless steel and titanium rivet stems break flush with the rivet head at the maximum grip range limit, and milling may not be necessary. The action of closing an Avdel rivet is shown in Figure 17.2.

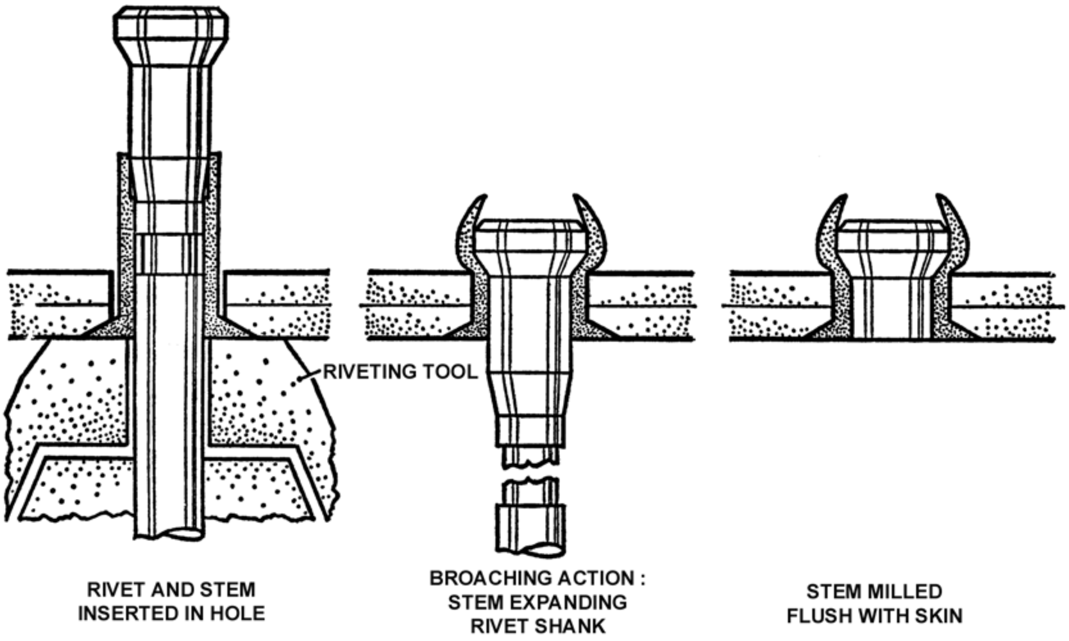


Fig. 17.2, Closing Avdel Rivets.

The Avdel rivets which have been given AGS number are shown in Table 17.2, and some of the more common rivets which may be used on aircraft, but do not have AGS numbers, are also included.

The code used for the identification Avdel rivets is the same as that used for Chobert rivets, i.e. the AGS number or the manufacturer's product code, followed by the size code.

The oversize rivets listed in Table 17.2 are used for repair purposes. The increases in diameter is similar to that quoted for Chobert rivets, and the same advantages apply.

Avdel rivets are lubricated by the manufacture to facilitate forming the rivet and on no account should the rivets be cleaned in solvent before use. These lubricants used are specially prepared for each type to obtain consistent results.

TABLE 17.2
AVDEL RIVETS

AGS Number	Master's code	Head Type	Material spec.		Finish	Remarks
			Body	Stem		
2065	4022	snap	L86	DTD 5074	anodised	-
2066	4032	100° countersunk	L86	DTD 5074	anodised	stem dyed red
-	4102	snap	L86	DTD 5074	anodised	oversize rivet, stem dyed violet
-	4132	100° countersunk	L86	DTD 5074	anodised	oversize rivet, stem dyed green
3920	4051	snap	DTD 189	FV 448	plain	stainless steel
3921	4057	100° countersunk	DTD 189	FV 448	plain	stainless steel
3922	4061	snap	DTD 189	FV 448	body cad. plated	stainless steel
3923	4067	100° countersunk	DTD 189	FV 448	body cad. plated	stainless steel
-	4074	universal	I.M.I. 230	I.M.I. 138 A	plain	titanium
-	4077	100° countersunk	I.M.I. 230	I.M.I. 138 A	plain	titanium

NOTE

Until recently all Avdel rivets manufactured from L 86 were dyed violet. This practice has been discontinued because of the frequent need to use these rivets in exterior aluminium surfaces which are not subsequently painted. The stems only are now dyed for identification purposes.

The shear strength of Avdel rivets is similar to that of slid rivets and is somewhat greater than that of Chobert rivets of similar material and size.

Tucker 'POP' Rivets

Tucker 'pop' rivets are manufactured with either domed or countersunk heads, and are supplied threaded on individual mandrels. There are, basically, two different types of rivets, known as 'standard' (open) and 'sealed'. The action of closing both types of rivet is shown in figure 17.3.

The mandrels of standard type rivets are of two; types, namely break head and break stem. With the former type the mandrel head separates from the formed rivet, but with the latter the heads retained in the rivet bore and provides a measure of sealing. The break head rivets are not widely used on aircraft due to ;the difficulty of recovering broken mandrel heads.

These mandrels of sealed type rivets are also of two types, the short break and the long break. The short break mandrel breaks immediately under the head, but the long break mandrel breaks outside the rivet has greatly increasing shear strength of the rivet and providing a flush finish when the protruding stem is nipped off.

A wide variety of tools is available for closing 'pop' rivets, ranging from pillar type hand tools to pneumatically or hydraulically operated power tools. A range of interchangeable heads for these tools permits closing the rivets where access is restricted.

The manufacture's identification code varies according to the type of rivet (i.e. standard or sealed) but similar letters are used to indicate material and head shape as follows:-

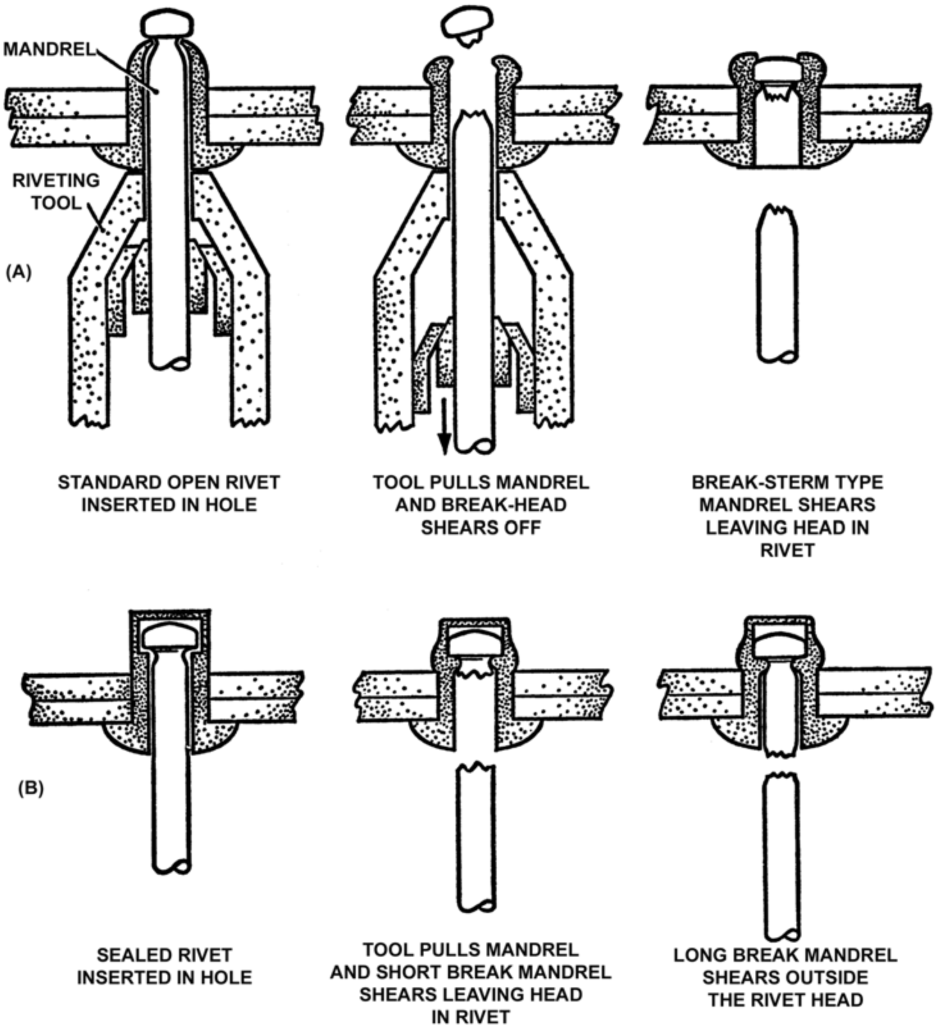


Fig. 17.3, Closing Tucker 'Pop' Rivets

i. Standard rivets

T = Tucker
L,A,S or C = Monel (DTD 10B), steel (E.N.2a) or copper respectively.
P = 'pop' rivet
D or K = domed or countersunk head (120°) respectively.
BH or BS = break head or break stem respectively.

Size is indicated by three figures, the first indicating diameter and the last two the length of shank.

Thus a rivet coded TAP\K 412 BH would be a Tucker, L58, ; pop; rivet, with a countersunk head, 4\32 (1\8) inch diameter with a shank length of 0.12 inch and a break head mandrel.

ii. Sealed rivets

A or C = L58 of copper respectively.
D or K = Domed or countersunk head (120°) respectively.
R = Reinforced (i.e. long break mandrel).

Size is indicated by two or three figures, the first indicating diameter and the remainder the maximum riveting thickness.

Thus a rivet coded AD 48R would be an L58, domed head rivet, 4\32 $\left(\frac{1}{8}\right)$ inch thick and having a long break mandrel.

NOTE 1

The above details apply to the majority of aircraft rivets but rivets of different materials and head shapes are also available.

NOTE 2

Mandrels are normally of steel but are also available in different materials .

AGS numbers have been given to some of the standard 'pop' rivets and the most common are as follows:-

AGS 2048, L58 domed head
AGS 2049, L58 120° countersunk head.
AGS 2050, Monel (DTD 10B) domed head
AGS 2051, Monel (DTD 10B)120° countersunk head
AGS 2070, Monel (DTD 10B) 100° countersunk head

The AGS number is followed by the manufacture's coding for size and mandrel type as discussed in the previous paragraph.

iii. Cherry Rivets

These are rivets of American manufacture and are very similar to Avdel rivets, except that the stem is positively locked in the rivet bore. During the final stages of forming, a locking collar, located in a recess in the rivet head, is forced into a groove in the stem, and the finished blind head is flatter and broader than the standard head. The action of closing a Cherry rivet is shown in figure 17.4.

After forming, the stem protrudes slightly beyond the rivet head and this excess, plus part of the locking collar, may be milled off to provided a flush finish.

Cherry rivets are installed using hand or power operated tools and it is important that the tools are fitted with the correct type of head for the particular size or type of rivet. Details are normally supplied by either the aircraft or tool manufacturer.

Cherry rivets are identified by a four figure number followed by a figure indicating the diameter in thirty-seconds $\left(\frac{1}{32}\right)$ of an inch and further figure indicating the maximum grip in sixteenths of an inch. As an example , CR 2162-3-6 refers to a Cherry rivet in aluminium alloy, with a countersunk head and standard stem, 3\32 inch diameter and a maximum grip of 3\8 inch. Table 17.3 shows some of more common Cherry rivets, together with identification details.

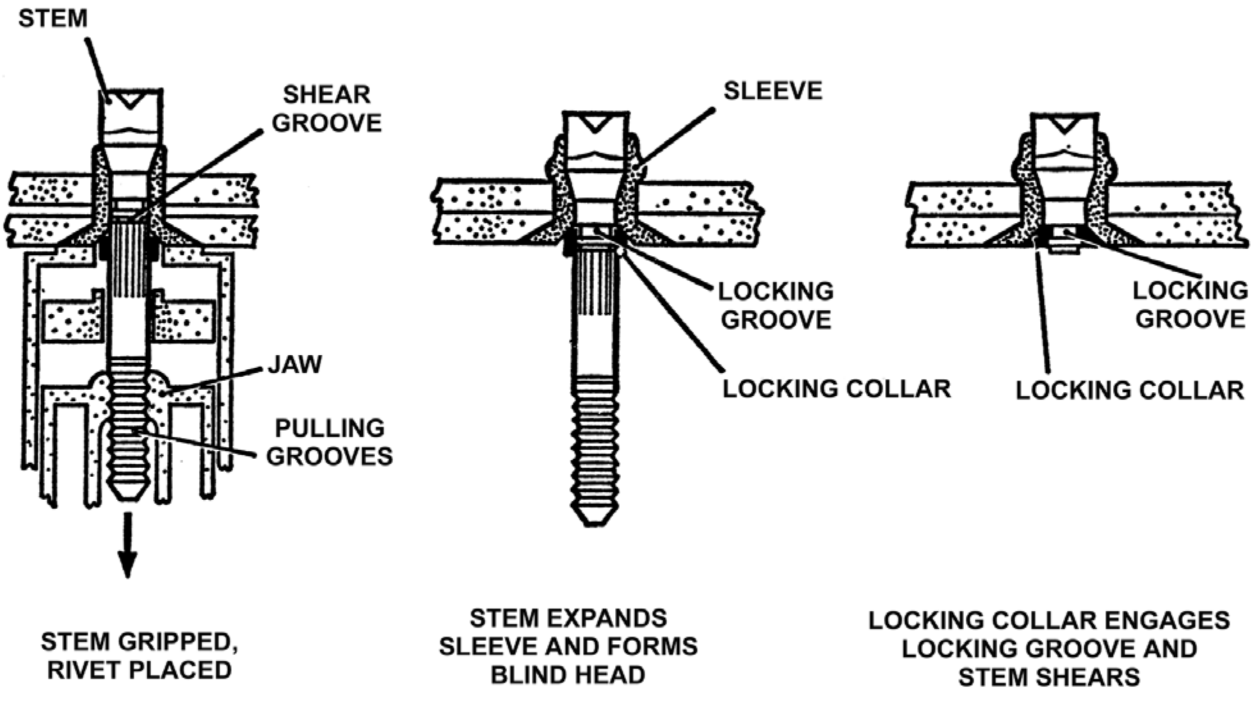


Fig. 17.4, Closing Cherry Rivets.

TABLE 17.3
CHERRYRIVETS

			Material		Finish	
Code	**Type**	**Head**	**Rivet**	**Stem**	**Rivet**	**Stem**
CR 2162	standard	countersunk	2017	7075	205 Alumite	1200 Alodine
CR 2163	standard	universal	2017	7075	205 Alumite	1200 Alodine
CR25625	standard	countersunk	monel	monel	silver plate	natural
CR25635	standard	universal	monel	monel	silver plate	natural
CR 2662	standard	countersunk	st. steel	st. steel	dry film	natural
CR 2663	standard	universal	st. steel	st. steel	dry film	natural
CR 2248	bulbed	countersunk	5056	steel	anodised	cad. plate
CR 2249	bulbed	universal	5056	steel	anodised	cad. plate

NOTE : A figure indicating maximum grip is marked on the rivet head.

TUBULAR RIVETS

Tubular rivets were, at one time, quite often used on tubular structures, such as engine mountings or fuselage frames, for joining tubes to fittings, or for repair work. These parts are now more often welded or fixed with taper pins, but tubular rivets may still be found on a number of aircraft. These rivets are closed by hammering, using specially shaped punches and snaps, and care is necessary to prevent buckling the rivet or tube. To prevent buckling and to maintain the tube shape, distance tubes are often used.

The most common type of tubular rivet is the one manufactured in accordance with AGS 501, and is obtainable in various material, diameters and gauges. Another type of tubular rivet (covered by AGS 513,514,515 and 516) is the 'split' or 'Cox' rivet, which is formed from sheet material and may have a straight or serrated joint running axially along the rivet length. This type of rivet is only used in non-structural application.

SPECIAL FASTENERS

The special fasteners discussed in this paragraph are closed by means of a collar which is swaged into grooves in the fastener shank or expanded over the shank to form a blind head. The fasteners are generally used instead of bolts and present a considerable saving in weight.

Hi-shear

The Hi-shear fastener consists of a pin of high shear strength and a collar of softer material which is forced into the pin groove by the riveting action (see Figure 17.5). the pins are supplied with standard or close tolerance shanks and may have either of two; differently shaped grooves (the '100' series which uses aluminium alloy collar only, and the '200' series which uses collars in a variety of materials). Some pins are supplied with oversize shanks for repair work.

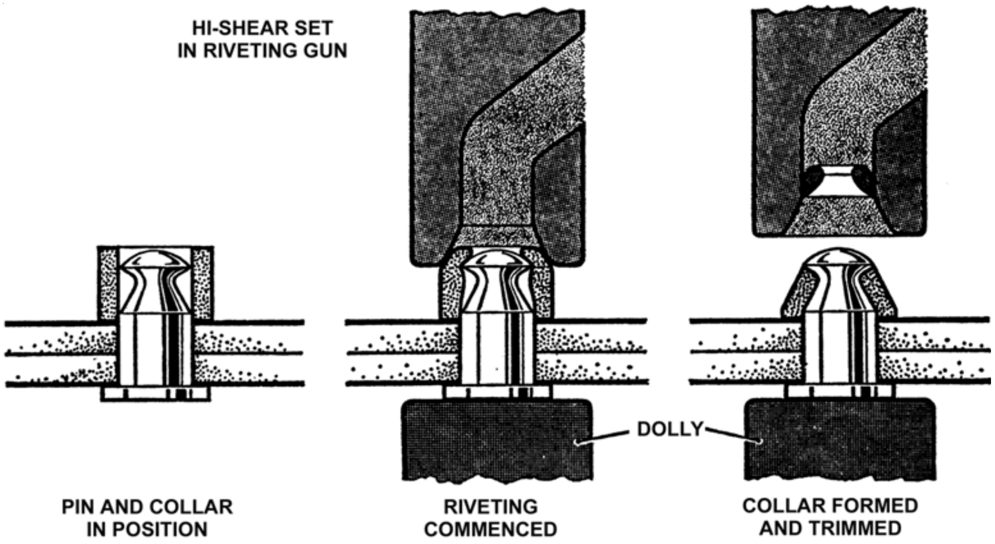


Fig. 17.5, Closing Hi-Shear Fasteners.

For ordering purposes Hi-shear pins and collars are identified by a prefix (BBH), followed by a series of numbers or letters indicating type, material and size. Pins and collars are ordered separately from the following codes:-

i. A three figure number indicating shank tolerance and collar material.

ii. A letter indicating head shape (C = countersunk , F = flat).

iii. A letter indicating pin material (N=55\65 ton steel, H=75\85ton steel, S = stainless steel, K = monel, T = titanium and A = aluminium alloy).

iv. Two figures indicating nominal diameter in thirty-seconds of an inch $\left(\frac{1}{32}\text{inch}\right)$ (in addition the letters C & D may be used for pins the same sizes as No.8 and No. 10 Unified bolts).

v. Two figures indicating maximum grip length in sixteenths of an inch.

As an examples, a close tolerance flat head pin in stainless steel, 1\8 inch diameter, with a grip length of ½- inch and for use with an aluminium alloy collar, would be BBH\101\FS\04\08; the matching collar would be BBH\104\04.

For recognition purposes symbols are marked on pin head, or a dyed finish is added ,as shown in Table 17.4. In addition the letter ‘P’ is added to precision (close tolerance) pins, and ‘1\32 or ‘1\64’ added to oversize pins as appropriate.

TABLE 17.4
HI-SHEAR RECOGNITION FEATURES

Material	Marking	Finish
Pins		
55/65 ton steel	B +	cadmium plated
75/85 ton steel	Ⓑ	cadmium plated
stainless steel	$\underline{\cdot\ \mathrm{B}\ \cdot}$	natural
monel	BM	natural
titanium	BT	natural
aluminium alloy	nil	anodised and dyed blue
Collars		
(a) for '100' series pins : -		
aluminium alloy	nil	anodised and dyed mauve
(b) for '200' series pins :-		
aluminium alloy	nil	anodised and dyed green
stainless steel	nil	natural
mild steel	nil	cadmium plated
annealed monel	nil	natural

Hi-shear pins are placed using a special hi-shear rivet set which forms and trims the collar. Collars are pre-lubricated and should not be washed in solvent before use.

Some Hi-shear pins were produced with a grooved shank to release trapped jointing compound; in all other cases where wet-assembly is called for the exposed pin shank must be wiped clean to ensure correct forming of the collar.

Avdelok Fasteners

These fasteners are typical of a wide variety of proprietary fasteners available in America and the United Kingdom. The bolt portion of the fastener is solid and a collar is swaged onto grooves in the bolt shank as shown in Figure 17.6. When swaging is complete the bolt shears flush with the collar. Avdelok fasteners are manufactured with a number of different head shapes, in steel or aluminium alloy, with diameters of 3\16 inch to ½ - inch. They are normally placed with power operated tools.

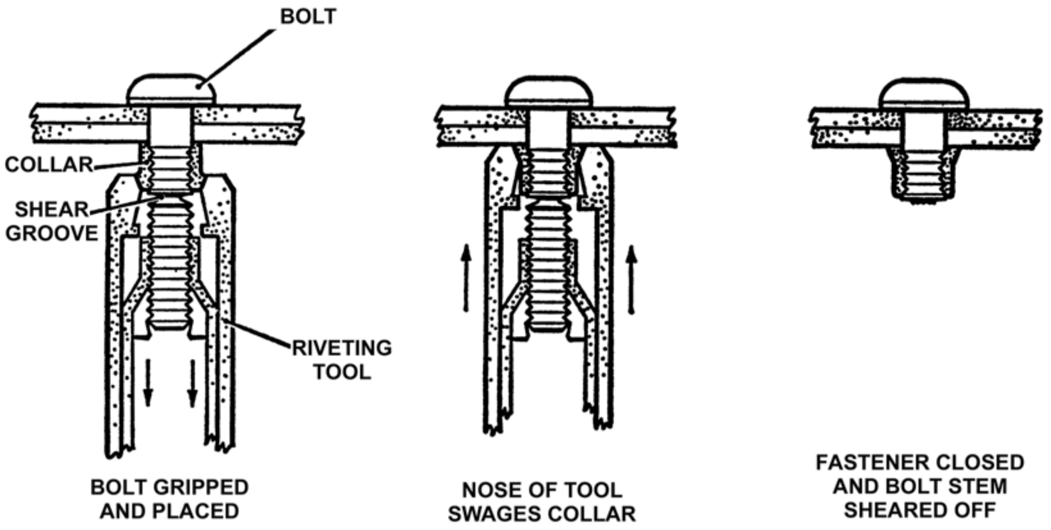


Fig. 17.6, Closing Avdelok Fasteners

Some aircraft manufacturers recommend that the holes for Avedelok fasteners should be reamed to an interference fit, and lay down the tolerance to be achieved. This practice requires a different technique for placing the fasteners, the bolt first being inserted without its collar and pulled into place by use of the riveting gun, then the collar is fitted and swaged by a second operation of the gun.

As with other similar fasters the fasteners the Avdelok is pre-lubricated and should not be de-greased before assembly except that, if an interference fit is specified, lubricant must be removed from the bolt. If wet assembly is specified the specified sealant must be removed from the bolt shank before swaging.

Avdelok fasteners are identified by a code system similar to that used for Chobert and Avdel rivets, namely a four figure product code and a four figure size code.

Jo-bolts

Although Jo-bolts may be classified as blind rivets, the method of closing is different from the methods previously discussed. The complete item consists of a threaded bolt with a round head, a rivet shaped nut and a sleeve, assembled as illustrated in Figure 17.7. Rotation of the bolt forces the sleeve up the tapered nut shank, clamping the materials to be joined, and at a predetermined load the bolt shears just inside the nut head leaving ,virtually, a solid steel rivet in the hole.

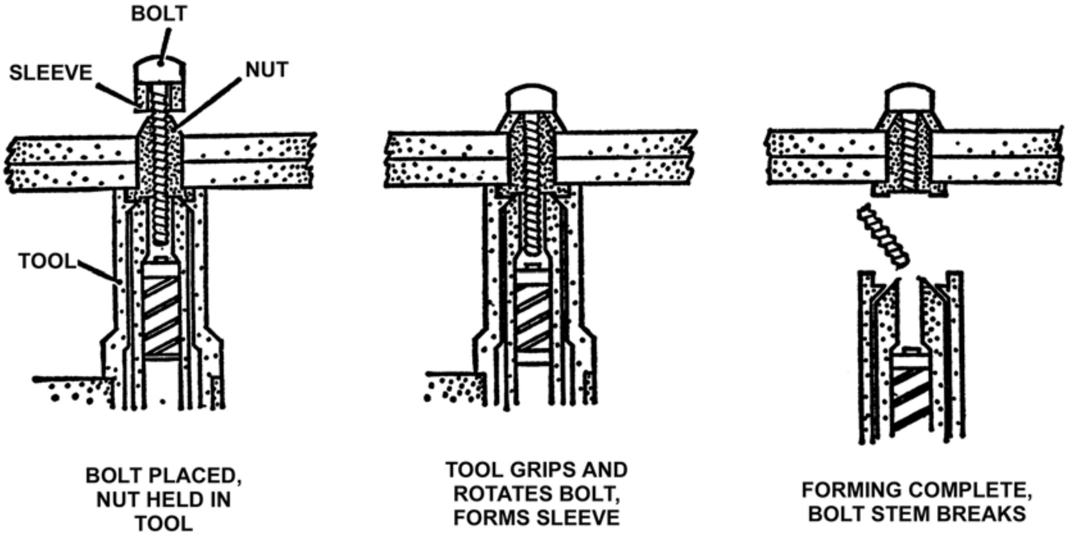


Fig. 17.7, Closing Jo-Bolts.

Jo-bolts are manufactured with hexagon or 100° countersunk heads, in either stainless or alloy steel, and have a shear strength almost equal to a bolt of equivalent size and material. The bolts are pre-lubricated and must not be washed in solvent, since this would alter the gripping strength at which the bolt breaks.

The tools used for placing Jo-bolts are in two concentric parts, the outer part holding the nut and the inner part gripping the bolts shank. Different adaptors must be fitted to the tools to accommodate the different size hexagon heads, or cruciform slots of countersunk bolts.

Jo-bolts are identified by an eight figure code number, the first four figures indicating type and material, and the remainder the size, in a similar way to Avdel rivets. As an example the code 2103-0607 indicates a 100° counter sunk bolt in cadmium plated alloy steel, with a diameter of 3/16 inch and nominal grip of 7/16 inch.

Rivnuts

Rivnuts were originally developed for securing rubber de-icing boots to the leading edges of aerofoil sections but they are now also used, for example, for securing floor coverings and other non-structural parts. They are a form of blind rivet which can be used as an anchor nut, the internal bore being threaded to receive a bolt or screw. Rivnuts used on de-icing boots have a 6-32 thread and have either flat or countersunk heads. The countersunk head types are open ended and may or may not have a locating key, but the head types all have a locating key and are supplied with either a closed or open end. Marks on the head indicate length in accordance with a manufacturer's code. Rivnuts are installed with a special tool fitted with a threaded mandrel; the mandrel is screwed into the rivnut, and when the gun is operated the shank expands as shown in Figure 17.8.

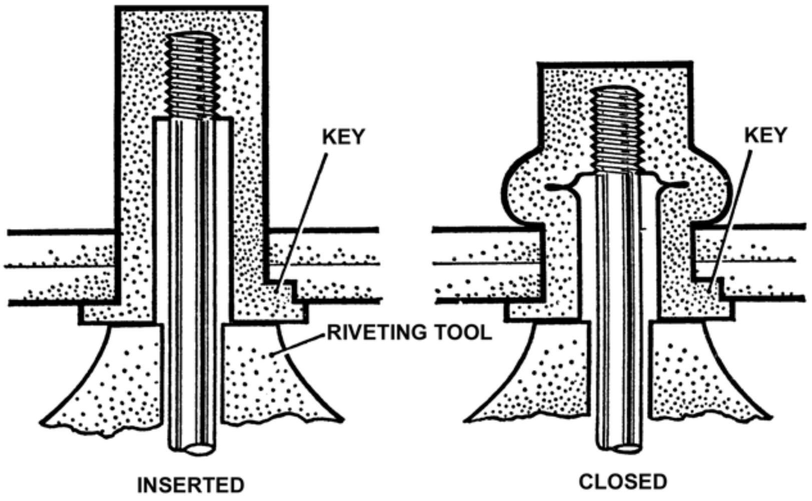


Fig. 17.8, Closing Rivnuts.

■■■

CHAPTER : 18
RIVETING PRACTICE

RIVETING PRACTICE (CALCULATIONS AND TOOLS)

Edge Distance Calculation

Edge distance is the distance from the edge of the material to the center of the nearest rivet hole (Fig. 18.1). If the drawing does not specify a minimum edge distance, the preferred edge distance is double the diameter of the rivet shank (Fig. 18.2).

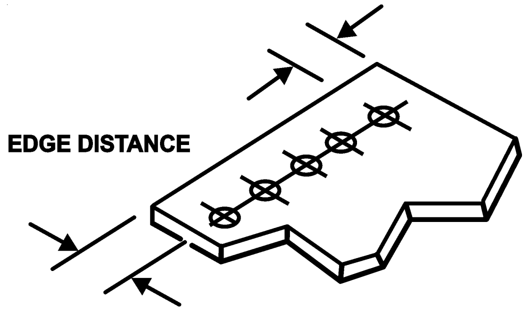


Fig. 18.1, Illustration of edge distance.

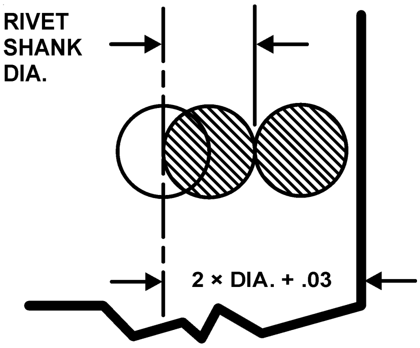
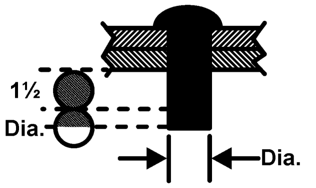


Fig. 18.2, Determining edge distance.

Rivet Length Calculation

Solid-shank rivet lengths are never designated on the blue-print; the mechanic must select the proper length (Fig. 18.3).

MS20470 & MS20426



The length of the rivet shank extending beyond the material should be 1½ times the diameter of the shank

Rivet Dia.	Drill Dia.	Upset Dia.		Upset Height	
		Max.	Min.	Max.	Min.
1/16	#51	1/8	5/64	1/16	1/32
3/32	#40	5/32	1/8	1/16	1/32
1/8	#30	7/32	11/64	5/64	3/64
5/32	#21	9/32	13/64	3/32	1/16
3/16	#11	11/32	1/4	1/8	5/64
1/4	6.4 MM	27/64	21/64	5/32	3/32
5/16	#0	5/8	13/32	5/16	1/8

Rivet Length = Allowance + Material Thickness

(L = A + MT)

Rivet Diameter	Allowance
1/8	3/16
5/32	1/4
3/16	5/16
1/4	3/8

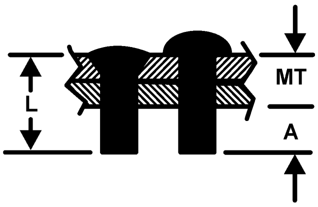


Fig. 18.3, Determining Rivet Length.

Hole Preparation

Drill sizes for various rivet diameters is shown in Fig. 18.4. Holes must be clean, round, and of the proper size. Forcing a rivet into a small hole will usually cause a burr to form under the rivet head.

Riveting

TO DRILL A HOLE FOR THIS SIZE RIVET	USE THIS SIZE DRILL
1/16"	#51 (.0670)
3/32"	#40 (0.0980)
1/8"	#30 (0.1285)
5/32"	#21 (0.159)
3/16"	#11 (0.191)
1/4"	6.4 MM (0.252)

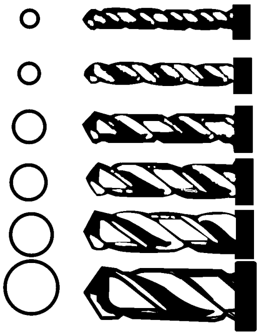
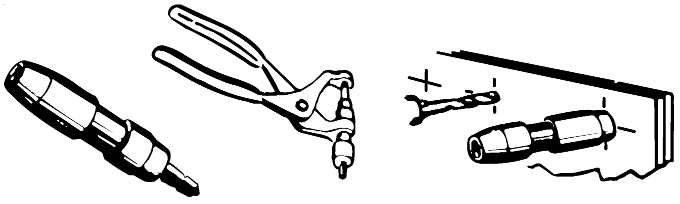


Fig. 18.4, Drill sizes for various rivet diameters.

Use of Clecos

A cleco is a spring-loaded clamp used to hold parts together for riveting. Special pliers are used to insert clecos into holes (Fig. 18.5).



Cleco size	3/32	1/8	5/32	3/16
Color	Silver	Copper	Black	Brass

Fig. 18.5, Clecos are inserted into holes with special cleco pliers. Cleco sizes are identified by colors.

Driving Solid-Shank Rivets

Solid rivets can sometimes be driven and bucked by one operator using the conventional gun and bucking bar method when there is easy access to both sides of the work. In most cases, however, two operators are required to drive conventional solid-shank rivets.

Hand Riveting

Hand riveting might be necessary in some cases. It is accomplished by holding a bucking bar against the rivet head, using a draw tool and a hammer to bring the sheets together, and a hand set and hammer to form the driven head (Fig. 18.6). For protruding head rivets, the bucking bar should have a cup the same size and shape as the rivet head. The hand set can be short or long, as required. Do not hammer directly on the rivet shank.

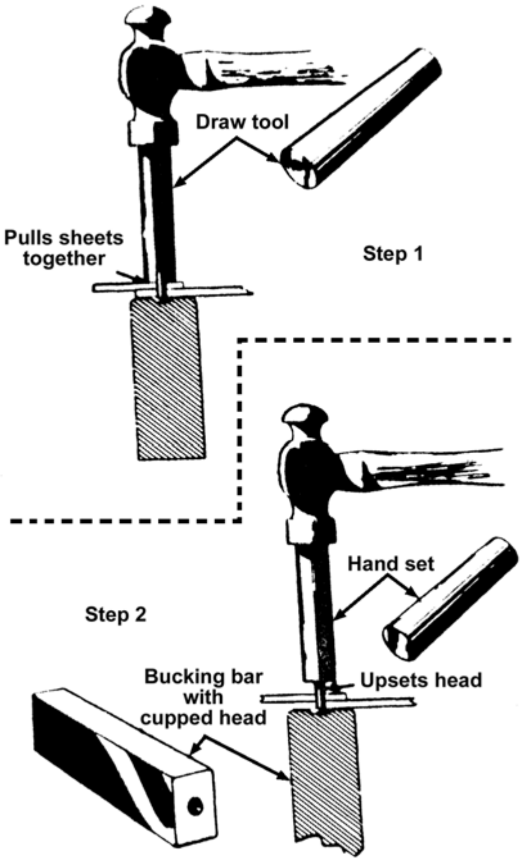


Fig. 18.6, Hand Riveting Procedure.

Rivet Guns

Rivet guns vary in size, type of handle, number of strokes per minute, provisions for regulating speed, and a few other features. But, in general operation, they are all basically the same (Fig. 18.7). The mechanic should use a rivet-gun size that best suits the size of the rivet being driven. Avoid using too light a rivet gun because the driven head should be upset with the fewest blows possible.

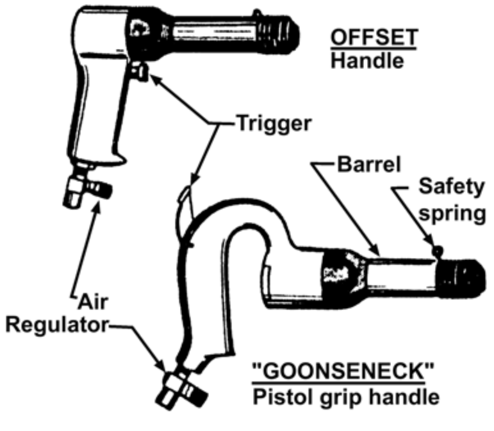


Fig. 18.7, Typical rivet guns.

NOTE

Always select a rivet gun size and bucking bar weight that will drive the rivet with as few blows a possible.

Rivet Sets

Rivet sets (Fig. 18.8) are steel shafts that are inserted into the barrel of the rivet gun to transfer the vibrating power from the gun to the rivet head (Fig. 18.9).

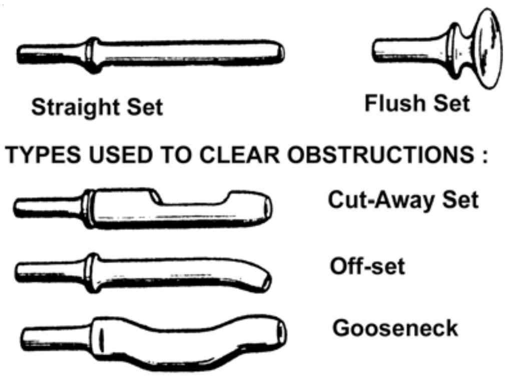
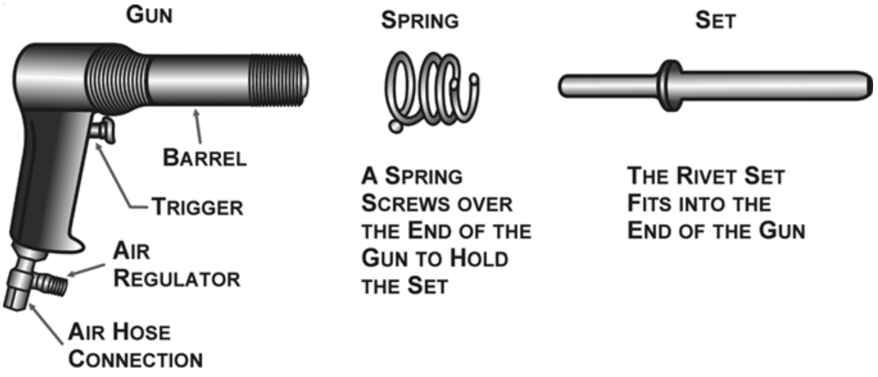


Fig. 18.8, Typical rivet sets.



SAFETY A rivet gun is dangerous - never use one without a retainer spring

Fig. 18.9, The rivet gun and the set go together like this.

Select a rivet set for the style of head and size of the rivet. Universal rivet sets can be identified with the tool number and size of the rivet. Flush sets can be identified only with the tool number (Fig. 18.10). Also shown in Fig. 18.10 is the result of using incorrect sets.

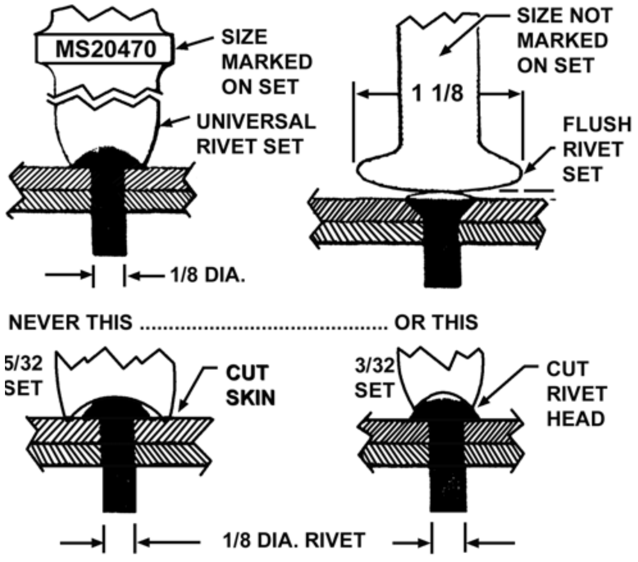


Fig. 18.10, The correct set must be used for the rivet being driven.

Bucking Bars

A bucking bar is a piece of steel used to upset the driven head of the rivet. Bucking bars are made in a variety of sizes and shapes to fit various situations. Bucking bars must be handled carefully to prevent marring surfaces. When choosing a bucking bar to get into small places, choose one in which the center of gravity falls as near as possible over the rivet shank. Avoid using too light of a bucking bar because this causes excessive deflection of the material being riveted that, in turn, might cause marking of the outer skin by the rivet set. A bucking bar that is too heavy will cause a flattened driven head and might cause a loose manufactured head. Remember, you should use as heavy a bar as possible to drive the rivet with as few blows as possible. Figure 18.11 shows some typical bucking bar shapes.

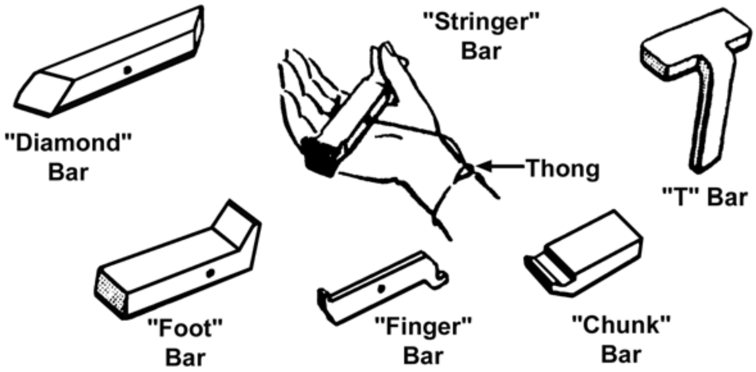


Fig. 18.11, Some typical bucking bars.

Riveting Procedure

Operate a rivet gun and install rivets as follows :

1. Install the proper rivet set in gun and attach the rivet set retaining spring, if possible. Certain flush sets have no provision for a retaining spring.

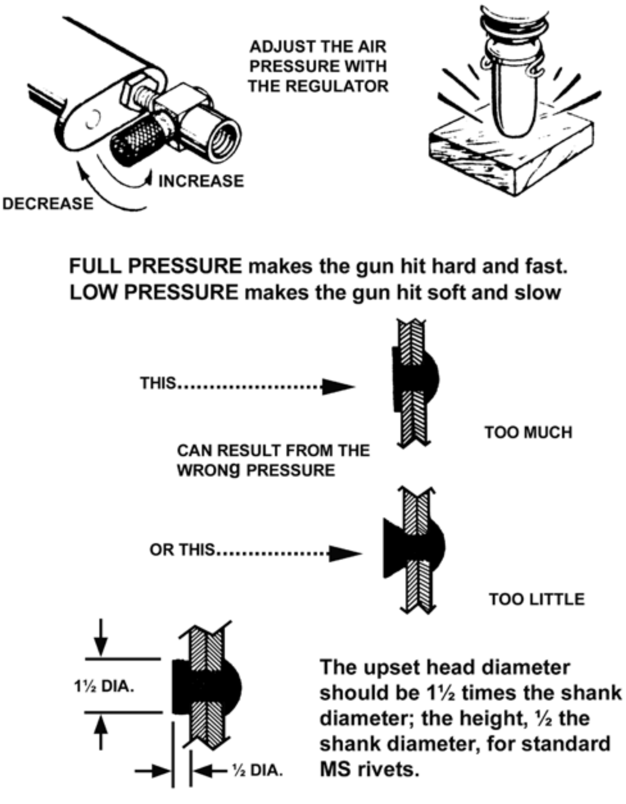


Fig. 18.12, Adjust the air regulator that controls the hitting power of the gun by holding the rivet set against a block of wood.

2. Connect the air hose to the gun.
3. Adjust the air regulator (Fig. 18.12), which controls the pressure or hitting power of the rivet gun, by holding the rivet set against a block of wood while pulling the trigger, which controls the operating time of the gun. The operator should time the gun to form the head in one "burst," if possible.
4. Insert proper rivet in hole.
5. Hold or wait for the bucker to hold the bucking bar on the shank of the rivet. The gun operator should "feel" the pressure being applied by the bucker and try to equalize this pressure.
6. Pull the gun trigger to release a short burst of blows. The rivet should now be properly driven, if the timing was correct, and provided that the bucking bar and gun were held firmly and perpendicular (square) with the work (Fig. 18.13).

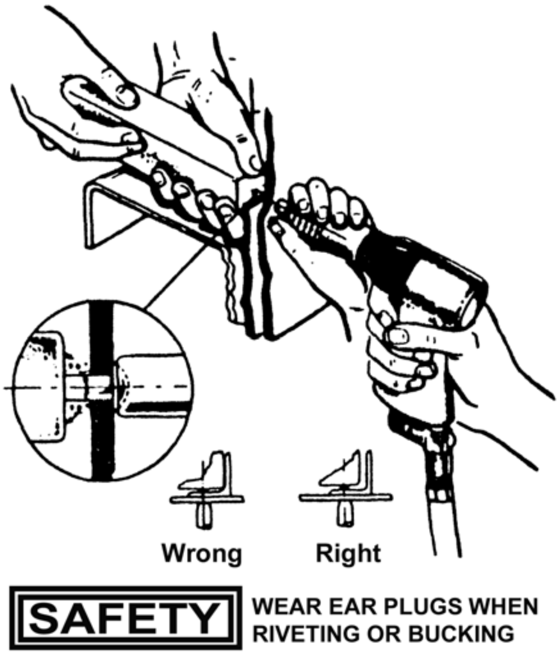


Fig. 18.13, Holding rivet gun and bucking bar on rivet.

Rivet gun operators should always be familiar with the type of structure beneath the skin being riveted and must realize the problems of the bucker (Fig. 18.14).

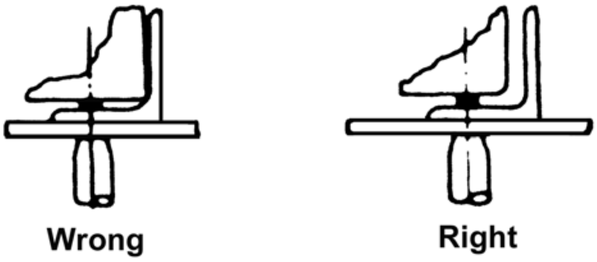


Fig. 18.14, The bucker should not let the sharp corner of a bucking bar contact an inside radius of the skin or any other object.

CAUTION

Never operate a rivet gun on a rivet, unless it is being bucked. The bucker should always wait for the gun operator to stop before getting off a rivet.

REMOVAL OF RIVETS

Their are several methods of removing the rivets and fasteners and these are outlined in the following paragraphs. For any particular situation the thickness and strength of the structure should be considered and the method likely to cause the least damage should be used. Before refitting a rivet of the same diameter, the hole should be checked to ensure that its diameter is within the limits specified by the aircraft manufacturer. If it is to within limits, an approved oversize rivet must be fitted and the hole enlarged accordingly.

The usual method of removing solid rivets is as follows:-

i. Centre punch the manufactured head.

ii. Drill down to the depth of the head with a drill slightly smaller than the rivet shank.

iii. Carefully tap off the head with a flat chisel or prize off with a pin punch.

iv. Punch out the remainder of the rivet with a parallel punch of the same diameter as the rivet shank, supporting the underside with a hollow dolly as necessary.

The utmost care should be taken when drilling and punching, to ensure that the original hole is not enlarged.

When removing rivets from assemblies which include bonded laminations or reinforcements it is essential not to apply shear loads liable to part the bond.

A different method of removing solid rivets, which is specified by some aircraft manufacturers, is to drill off the tail of the rivet with a drill slightly larger than the rivet shank and then punch out the shank and manufactured head.

Cherry rivets may be removed by punching out the stem from the locked end, then drilling off the head and punching out the shank with a parallel punch. If the rivets are installed in thin sheet, however, the locking collar should be removed first by drilling into the stem with a pilot drill, then opening up the hole to; shank diameter and prizing out the collar.

Other types of blind rivet may be removed by drilling off the head with a drill the same size as the hole and punching out the remainder of the rivet.

Fasteners which have collars swaged onto the shank (i.e. Hi-shear and Avdelok) may be removed by either of two methods:-

i. Using a hollow mill with an internal diameter slightly larger than the fastener shank, the collar should be milled off to just above the skin surface. These fasteners may then be driven out, using a hollow dolly to support the structure.

ii. The head should be removed by the method described in this topic and the remaining pin and collar punched out.

In some instances a drill-out busing is available for use with particular fasteners and this may be used as a guide while drilling out the head or shank.

NOTE

When drilling out loose rivets, care must be taken to prevent the rivet from rotating with the drill, as this would tend to enlarge the hole and damage the skin surface under the head.

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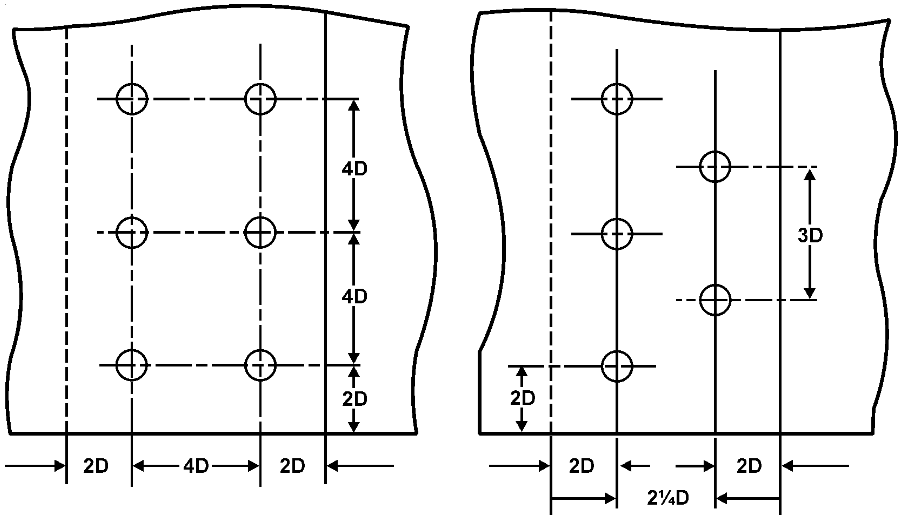
CHAPTER : 19
RIVETING METHODS

GENERAL

Information on the size and type of rivets to be used, and the spacing to be employed for a particular repair, is normally specified in an approved repair scheme for a particular aircraft type. Unless otherwise stated the repair should follow the system of riveting used elsewhere on that aircraft at similar locations. It must be appreciated that the original pattern of riveting will have been deliberately selected and on all modern aircraft will have been proven in both static and fatique structural test programme. In carrying out any repair of major structural components, such as pressurised cabins and integral fuel tanks, the same type of riveting and a comparable quality of riveted assembly are vital to the integrity of the structure. If departure from the normal methods of construction is necessary, for example, different rivets or rivet spacing, approval of the manufacturer should be sought, since the strength of the repair might be affected . Provided that the approved repair scheme is followed in every detail, and that drilling and riveting completion, the repair should be inspected as outlined in paragraph below and any exposed metal reprotected.

RIVET SELECTION

A number of factors must be taken into account when selecting the rivets to be used for a particular application . Generally the strength of the rivets must be similar to that of the material in which they are used; the size, number and spacing of rivets is calculated from the tensile strength and bearing strength of the sheet material and the shear strength of the rivets. The rivet diameter should be approximately three times the thickness of a single sheet of the material being joined, for example, 1\8 inch diameter rivets should normally be used with 20 s.w.g. (0.036 inch) sheet, and 5\32 inch diameter rivets with 18 s.w.g. (0.048 inch) sheet, but this may be unsuitable when holes are cut countersunk.



(D = DIAMETER OF RIVET SHANK)

Fig. 19.1, Minimum Spacing for Riveted Joints.

Figure 19.1 shows the spacing normally applied to double chain and staggered lap joints to obtain maximum strength; in other types of riveted structures a rivet pitch (i.e. distance between rivets in a row) of four times rivet diameter (D) and distance from sheet edge (land) of 2D are typical. Where a rivet is used to fasten an angled member, the rivet must not be so close to the bend that rivet cannot be properly closed when using the appropriate dollies or special tools.

HOLE PREPARATION

Marking Out

Careful marking out is a prerequisite for accurate drilling. Aluminium alloy parts used on aircraft should not be marked out with a scriber or other tool which will scratch the surface, unless the marks are subsequently machined off or otherwise removed. A thin coat of zinc chromate primer makes a suitable background for pencil lines, but it may be preferable to manufacture a template which can be used as a drilling jig on the aircraft.

Hole size

The size of the rivet holes has a positive bearing on the strength of a riveted joint. A clearance must exist between the rivet and the hole in which it is fitted to accommodate expansion of the shank during forming. If the clearance is too small the sheets will tend to buckle , whereas if the clearance is too large separation of the sheets may occur (see figure 4). The selection of the correct size rivet countersink, dimple and rivet hole, should be made by reference to tables published by the aircraft manufacturer. The recommended sizes vary according to the gauge of the structural materials being joined and the size, from, length and material of the rivets being used. In general the harder and longer the rivet the smaller the clearance, but close tolerance holes and interference fits are often a requirement.

As a result of laboratory tests and engineering development at the design stage, carefully controlled hole sizes and rivet fits are used in critical fatigues-prone locations. Should it be necessary to disturb structure of this type it is imperative that reassembly be carried out in accordance with the original drawings or repair schemes, or as advised by the aircraft manufacturer.

In order to allow for slight misalignment during assembly work, it is usual to drill pilot holes at positions where rivets are to be fitted. When the assembled structure is ready for riveting, the holes should then be opened out to the required size.

When a structure has to be dimpled to accommodate countersunk rivets, the holes should first be drilled under size, since the dimpling action enlarges the hole. After the dimple is formed the hole may then be drilled or reamed out to the appropriate size; this action must also remove any small radial cracks which have formed round the hole during the dimpling operation. Some aircraft manufacturers may permit dimpling to be carried out from final size holes, but this practice is normally only applicable to lightly loaded structures.

Drilling Technique

It is always important to use a drill which is sharp and accurately ground, and to prevent the drill ‘wandering off’ it is advisable to mark the drilling position with a centre punch. Care must also be taken to ensure that the drill is held perpendicular to the work surface, and it may be advisable in certain circumstances to use a drilling jig to prevent error. A badly drilled hole will prevent accurate riveting and may result in failure to meet the design strength requirements of a joint.

NOTE

When drilling out rivets on complete aircraft care must be taken to prevent damage to pipes, wiring looms or subsidiary structure, and precautions taken to prevent the ingress and facilitate recovery of swarf and pieces of rivets. An oiled or grease paper may be used under the hole to collect swarf while drilling.

Deburring of Holes

One aspect of riveting which often receives insufficient attention is the deburring of holes. It is most important that all rough edges and swarf are removed after drilling or reaming operations. For example, where holes are finally drilled on assembly, the structure must be disassembled for deburring and swarf removal before final assembly and riveting. A special deburring tool must be used for removing rough edges, an ordinary drill larger than the rivet hole being considered unsuitable. A power driven cutter with a locating spigot and concentric stop sleeve is normally used when a large numbers of holes have to be deburred. Burrs should not be removed with files or emery paper.

COUNTERSINKING

When countersunk rivet is to be fitted, there are two methods of accommodating the rivet head to ensure a flush fit. Suitable-countersinking is employed where sheet thickness is greater than the depth of the rivet head, but for thinner sheets dimpling is necessary. Where sheets of different thicknesses are joined together it may be found that both methods are used, a thin outer sheet being dimpled into a countersunk thick inner sheet.

Cut-countersinking

Table 1 shows the minimum sheet thickness which may be countersunk for particular rivet diameters, and is applicable where 100 or 120 countersunk head rivets are used. Where special rivets with different head angles are used the aircraft manufacturer may specify a different minimum sheet thickness, and when oversize rivets are being fitted it may be recommended that the rivet heads are milled in preference to cut-countersinking into supporting structure.

Special countersinking tools should be used for cut-countersinking. These tools should have a centralising spigot and an adjustable depth stop which will limit the depth of cut. The rivet head should always be slightly protrued of the work before riveting, and this can be set by trial drilling in scrap material. Aircraft manufactures usually specify a tolerance on head protrusion after riveting, and this is usually of the order of 0.005 inch above the skin surface. It is not normally permissible for the rivet head to be below the skin surface.

TABLE 1, MINIMUM SHEET THICKNESS FOR COUNTERSINKING

Rivet diameter (inch)	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{1}{4}$
Minimum sheet thickness (s.w.g.)	18	16	14	12

Dimpling

This is a process for indenting thin sheet material (not normally thicker than 16 s.w.g) around a drilled hole to accommodate a countersunk rivet. If correctly preformed, dimpling has a beneficial effect on the strength of a joint, but the method of dimpling must be related to; the ductility of the material to prevent over stressing and cracking.

Dimpling Characteristics

The aluminium alloy skin panels commonly used for stressed skin structures are either solution treated and naturally aged or solution treated and artificially aged. The naturally aged materials and some of the artificially aged clad materials may be satisfactorily dimpled at room temperature, although if dimples of 90° or less are required, hot dimpling may be specified. Carefully controlled spin dimpling processes are considered suitable for L70, L72, L73, DTD 746 and 2024-T4 aluminium material and stainless steel, but hot dimpling should be used for the stronger but less ductile L71, DTD 687, 2014-T6 and 7075-T6 aluminium alloy, and for titanium.

Control Tests for Dimpled Sheet

Before dimpling any aircraft material of which the dimpling characteristics are uncertain, either because of lack of familiarity with the material itself or because of the use of a new dimpling technique or tool, tests should be made on sample material of the same gauge, specification and heat treatment condition.

i. Specimens of the material should be cut approximately 8 inches long and 1 inch wide, and dimpled along the centre ling of the strip at the pitch to be used on the aircraft. When the strip is bent across the dimples as shown in Figure 19.2, cracks across the dimples at the bend may be expected and are acceptable, but if other radial or circumferential cracks develop the process must be considered unsatisfactory.

ii. Before any method of dimpling is approved for production, its suitability for the particular combination of material, gauge, dimple and rivet size should be assessed by the Design Department. A number of dimpled and riveted specimens should be sectioned to check the nesting of the dimples and the fit of the rivet.

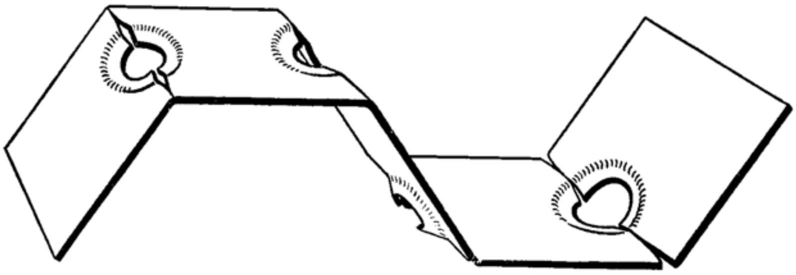


Fig. 19.2, Dimple Test Specimen

Punch Dimpling

This is the simplest method of dimpling but is generally only suitable for minor repairs in sheet steel or soft aluminium alloys. The type of tool used is similar to a center punch but has a spigot which engages in a female tool of the same form. These hole should first be drilled to the spigot size and then the male die should be driven or squeezed into the female die to from the dimple.

Spin Dimpling

This is the most widely used method of cold-dimpling. The sheet is first pre-drilled and backed by a female die as for punch dimpling, then a rotating male die is pressed into the hole. The metal around the rivet hole is stretched over the edge of the female die and, if the material is clad, the aluminium cladding is spread by the spinning action. The cladding may from a ridge around the outside of the dimple but this will only be slight, and should not be removed.

Hot Dimpling

There are basically two method of hot dimpling. In the first method, sometimes known as 'coin dimpling', electrically heated dies are used; in the second, the sheet is heated by its resistance to the passage of an electric current. Each material has a different rate of conducting heat, or a different electrical resistance, and gauges. These details are normally found by experiment and the instructions given by the aircraft manufacturer should be followed.

NOTE

In order to obtain consistent results during aircraft construction, large static machines with automatically controlled temperature, current and tool pressure are often used but for repair work portable hot squeeze-dimpling tools are generally satisfactory.

Dimpling Technique

To ensure that rows of dimples fit satisfactorily together, the pilot holes should be drilled with the structure fully assembled. The structure may then be disassembled and the individual components deburred and dimpled separately. However, if sheets are to be bonded together, it may be recommended that dimpling is carried out after bonding.

i. To produce dimples which are free from cracks around the holes it is essential that the pilot holes are free from burrs or other defects and that the correct lubricant is used. The ideal procedure is to drill the holes under size, ream to suit the size of dimpling tool spigot, then deburr or both sides before dimpling. For maximum shear strength the hole should be finally drilled or reamed to give a hole with parallel sides and ideal rivet clearance. This second drilling should start from the dimpled side so that any burrs are on the raised edge and easily removed with a deburring tool.

ii. When countersunk rivets are used to join several thin sheets of material there are two ways in which dimples may be formed. If the same tool are used for successive sheets the dimples will be identical, but will not nest satisfactorily. This may be acceptable when joining two sheets, of a ductile material but, for stiffer materials and when joining more than two sheets, the dimples may be over stressed by the riveting action. A more satisfactory method is to; use tools of a slightly larger diameter and shallower angle with successive sheets, the innermost sheet having the largest and shallowest dimple.

Use of Sealants

After components have been prepared for riveting the mating surfaces are normally given a coat of jointing compound as sealant before final assembly the purpose of joining compound is to inhibit electrolytic action between materials of different electrical potential and prevent the ingress of moisture, whereas a sealant (normally a poly sulphide type synthetic rubber) is used to seal joints in fuel tanks and pressurised compartments. Jointing compound should be applied in a thin even film, just sufficient to ensure that all mating surfaces, including rivets, are adequately covered, but sealant should normally be applied in a layer approximately 0.030 inch thick so that it exudes from the joint when the rivets are closed. It may be recommended that rivets are dipped in the compound before use but the exposed shanks of some types of rivets should, after insertion, be carefully wiped clean to ensure correct closing of the rivet . Riveting must be completed before the compound or sealant has set and any excess material on external surfaces should be wiped off or to a prescribed fillet while still wet.

SUPPORT AND ALIGNMENT OF STRUCTURE

During the manufacture of an aircraft extensive jigging is used to locate detail parts in accurate relationship to one another while they are being secured by rivets or other types of fasteners. This provides not only for interchangeability of structural components but for correct external contour. When carrying out repairs on riveted structures, adequate support must be provided to maintain the original size, contour and alignment; this is particularly important in the case of extensive repairs. On high speed aircraft the achievement of correct external contour is vital, but on all aircraft care should be taken to prevent an increase in aerodynamic drag through poor shape or finish.

Major stress concentrations are spread from principal transport joints into the lighter structure through progressively reduced reinforcing fittings. Such assemblies involve the use of bushes, taper pins, bolts and rivets, each designed to take a share of the load. The sequence of assembly during repair or replacement may be vital to ensure correct alignment and the use of jigs may be required when drilling or reaming holes for rivets.

During the assembly of sheet metal fabricated structure each mating part must fit snugly together. This accuracy of fit must be achieved before the application of intervening material and any forming or packing necessary must be carried out before final assembly. Panel shape should be adjusted to achieve perfect fit against supporting frames, stringers or ribs.

On high speed aircraft embodying heavy riveted skins or bonded laminated reinforcements which are extremely rigid, the design may call for the use of sophisticated skin grip to hold the skin in contact with the structure during riveting. Certain forms of interfying sealant require a specific torque loading to be applied to such grips, with a minimum time of clamping and a maximum time between releasing the grips and closing the rivets. Such precautions as these should be obtained from the manufacturers process sheets or the aircraft Repair Manual.

CLOSING RIVETS

When the appropriate actions of drilling, countersinking, dimpling, deburring, cleaning and adjustment have been completed, the work to be riveted should be assembled, sealant applied, and mating surfaces brought tightly into contact by use of skin grips, care being taken not to damage the skin surface. It is important that no gaps are present between layers, as this will prevent the correct forming of the rivet and reduce shear strength. Riveting may stretch thin sheets slightly, particularly with minimum rivet clearances, and this should not be allowed to accumulate by riveting, for example, straight along a line of rivets. The correct sequence of closing rivets can only be obtained by experience, and with each type of joint the order of riveting may vary slightly.

Solid rivets

The length of protruding shank which is flattened to close a rivet is known as the ‘allowance‘, and is expressed in terms of the rivet diameter ’D’. For normal reaction riveting the allowance is 1.5 D, and this is sufficient to form a flat head 1.5D in diameter and 0.5D thick; for this type of riveting these are the dimensions to be aimed at. On the rare occasions on which hand riveting may be required, an allowance of 1.5d is sufficient to form a snap head and 0.75D is sufficient to form a countersunk head. Rivets should always be used which are manufactured to the length required; cutting rivets to length is not recommended, since any tool marks in the rivet tail are possible sources of cracks when the tail is hammered.

Hand Hammering

Riveting by hand is only appropriate to certain types of older aircraft and elementary repairs to simple structures. When solid rivets are closed with a hand hammer, the manufactured (preformed) head should be supported by a suitably shaped dolly and the tail hammered to a thickness of 0.5D; if a snap head is required on the shank end, the tail should first be partly formed by hammer blows, than finished with a suitably shaped snap. It is most important that the dolly is backed by a heavy block or holder, and as few hammer blows as possible used. A large number of light blows will work-harden the rivet and result in cracks in the tail or difficulty in forming.

Pneumatic Hammering

In some instances it may be specified that a similar procedure should be used for pneumatic hammering as is described before. However, since the preformed rivet head is invariably on the outside of the aircraft and access to the interior often restricted, a type of riveting known as reaction riveting is more generally used. A suitably shaped snap (or ‘set’) is held in the riveting gun and a dolly (or ‘bucking bar’) held against the tail end. When the riveting gun is operated the tail is spread by the reaction of the dolly.

i. To prevent damage to the surface of the work when protruding head rivets are being closed, the radius of the recess in the snap should be slightly greater than the radius of the rivet head. For this reason, since rivets to different specifications (e.g. SP or AS) have slightly different shaped heads, use of the correct snaps is imperative.

ii. When flush rivets are being closed a snap should be used, but it may be found advantageous to use one with a slightly convex surface to prevent damaging the surrounding skin.

iii. The dolly should be as heavy as practicable, bearing in mind the space available, and should have a smooth surface to prevent damage to the rivet tail.

iv. The type of gun to use will depend on the size and type of rivets, but generally on aircraft work a fast-hitting type is used on rivets up to 1\4 inch diameter and a single-blow or slow, long-stroke type for larger rivets. As with hand hammering a few heavy blows are preferable to a large number of light blows.

Squeeze riveting

On large modern aircraft, extensive use of squeeze riveting is made when securing span wise stringers to preformed wing skins. It is part of an automatic process using large tape-controlled machines which drill, countersink, deburr, rivet and mill flush in one continuous action. This method of riveting is also used for the production of small assemblies or , when both sides of the work are accessible, during repair work. Squeeze riveting is also preferred when bonded laminated structures are to be riveted since, unless skill and care are exercise, reaction riveting tends to damage the bond. The rivets are closed by hydraulically or pneumatically operated machines, of which both static and portable types are available.

i. Before riveting with squeeze tools the working pressure should be adjusted, by experiment, to obtain the optimum value for the work in hand. Test pieces of the same materials, thickness and rivet diameter as the work in hand should be used and may be sectioned across the rivets to study the plastic distortion to be used for all work for which similar conditions apply, but must be readjusted if any changes occur in material, thickness or rivet size.

Blind Rivets

Special tools are required to close blind rivets, and it must be ensured that the correct types of nose piece and gripping jaws are fitted for the type and size of rivet to be closed.

Chobert rivets

A different sized mandrel is used with each diameter of rivet and it is important that the correct mandrel is selected. Before use it should be checked for diameter using an approved gauge, inspected for scratches or other damage likely to mark the rivet bore, and must be clean and lightly lubricated. Mandrels are subject to wear during use, and should normally be replaced when the head diameter has been reduced by approximately 0.002 inch. Use of a mandrel worn beyond these limits may result in incomplete closing of the rivet.

i. The correct length rivet must be chosen for the work in hand, and it should be noted that the size code for the rivet indicates the rivet length, but reference should be made to the manufacturer’s literature or the appropriate aircraft manual for exact details.

ii. In the case of single action tools the mandrel should be threaded through the rivet and inserted into the tool until the rivet head contacts the tool nose piece. The rivet should then be pushed into the hole and steady pressure applied at right angles to the work while the broaching action is completed.

iii. It is advisable to use a repetition gun when a large number of rivets have to be closed. The mandrels in these tools may be threaded into a tube containing approximately thirty rivets, and these are automatically positioned as each rivet is closed. High rates of closing are easily obtained.

iv. When sealing pins are used it must be ensured that they are the correct diameter for the particular rivet.

Avdel rivets

Avdel rivets are coded according to diameter and length, the grip, like Chobert rivets, being approximately 1\8 inch less than the length. They are pre-lubricated and must not be washed in solvent before use, but surplus sealant or jointing compound could be detrimental to the forming process and should be wiped off.

i. Each rivet should be assembled individually into the riveting gun, then inserted into the prepared hole and steady pressure applied at right angles to the work whilst the gun is operated.

ii. Milling of the sheared ends of stems is quite often specified and this normally involves the use of a special milling attachment on a standard air-operated drill, an adjustable stop being set to prevent cutting the rivet head or adjacent skin.

iii. When the rivets have been closed, the tightness of the stem should be checked with an Avdel Pin Tester, which is a tool having a retractable spring-loaded pin. The pin is pushed against the stem, and tightness may be considered satisfactory if there is no stem movement when the spring is fully compressed.

Cherry Rivets

A gauge is supplied by the manufacture of these rivets, which may be inserted into the rivet hole to measure the thickness of material to be riveted. The maximum grip of each rivet is marked on the rivet head, in sixteenths of an inch, and this figure should correspond to the gauge reading.

i. It is important that the appropriate pulling head for the riveting tool should be used, in accordance with the type and size of rivet. The rivet should be inserted into the prepared hole and the gun pressed over the stem until firm resistance is felt. The gun should then be operated while light pressure is applied towards the rivet.

ii. To check the stem locking ,a stem tester should be pressed against the sheared end of the stem; as with Avdel rivets, the stem locking may be considered satisfactory if no movement results when the tester is fully compressed.

iii. The sheared stem and locking collar may be milled to maintain specified protrusion limits, but care must be taken not to remove material from the rivet head or surrounding skin.

iv. On aircraft which have a bare metal exterior finish, it is sometimes specified that clear varnish should be applied to the heads of these rivets.

Pop Rivets

These rivets are most often closed by hand tools of the ‘lazytong’ type when used for repair work, although other types of hand and power tools are also available. The mandrel should be inserted while the tool is extended, the rivet placed in position and the tool operated by pressing firmly towards the rivet until the mandrel shears. If break-head type rivets are used the sheared heads should be collected, and not allowed to fall inside the aircraft structure. Long-break mandrels are specified where increased shear strength is required and should not be replaced by break-head or short-break types.

SPECIAL FASTENERS

Hi-Shear

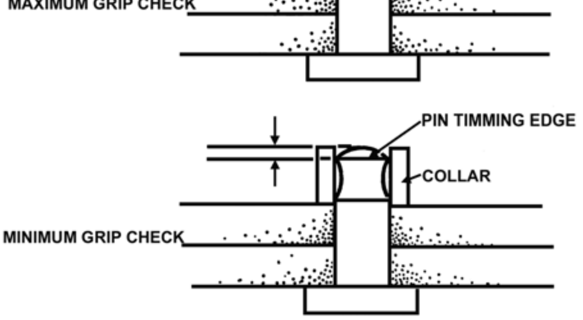


Fig. 19.3, Hi-Shear Pin Length Check

With these fasteners a simple check may be carried out to ensure that the pin is the correct length for the work to be joined. With the pin inserted in the hole, the edge of the pin groove should be protrued of the work surface and with the collar fitted the pin trimming edge should be inside the collar as a shown in figure 19.3. The fasteners are normally closed by hammering a special hi shear set against the collar, the pin head been supported by a dolly, but squeeze or reaction riveting may also be used if the normal method is impracticable.

Avdelok

The plain shank of these fasteners should be approximately equal to the thickness to be joined. The fasteners are normally closed by power operated tools, the gripping jaws pulling on the shank and the nose piece pushing against the collar, first clamping the plates together then swaging the collar into grooves on the shank. When swaging is complete the pin shears approximately level with the collar. If an interferance fit is specified closing should be in two operations, the first (without the collar fitted) pulling the pin into place and the second (with collar fitted) completing with swaging operation.

Jo-bolts

Due to the method of closure of these fasteners it is particularly important that the nut length is suitable for the thickness of the work. If the maximum grip of the fastener exceeds the thickness of work by more than 1\16 inch then the sleeve may not be properly expanded and a loose fastener could result.

i. The tool used to close these fasteners consists of an outer portion to prevent the nut from turning and an inner portion by means of which the bolt is rotated. Rotation of the bolt (which has a left-hand thread) forces a sleeve up the tapered nut shank to form a blind head; when the work is securely clamped, continued rotation shears the bolt inside the nut head. Grip of the bolt may be checked by attempting to turn the nut anticlockwise (i.e. tightening further)
ii. Different adaptors for the tools must be used for each size and type of Jo-bolt.

Rivnuts

When Rivnuts have a locating key to prevent rotation, the keyway should be cut with a special tool supplied by the nut manufacturer. To close Rivnuts the threaded mandrel of the special tool is screwed into the nut, and when the tool is operated the nut shank bulges towards the far side of the work to form a blind head. When the mandrel is removed a fixed nut is left in the in the structure and may be used for the attachment of de-icing boots ,etc.

INSPECTION

Riveted structures should be inspected after each of the following operations:-

i. After, marking-out, to ensure conformity with the repair scheme or the riveting methods used elsewhere on the aircraft.
ii. After drilling, to confirm the position of holes and ensure that hole size and condition are suitable for the type of rivets to be used.
iii. After countersink or dimpling, to check the mating of the parts involved, the condition of the countersink or dimple, and the flushness of rivet heads.
iv. After final assembly prior to riveting, to confirm the fit of the component and condition of any protective treatments.
v. After riveting, to ensure that rivets are satisfactorily formed, that there has been no significant distortion of the parts and, where specified, that jointing compound has been correctly applied.

It is important to ensure that techniques used for dimpling, countersinking, deburring, etc. are satisfactory, having regard to the type of materials and the tools available. As an example, the tools used to countersink aluminium alloys might be quite unsuitable for use with titanium, which work-hardens very quickly. Satisfactory techniques are best established by the manufacture of test pieces in similar materials, and using the same tools that will be used in the final work. Test pieces can be inspected by both destructive and non-destructive methods, and any faults eradicated by variation of the technique, until satisfactory samples are produced.

Pre-riveting inspections

Particular attention should be paid to the following points when inspecting parts prior to riveting.

i. Holes should be round, drilled at right angles to the work surface, have a diameter within the limits quoted by the aircraft manufacturer for the type of rivet, and sharp corners should be removed but not excessively chamfered. In certain instances a surface roughness may be specified by the manufacturer, and this should be checked by accepted methods. Normally, a finish consistent with good workshop practice and without axial scores, is satisfactory.
ii. A countersunk surface must be coaxial with the hole and cut to the required angle. The depth must be such that the rivet will comply with the flushness requirements of the aircraft manufacturer and on no account may the rivet head be below the skin surface. As with ordinary holes a surface roughness may be specified, but provided the countersunk surface is free from ‘chatter’ marks a finish consistent with good workshop practice is normally adequate.
iii. Dimples should be free from scores and should be of the correct angle. In this respect it should be noted that if

several sheets are dimpled for a countersunk rivet , the angle of the dimple in insuccessful sheets should vary to ensure correct nesting. Small radial cracks round the hole are generally acceptable in tertiary structures which have been dimpled from final size holes, but circumferential cracks round the dimple are cause for rejection.

iv. Mating parts should fit snugly without bending or forcing and should conform to the shape of the surrounding area.

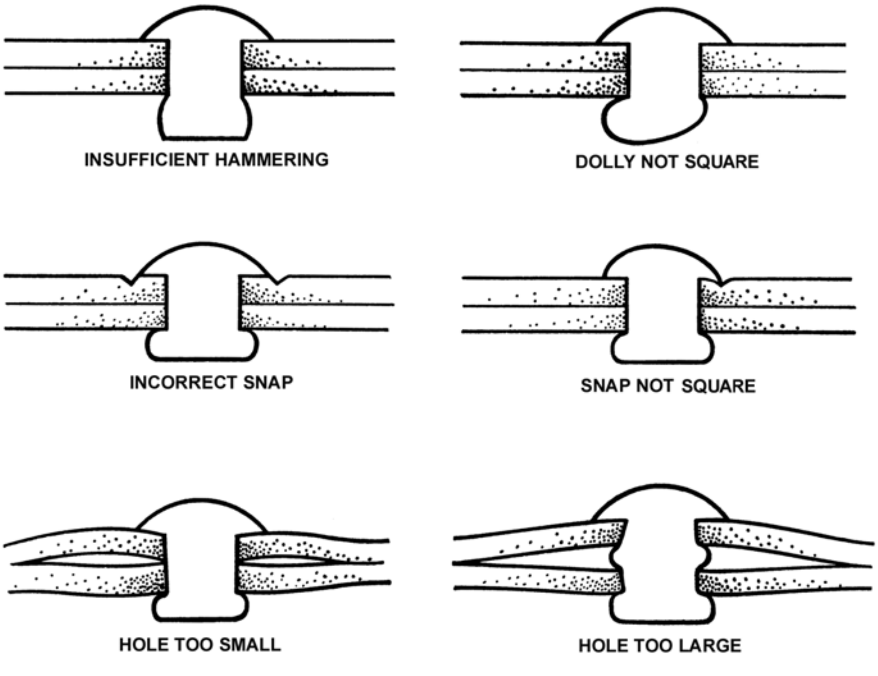
v. Before final assembly all parts should be separately deburred and swarf removed. The final protective treatment should be checked and, if necessary, rectified before application of jointing compound

INSPECTION OF RIVETS

After the rivets have been closed they should be inspected to ensure that they are tight and fully formed. Rivet head must not be deformed or cracked, and the surrounding area should be free from distortion and undamaged by the riveting tools. Rivets which are obviously not performing their function should be replaced, but replacement of rivets which are found to be only slightly below standard might do more harm than leaving them in position, particularly in thin materials. Before rejecting such rivets, the strength requirements of the particular joint and the effectiveness of the rivets, in question, should be considered. When a flushness tolerance is specified for countersunk rivets, this is normally checked before riveting is commenced; however, the milling of solid rivet heads may sometimes be permitted after riveting to obtain a uniform protrusion. In this case protective treatments must be re-applied after milling.

Solid Rivets

Figure 19.4, shows some of the faults which may be found with solid rivets. Superficial cracks a round the periphery of the head are usually acceptable, but not if intersecting cracks could lead to part of the head breaking off. Cracks in the inner area of the head, corresponding to the shank diameter, are not permitted. If snap heads are formed on the tail of the rivet a number of further faults may occur. These include a 'flash' round the rivet head if the shank was too long, and a small head, possibly accompanied by snap marks on the skin, if the shank was too short.



INSUFFICIENT HAMMERING

DOLLY NOT SQUARE

INCORRECT SNAP

SNAP NOT SQUARE

HOLE TOO SMALL

HOLE TOO LARGE

Fig. 19.4, Typical Riveting Faults.

Blind Rivets

The blind heads formed when these rivets are closed are not usually accessible for visual inspection and in some cases radiological examination may be specified. Visual inspection is normally limited to ensuring that the head is square to and in contact with the skin surface, that the locking collar (Cherry rivets) is properly engaged, and that no damage or buckling has been caused to the surrounding area. Where required, the flushness of countersunk rivets should also be checked.

Special Fasteners

These should be inspected to ensure that the axis of the fastener is at right angles to the work, that the head or collar, as appropriate, is correctly formed in accordance with the manufacturer's instructions, and that the work is not cracked or otherwise damaged around the hole.

Post Repair Inspections

When a riveted repair has been completed and finally checked for freedom from swarf and foreign matter, consideration should be given to the necessity for tests or inspections to determine whether the component is fit once again for service. The nature of the test or inspection will depend on the type of component repaired, but one or other of the following examples may be applicable:-

i. Flying control surfaces should be checked for balance and operation.
ii. Pressure cabins may require a pneumatic inflation and leak test or proof pressure test in accordance with the approved aircraft manual.
iii. Integral fuel tanks should be given a pressure test, followed by a flow test or other test relevant to the repair.
iv. Structure adjacent to moving mechanisms. The moving parts should be operated through their complete range of movement to ensure freedom from fouling . In some cases a minimum clearance may be specified to allow for flexing during aircraft operation.

■■■

CHAPTER : 20
GEARS, GEAR TRAINS AND BEARINGS

20.1 DETAILED KNOWLEDGE OF GEARS, GEAR MATERIALS, CLASSIFICATIONS

A gear is an important machine element which is used for transmission of power or motion or both from one shaft to the other. It is normally a round blank carrying projections or teeth along its periphery which enable a positive drive. Gears are vastly employed to from mechanisms for transmission of power from one part to the other in a machine and to effect change in speed or torque or both of one part with respect to the other. Many factors, such as the relative position of the two shafts, the load or power they are expected to transmit, space limitation, running conditions, speeds to be employed and similar other factors.

Gear making is a highly specialised job and so is their design. In this chapter we will confine our discussions to the former part, i.e., Gear making only and for the latter one, i.e., 'Gear design' some standard textbook on the subject may be consulted. A specific point to note here is that all gear cutting machines are single purpose machines as they can be used only for gear cutting. Even more specialised are those machines which cut only one type of gears. Milling machine, however, is a multipurpose machine which, in addition to gear cutting, performs many other operations but it is not suitable for mass production of gears. Its use is, therefore, confined to tool room work only where only a few gears are required to be cut or general repair work is carried out.

Developmental Background

The friction wheels are supposed to be the forerunners of the modern toothed wheels or gears. The friction wheels were simple round discs mounted at the ends of two shafts. The power transmission from one shaft to the other was due to the friction between the mating surfaces of the two wheels. That is why the name 'Friction wheels' was given to these wheels.

The principle of operation of two types of such wheels is shown in Fig. 20.1. The two mating wheels are pressed against each other and the amount of power transmission depends upon the friction between the mating surfaces of the two wheels. Inserts of some compressible material were normally used to increase the friction between the two wheels and, hence, their transmission efficiency. However, in modern practice, since the development of the toothed wheels, the use of friction gears is very rare except in case of very light items in which the torque is very low, such as in the table drive of record players.

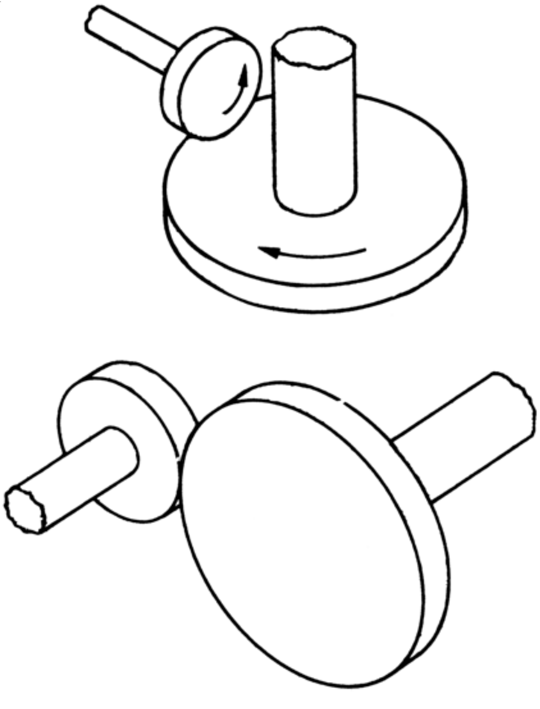


Fig. 20.1, Examples of two types of friction wheels.

20.1.1 On the Basis of Axes of Shaft

I. Spur Gears

They are the simplest of all the gears and are easiest in production. The teeth cut along the periphery are parallel to the axis of the gear. They are used to transmit power or motion between parallel shafts. Out of the two mating gears, the smaller is known as a pinion and larger one a wheel. (Fig. 20.2)

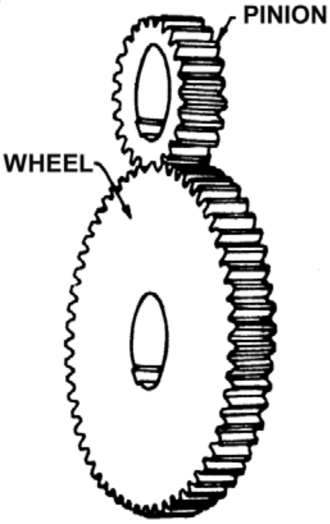


Fig. 20.2, Spur gears.

II. Helical Gears

These gears are more expensive and difficult in production than the former. The teeth along the periphery are at the angle to the axis of the gear. Each of these teeth forms a part of a helix or spiral. These gears are stronger and quicker than the spur gears because more number of teeth are in mesh at the same time and the engagement of teeth is gradual. With the result they provide a much smoother operation than the former and are preferred where very high speeds are employed. They may be used for transmission of power between both parallel as well as non-parallel shafts. These shafts may be coplaner or lie in different planes. The main disadvantages with these gears is that during the operation they develop an end thrust and for neutralising the same we have to employ a thrust bearing. Alternatively the single helical gears can be replaced by double helical gears, called herring bone gears.

III. Bevel Gears

They are used to connect shafts at any desired angle to one another, but not parallel. The most common angle between the connected shafts is normally 90°. The shafts may lie in the same plane or different planes. If power transmission is the only object the two mating gears may have same numbers or teeth, but if some speed reduction is also desired the number of teeth in the two will differ. The toothed body of bevel gear is actually a frustum of a cone. The straight bevel gear carries straight teeth which, if extended, will meet at a common point called apex. Apex also forms the point of intersection of the axes of the connected shafts. If the gear carries spiral teeth it is known as spiral bevel gear. Mitre gears is the name given to a pair of mating bevel gears in which each will have the same number of teeth and their axes will intersect at right angles to each other. Crown gear is the term used to denote a bevel gear which is cut on a plane surface instead of the usual conical one.

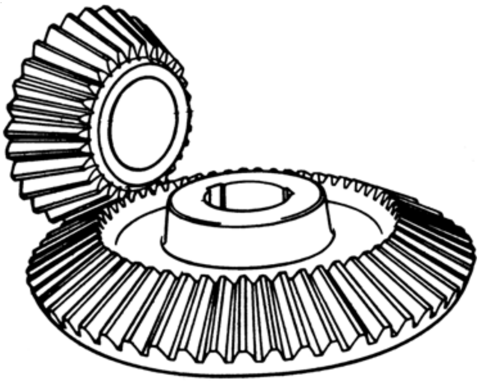


Fig. 20.3, Bevel gears (Straight Teeth)

IV. Spiral Gears

Skew or Spiral gearing illustrated in Fig. 20.4 is used to connect non-parallel, non-intersecting shafts. The pitch surfaces are cylindrical and the teeth have point contact. These gears are, therefore, suitable only for transmitting small power. The center distance for a pair of spiral gears is the shortest distance between the two shafts making any angle between them.

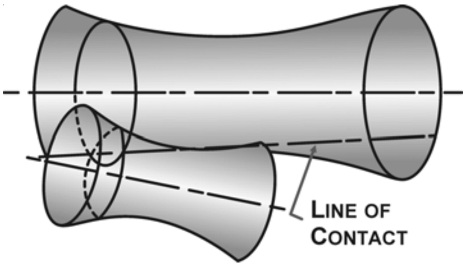


Fig. 20.4, Spiral Gear

V. Rack & Pinion

A rack can be best described as a gear of infinite radius. It works in conjunction with a small gear, called pinion. The combination provides a means to convert the reciprocating motion into rotary motion and vice versa.

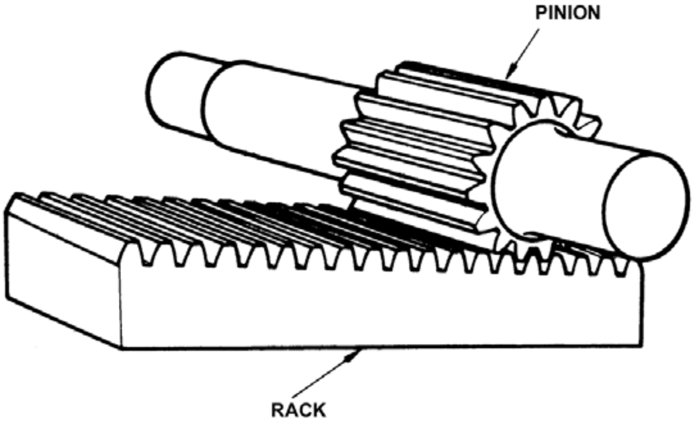


Fig. 20.5, Rack and pinion.

VI. Worm & worm wheel

A worm is more or less similar to a screw having single or multiple start threads which form the teeth of the worm. This worm drives the worm gear to enable transmission of power. The drive is non-reversible, i.e., the worm is always the driver and the worm gear the driven, or in other words we can say that worm gear cannot drive the worm. This is so due to small helix of worm gear teeth. So, for a non-reversible type gear drive this combination is an automatic choice. Another specific use of this combination is in speed reduction. By using a worm gear having many teeth considerable speed reduction can be effected which is not possible through other gearing systems within a limited space. The axes of worm gear are non-intersecting and at right angles. (Fig. 20.6).

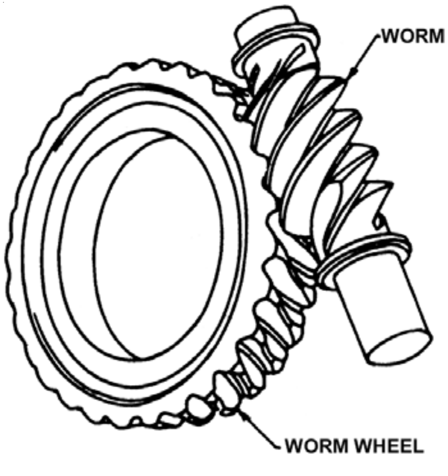


Fig. 20.6, Worm and worm gear (or worm wheel)

20.1.2 On the Basis of Linear Velocity

I. Low Velocity Gears

The gears having velocity less than 3 m/s are termed as low velocity gears.

II. Medium Velocity Gears

Gears having velocity between 3 and 15 m/s are known as medium velocity gears.

III. High Velocity Gears

The velocity of gears is more than 15 m/s, then these are called high speed gears.

18.2 TERMINOLOGY OF GEARS

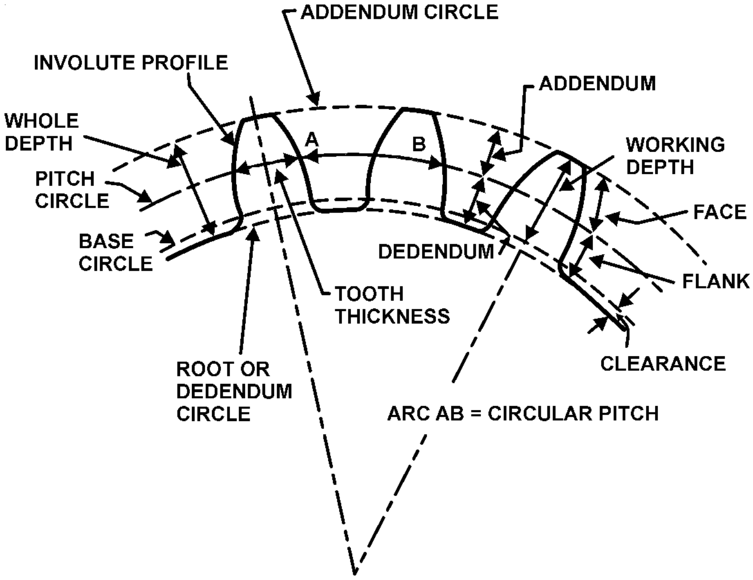


Fig.20.7, Terms used in gears.

Addendum circle

The circle which limits the tops of the gear teeth and represents its maximum diameter is called Addendum circle.

Addendum

It is the radial distance between the addendum circle and pitch circle.

Pitch circle

The circle on which fall the centres of the pitch cylinders, on which the tooth profiles are formed, is called pitch circle.

Dedendum

It is the radial distance between the pitch circle and the root circle.

Clearance

The distance between the top of a tooth of one gear and the bottom of the corresponding space of the mating gear is known as clearance.

Basic circle

It occurs only in involute gears and is that circle from which the involute curve of the tooth profile is generated.

Pressure angle

The angle made by the line of action with the common tangent to the pitch circle is called pressure angle. Its value is 14° or 20° for involute gears.

Face

The portion of tooth lying between the addendum 'circle and pitch circle is called face.

Flank

Portion of the tooth lying between the pitch circle and dedendum circle is called flank.

Thickness

Width of the tooth measured along the pitch circle is called the tooth thickness.

Backlash

The difference between actual tooth thickness and the width of space, with which it meshes, is known as backlash.

Circular pitch (p)

It is the distance between corresponding points of adjacent teeth measured along the pitch circle.

Diametral pitch (P)

It is a number that represents the number of teeth on the gear per unit of diameter of the pitch circle.

i.e., $P = \frac{N}{d}$

where, N = number of teeth in the gear
and d = diameter of pitch circle.

Module (M)

It can be described as the metric standard for pitch. It is the linear distance in mm that each tooth of the gear would occupy if the gear teeth were spaced along the pitch diameter.

Important ratios

Let, d = pitch circle dia
R = pitch circle radius
P = diametral pitch
p = circular pitch
M = module
N = No. of teeth in gear
Add. = Addendum
Ded. = Dedendum

Then, $P = \frac{N \text{ (No. of teeth in gear)}}{d \text{ (dia. of pitch circle)}}$

or, $$d = \frac{N}{P} \qquad \text{(i)}$$

Also, $$M = \frac{d}{N} = \frac{1}{P} \qquad \text{(ii)}$$

or, $d = M \times N$

Now, $\pi d = N \times P$

$$\therefore \quad d = \frac{N.P}{\pi} \qquad \text{(iii)}$$

Equating (i) and (iii)

$$\frac{N}{P} = \frac{N.p}{\pi}$$

or $$p = \frac{\pi.N}{P.N} = \frac{\pi}{P} \qquad \text{(iv)}$$

Again, $$p = \frac{N}{d} \text{ or } d = \frac{N}{P} \qquad \text{(v)}$$

and, $$M = \frac{\text{pitch circle dia.}}{\text{no. of teeth}} = \frac{d}{N} \text{or } d = MN \qquad \text{(vi)}$$

Equating (v) and (vi), we get :

$$MN = \frac{N}{p}$$

or, $$M = \frac{N}{N.P} = \frac{1}{p} \qquad \text{(vii)}$$

Standard modules

The Indian Standards Institution has recommended the following modules (in mm) in order of preference.

First choice

1, 1.25, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 16, 20.

Second choice

1.125, 1.375, 1.75, 2.25, 2.75, 3.5, 4.5, 5.5, 7.9, 11, 14, 18.

Third choice

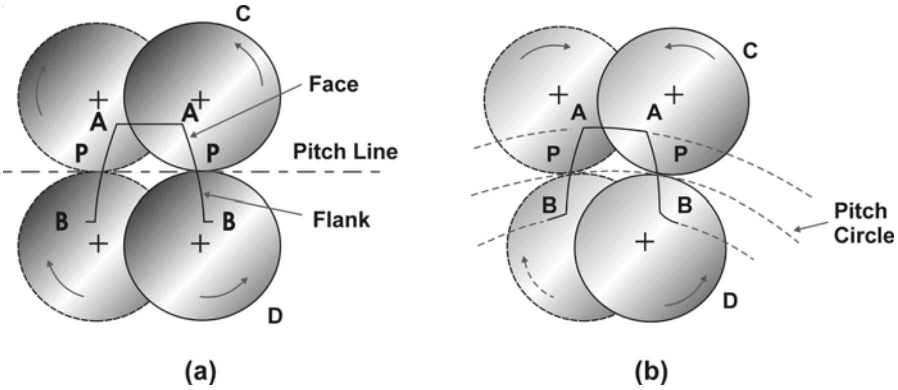
3.25, 3.75, 6.5.

18.3 TEETH, CYCLOIDAL & INVOLUTE

Cycloidal Teeth

A cycloid is the curve traced by a point on the circumference of a circle which rolls without slipping on a fixed straight line. When a circle rolls without slipping on the outside of a fixed circle, the curve traced by a point on the circumference of a circle is known as epi-cycloid. On the other hand, if a circle rolls without slipping on the inside of a fixed circle, then the curve traced by a point on the circumference of a circle is called hypo-cycloid.

In Fig. 20.8 (a), the fixed line or pitch line of a rack is shown. When the circle C rolls without slipping above the pitch line in the direction as indicated in Fig. 20.8 (a), then the point P on the circle traces epi-cycloid PA. This represents the face of the cycloidal tooth profile. When the circle D rolls without slipping below the pitch line, then the point P on the circle D traces hypo-cycloid PB, which represents the flank of the cycloidal tooth. The profile BPA is one side of the cycloidal rack tooth. Similarly, the two curves P'A' and P'B' forming the opposite side of the tooth profile are traced by the point P' when the circles C and D roll in the opposite directions.



(a) (b)

Fig. 20.8, Construction of cycloidal teeth of a gear.

In the similar way, the cycloidal teeth of a gear may be constructed as shown in Fig. 20.8 (b). The circle C is rolled without slipping on the outside of the pitch circle and the point P on the circle C traces epi-cycloid PA, which represents the face of the cycloidal tooth. The circle D is rolled on the inside of pitch circle and the point P on the circle D traces hypo-cycloid PB, which represents the flank of the tooth profile. The profile BPA is one side of the cycloidal tooth. The opposite side of the tooth is traced as explained above.

The construction of the two mating cycloidal teeth is shown in Fig. 20.9. A point on the circle D will trace the flank of the tooth T_1 when circle D rolls without slipping on the inside of pitch circle of wheel 1 and face of tooth T_2 when the circle D rolls without slipping on the outside of pitch circle of wheel 2. Similarly, a point on the circle C will trace the face of tooth T_1 and flank of tooth T_2. The rolling circles C and D may have unequal diameters, but if several wheels are to be interchangeable, they must have rolling circles of equal diameters.

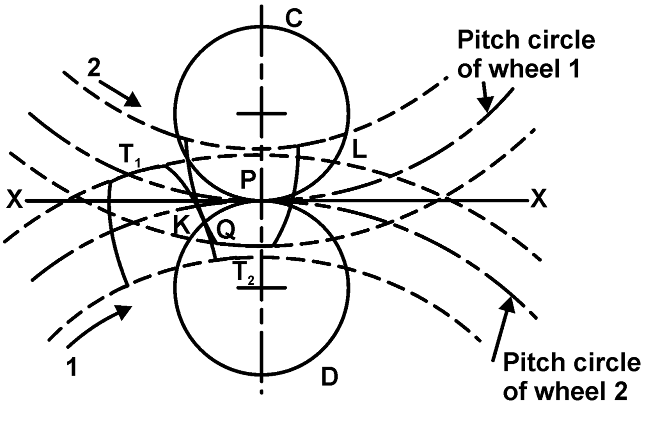


Fig. 20.9, Construction of two mating cycloidal teeth.

A little consideration will show, that the common normal XX at the point of contact between two cyclidal teeth always passes through the pitch point, which is the fundamental condition for a constant velocity ratio.

Involute Teeth

An involute of a circle is a plane curve generated by a point on a tangent, which rolls on the circle without slipping or by a point on a taut string which in unwrapped from a reel as shown in Fig. 20.10. In connection with toothed wheels, the circle is known as base circle. The involute is traced as follows :

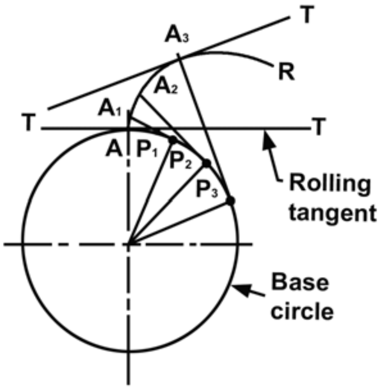


Fig. 20.10, Construction of involute.

Let A be the starting point of the involute. The base circle is divided into equal number of parts e.g. AP_1, P_1P_2, P_2P_3 etc. The tangents at P_1, P_2, P_3 etc. are drawn and the length P_1A_1, P_2A_2, P_3A_3 equal to the arcs AP_1, AP_2 and AP_3 are set off. Joining the points A, A_1, A_2, A_3 etc, we obtain the involute curve AR. A little consideration will show, that at any instant A_3, the tangent A_3T to the involute is perpendicular to P_3A_3 and P_3A_3 is the normal to the involute. In other words normal at any point of an involute is a tangent to the circle.

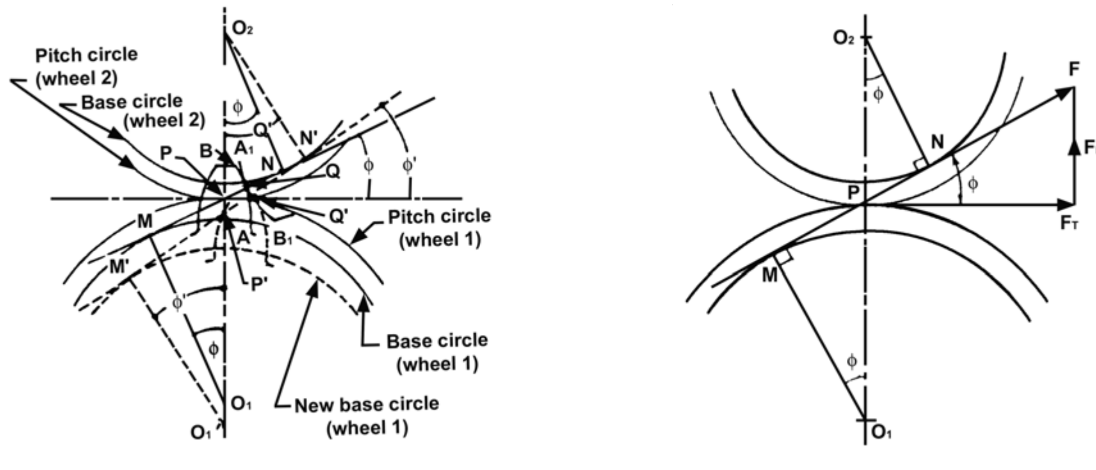
Now, let O_1 and O_2 be the fixed centres of the two base circles as shown in Fig. 20.11 (a). Let the corresponding involutes AB and A_1B_1 be in contact at point Q. MQ and NQ are normals to the involutes at Q and are tangents to base circles. Since the normal of an involute at a given point is the tangent drawn from that point to the base circle, therefore the common normal MN at Q is also the common tangent to the two base circles. We see that the common normal MN intersects the line of centres O_1O_2 at the fixed point P (called pitch point). Therefore the involute teeth satisfy the fundamental condition of constant velocity ratio.

From similar Triangles O_2NP and O_1MP,

$$\frac{O_1M}{O_2N} = \frac{O_1P}{O_2P} = \frac{\omega_2}{\omega_1}$$

which determines the ratio of the radii of the two base circles. The radii of the base circles is given by

$$O_1M = O_1P\cos\phi, \text{ and } O_2N = O_2P\cos\phi$$



(a) (b)

Fig. 20.11, Involute teeth

Also the centre distance between the base circles,

$$O_1O_2 = O_1P + O_2P = \frac{O_1M}{\cos\phi} + \frac{O_2N}{\cos\phi} = \frac{O_1M + O_2N}{\cos\phi}$$

where ϕ is the pressure angle or the angle of obliquity. It is the angle which the common normal to the base circles (i.e. MN) makes with the common tangent to the pitch circles.

When the power is being transmitted, the maximum tooth pressure (neglecting friction at the teeth) is exerted along the common normal through the pitch point. This force may be resolved into tangential and radial or normal components. These components acts along and at right angles to the common tangent to the pitch circles.

If F is the maximum tooth pressure as shown in Fig. 20.11 (b), then

Tangential force, $F_T = F\cos\phi$

and radial or normal force, $F_R = F\sin\phi$

$\therefore$ Torque exerted on the gear shaft

$= F_T \times r$, where r is the pitch circle radius of the gear.

Note

The tangential force provides the driving torque and the radial or normal force produces radial deflection of the rim and bending of the shafts.

20.4 INTERFERENCE

Fig. 20.12 shows a pinion with centre O_1, in mesh with wheel or gear with centre O_2. MN is the common tangent to the base circles and KL is the path of contact between the two mating teeth.

A little consideration will show, that if the radius of the addendum circle of pinion is increased to O_1N, the point of contact L will move from L to N. When this radius is further increased, the point of contact L will be on the inside of base circle of wheel and not on the involute profile of tooth on wheel. The tip of tooth on the pinion will then undercut the tooth on the wheel. This effect is known as interference, and occurs when the teeth are being cut. In brief, the phenomenon when the tip of tooth undercuts the root on its mating gear is known as interference.

Similarly, if the radius of the addendum circle of the wheel increases beyond O_2M, then the tip of tooth on wheel will cause interference with the tooth on pinion. The points M and N are called interference points. Obviously, interference may be avoided if the path of contact does not extend beyond interference points. The limiting value of the radius of the addendum circle of the pinion is O_1N and of the wheel is O_2M.

From the above discussion, we conclude that the interference may only be avoided, if the point of contact between the two teeth is always on the involute profiles of both the teeth. In other words, interference may only be prevented, if the addendum circles of the two mating gears cut the common tangent to the base circles between the points of tangency.

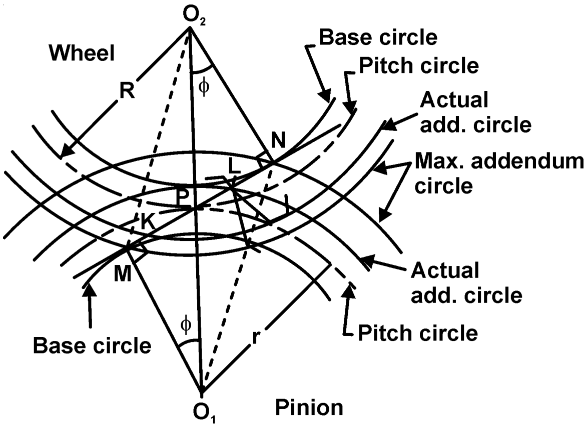


Fig. 20.12, Interference in involute gears.

18.5 TYPE OF GEAR TRAINS

I. Simple Gear Trains

When the distance between the two shafts is small, the two gears 1 and 2 are made to mesh with each other to transmit motion from one shaft to the other, as shown in Fig. 20.13 (a). Since the gear 1 drives the gear 2, therefore gear 1 is called the driver and the gear 2 is called the driven or follower. It may be noted that the motion of the driven gear is opposite to the motion of driving gear.

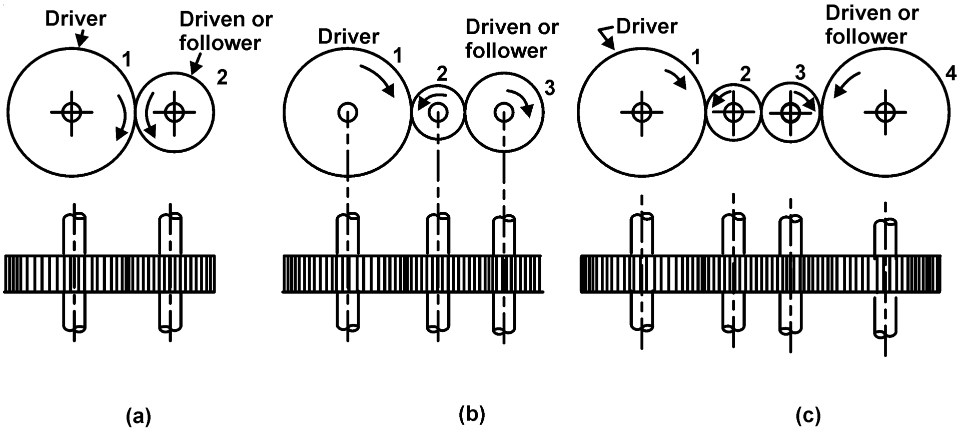


Fig. 20.13, Simple gear train.

Let N_1 = Speed of gear 1 (or driver) in r.p.m.,

N_2 = Speed of gear 2 (or driven or follower) in r.p.m.,

T_1 = Number of teeth on gear 1, and

T_2 = Number of teeth on gear 2.

Since the speed ratio (or velocity ratio) of gear train is the ratio of the speed of the driver to the speed of the driven or follower and ratio of speeds of any pair of gears in mesh is the inverse of their number of teeth, therefore

$$\text{Speed ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

It may be noted that ratio of the speed of the driven or follower to the speed of the driver is known as train value of the gear train. Mathematically

$$\text{Train value} = \frac{N_2}{N_1} = \frac{T_1}{T_2}$$

From above, we see that the train value is the reciprocal of speed ratio.

II. Compound Gear Train

When there are more than one gear on a shaft, as shown in Fig. 20.14, it is called a compound train of gear.

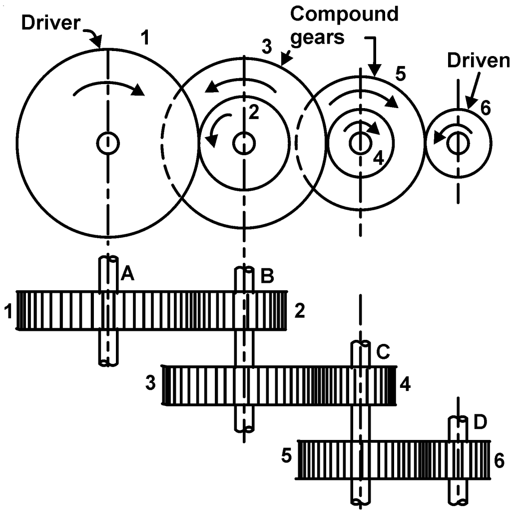


Fig. 20.14, Compound gear train.

We have seen earlier that the idle gears, in a simple train of gears do not effect the speed ratio of the system. But these gears are useful in bridging over the space between the driver and the driven.

But whenever the distance between the driver and the driven or follower has to be bridged over by intermediate gears and at the same time a great (or much less) speed ratio is required, then the advantage of intermediate gears is intensified by providing compound gears on intermediate shafts. In this case, each intermediate shaft has two gears rigidly fixed to it so that they may have the same speed. One of these two gears meshes with the driver and the other with the driven or follower attached to the next shaft as shown in Fig. 20.14.

In a compound train of gears, as shown in Fig. 20.14, the gear 1 is the driving gear mounted on shaft a, gears 2 and 3 are compound gears which are mounted on shaft B. The gears 4 and 5 are also compound gears which are mounted on shaft C and the gear 6 is the driven gear mounted on shaft D.

III. Design of Spur Gears

Sometimes, the spur gear (i.e. driver and driven) are to be designed for the given velocity ratio and distance between the centres of their shafts.

Let x = Distance between the centres of two shafts,
N_1 = Speed of the driver,
T_1 = Number of teeth on the driver,
d_1 = Pitch circle diameter of the driver,
N_2, T_2 and d_2 = Corresponding values for the driven or follower, and
pc = Circular pitch

We know that the distance between the centres of two shafts,

$$x = \frac{d_1 + d_2}{2} \qquad \text{(i)}$$

and speed ratio or velocity ratio,

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{T_2}{T_1} \qquad \text{(ii)}$$

From the above equations, we can conveniently find out the values of d1 and d2 (or T_1 and T_2) and the circular pitch (p_c). The values of T_1 and T_2, as obtained above, may or may not be whole numbers. But in a gear since the number of its teeth is always a whole number, therefore a slight alterations must be made in the values of x, d_1 and d_2, so that the number of teeth in the two gears may be a complete number.

IV. Reverted Gear Train

When the axes of the first gear (i.e. first driver) and the last gear (i.e. last driven or follower) are co-axial, then the gear train is known as reverted gear train as shown in Fig. 20.15.

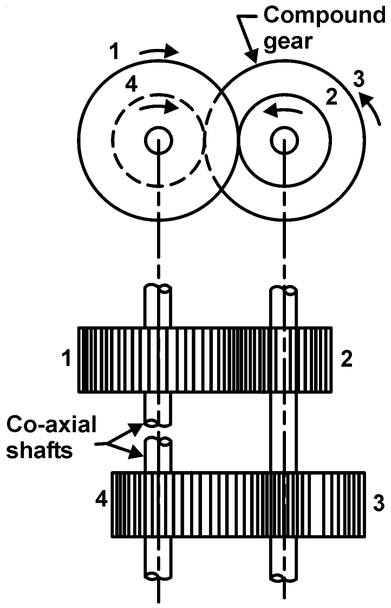


Fig. 20.15, Reverted gear train.

We see that gear 1 (i.e. first driver) drives the gear 2 (i.e. first driven or follower) in the opposite direction. Since the gears 2 and 3 are mounted on the same shaft, therefore they form a compound gear and the gear 3 will rotate in the same direction as that of gear 2. The gear 3 (which is now the second driver) drives the gear 4 (i.e. the last driven or follower) in the same direction as that of gear 1. Thus we see that in a reverted gear train, the motion of the first gear and the last gear is like.

Let T_1 = Number of teeth on gear 1,
r_1 = Pitch circle radius of gear 1, and
N_1 = Speed of gear 1 in r.p.m.

Similarly,

T_2, T_3, T_4 = Number of teeth on respective gears,
r_2, r_3, r_4 = Pitch circle radii of respective gears, and
N_2, N_3, N_4 = Speed of respective gears in r.p.m.

Since the distance between the centres of the shafts of gears 1 and 2 as well as gears 3 and 4 is same, therefore

$$r_1 + r_2 = r_3 + r_4 \qquad \text{(i)}$$

Also, the circular pitch or module of all the gears is assumed to be same, therefore number of teeth on each gear is directly proportional to its circumference or radius.

$$\therefore \qquad T_1 + T_2 = T_3 + T_4 \qquad \text{(ii)}$$

and
$$\text{Speed ratio} = \frac{\text{Product of number of teeth on drivens}}{\text{Product of number of teeth on drivers}}$$

or
$$\frac{N_1}{N_4} = \frac{T_2 \times T_4}{T_1 \times T_3} \qquad \text{(iii)}$$

From equations (i), (ii) and (iii), we can determine the number of teeth on each gear for the given centre distance, speed ratio and module only when the number of teeth on one gear is chosen arbitrarily.

The reverted gear trains are used tin automotive transmissions, lathe back gears, industrial speed reducers, and in clocks (where the minute and hour hand shafts are co-axial)

V. Epicyclic Gear Train

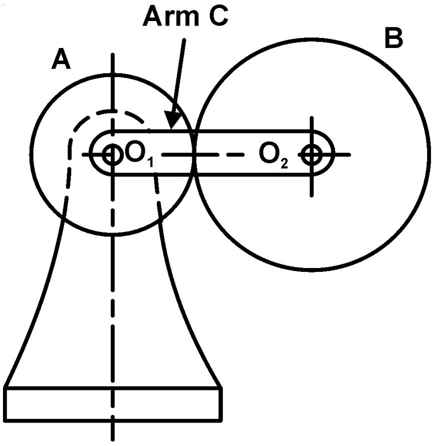


Fig. 20.16, Epicyclic gear train.

We have already discussed that in an epicyclic gear train, the axes of the shafts, over which the gears are mounted, may move relative to a fixed axis. A simple epicyclic gear train is shown in Fig. 20.16, where a gear a and the arm C have a common axis at O_1 about which they can rotate. The gear B meshes with gear A and has its axis on the arm at O_2, about which the gear B can rotate. If the arm is fixed, the gear train is simple and gear A can drive gear B or vice versa, but if gear A is fixed and the arm is rotated about the axis of gear A (i.e. O_1), then the gear B is forced to rotate upon and around gear A. Such a motion is called epicyclic and the gear trains arranged in such a manner that one or more of their members move upon an around another member are known as epicyclic gear trains (epi. means upon and cyclic means around). The epicyclic gear trains may be simple or compound.

The epicyclic gear trains are useful for transmitting high velocity ratios with gears of moderate size in a comparatively lesser space. The epicyclic gear trains are used in the back gear of lathe, differential gears of the automobiles, hoists, pulley blocks, wrist watches etc.

■ ■ ■

CHAPTER : 21
BEARINGS

INTRODUCTION

This chapter gives information on the uses of the various types of ball and roller bearings, and general guidance on installation, maintenance and inspection. Methods of assessing wear are described, but the appropriate aircraft manual should be consulted for the amount of play or clearance permitted, in any installation in which rolling bearings are used.

SHAFT BEARINGS

Bearing play an important role in power transmission and their fitting and maintenance must, therefore, be given a careful consideration. A proper bearing should always be selected for a particular use. During use, excessive pressure must be avoided as the same is likely to squeeze out the oil, causing abrasion of the metals in contact and a sudden rise in temperature. The various metals generally used to form bearing surfaces are cast iron, steel, bronze and babbitt metal. Out of these, cast iron should be used only for light pressures and speeds. All the bearings should have a continuous lubrication, ring lubrication being the most common method for the same. A particular precaution should always be taken that no dirt or other foreign material enters between the shaft and the bearing, otherwise it will cause abrasion and reduce the life of the bearing.

Bearings provide support to different shafts and spindles during power transmission. In group drive system, they support the main driving shaft and the countershafts and the machine spindles of the driven shafts of the machinery. In individual drive system also they provide support to countershafts and machine spindles. In the former case, rails, hangers and brackets are used to support the bearings at proper locations. The choice of a hanger or a bracket will depend upon the position of the shaft to be supported. If the main driving shaft is located away from the vertical wall of the workshop, horizontal rails can be grouted in the walls and the bearings mounted over them to support the running shaft. If the main shaft is to run close to the roof, hangers can be suspended from the roof at suitable locations and bearings supported in them. In this system, the countershafts are generally mounted close to the walls and are usually supported in bearings mounted in the brackets grouted in the walls. In individual drive also, countershafts and machine spindles are required to be supported in suitable bearings. So, this can be taken as master rule that whenever and wherever shafts and spindles are used for power transmission, bearings are essentially required to support them and enable them to run true.

TYPES OF PLAIN BEARINGS

The common plain shaft bearings are mainly classified into the following three groups :

1. Journal bearings

These are the simplest of all the bearings. In its simplest form, called the Simple or Solid bearing, it is a solid block carrying a central hole to accommodate the shaft journal. That portion of the shaft which remains inside the bearing is called journal. This bearing, shown in Fig. 21.1, bears the load of the shaft in a direction normal to the axis of the shaft, as shown. A countersunk hole at the top is provided for lubrication purpose. This bearing is, however, hardly used these days.

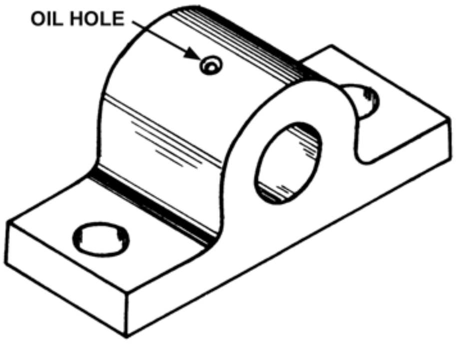


Fig. 21.1, A simple or solid journal bearing.

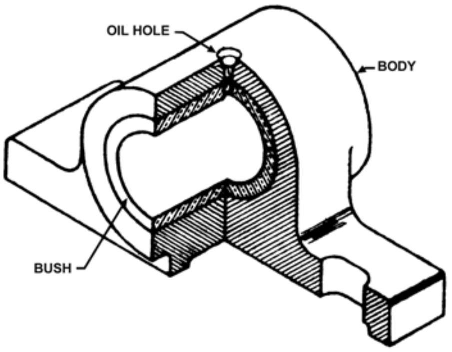


Fig. 21.2, A bushed bearing.

An improved variety of this type of bearing, known as Bushed Bearing, is shown in Fig. 21.2. It carries a brass or gun metal bush and, as usual, a lubrication hole at the top. The main advantage of using the bush is that it can be replaced by another bush when it is worn out. Thus, the same bearing block can continue to be used by replacing the worn out bushes.

A highly improved variety of bushed bearing, which suits best for supporting large sized shafts running at higher loads and higher speeds, is a Plummer Block or Pedastal Bearing, shown at Fig. 21.3. It, however, needs a careful and proper lubrication for its efficient performance. As shown, it mainly consists of a cast iron pedastal, as the main supporting member, bushes iron pedastal, as the main supporting member, bushes made of a gun metal or bronze in two halves, a cast iron-cap and mild steel bolts and nuts to complete the assembly. The bushes are also known as brasses or steps. Provision is always made to prevent rotation of brasses. The following main advantages are associated with the use of this bearing :

a. Removal and replacement of brasses is easy, because they are made in two halves.
b. Placement and removal of the shaft is easy, because only the cap is to be removed for the purpose.
c. At site adjustment for wear in brasses is possible by simply tightening the cap.
d. Chances of axial movement of brasses are eliminated by providing flanges or collars on either end.
e. Changes of rotation of brasses are eliminated by proper design, such as providing sungs, providing flats on the outer surface etc.,

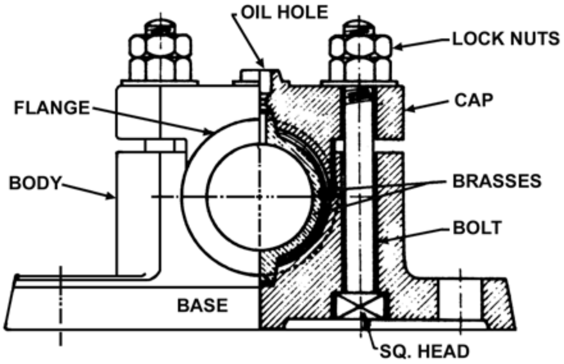


Fig. 21.3, A plummer block or pedastal bearing.

2. Footstep bearing

It is also known as Pivot Bearing and is used to support a vertical shaft. As shown in Fig. 21.4, it consists of a supporting casting or body with a sole, a gun metal bush or liner with a collar at its top and a gun metal disc or pad. A snug is provided at the bottom of the pad to prevent its rotation. The four holes in the sole enable fastening of the bearing by means of bolts and nuts to a suitable supporting base. A neck is provided in the bush below the collar to prevent its rotation. The top inside surface of the bush is made slightly larger than the shaft to provide clearance for lubrication. If the gunmetal bush or disc is worn out during use it can be replaced by a new one instead of replacing the complete bearing. The pressure in this bearing is exerted by the shaft in a vertical direction i.e. parallel to its axis.

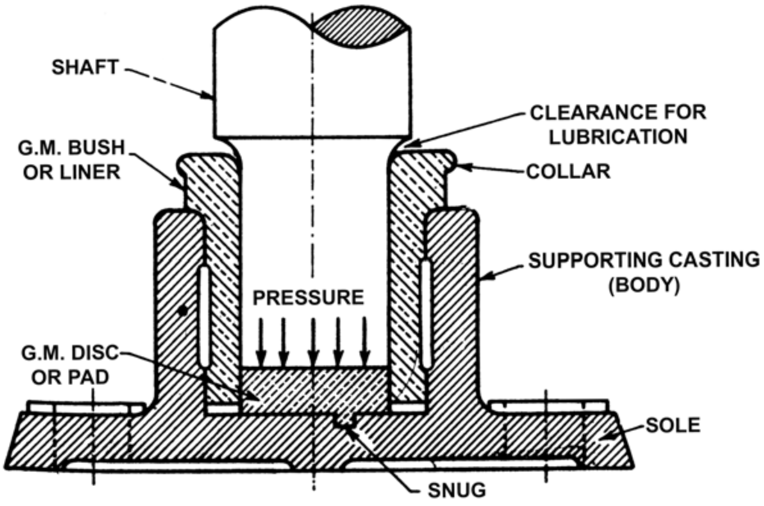


Fig. 21.4, A footstep or pivot bearing.

3. Thrust or collar bearings

These bearings are used to support those shafts which exert end thrust, i.e., the pressure is parallel to the axis of the shaft in a horizontal direction. Obviously, the support pressure also acts parallel to the shaft. Examples of use of such bearings can be seen in different types of turbines, propeller shafts and metal working machinery, etc. In pivot bearing also the bearing pressure acts parallel to the axis of the shaft, but in that case the shaft is supported at its end and does not pass through the bearing. In case of the thrust bearing, the shaft passes through and extends beyond the bearing.

The shaft, according to requirement, may carry one or more collars. These collars rest against the bearing surfaces. When the shaft carries only one collar the thrust bearing is known as a single collar thrust bearing or simply a collar bearing, and when it carries more than one collars the bearing is called a multicollar thrust bearing or simply a Thrust bearing. These two types of bearings with their main features are shown schematically in Figs. 21.5 and 21.6 respectively. Construction details of these can, however, be obtained from some good book on machine drawing and design, if needed.

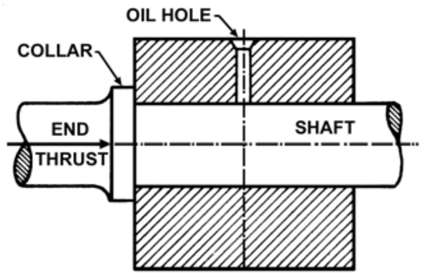


Fig. 21.5, A collar bearing.

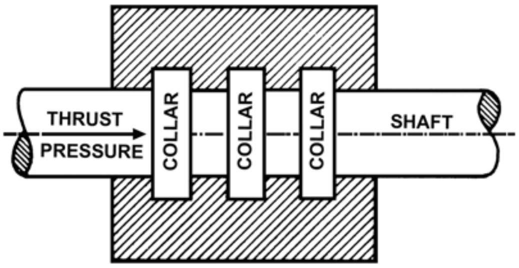


Fig. 21.6, A thrust bearing.

Common features of plain bearings

The term 'Plain bearings' encompasses all the types of bearings discussed above. The following features are common in all these bearings :

a. The shaft journal rotates in a housing (solid bearing), a bush or liner.
b. There is always a sliding friction between the shaft and the bush or liner.
c. The starting friction in these bearings is high.
d. As compared to other types of bearings, say ball or roller, the frictional losses are more.
e. For easy adjustment, most of the plain bearings are made in two parts - a body and the cap.
f. Adequate clearance is always provided between the shaft journal and bearing surface so as to accommodate the lubricant.
g. Although they do not possess a high degree of precision, these bearings are very rigid and strong. They are, therefore, widely used where strength and rigidity are prime considerations.
h. These bearings are simple in construction and manufacturing and are cheap.
i. For efficient operation and longer life, all these bearings require very regular and effective lubrication.

TYPES OF ROLLER BEARINGS AND THEIR USES

Bearings are broadly classified by the type of rolling element used in their construction. Ball bearings employ steel balls which rotate in grooved raceways, whilst roller bearings utilise cylindrical, tapered or spherical rollers, running in suitably shaped raceways. Both types of bearings are designed for operation under continuous rotary or oscillatory conditions, but, whilst ball bearings and tapered roller bearings accept both radial and axial loads, other types of roller bearings accept mainly radial loads. The following paragraphs amplify the uses of the various types of bearings, and examples are shown in Figure 21.7.

Caged bearing are in general use for engine applications and in equipment with rotational speeds in excess of approximately 100 rev/min. Most other bearings on an aircraft are intended for oscillating or slow rotation conditions and do not have a cage; they are generally shielded or sealed and pre-packed with grease, but some have re lubrication facilities.

Ball Bearings

These bearings may be divided into four main groups, namely radial, angular contact, thrust and instrument precision bearings.

Radial Bearings

This is the most common type of rolling bearing and is found in all forms of transmission assemblies such as shafts, gears and control-rod end fittings. The bearings are manufactured with the balls in either single or double rows, rigid for normal applications, or self-aligning for positions where accurate alignment cannot be maintained. Such bearings may also be provided with metal shields or synthetic rubber seals to prevent the ingress of foreign matter and retain the lubricant, and with a cir clip groove or flange for retention purposes. The balls are often retained in a cage, but in some case filling slots in the inner and outer rings permit individual insertion of the balls, thus allowing a larger number of balls to be used and giving the bearing a greater radial load capacity; however, axial loads are limited due to the presence of the raceway interruptions.

Angular Contact Bearings

These bearings are capable of accepting radial loads, and axial loads in one direction. The outer ring is recessed on one side to allow the ball and cage assembly to be fitted, thus enabling more balls to be used and the cage to be in one piece.

The axial loading capacity of an angular contact bearing depends to a large extent on the contact angle. To achieve the contact angle large radial internal clearances are usually employed; the standards of clearance specified for radial bearings do not normally apply.

i. In applications where axial loads will always be in one direction, a single angular contact bearing may be used, but where axial loads vary in direction an opposed pair of bearings is often used, and adjusted to maintain the required axial clearance.

ii. A particular type of angular contact bearing, known as a duplex bearing, is fitted with a split inner or outer ring, and is designed to take axial loads in either direction. The balls make contact with two separate raceways in each ring, and one essential condition of operation is that the bearing should never run unloaded. The bearings are not adjustable, and radial loads should always be lighter than axial loads. This is a most efficient form of thrust bearing and is not speed limited as is the washer type described below.

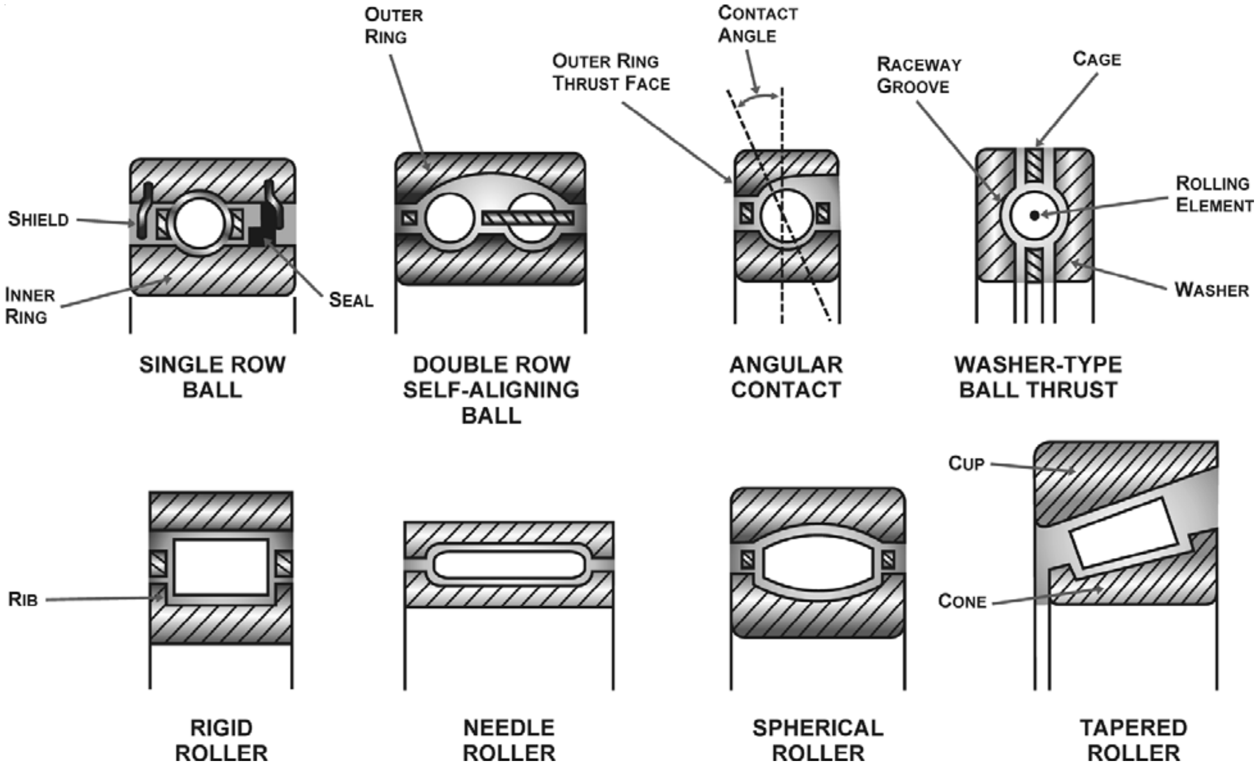


Fig.21.7, Examples of Ball and Roller Bearings

Thrust Bearings

Thrust bearings are designed for axial loading only, and are normally used in conjunction with a roller bearing or radial ball bearing. The balls are retained in a cage and run between washers having either flat or grooved raceways. Centrifugal loading on the balls has an adverse effect on the bearings and they are, therefore, most suitable for carrying heavy loads at low speeds.

Instrument Precision Bearings

These bearings are used mainly in instrument and communication equipment, and care manufactured to a high degree of accuracy and finish. They are generally of the radial bearing type without filling slots, although other types are obtainable. Tolerances quoted in BS 3469 for instrument precision bearings are closer than those quoted in BS 292 for standard ball and roller bearings, and only three classes of radial internal clearance are specified. BS 3469 also contains details of test procedures for instrument precision bearings.

NOTE

Neither BS 3469 nor BS 292 quotes tolerances for axial clearance.

Roller Bearings

Roller bearings may be divided into three main groups, according to whether they have cylindrical, spherical or tapered rollers.

Cylindrical Roller Bearings

These bearings are capable of carrying greater radial loads than ball bearings of similar external dimensions, due to the greater contact area of the rolling elements. Bearings with ribs on both rings will also carry light, intermittent, axial loads.

i. The type of cylindrical roller bearing most commonly used is that in which the diameter and length of the rollers are equal, and standard sizes within this type are listed in BS 292. Bearings having rollers of a length greater than their diameter are also used for special applications.

ii. A different kind of bearing in this category is the needle roller bearing, in which the length of the rollers is several times greater than their diameter. These bearings are designed for pure radial loads and are often used in locations where the movement is oscillatory rather than rotary, such as universal couplings and control-rod ends. Needle bearing are particularly useful in locations where space is limited, and are often supplied as a cage and roller assembly, the shaft of the components acting as the inner ring. The dimensions and surface finish of the shaft must be closely controlled to the standards specified by the bearing manufacturer. These bearings are particularly susceptible to the effects of misalignment and lack of lubricant, and may also be subject to brinelling, due to the lack of rotational movement.

NOTE

"Brinelling" is indentation of the surface of a material, resembling the indentations formed during a Brinell hardness test.

Tapered Roller Bearings

These bearings are designed so that the axes of the rollers form an angle with the shaft axis. They are capable of accepting simultaneous radial loads and axial loads in one direction, the proportions of the loads determining the taper angle. Tapered roller bearings are often mounted back to back in pairs, and adjusted against each other to obtain a working clearance. Because the axial load on the rollers results in rubbing contact on the cone rib, careful lubrication is essential, particularly at high speeds.

Spherical Roller Bearings

A spherical roller bearing may have one or two rows of rollers which run in a spherical raceway in the outer ring, thus enabling the bearing to accept a minor degree of misalignment between opposite bearings. The bearing is capable of withstanding heavy radial loads, and moderate axial loads from either direction.

RADIAL INTERNAL CLEARANCE

Radial ball bearings and cylindrical roller bearings are manufactured with various amounts of radial internal clearance. Standard bearings are available in four grades of fit, namely Group 2, Normal Group, Group 3 and Group 4, while instrument precision bearings are supplied in the first three groups only. Bearings are usually marked in some way to indicate the class of fit, a system of dots, circles or letters often being used. It is important that replacement bearings are of the same standard.

Group2 bearings have the smallest radial internal clearance and are normally used in precision work where minimum axial and radial movement is required. These bearings should not be used where operating conditions, such as high temperatures, could reduce internal clearances, and are not suitable for use as thrust bearings or for high speed.

Normal Group bearings are used for most general applications where only one ring is an interference fit and where no appreciable transfer of heat to the bearing is likely to occur.

Group3 bearings have a greater radial internal clearance than Normal Group bearings and are used where both rings are an interference fit, or where one ring is an interference fit and some transfer of heat must be accepted. They are also used for high speeds and where axial loading predominates.

Group 4 bearings have the largest radial internal clearance; they are used where both rings are an interference fit, and the transfer or heat reduces internal clearances.

LUBRICATION

Adequate lubrication is essential for all types of rolling bearings. The purposes of the lubricant are to lubricate the areas of rubbing contact, e.g. between the rolling elements and the cage, to protect the bearing from corrosion, and to dissipate heat. For low rotational speeds, or for oscillating functions such as are found in a number of airframe applications, grease is a suitable lubricant; at higher rotational speeds grease would generate excessive temperatures because of churning, and oil is more suitable. Because of the variety of uses to which rolling bearings are put, and the varying requirements of different locations, it is important that only those lubricants recommended in the approved Maintenance Manual should be used.

External bearings on aircraft are often of the pre-packed, shielded or sealed types, and are usually packed with antifreeze grease because of the low temperatures encountered; theses bearings cannot normally be re-packed with grease, and when un serviceable, must be rejected. Wheel bearings are normally tapered roller bearings, and should be re-packed with the correct grease when refitting the wheel.

Bearings fitted in engines and gearboxes are generally lubricated by oil spray, splash, mist, drip feed, or controlled level oil bath, and loss of lubricant is prevented by the use of oil retaining devices such as labyrinth seals, felt or rubber washers, and oil throwers.

INSTALLATION OF BEARINGS

The majority of bearing failures are caused by faulty installation, unsatisfactory lubrication, or inadequate protection against the entry of liquids, dirt or grit. To obtain the maximum life from a bearing, therefore, great care must be exercised during installation and maintenance, and strict cleanliness must be maintained at all times.

Where bearings carry axial loads only, the rings need only be a push fit in the housing or on the shaft, as appropriate, but bearings which carry radial loads must be installed with an interference fit between the revolving ring and its housing or shaft, otherwise creep or spin may take place and result in damage to both components. In instances where light alloy housing are used, the bearing may appear to be a loose fit during installation owing to the need to control bearing fit in the housing at the low temperatures experienced at high altitude.

Before installation, a bearing should be checked to ensue that it is free from damage and corrosion, and that it rotates freely. In some cases bearings are packed with storage grease, which is unsuitable for service use and must be removed by washing in a suitable solvent as specified below in topic clearance bearings. All open bearings should be lubricated with the specified oil or grease before installation.

Bearings must be assembled the right way round, i.e. as specified in the appropriate drawing or manual, and should be seated squarely against the shoulders on shafts or housing so that raceway are at right angles to the shaft axis. Damage to the shoulders stress on the bearing and promote rapid wear. It is important, therefore, to ensure that there is no damage likely to prevent correct seating of the bearing rings, and that all mating surfaces are scrupulously clean.

NOTE

Some bearings are supplied as matched pairs, and it is important that they are mounted correctly.

Bearings may often be installed using finger pressure only, but where one ring is an interference fit (usually the rotating inner spring), an assembly tool or press should be used; in some instances it may also be necessary to freeze the shaft or heat the bearing in hot oil, depending on the degree of interference specified. If these tools are not available, the use of a soft steel or brass tube drift may be permitted in some instances; any force necessary must be applied only to the ring concerned, since force applied to the companion ring may result in damage to the rolling elements, or brinelling of the raceways.

NOTE

If a drift is used, the tube must be a close fit over the shaft and must not transmit force to the ring ribs. Light taps from a hammer should be distributed evenly round the top of the drift, to prevent misalignment. On no account should a copper drift be used, as work-hardening could result in chips of copper entering the bearing.

Retaining devices are used to prevent axial movements of the inner and outer rings of a bearing. Stationary outer rings are normally held in place by circlips or retaining plates, and shims are often used in conjunction with the latter to adjust the clearances in thrust or location bearings. All bearings capable of clearance adjustment must be adjusted to the correct clearance or preload specified in the relevant Maintenance or Overhaul Manual, otherwise damage or excessive wear may result. Rotating inner rings are usually firmly held by means of a washer and nut on the shaft and, although the thread may be handed to prevent loosening during operation, care should be taken to ensure that the nut is securely locked to the shaft.

NOTE

In the case of rod end bearings, the out races may be retained in their housing by indentations at the entry faces of the housing, or by use of an epoxy sealer.

On completing of assembly , the bearing housing should, where applicable, be lightly packed with grease to provide, an adequate reserve of lubricant, and oil-lubricated bearing should be lightly lubricated with the appropriate oil. Excessive greasing should be avoided, however, since grease is expelled from the bearing as soon as it begins to rotate, and , if insufficient space is left, churning and overheating may occur, causing the grease to run out and the bearing to fail; as a rough guide, the bearing should be approximately one third full.

MAINTENANCE OF BEARINGS

Ball and roller bearings if properly lubricated and installed, have a long life and require little attention. Bearings failures may have serious results, however, and aircraft Maintenance Manuals and approved Maintenance Schedules included inspections and, where applicable, lubrication for all types of rolling bearings.

Lubrication

Most bearings used in airframe applications are shielded or sealed to prevent the entry of dirt or fluids which could adversely affect bearing life; these bearings cannot normally be regreased, and must be replaced if it is evident that the lubricant has been washed out, or otherwise lost through failure of the seals or bearing wear. Grease nipples are provided for some open bearings so that the grease may be replenished at specified intervals, or when grease is lost through the use of solvents, paint strippers, detergents or de-icing fluid. Nipples should be wiped clean before applying the grease gun, to prevent the entry of dirt into the bearing. Grease forced into the bearing will displace the old grease, and any surplus exuding from the bearing should be wiped off with a clean lint-free cloth.

INSPECTION

Ball and roller bearings are deliberately selected by aircraft and component designers, for use in installation where play or lost motion are unacceptable; wear or corrosion, once started, progress rapidly, and bearings showing evidence of these faults should be discarded. Frequent removal of bearings from shafts or housings may result in damage to either the bearing rings or mating surfaces, and for this reason a routine inspection of a bearing is normally carried out in situ; wheel bearings, however ,are normally inspected when the wheel is removed. If doubt exists as to the serviceability of a bearing, it should be removed, cleaned and inspected .

It may not often be possible to examine the rolling elements and raceways while a bearing is in position, but is usually possible to examine the rings externally for overheating, damage and corrosion, and to examine the cage for loose rivets and damage, after removing surplus grease with a clean lint-free cloth. In all cases a bearing should be checked for wear as follows :-

i. Actuate the moving parts slowly to check for smoothness of operation. Roughness may result from grit in the bearing or surface damage to the rolling elements or raceways, caused by corrosion or excessive wear.
ii. Check for wear by moving the inner race or shaft in both axial and radial directions. The amount of clearance will depend to a large extent on the initial grade of fit of the bearing, but some wear will be acceptable with all classes of fit and may only be considered as unsatisfactory if it leads to excessive backlash in controls, or vibration during operation.
iii. Check shielded bearings to ensure that there is no rubbing contact between the stationary and rotating components. Contact between the shield and inner ring is evidence of excessive wear in the bearing and could lead to contamination of the lubricant by particles of metal rubbed off the shield.

With some bearings, creep or spinning of the races may occur and lead to damage to the shaft or outer ring housing. Where housing end covers or shaft nuts can be removed, these faults may be recognised by polishing of the ring faces.

The internal condition of a bearing may sometimes be revealed by an examination of the lubricant exuding from the bearing. Metal particles reflect light, and give a rough feeling when the lubricant is rubbed into the palm of the hand.

A problem frequently encountered with airframe bearings is moisture contamination, which may result in freezing in a inability to operate a control in low temperature conditions. Every precaution should be taken to prevent the entry to liquids into bearings, and re lubrication of open bearings is often specified after washing. During inspection ,particular attention should be given to rust stains, which may be a good indication of the presence of moisture.

The condition of landing wheel bearings on small aircraft, on which wheels are changed at infrequent intervals, may be checked by rocking and spinning the wheel. This check would normally be impractical and unnecessary on larger aircraft, since the wheels are changed more frequently in order to replace worn tyres.

REMOVAL OF BEARINGS

Many roller bearings are made in two parts, which can be separated for cleaning and inspection without removing he outer ring from its housing or the inner ring from its shaft; all that is necessary is partial dismantling of the associated components to allow the bearing to be inspected and rotated. When it is necessary to remove separated rings or completed bearings, care is necessary to ensure that they are light hammer blows transmitted through the medium of a soft tubular drift may prove effective. Any force necessary should be applied to the ring concerned, since force applied to the companion ring may result in damage to the raceways and rolling elements. Force should not be applied to the ribs of a roller bearing as this may result in fracture or damaged, which would necessitate the rejection of the bearing.

NOTE

Bearings are selectively assembled to match rolling elements very closely for size, and ensure correct internal clearances. When disassembly between partly dismantled bearings, and are reassemble in their original configuration.

CLEANING BEARINGS

Bearings to be cleaned for further examination should first be wiped free of all grease adhering to the surfaces; dry compressed air will assist in dislodging it form the cage and rolling elements, but the bearing should not be allowed to rotate.

The bearings should then be soaked or swilled in white spirit to remove any remaining grease or dirt. It is permissible to oscillate or turn the races slowly to ensure that all foreign matter has been removed, but the bearing should not be spun in this condition, otherwise the working surfaces may become damaged due to the lack of lubrication.
If a bearing cannot be completely cleaned by the above method, a forced jet of white spirit may be used to advantage. The jet may be obtained by fitting a pump to the washing tank, but an efficient filter must be provided.

Jet cleaning can be considerably assisted if the bearing is mounted on a tapered mandrel so that the inner ring will remain stationary, whilst allowing the outer ring to revolve slowly as a result of the fluid from the jet passing through the bearing.

After cleaning, the bearing should be dried with clean, warm, dry compressed air, taking care to permit only very slow rotation, and lightly lubricated with oil to prevent corrosion. The bearing should be slowly rotated during oiling to ensure that all surfaces are covered.

INSPECTION AFTER REMOVAL

After removal and cleaning, bearings should be inspected for corrosion, pitting, fracture, chip, discoloration and excessive internal clearances. With self-aligning bearings or bearings having detachable rings, the condition of the rolling elements and raceways can be seen by swivelling the outer ring through 90 or by separating the outer ring, as appropriate. With bearings having non-detachable rings, the raceways and balls or rollers are sometimes accessible for visual examination, but if not, the raceways and balls or rollers are sometimes accessible for visual examination, but if not, their condition may be judged by holding the inner ring and oscillating the outer ring. Provided their is no foreign matter inside the bearing, any roughness will indicate internal damage.

Slight corrosion on the outer surface of the rings is usually acceptable, provided that it does not prevent proper fit of the rings in housings or on shafts. Staining on the raceways or rolling elements may be acceptable on non-critical bearings, but deep pitting or scaling of the surface would not be acceptable on any types of bearings. Fracture, chips or damage to the rings, balls, rollers or cage, would necessitate rejecting the bearing.

If the rings show signs of creep or spinning, the outside and inside diameters of the bearing should be checked with a micrometer and plug gauge respectively. The shaft and housing should also be inspected for damage and wear, to ensure that a proper fit will be obtained when the bearing is replaced.

The running smoothness of a bearing may be determined by mounting it on a shaft which is mechanically rotated at 500 to 1000 rev\min. With the shaft running and the bearing oiled, the outer ring should be held, and the smoothness and resistance should be determined by applying alternate axial and radial loads in either direction. The outer ring must be square to the shaft, or a false impression of roughness may result.

Excessive wear in a bearing will result in large internal clearances, and a badly worn bearing will normally have been rejected following the initial inspection in situ. Axial clearance in a bearing is seldom quoted since it depends on the internal design of the particular bearing, but, where necessary, a rough guide to the radial internal clearance indicator, the average radial movement obtained at various angular positions of the outer ring. It is important that the outer ring is moved in the same plane as the inner ring, or an incorrect reading will result.

PROTECTION AGAINST CORROSION

Bearings which have been found satisfactory and are to be reused immediately, should be lubricated with oil or grease as appropriate, and reinstalled; bearings which are to be stored should be dipped in rust preventive oil, wrapped in grease proof paper and suitably boxed and labelled. Bearings should be stored horizontally, in a clean, dry atmosphere, and it is recommended that, after one year in storage, the bearings should be inspected for corrosion and re-protected.

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CHAPTER : 22

KNOWLEDGE OF VARIOUS TYPES OF THREADS, USED IN BRITISH & AMERICAN SYSTEM

22.1 CLASSIFICATION OF TYPES OF THREADS

22.1.1 Type of V-threads

I. BS Whitworth Thread

This form of thread is also known as British Standard Whitworth (B.S.W.) thread and has been adopted as standard form in the United Kingdom.

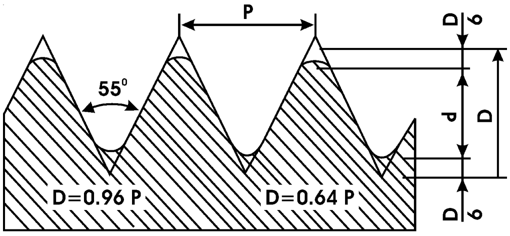

Fig. 22.1, Whitworth thread

The angle is 55°. The theoretical depth D = 0.96P, where P is the pitch of the thread. $\frac{1}{6}$ of the theoretical depth is rounded off at the top and at the bottom. Therefore, the actual depth d = 0.64P.

II. British Association Thread

It is generally used for small instrument screws. The angle of the thread is 47½°. 0.236 of the theoretical depth is rounded off at the top and at the bottom, leaving the actual depth equal to 0.6 P.

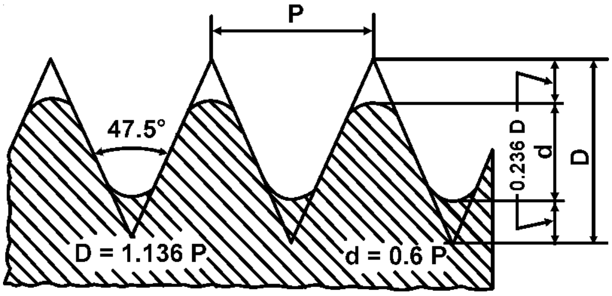

Fig. 22.2, British Association thread.

Theoretical depth, D = 1.136 P
Actual depth, d = 0.6 P.

III. British Standard Pipe Thread (B.S.P.) and British Standard Fine (B.S.F.)

These have the same Whitworth profile but their pitches are finer and hence, the depths smaller. Thus, they have large effective and core diameters than the B.S.W. thread. B.S.F. threads are generally used in automobile and aircraft work. B.S.P. threads are used for gas, steam or water pipes. They are specified by the bore of the pipe and not by the outside diameter. Thus, the outside diameter of a threaded pipe having a bore of 1" nominal diameter is 1.309". Pipes of 1" to 6" diameters have the same number of threads per inch.

IV. American Sellers Thread

This form of thread is adopted as a standard form in U.S.A. It has an angle of 60°. One-eighth of the theoretical depth is cut-off parallel to the axis of the screw at the top and at the bottom. The crests and the roots of this thread are therefore flat.

Theoretical depth, D = 0.866 P

Actual depth, $d = \frac{3}{4} D = 0.649$ P.

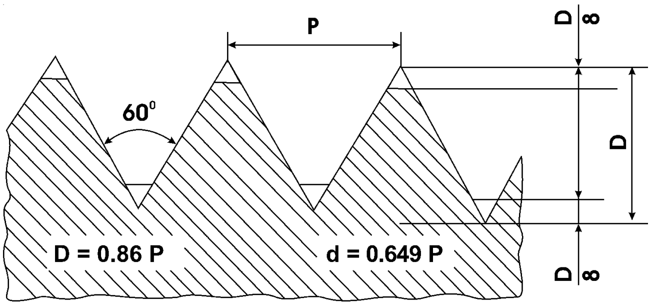

Fig. 22.3, American Sellers Thread

V. Unified Threads

In 1947, the International Organization for Standardization (I.S.O.) of which India, U.S.A., United Kingdom, Canada and a number of other countries are members, came into being, It decided to adopt the Unified screw thread profile as the I.S.O. basic profile. It also decided to recognize two separate I.S.O. series based on inch and metric systems of measurement, with this common basic profile for threads.

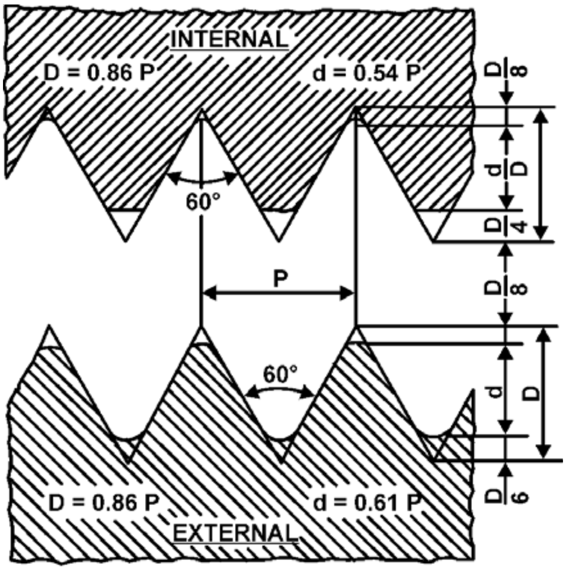

Fig. 22.4, Unified Thread

In this form of thread, the external thread (on a screw) varies slightly in shape from the internal thread (inside a nut) as can be seen from the figure. The angle of the thread is 60°. Roots of both - internal and external - threads are rounded, while the crests are cut parallel to the axis of the screw. The root of the internal thread is rounded within the depth of $\frac{D}{8}$ as shown in the figure.

External thread :

Theoretical depth, $D = 0.866 P$

Actual depth, $d = \frac{17}{24} D = 0.61 P.$

Internal thread:

Theoretical depth, $D = 0.866 P$

Actual depth, $d = \frac{5}{8} D = 0.54 P.$

The maximum depth of engagement between the external and the internal threads is $\frac{5}{8}$ D.

VI. Metric Threads

The Indian Standards Institution has recommended the adoption of the Unified screw thread profile based on metric system as a standard form for use in India, and has designated it as Metric screw thread with I.S.O. profile. In this system, the pitch of the thread (instead of the number of threads per unit length) is fixed.

Metric thread is designated by the letter M followed by the diameter, e.g. M 20, where 20 is the diameter of the screw in millimetres.

22.1.2 Types of Square Threads

I. Square Thread

This thread has its flanks or sides normal to the axis and hence, parallel to each other. It is generally used for transmission of power. It is also used for obtaining larger axial movement of the nut or the screw per revolution. For the same nominal diameter of the screw, the pitch of the square thread is usually greater than that of the triangular thread. The depth and the thickness of the thread are each equal to half the pitch.

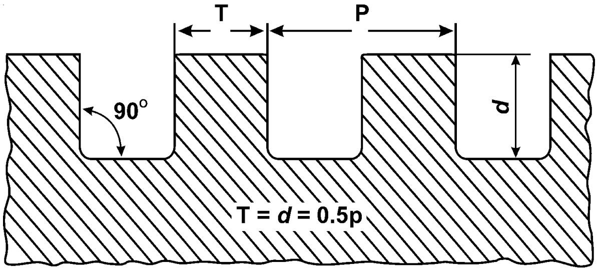

Fig. 22.5, Square thread

II. Butress Thread

This thread is a combination of the triangular and the square threads. One flank of the thread is perpendicular to the axis of the screw. The angle between its two flanks is 45°. The theoretical depth is equal to the pitch, one-eight of which, is cut-off parallel to the axis at the crest and at the root. This thread is suitable only when the force acts entirely in one direction as shown by the arrow F. Its use is commonly made in the screw of a bench-vice.

Theoretical depth, D = P

Actual depth, $d = \frac{3}{4} D = 0.75\,P.$

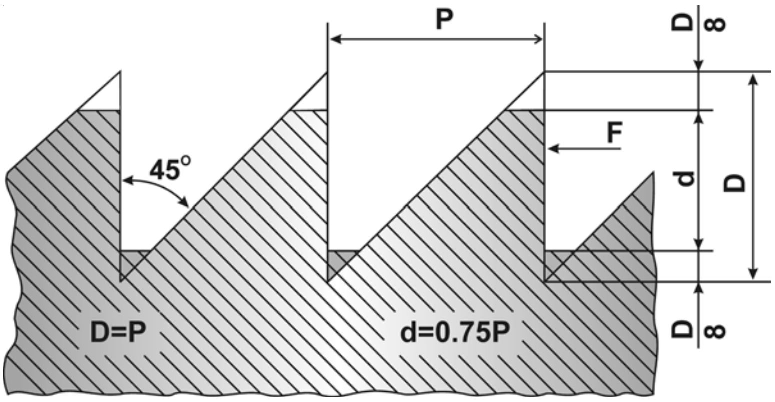

Fig. 22.6, Buttress Thread

III. Acme thread

This thread is a modification on the square thread. It is easier to cut and is stronger at the root than the square thread. It is particularly used where the nut, which is made in two parts, is required to engage with or disengage from a screw at frequent intervals as in the leading screw of the lathe. The thread angle is 29°. Depth d = ½P + 0.01” = 0.5 P + 0.25 mm. The thickness of the thread at the crest is equal to 0.3707 P.

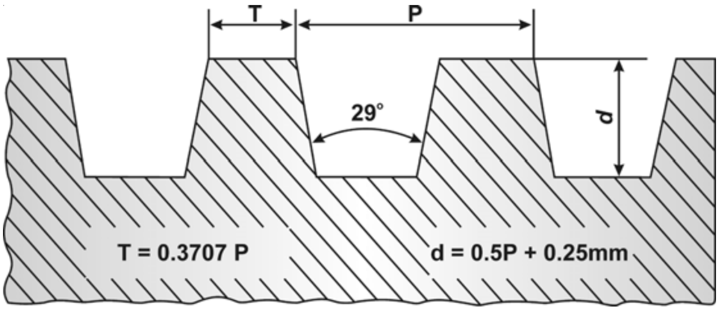

Fig. 22.7, Acme Thread

IV. Knuckle thread

This thread is also a modification of the squre thread. It is formed by rounding off the corners of the squre thread to such an extent that it has a completely rounded profile. Is section comprises of semi-circles of radious R = 0.25 P. The depth d = 0.5 P. This thread can withstand heavy wear and rough usage.

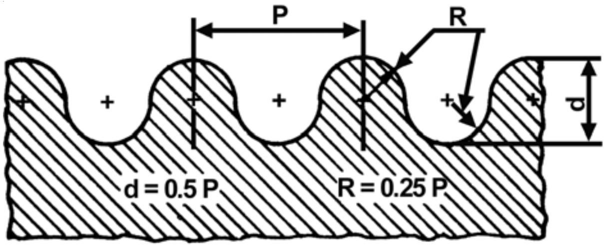

Fig. 22.8, Knuckle Thread.

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CHAPTER : 23
CONTROL CABLES

INTRODUCTION

Cables are the most widely used linkage in primary flight control systems. Cable-type linkage is also used in engine controls, emergency extension systems for the landing gear, and various other systems throughout the aircraft.

Cable-type linkage has several advantages over the other types. It is strong and light in weight, and its flexibility makes it easy to route through the aircraft. An aircraft cable has a high mechanical efficiency and can be set up without backlash, which is very important for precise control.

Cable linkage also has some disadvantages. Tension must be adjusted frequently due to stretching and temperature changes.

Aircraft control cables are fabricated from carbon steel or stainless steel.

23.1CABLE CONSTRUCTION

The cable used in British aircraft control systems is preformed, and complies with British Standards (BS) Specifications W9, W11, or W13, or with American Specification MIL-W-83420 (formerly MIL-W-1511 AND MIL-L-5424). Preforming is a process in which each individual strand is formed into the shape it will take up in the completed cable. This makes the cable more flexible, easier to splice, and more resistant to kinking. Preformed cable will not unravel; also, if a wire in a preformed cable should break, the broken wire will lie flat, and, therefore, be less likely to prevent the cable from passing round pulleys and through fairleads.

The construction of a cable is determined by the number of strands it contains, and by the number of individual wires in each strand. For examples, a cable designated 7 × 19, consists of 7 strands, each strand containing 19 wires. Wires are wound round a king wire in one or two layers, and strands are generally wound round a core strand in one layer, the direction of winding being stipulated in the relevant specification. The two most common forms of construction are illustrated in Fig. 23.1, and the construction of the various sizes of cable is included in Tables 23.1 and 23.2.

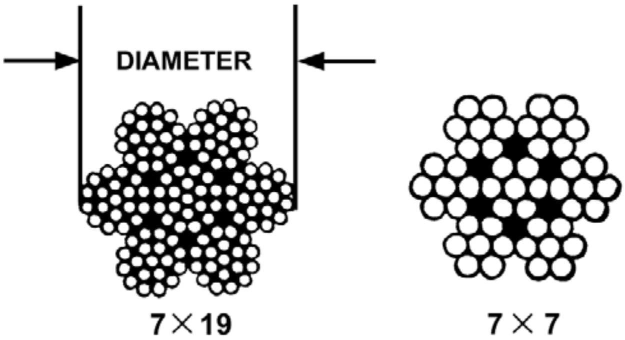
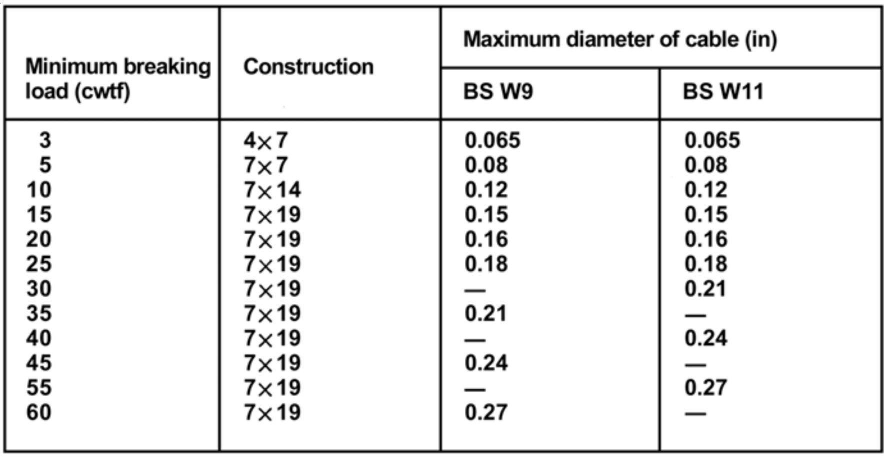


Fig. 23.1, Steel Wire Cable

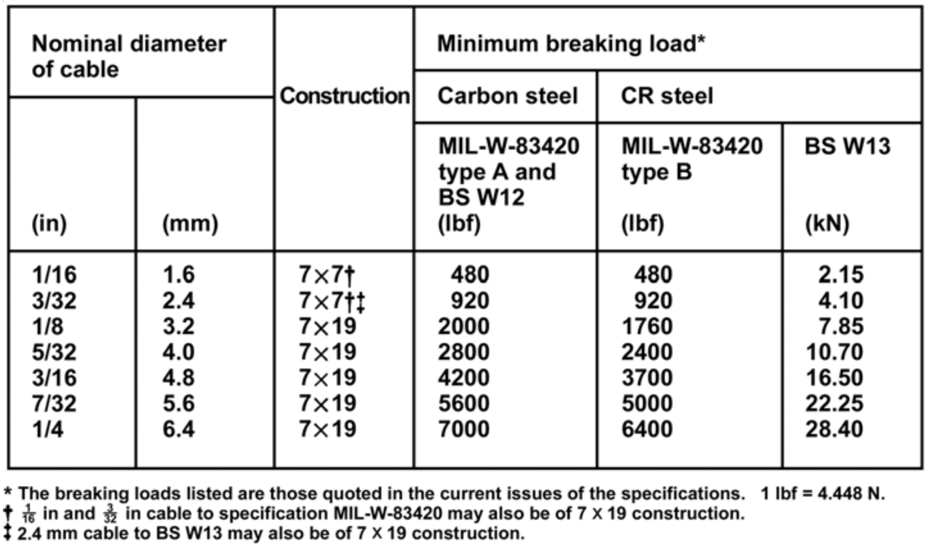
Preformed cable is manufactured from either galvanised carbon steel (BS W9 and W12, and American Standard MIL-W-83420, Composition B), and is impregnated with friction preventing lubricant during manufacture. The American specification also provides for a range of nylon-covered cable. Non-preformed single strand cable may be found on some aircraft, but will normally only be used for relatively unimportant systems. Tables 23.1 and 23.2 list the more common sizes of cable according to the method of classification.

TABLE 23.1
CABLE CLASSIFIED BY BREAKING LOAD IN HUNDREDWEIGHTS



Minimum breaking load (cwtf)	Construction	Maximum diameter of cable (in)	
		BS W9	BS W11
3	4×7	0.065	0.065
5	7×7	0.08	0.08
10	7×14	0.12	0.12
15	7×19	0.15	0.15
20	7×19	0.16	0.16
25	7×19	0.18	0.18
30	7×19	—	0.21
35	7×19	0.21	—
40	7×19	—	0.24
45	7×19	0.24	—
55	7×19	—	0.27
60	7×19	0.27	—

TABLE 23.2
CABLE CLASSIFIED BY NOMINAL DIAMETER



Nominal diameter of cable		Construction	Minimum breaking load*		
			Carbon steel	CR steel	
(in)	(mm)		MIL-W-83420 type A and BS W12 (lbf)	MIL-W-83420 type B (lbf)	BS W13 (kN)
1/16	1.6	7×7†	480	480	2.15
3/32	2.4	7×7†‡	920	920	4.10
1/8	3.2	7×19	2000	1760	7.85
5/32	4.0	7×19	2800	2400	10.70
3/16	4.8	7×19	4200	3700	16.50
7/32	5.6	7×19	5600	5000	22.25
1/4	6.4	7×19	7000	6400	28.40

* The breaking loads listed are those quoted in the current issues of the specifications. 1 lbf = 4.448 N.
† $\frac{1}{16}$ in and $\frac{3}{32}$ in cable to specification MIL-W-83420 may also be of 7 X 19 construction.
‡ 2.4 mm cable to BS W13 may also be of 7 X 19 construction.

23.2 CABLE FITTINGS

Cables may be equipped with several different types of fittings such as terminals, thimbles, bushings, and shackles.

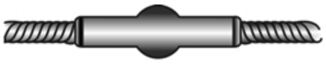
Terminal fittings are generally of the swaged type. They are available in the threaded end, fork end, eye end, single-shank ball end, and double-shank ball end. The threaded end, fork end, and eye end terminals are used to connect the cable to a turnbuckle, bellcrank, or other linkage in the system. The ball-end terminals are used for attaching cables to quadrants and special connections where space is limited. Fig. 23.2, illustrates the various types of terminal fittings.

The thimble, bushing, and shackle fittings may be used in place of some types of terminal fittings when facilities and supplies are limited and immediate replacement of the cable is necessary.

23.3 TURNBUCKLES

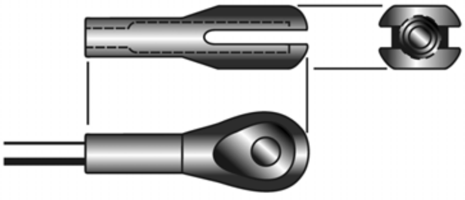
A turnbuckle assembly is a mechanical screw device consisting of two threaded terminals and a threaded barrel. Fig. 23.3 illustrates a typical turnbuckle assembly.

Turnbuckles are fitted in the cable assembly for the purpose of making minor adjustments in cable length and for adjusting cable tension. One of the terminals has right-hand threads and the other has left-hand threads. The barrel has matching right - and left - hand internal threads. The end of the barrel with the left-hand threads can usually be identified by a groove or knurl around that end of the barrel.

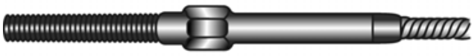


AN663 Double shank ball end terminal

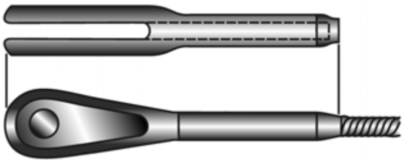
AN664 Single shank ball end terminal



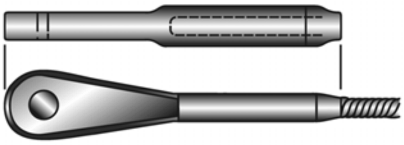
AN665 Rod end terminal



AN666 Threaded cable terminal



AN667 Fork end cable terminal



AN668 Eye end cable terminal

Fig. 23.2, Types of terminal fittings.

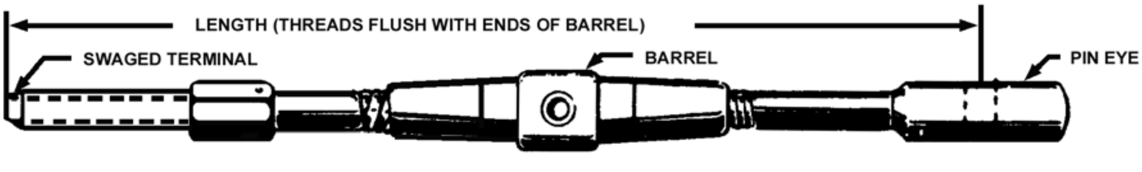


Fig. 23.3, Typical turnbuckle assembly.

When installing a turnbuckle in a control system, it is necessary to screw both of the terminals an equal number of turns into the barrel. It is also essential that all turnbuckle terminals be screwed into the barrel until not more than three threads are exposed on either side of the turn-buckle barrel.

After a turnbuckle is properly adjusted, it must be safetied. The methods of safetying turnbuckles are discussed later in this chapter.

Turnbuckles are a type of cable fastener that allows cable tension to be adjusted. A complete turnbuckle assembly consists of two ends, one with right-hand threads and the other having left-hand threads, with a brass barrel joining them. Minor cable adjustment is made by rotating the turnbuckle which effectively lengthens or shortens the cable's length.

To ensure that a turnbuckle develops full cable strength, there must be not more than three threads of either end sticking out of barrel. After cable tension is adjusted, the turnbuckle barrel is safetied to the two cable ends so that it cannot turn. (Fig. 23.4).

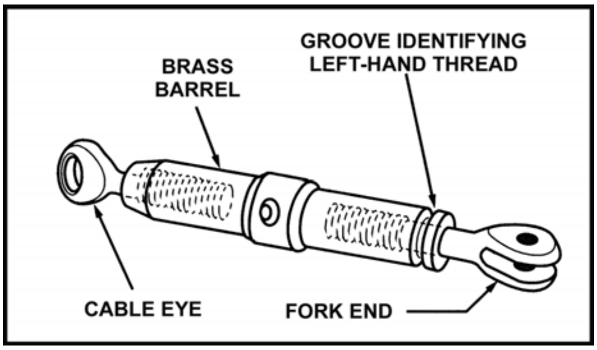


Fig. 23.4, Turnbuckles provide a means of adjusting control cables as they age and stretch.

23.3.1 Push Pull Tube Linkages

Push-pull tubes are used as linkage in various types of mechanically operated systems. This type linkage eliminates the problem of varying tension and permits the transfer of either compression or tension stress through a single tube.

A push-pull tube assembly consists of a hollow aluminium alloy or steel tube with an adjustable end fitting and a checknut at either end. (See Fig. 23.5) The checknuts secure the end fittings after the tube assembly has been adjusted to its correct length. Push-pull tubes are generally made in short lengths to prevent vibration and bending under compression loads.

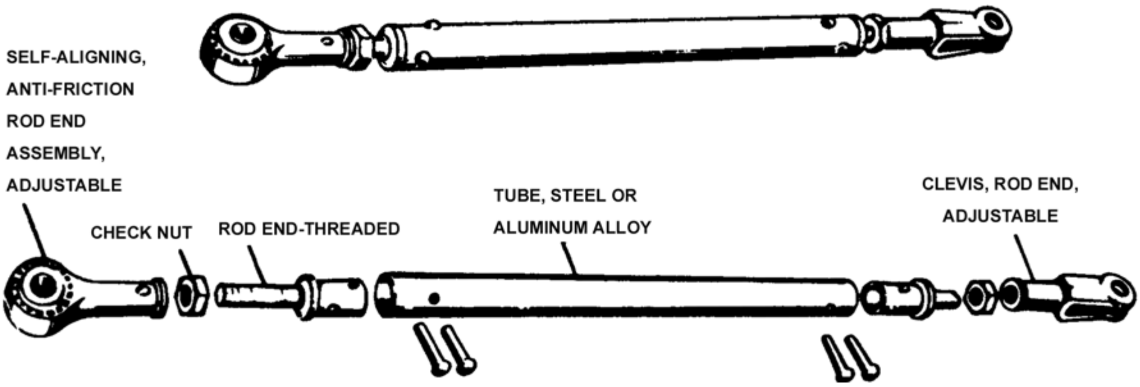


Fig. 23.5, Push-pull tube assembly.

23.3.2 Pins

The three main types of pins used in aircraft structures are the taper pin, flathead pin, and cotter pin. Pins are used in shear applications and for safetying. Roll pins are finding increasing uses in aircraft construction.

I. Taper pins

Plain and threaded taper pins (AN385 and AN 386) are used in joints which carry shear loads and where absence of play is essential. The plain taper pin is drilled and usually safetied with wire. The threaded taper pin is used with a taper-pin washer (AN975) and shear nut (safetied with cotter pin) or self-locking nut.

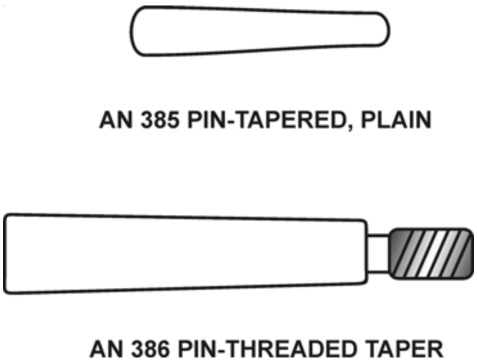
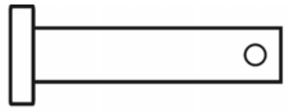


Fig. 23.6, Taper pins

II. Flat head pins

Commonly called a clevis pin, the flathead pin (MS20392) is used with tie-rod terminals and in secondary controls which are not subject to continuous operation. The pin is customarily installed with the head up so that if the cotter pin fails or works out, the pin will remain in place.



AN 392 thru AN406 PIN-CLEVIS

Fig.23.7, Flat Head Pins

III. Cotter pins

The AN380 cadmium-plated, low-carbon steel cotter pin is used for safetying bolts, screws, nuts, other pins, and in various applications where such safetying is necessary. The AN381 corrosion-resistant steel cotter pin is used in locations where nonmagnetic material is required, or in locations where resistance to corrosion is desired.

AN 380 PIN-COTTER

AN 381 PIN-COTTER, STAINLESS

Fig. 23.8, Cotter Pins

IV. Rollpins

The rollpin is a pressed-fit pin with chamfered ends. It is tubular in shape and is slotted the full length of the tube. The pin is inserted with hand tolls and is compressed as it is driven into place. Pressure exerted by the roll pin against the hole walls keeps it in place, until deliberately removed with a drift punch or pin punch.

23.4 SAFETY METHODS

Safetying is the process of securing all aircraft, bolts, nuts, screws, pins and other fasteners so that they do not work loose due to vibration. A familiarity with the various methods and means of safetying equipment on an aircraft is necessary in order to perform maintenance and inspection.

There are various methods of safetying aircraft parts. The most widely used methods are safety wire, cotter pins, lockwashers, snap-rings, and special nuts, such as self-locking nuts, pal nuts, and jamnuts. Some of these nuts and washers have been previously described in this chapter.

Safety wiring

Safety wiring is the most positive and satisfactory method of safetying capscrews, studs, nuts, boltheads, and turnbuckle barrels which cannot be safetied by any other practical means. It is a method of wiring together two or more units in such a manner that any tendency of one to loosen is counteracted by the tightening of the wire.

23.4.1 Safety wiring for nuts, bolts and screws

Nuts, bolts, and screws are safety wired by the single-wire or double-twist method. The double-twist method is the most common method of safety wiring. The single-wire method may be used on small screws in a closely spaced closed geometrical pattern, on parts in electrical systems, and in places that are extremely difficult to reach.

Fig. 23.9 is an illustration of various methods which are commonly used in safety wiring nuts, bolts, and screws. Careful study of Fig. 23.9 shows that :

a. Examples 1,2, and 5 illustrate the proper method of safety wiring bolts, screws, squarehead plugs, and similar parts when wired in pairs.
b. Example 3 illustrates several components wired in series.
c. Example 4 illustrates the proper method of wiring castellated nuts and studs. (Note that there is no loop around the nut).
d. Examples 6 and 7 illustrate a single-threaded component wired to a housing or lug.
e. Example 8 illustrates several components in a closely spaced closed geometrical pattern, using a single-wire method.

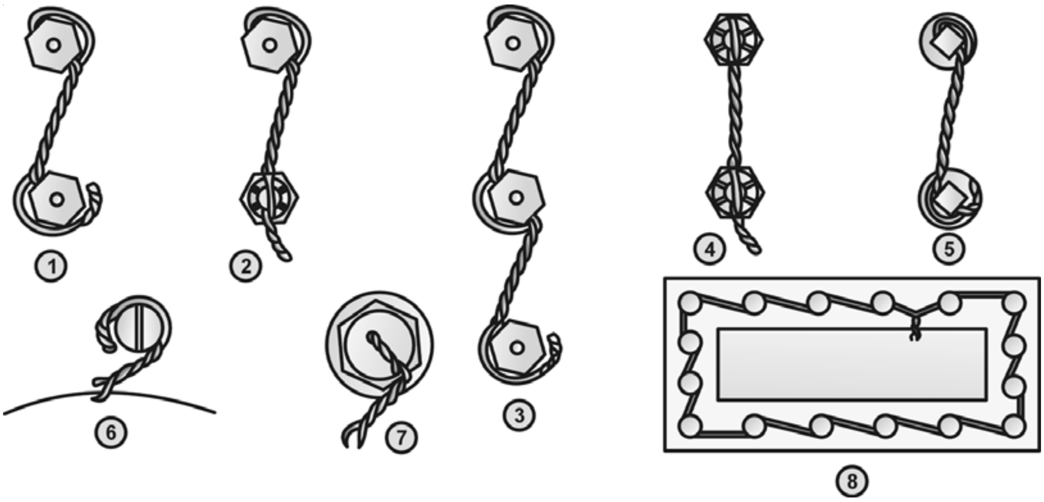


Fig. 23.9, Safety wiring methods.

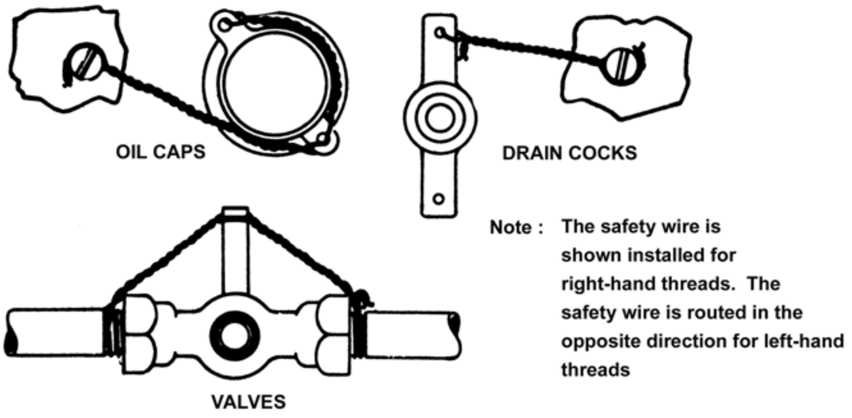
When drilled-head bolts, screws, or other parts are grouped together, they are more conveniently safety wired to each other in a series rather than individually. The number of nuts, bolts, or screws that may be safety wired together is dependent on the application. For instance, when safety-wiring widely spaced bolts by the double-twist method, a group of three should be the maximum number in a series.

When safety-wiring closely spaced bolts, the number that can be safety-wired by a 24-inch length of wire is the maximum in a series. The wire is arranged so that if the bolt or screw begins to loosen, the force applied tot he wire is in the tightening direction.

Parts being safety-wired should be torqued to recommend values and the holes aligned before attempting the safetying operation. Never over torque or loosen a torqued nut to align safety wire holes.

23.4.2 Safety wiring for oil caps, drain cocks and Valves

These units are safety wired as shown in Fig. 23.10. In the case of the oil cap, the wire is anchored to an adjacent fillister head screw.



Note : The safety wire is shown installed for right-hand threads. The safety wire is routed in the opposite direction for left-hand threads

Fig. 23.10, Safety wiring oil caps, drain cocks, and valves.

This system applies to any other unit which must be safety wired individually. Ordinarily, anchorage lips are conveniently located near these individual parts. When such provision is not made, the safety wire is fastened to some adjacent part of the assembly.

23.5 SWAGING

Swaging is an operation in which a metallic end fitting is secured to the end of a cable by plastic deformation of the hollow shank of the end fitting. The end of the cable is inserted into the hollow shank of the fitting, and the shank is then squeezed in a swaging machine, so that it grips the cable. This is the most satisfactory method of attaching an end fitting to a cable, and it can be expected to provided a cable assembly at least as strong as the cable itself. Most transport aircraft, and a large number of light aircraft, use control cables manufactured in this way.

Manufacturers of cable assemblies normally swage with rotary machines. In these machines the shank of the end fitting is placed between suitable dies, and is subjected to a series of forming blow, which reduce the shank diameter, and lock the fitting to the cable

Swaging may also be carried out on a portable swaging machine, which squeezes the shank of the end fitting between dies. The use of a portable swaging machine is discussed below.

A range of swaged end fittings is covered by BS specifications, but some older types of aircraft may be fitted with cable assemblies containing components employing with SBAC AS specification which are now obsolete. When it is necessary to make up control cables for these aircraft, approval may be granted for the use of equivalent BS parts, but the complete cable control run may have to be changed.

BS specifications provide a range of fittings which prevent incorrect assembly of control cables. Turn barrels and tension rods are designed to connect to screwed end and tapped end swaged fittings respectively. For each size of cable two alternative sizes of end fittings are available, and each size is provided with either a left or right hand thread. Swaged fittings can thus be arranged to ensure that a control run cannot be incorrectly assembled.

23.5.1 Swaging procedure

The procedure outlined below is applicable when a machine of the type illustrated in Fig. 23.11 is used. Where use of a different type of machine is authorised, the procedure is similar, except for the setting and operation of the machine, which in all cases should be in accordance with the manufacturer's instructions.

a. Ensure that the new cable is the correct size, by using a suitable gauge, or by measuring the diameter as indicated in Fig. 23.1.

b. Cut the cable to the length specified on the drawing, and ensure that the ends are clean and square.

   Note

   Swaging elongates the end fitting, and an allowance for this must be made when cutting the cable. The allowance to be made should be stated on the appropriate drawing or specification.

c. Select the appropriate end fitting, and clean it by immersing it in solvent; then shake, and wipes dry.

d. Assemble the end fitting to drawing requirements. With drilled-through fittings, the cable end must pass the inspection hole, but be clear of the locking wire hole. For fittings with a blind hole, the cable must bottom in the hole. Bottoming may be checked by marking the cable with paint, at a distance from the end equal to the depth of the hole, and by ensuring that the paint mark reaches the fitting when the cable is inserted. When the cable and the fitting are correctly assembled, they should both be lightly lubricated.

e. Fit the dies for the particular end fitting in the swaging machine, open the handles of the machine, and unscrew the adjuster until the end fitting can be placed in the dies. With the end fitting centred in the die recess, close the handles fully, and screw in the adjuster until the dies grip the fitting. Open the handles, and tighten the adjuster by the amount of squeeze required for the particular end fitting; normally this should be approximately 0.18 mm (0.007 in).

f. Place the fitting in the position shown in the small sketch in Fig. 23.2, so as to swage to within approximately 1.2 mm (0.050 in) from the inspection hole. Check that the cable is in the correct position [see (d)], and operate the handles to squeeze the fitting.

g. Release the handles and rotate the fitting through approximately 50°. Repeat the squeezing and rotating until the fitting has been moved one full turn.

h. Withdraw the end fitting from the dies 1.6 mm (1\16 in) and repeat the cycle of squeezing and turning.

j. Continue operation until the whole shank is swaged. Check the diameter of the shank, and if it has not been reduced to the size required by the appropriate drawing or specification, reset the adjusting screw and repeat the swaging operation.

k. When the shank of the end fitting has been reduced to the correct diameter, remove and inspect the fitting

l. Fit the identification device as prescribed in the drawing, and mark it with the cable part number in the prescribed manner (in some cases the part number may be etched directly onto the end fitting). The identification may be in the form of a wired-on tag, , or a cylindrical sleeve lightly swaged onto the shank of the end fitting.

m. Assemble any fittings, such as cable stops, on the cable, and swage on the opposite end fitting.

n. Dip the end fittings in lanolin, to prevent corrosion resulting from damaged plating, and to exclude moisture.

23.5.2 Portable swaging machine

Although unserviceable cables are usually replaced by cables which have been manufactured, pre-stretched and proof loaded in accordance with an approved drawing, and which have been supplied by the aircraft manufacturer, occasions may arise when such a cable is not available, and it is necessary appropriate drawings or instructions are available, end fittings may be swaged onto a cable using a hand-operated machine such as the one illustrated in Fig. 23.11.

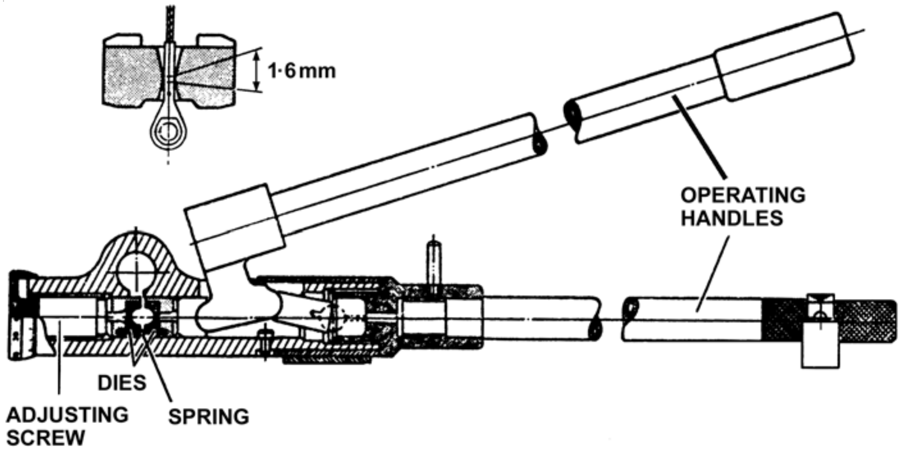


Fig. 23.11, Portable Swaging Machine

Note

The proficiency of a person engaged in the manufacture of locally made cable assemblies, should be established by trial swagings on test cables, which should be tested to the satisfaction of the supervising inspector. The effectiveness of subsequent swaging operations should be checked periodically, by selecting a representative sample, and subjecting it to a tensile test to destruction.

A portable swaging machine is supplied with sets of dies for swaging various types of fittings to cable appropriate size, and with gauges for checking shank diameter after swaging. It is normally mounted on a widen block, and should be used on a low bench so that adequate pressure can be applied to the lever. An adjusting screw in the head of the machine alters the amount of squeeze applied, and a graduated scale permits accurate setting.

23.5.3 Inspection of swaged fitting

On completion of the swaging operations, the following inspection should be carried out.

a. Check that the correct combination of cable and fittings has been used .
b. Re-check the diameter of the swaged shank, using a GO-NOT GO gauge or a micrometer. If the diameter of the fitting is too small, it has been over-swaged, and the cable and the fitting must be rejected. Excessive work hardening of the fitting will cause it to crack, and may also damage the cable.
c. Check, by means of the inspection hole or paint mark, that the cable is correctly engaged in the end fitting
d. Check that the swaging operation has not disturbed the lay of the cable, where the cable enters the end fitting.
e. Ensure that the shank is smooth, parallel, and in line with the head of the fitting, and that the swaged shank length is correct.
f. Proof load the completed cable assembly in accordance with the appropriate drawing .
g. Inspect the fittings for cracks using a lens of 10 × magnification, or carry out a crack detection test, using magnetic or dye processes, as appropriate.
h. Check that the cable assembly is the correct length), and ensure that any required identification marking, including evidence of proof loading, has been carried out, and that any specified protective treatment has been applied.

Note

The first swaged fitting in a production batch is usually sectioned after proof loading, so that the interior surface can be examined for cracks. If this check is satisfactory, the settings on the swaging machine should be noted, and used for completion of the batch.

23.6 SWAGED SPLICES

A number of proprietary methods are used to secure cable in the from of a loop, which may then be attach the cable to a terminal fitting or turn buckle. The ‘Talurit’ swaged splice is approved for use on some British aircraft control cables, and is also widely used on ground equipment. The process provides a cable assembly 90% of the breaking strength of the cable. It may only be used to replace cables employing the same type of splice, or hand splices, and must not be used where swaged end fittings were used previously.

A typical ‘Talurit’ splice is illustrated in Fig. 23.12, to make this type of splice, the end of the cable is threaded through a ferrule of the appropriate size, looped, and passed back through the ferrule. A thimble is fitted in the loop, and the ferrule is squeezed between swages (dies) in a hand-operated or power-operated press. The metal of the ferrule is extruded between the two paralleled lengths of cable, and around the cable strands, and firmly locks the cable without disturbing its lay.

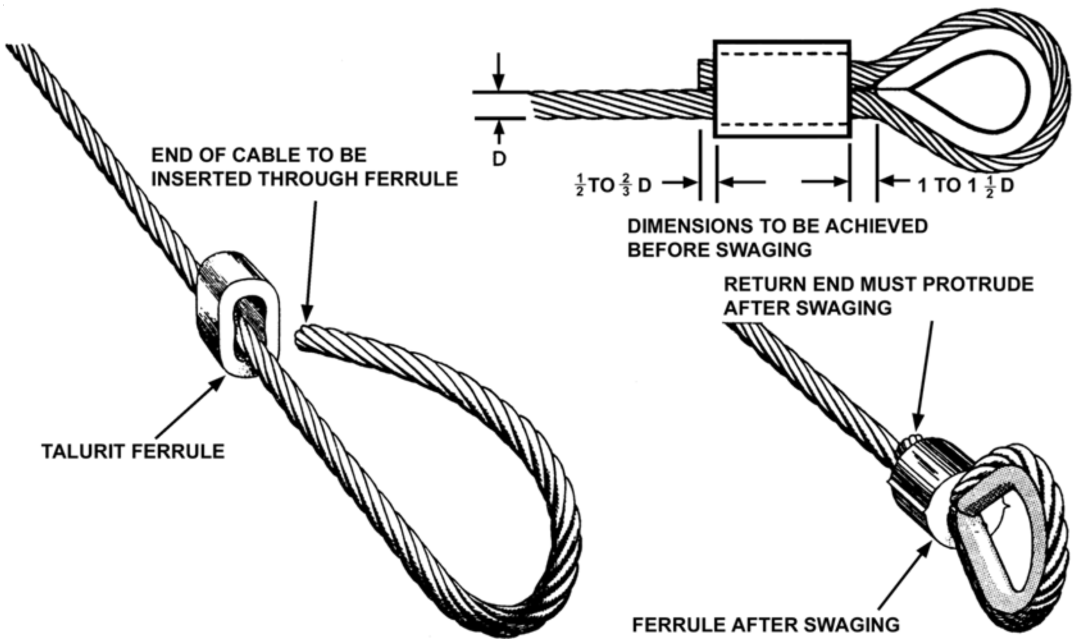


Fig. 23.12, 'Talurit' Swaged Splice

Ferrules are made in a variety of shapes, sizes and materials. Aluminium alloy ferrules are used with galvanised or tinned carbon steel cable, and copper ferrules are used with corrosion resisting steel cable.

When making a splice, the proper ferrule should be selected by the code numbers indicated on the appropriate drawing, and the associated swages should be fitted to the press. The loop and thimble should be adjusted after the swages have closed sufficiently to grip the ferrule; the cable must grip the thimble firmly, and the dimensions indicated in Fig. 23.12, must be obtained before swaging commences.

The press should be operated until the faces of the swages are touching, then the pressure should be released. Continuing to apply pressure after the faces have met, may cause damage to the press and swages. Only one pressing operation is normally required, but some long ferrules are designed for swaging in two separate operations, the swages in these cases being half the length of the ferrule.

After swaging , surplus metal is visible as a flash along each side of the ferrule, and may be removed with a file. If no flash has been formed, the sizes of the ferrule and swages should be re-checked, and it should be ascertained that the press is operating correctly.

The inspection of the finished splice consists of ensuring that the ferrule is correctly formed and not cracked, and of carrying out a proof test. In some instances a dimensional check is also specified, but, since the swages meet during the pressing operation, little variation in diameter will normally be obtained.

23.6.1Manual Splicing

Although manual splicing may be permitted for some particular applications, it is seldom used on modern aircraft. It is less strong than either the swaged fitting or the swaged splice, and considerable experience is required in order to consistently obtain splices of adequate strength by this method. Persons engaged on splicing should be given an initial competency test, and representative samples of their work should be selected periodically, for tensile tests. Splices on cable manufactured to BS W9 OR W11, should not fail at less than 80% of the breaking strength of the cable. There are several methods of splicing, the procedure in each case varying in detail. A recommended method is given in the following paragraph, but other methods may be used, provided that the resulting splice is no less strong.

23.6.2 Splicing Procedure

The cable is normally spliced around a brass or steel thimble. The identification tag and, where applicable, the turn buckle eye-end, should be placed on the thimble, and the centre of the thimble bound to the cable. These cable should be whipped with waxed thread on either side of the thimble, as shown in Fig. 23.14.

Note

When cutting the cables to length , approximately 23 cm (9 in) should be allowed for each splice on cables up to 3.2 mm (1\8 in) diameter, and 30 cm (12 in) should be allowed for each splice in cable between 4.0 mm (5\32 in) and 6.4 mm (1\4 in) diameter.

The method of whipping with a waxed thread is illustrated in Fig. 23.13. A loop is formed in the thread (sketch A), and binding commenced from the open end of the loop towards the closed end (sketch B). When a sufficient length has been whipped, end ‘b’ of the thread is passed through the loop, and secured under the whipping by pulling end ‘a’ (sketch C); the loose ends are then cut off.

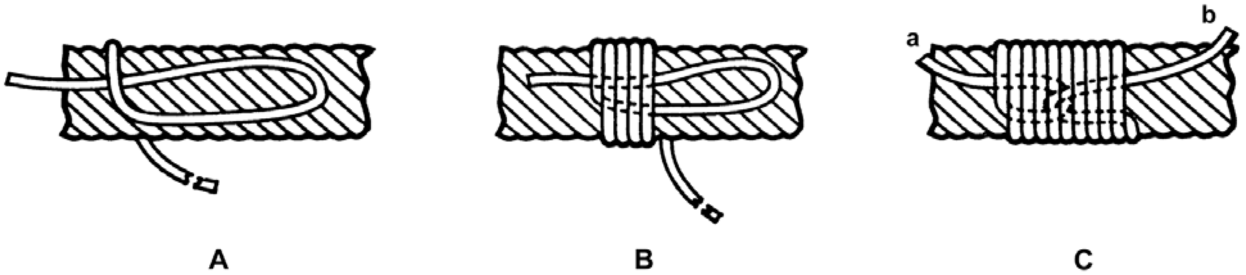


Fig. 23.13, Method of Whipping

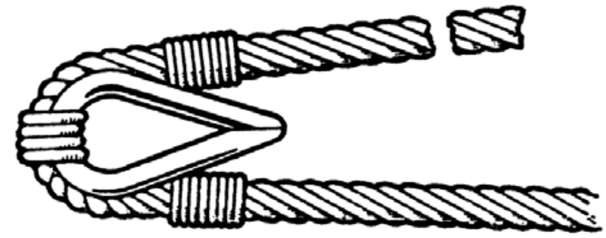


Fig. 23.14, Whipping of Cable

It is essential that the cable and thimble are securely held in a vice, using cable clamps or specially prepared vice blocks, and bound with a Fig. of eight binding as illustrated in Fig. 23.15. No attempt should be made to splice a cable without fully effective clamping devices.

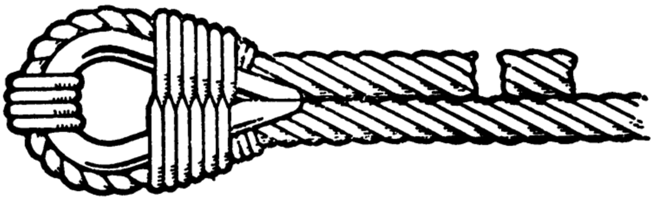


Fig. 23.15, Figure-of-Eight Binding

The strands at the end of the cable should be separated, and whipped or soldered to prevent unlaying of single wires. The cable is then ready for splicing.

Note

For descriptive purposes, the six outer strands of the free end of the cable will, in paragraphs below, be called the ‘free strands’, and will be numbered 1 to 6, while outer strands of the main cable will be lettered ‘a’ to `f’, as shown in Fig. 23.16 & 23.17.

The core strand should be positioned so that there are three free stands on either side, and it should be bent back slightly. The first round of tucks should be completed as follows-3 under a, 1 under b and c, 2 under b (see Fig. 23.16); turn over and tuck 4 under f, 5 under e, and 6 under d (see Fig. 23.17). All free strands should be pulled tight, and then bent back to lock them in position. Care should be taken to avoid disturbing the lay of the cable by excessive pulling.

The core strand should be taken forward and temporarily secured to the main cable with thread, then pulled under a suitable free strand into the centre of the splice. The six free strands should then, in turn, be tucked over a strand and under a strand, e.g. 3 over b and under c, 1 over d and under e. On completing the second round of tucks, the free strands should be pulled tight, and locked back as before.

The third round of tucks should be completed in a similar manner to the second, taking care to bury the core strand in the centre of the splice.

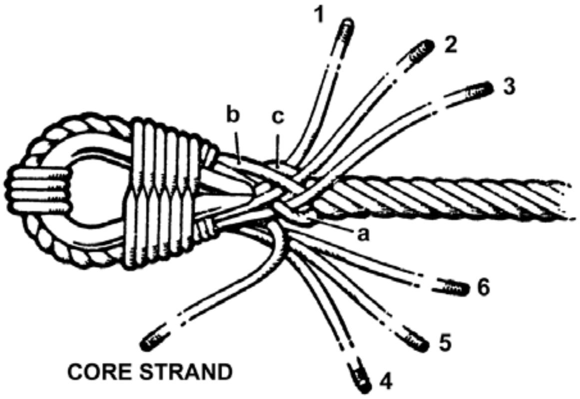


Fig. 23.16, First Round of Tucks (Front)

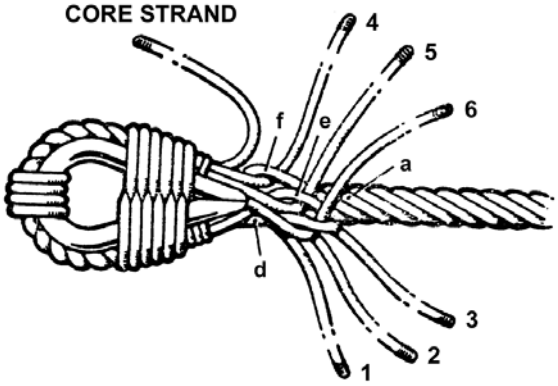


Fig. 23.17, First Round of Tucks (Reverse)

The last full round of tucks, i.e. the fourth, should be the same as the second and third rounds.

The half round of tucks for finishing the splice should be completed by tucking alternate free strands over one, and under two main cable strands. To finish and shape the splice, it should be beaten with a hardwood or rawhide mallet on a hardwood block, while the cable is held taut. The splice should be rotated against the direction of tucking during the beating process. Excessive hammering must be avoided. Free strands should be cut flush with the splice, and the last one and a half tucks should be whipped with waxed cord. The central binding and figure-of-eight lashing should be removed.

If both ends of the cable are to be spliced, the cable length should be checked before commencing the second splice, so that the completed cable will be of the required length.

23.6.3 Inspection of Splices

The splice should be inspected for symmetry and appearance. The wires should be close together, and no light should show between the strands or wires. A typical splice is shown in Fig. 23.18

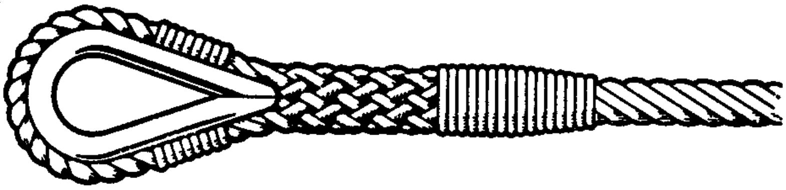


Fig. 23.18, Typical Spliced Joint

The resistance of the splice to bending should be checked. A bad splice will not be resistant to bending, and, when it is bent, the strands and wires will slacken.

The tightness of the thimble in the loop should be checked. The lay of the strands in the cable should be maintained as far as the splice permits, as disturbance in the lay of the cable adjacent to the splice may result in considerable weakening of the cable. The completed cable must be proof loaded.

23.6.4 Proof loading

All cables must be proof loaded after swaging or splicing, by subjecting the cable to a specified load. The purpose of proof loading is both to ensure that the end fittings are satisfactorily installed, and to pre-stretch the cable, i.e. to bed-in the strands and wires. British practice is to load the cable to 50% of its declared minimum breaking strength, and American practice is to load the cable to 60% of its declared minimum breaking strength. If no specific instructions are included in the drawing, then loading of the cable should be carried out in accordance with whichever of these practises is appropriate.

If end fittings have been fitted or splices have been made on pre-stretched cable, no appreciable elongation will result from proof loading. If the cable was not pre stretched, it may be expected to elongate slightly, and this should have been taken into consideration on the appropriate drawing.

A test rig suitable for proof loading cables is illustrated in Fig. 23.19, but other similar methods would be acceptable. These cable should be contained within a trough or other protective structure, to safeguard the operator in the event of failure of the cable. Adaptors should be used to attach the cable end fittings to the test rig, and these should be at least as strong as the cable. Particular care should be taken not to damage the thimbles on spliced cables; packing or bushes should be used to spread the load.

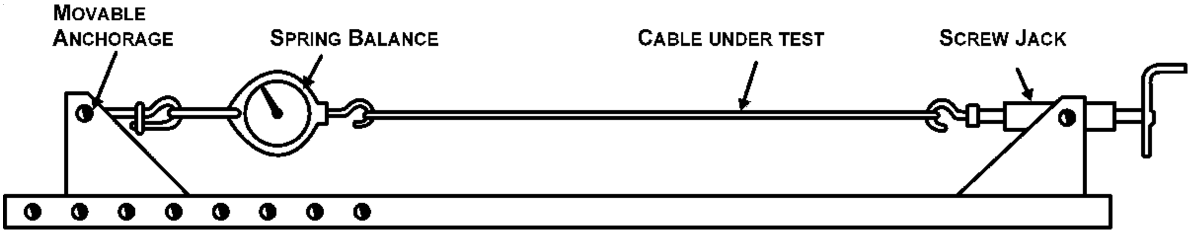


Fig. 23.19, Test Rig for Proof Loading

Before proof loading a cable with swaged end fittings, the cable should be painted with a quick-drying paint at its point of entry into the fittings, and allowed to dry. Cracking of the dried paint during proof loading will indicate slipping of the cable resulting from an unsatisfactory joint.

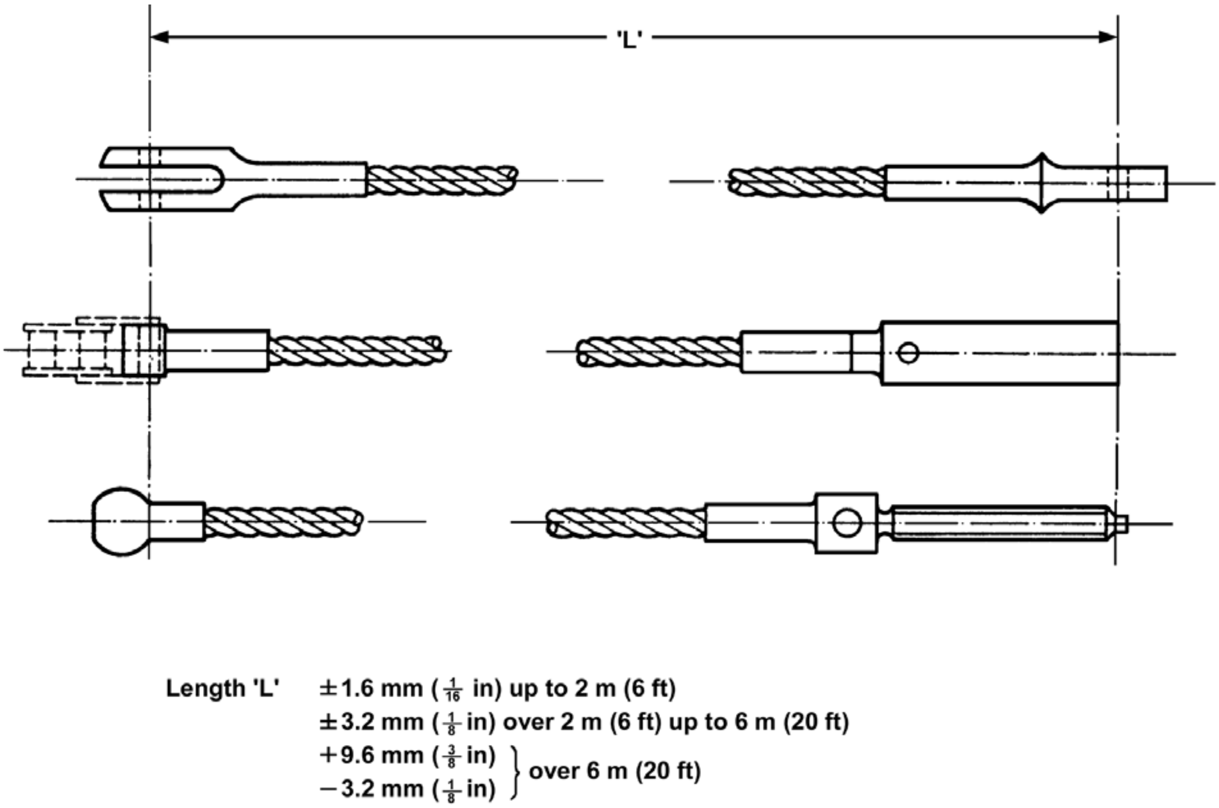


Fig. 23.20, Length of Assemblies

The test should consist of slowly applying the specified load, maintaining this load for a minimum specified period (normally 30 seconds for swaged fittings, but up to 3 minutes for splices), then releasing it, and carefully examining the cable for signs of pulling out of the end fittings, or stretching of the splice.

The end fittings should be checked for cracks using an electromagnetic method or, if the fitting is of stainless steel, a penetrant dye process (for details of these process read N.D.T.).

The length of the completed cable assembly should be measured after proof loading. Prior to measurement cables longer than 120 cm (4 ft) should be tensioned with a load of approximately 550 N (112 1bf), or 2% of the breaking load of the cable, whichever is the least. Fig. 23.20 shows the datum points and tolerances for the measurement of cables fitted with swaged end fittings to British Standards. Cables with different types of end fittings, or loops, should be measured according to the appropriate drawings or specifications.

■■■