Maintenance Practices

[According To The Syllabus Prescribed By EASA For Module 7 (Maintenance Practices) And DGCA For AME Knowledge Examination]

FIRST EDITION

MAINTENANCE 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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Shri. Laxmi Narain Verma

[Who Lived An Honest Life]

Preface

This book is prepared by LNVM Society Group of Institute. The book is designed to aid the students in their day to day study. The chapters in this book discussed are on Maintenance Practices.

This volume gives the information about the requirements of Aircraft System Maintenance and contains safety precautions, Aircraft and workshop, work shop practices, handling of precision measuring tools and gauges, cutting tools, lathe and milling machines, lubrication equipments and methods, operation, function and use of electrical test equipments, Avionics general test equipments, engineering drawing, schedule of fits and clearance, electrical cable and connectors, Aircraft weight and balance etc. Since the maintenance of Aircraft is most important and critical phase, all the materials connected with Aircraft Servicing and maintenance has been taken care as per EASA module 7 and covered up in this book.

This book will also be of great help to the students appearing for DGCA, AME knowledge examination.

I am highly thankful to our Director Mr. C.C. Ashoka for his able guidance, encouragement and active involvement to make this book take its shape.

I would very much appreciate criticism, suggestion and detection of errors from the readers which will be gratefully acknowledged.

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CHAPTER-1
SAFETY PRECAUTIONS : AIRCRAFT & WORKSHOP

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.

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 workpiaces 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 jewelry 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.

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.

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.

OILS & VARIOUS CHEMICALS

Grease 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.

REMEDIAL MEASURES TO BE TAKEN IN CASE OF

a. Fire

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 watched 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^2g 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.

b. Accident

Accidents in the workplace are one of the leading causes of death and disability in the United States. One reason for this is that after working at a job for a period of time, many people become complacent and do not give workplace safety the attention it requires. Aircraft operation areas contain many dangers to personnel, but a sound safety program and an aware workforce can reduce these dangers dramatically. Make workplace safety one of your primary job duties.

TYPES OF EXTINGUISHANT

The extinguishants in general use are described in the following paragraphs.

Methylbromide (M.B.)

This extinguishant boils at 4.6°C and is commonly used in fixed systems, particularly for the protection of power plants. Because of its toxicity, Methyl Bromide should not be used in confined spaces, flight crew compartments or passenger cabins. The effects of breathing the vapours may not be immediately apparent, but serious or even fatal after effects may be sustained at a later stage.

Bromochlorodifluromethane (B.C.F.)

This is semi-toxic extinguishant is particularly effective against electrical and flammable liquid fires. It is used in power plant systems, and for the protection of auxiliary power units in some aircraft; it is also used in certain types of portable extinguisher. It becomes gaseous at normal temperatures and condenses to liquid at-4°C (25°F), and can be stored and discharged at moderate pressures. It has little or no corrosive effect, although halogen acids will be formed if its products which have been decomposed by fire come into contact with water, e.g. condensation caused by fire. In contact with fire, B.C.F. volatilises instantly, giving rapid flame extinction with little or no deleterious effect on metallic, wooden, plastic or fabric materials.

Carbondioxide (CO_2)

This gas extinguishant is also effective against electrical and flammable liquid fires and is used principally in portable fire extinguishers. It is noncorrosive and if the concentration needed to extinguish a fire is excessive it can have appreciable toxic effects. When discharged in a confined space, the vapour cloud can reduce visibility temporarily.

Water

In many aircraft, certain of the portable fire extinguishers in passenger cabins are of the water type, designed for combating fires involving ordinary combustible material such as paper, fabric, etc., where the quenching and cooling effects of water are of prime importance. These extinguishers are not suitable against electrical fires. An anti-freezing agent is normally included to permit operation at temperatures as low as -20°C. Typical examples are the water/glycol extinguisher with 38% of inhibited ethylene glycol, and the 'wet-water' extinguisher with glycol, wetting agents to reduce surface tension, and inhibitors to impart anti-corrosive characteristics.

Bromotrifluromethane (B.T.M.)

This semi-toxic extinguishant is used in fixed systems for the protection of power plant and auxiliary power units. It is also widely used in cargo compartment fire suppression systems of some types of aircraft.

Dry Chemical

Dry chemical extinguishant takes the form of a non-toxic powder, e.g. potassium bicarbonate, and is used in portable fire extinguishers fitted in certain types of aircraft. It is very effective against fires involving flammable liquids and free burning material such as wood, fabrics and paper. Use of the extinguishant against fires in electrical equipment is not recommended, since it could render contactors and switches un-serviceable which may otherwise be functioning correctly in adjacent equipment. It does not have a quenching effect and thereby the dangers of distortion or explosion when used on hot surfaces, such as overheated wheel brakes, are minimised. Some dry chemical powders have a corrosive effect on some metals (including aluminium) which may require special attention when cleaning-up after the discharge of an extinguisher. Dry chemical extinguishers should not be used in flight crew compartments or passenger cabins where visibility would be seriously affected both during the discharge of powder and also as a result of its deposition on transparencies and instruments.

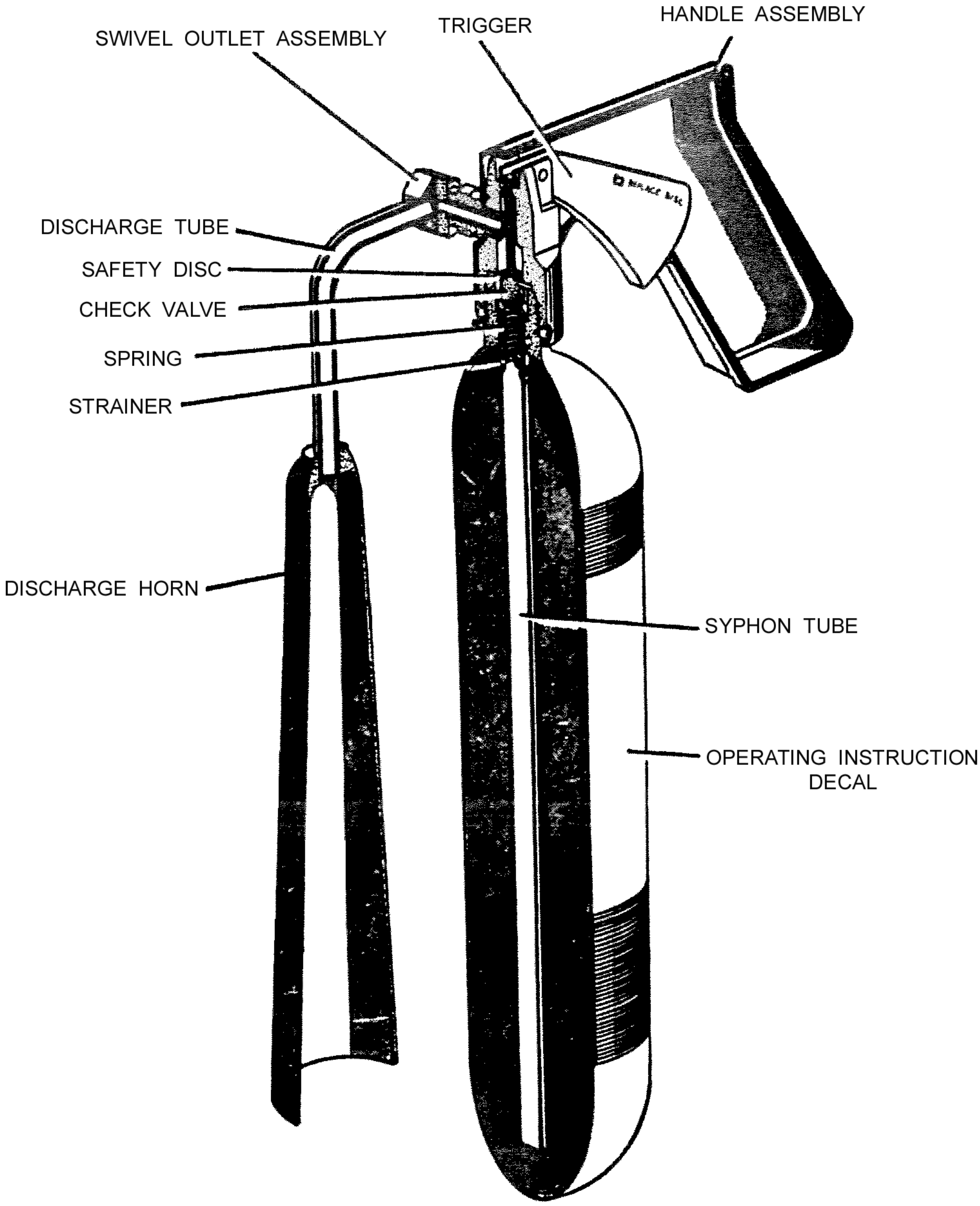

Fig.1.1, Typical portable CO_2

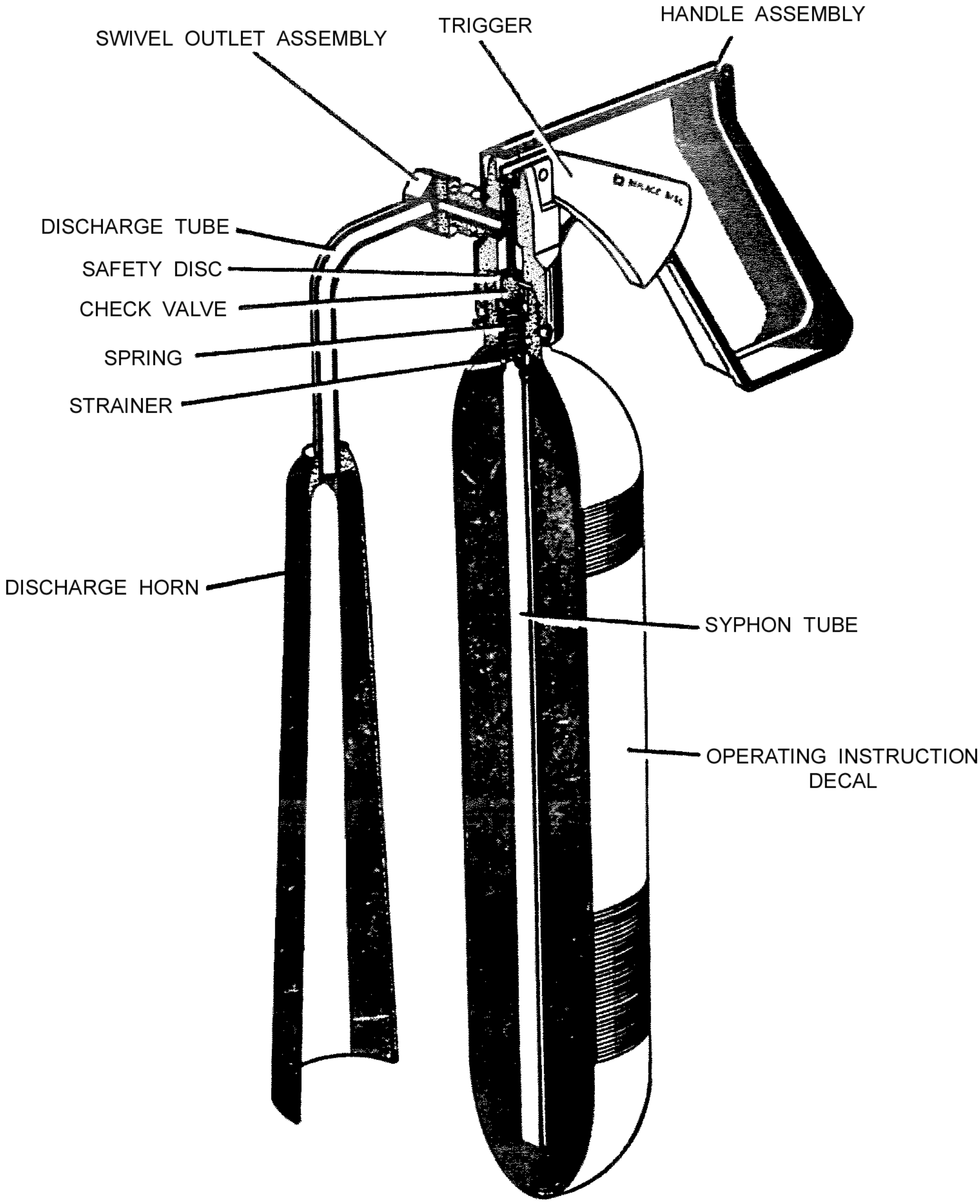

Fig. 1.2. Typical water extinguisher.

KNOWLEDGE OF FIRE EXTINGUISHING AGENTS

Portable Extinguishers

The portable extinguishers in common use are of the CO_2 type and the water type. Extinguishers containing extinguishant B.C.F. are also used in some aircraft. The type of extinguisher installed in a particular location is chosen to be appropriate to the nature of the possible fires in the compartment in which it is installed. Extinguishers are located in accessible positions and installed in suitable attachment brackets with quick-release metal straps. Brief descriptions of their construction and operation are given in the following paragraphs for general guidance.

CO_2 Extinguishers

A typical extinguisher (Fig.1.1)., comprises a steel cylinder and an operating head incorporating a pistol-type firing mechanism, check valve assembly and discharge horn which characterises CO_2 extinguishers generally. When the trigger is pressed, a lock wire and seal are broken and the spindle of the check valve assembly is forced downward, thereby removing the valve from its seat. This allows the extinguishant to flow up the siphon tube, through the centre of a safety disc, to discharge from the discharge horn. Releasing of the trigger alloys the valve to reset and seal off the flow. The purpose of the safety disc is to permit the release of extinguishant in the event of excessive internal pressures. When a safety disc bursts, the trigger of the firing mechanism springs downward and exposes the instruction 'REPLACED DISC' engraved on the side of the trigger.

Water Extinguishers

A typical extinguisher incorporating an antifreeze agent is shown in Fig.1.2. It comprises a cylinder and a valve body which houses a lever operated check valve assembly and a nozzle. A cartridge holder containing a cartridge of CO_2 is secured to the valve body, and, in addition to its main operating function, serves as a hand-grip. When the cartridge holder is twisted the cartridge is punctured causing the CO_2 to be released into the cylinder, thereby pressurising it. Depression of the check valve assembly lever moves the valve from its seating at the top of a syphon tube, allowing the extinguishant to be forced up the tube and to discharge through the nozzle. When the lever is released, the valve is returned to its seating under the action of a spring, and the flow of extinguishant is sealed off.

Some water extinguishers have a plastic head which contains an operating trigger and plunger mechanism, and screws into a threaded boss on the metallic container. The complete assembly is sealed by a rubber sealing ring. When the trigger is squeezed, the plunger mechanism breaks a seal within the operating head and thereby releases the extinguishant. The discharge is subsequently controlled by maintaining or releasing pressure on the trigger. In some cases, the containers are expendable and scrapped after discharge, and only the operating heads are subject to inspection and overhaul procedures.

Weight And Pressure Checks

The fully charged weight of an extinguisher should be checked at the periods specified in the approved Maintenance Schedule, and before installation, to verify that no loss of extinguishant has occurred. The weight, including blanking caps and washers, but excluding cartridge units, is normally indicated on the container or operating head. For an extinguisher embodying a discharge indicator switch, the weight of the switch cable assembly is also excluded.

The date of weighing and the weight should, where specified, be recorded on record cards made out for each type of extinguisher, and also on labels for attachment to extinguishers. If the weight of an extinguisher is below the indicated value the extinguisher must be withdrawn from service for recharging.

For extinguishers fitted with pressure gauges, checks must be made to ensure that indicated pressures are within the permissible tolerances relevant to the temperature of the extinguishers. The relationship between pressures and temperatures is normally presented in the form of a graph contained within the appropriate aircraft Maintenance Manuals.

In certain types of portable extinguishers, a check on the contents is facilitated by means of a disc type pressure indicator in the base of the container. If the discharge pressure is below the specified value, the disc can be pushed in by normal thumb pressure.

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CHAPTER-2
WORKSHOP PRACTICES

CARE TO BE TAKEN WHEN HANDLING WITH

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.

Holding tools are very important to an aircraft maintenance technician. These tools come in a variety of shapes and sizes, and are designed for different tasks and needs. The proper use of holding tools helps ensure a professional looking job. However, care must be taken to use the proper tool for the job.

Workshop Materials Safety

EASA regulations require an employer to have copies of relevant Material Safety Data Sheets that are readily available to all shop personnel at all times. These data sheets allow for quick reference in case of a chemical spill or injury. In the case of chemical injury, a copy of the pertinent data sheets(s) should be sent along to the emergency room to ensure proper medical attention.

A Material Safety Data Sheet consists of nine basic sections:

1. Product identification including trade name and the address and emergency phone number of the manufacturer/ supplier.
2. Principal ingredients including percentages of mixture by weight.
3. Physical data describing the substance’s appearance, odor, and specific technical information such as boiling point, vapor pressure, solubility etc.
4. Fire and explosion hazard potential.
5. Reactivity data including stability and incorruptibility with other substances.
6. First aid and health hazard data.
7. Ventilation and personal protection - glove goggles, respirator, etc.
8. Storage and handling precautions.
9. Spill, leak, and disposal procedures.

UNDERSTANDING TERMS

1. Allowance (engineering)

In engineering and machining, an allowance is a planned deviation between an actual dimension and a nominal or theoretical dimension, or between an intermediate-stage dimension and an intended final dimension. The unifying abstract concept is that a certain amount of difference allows for some known factor of compensation or interference. For example, an area of excess metal may be left because it is needed to complete subsequent machining. Common cases are listed below. An allowance, which is a planned deviation from an ideal, is contrasted with a tolerance, which accounts for expected but unplanned deviations.

Examples of Engineering and Machining Allowances

1. Outer dimensions (such as the length of a bar) may be cut intentionally oversize, or inner dimensions (such as the diameter of a hole) may be cut intentionally undersize, to allow for a predictable dimensional change following future cutting, grinding, or heat-treating operations. For example :

a. The outer diameter of a pin may be ground to 0.0005 inches (0.013 mm) oversize because it is known that subsequent heat-treatment of the pin is going to cause it to shrink by 0.0005 inches (0.013 mm).

b. A hole may be drilled 0.012 inches (0.30 mm) undersize to allow for the material that will be removed by subsequent reaming.

2. Outer dimensions (such as the diameter of a railroad car’s axle) may be cut intentionally oversize, or inner dimensions (such as the diameter of the railroad car’s wheel hub may be cut intentionally undersize, to allow for an interference fit (press fit).
3. A part may be cast intentionally too big when it is desired to later machine the surface. This ensures that the roughness that the casting process leaves is removed, and a smooth machined surface is produced. This

machining allowance may be e.g. 1mm, but this depends on the size of the part and the accuracy of the casting process.

Concepts of Allowance and Tolerance

Often the terms allowance and tolerance are used imprecisely and are improperly interchanged in engineering contexts. This is logical because both words generally can relate to the abstract concept of permission - that is, of a limit on what is acceptable. However, in engineering, separate meanings are enforced, as explained below.

A tolerance is the limit of acceptable unintended deviation from a nominal or theoretical dimension. Therefore, a pair of tolerances, upper and lower, defines a range within which an actual dimension may fall while still being acceptable.

In contrast, an allowance is a planned deviation from the nominal or theoretical dimension.

Example

An example of the concept of tolerance is this : a shaft for a machine is intended to be precisely 10 mm in diameter : 10 mm is the nominal dimension. The engineer designing the machine knows that in reality, the grinding operation that produces the final diameter may introduce a certain small but unavoidable amount of random error. Therefore, she specifies a tolerance of $\pm$ 00.001 mm)"plus-or-minus" 0.001 mm). As long as the grinding machine operator can produce a shaft with actual diameter somewhere between 9.999 mm and 10.001 mm, the shaft is acceptable. Understanding how much error is predictable in a process - and how much is easily avoidable; how much is unavoidable (or whose avoidance is possible but simply too expensive to justify); and how much is truly acceptable - involves considerable judgement, intelligence, and experience, which is one reason why some engineers are better than others.

An example of the concept of allowance can be shown in relation to the hole that this shaft must enter. It is evident that the above shaft cannot be certain to freely enter a hole that is also 10 mm with the same tolerance. It might, if the actual shaft diameter is 9.999 mm and the actual hole diameter is 10.001 mm, but it would not if conversely the actual shaft diameter is 10.001 mm and the actual hole diameter is 9.999 mm.

To be sure that there will be enough clearance between the shaft and its hole, taking account of the tolerance, an allowance is intentionally introduced in the dimensions specified. The hole diameter might be specified as 10.003 mm with a manufacturing tolerance of $\pm$ 0.00 mm ("plus-or-minus" 0.001mm). This means that the smallest acceptable hole diameter will be 10.002 mm while the largest acceptable shaft diameter will be 10.001 mm, leaving an "allowance" of 0.001 mm. The minimum clearance between the hole and the shaft will then be 0.001 mm at what is referred to as "maximum material condition".

2. Tolerance

As it is not possible to machine either the hole or shaft exactly to a definite size it is the hole is necessary to allow for permissible variations on each. These variations are termed "Tolerances" . Thus the tolerance on a dimension is the variation tolerated on the dimension, and may be considered as a numeral expression of the desired quality of workmanship; it is the difference between the high and low, ,limits size for that dimension. For example, a part that should be exactly 1in. dia (nominal size) will be accepted for certain purpose if it is within the limits of 1.001 in. (high limit) and 0.999 in. (low limit; tolerance equals 0.002 in. The nominal size and the tolerance may be expressed as follows,

i.e. 1.000 $\pm$ 0.001 but sometimes the nominal size is not given, only the low and high limits, e.g. $\frac{0.999\text{ in.}}{1.001\text{in.}}$.

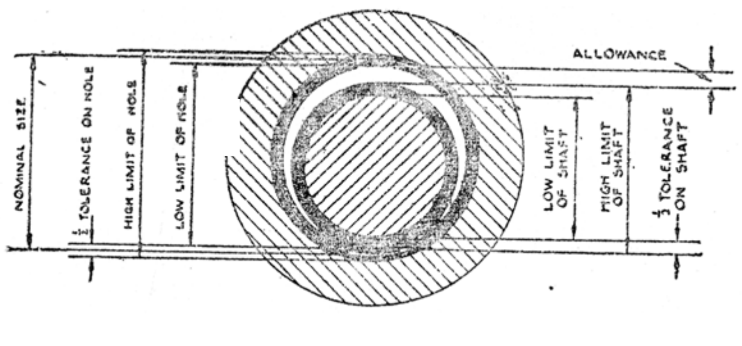


Fig. 2.1, Diagram of Clearance Fit.

Tolerance may be allowed in one of the two ways. For example, a 4 in. dia. hole, with a tolerance of 0.004 in. could be produced within the following limiting sizes.

4.004in High Limit 4.000in Low Limit	or	4.002in High Limit 3.998in. Low Limit

In the first instance, the tolerance in one direction, the low limit being the nominal size; this is therefore termed Unilateral system. In the second instance, the nominal size of the hole is an intermediate figure, the limits going both above and below it; this system is therefore termed as Bilateral system.

The above diagram shows the tolerance in addition to the limits and nominadil mension for a clearance fit using bilateral limits and hole basis. The Newall system is a bilateral system; the British Standard system can either be used as unilateral or bilateral system.

3. Workmanship Standards

Workmanship is defined the control of design features, materials and assembly processes to achieve the desired durability and reliability for subassembly interconnections, specifically those in printed wiring assemblies and cable harnesses, and the use of inspection techniques and criteria to assure interconnect quality. Workmanship promotes standardized designs and fabrication practices to enhance durability and reliability and restricts the use of designs and manufacturing processes known to reduce those qualities.

CALIBRATION OF VARIOUS TOOLS & EQUIPMENTS, CALIBRATION STANDARDS

Recommended Practices

In order to comply with the requirements prescribed in CAR Parts 43, 145, and 148 regarding the maintenance and manufacture of aircraft and components, various precision (calibrated) tools, and inspection, measuring and test equipment must be used to ensure aircraft, engines and components conform to the manufacturer's specification. These tools, and the inspection, measuring and test equipment must be periodically calibrated as recommended by the Manufacturer or operator.

Where a process, or sequence of processes, requires calibrated tools or equipment to be used to determine conformance to specification of the aircraft or component for certification for release-to service then calibrated equipment must be used at each step in the process.

In various industrial, aerospace and defence organisations, it has been a long standing practice to permit the use of workshop equipment that is not subjected to periodic calibration if no test data needs to be recorded. This may include a null indication measurement, waveform monitoring, continuity checking, troubleshooting, or determining or assessing the feasibility of repairing versus scrapping an item. In these cases the equipment must be clearly identified as "NOT FOR CALIBRATED TESTING" or "NO CALIBRATION REQUIRED". Equipment so identified cannot be utilised for conformance acceptance or certification for release-to-service.

Note:

Where both calibrated and un-calibrated equipment are located in the same workshop, procedures must be established to ensure that un-calibrated equipment is used for trouble shooting only and not for final certification or for release-to-service.

Calibration

Calibration ensures the accuracy of the tools, and inspection, measuring and test equipment used to return aircraft, engines and components to service. Calibration minimises measurement errors and uncertainties to acceptable levels.

For calibration of tools, and inspection, measuring and test equipment, acceptable levels of uncertainty are defined by the tolerance limits of the equipment's parameters established by the manufacturer. The outcome is maintenance of the equipment within the defined accuracy of the manufacturer's design tolerances.

Calibration is as defined as :

The application of specifically known and accurately measured input to ensure that an item will produce a specifically known output which is accurately measured or indicated. Calibration includes adjustment or recording of corrections as appropriate".

Options for Calibration

Tools and inspection and test equipment that require calibration must be calibrated by

1. An Accredited Calibration Laboratory; or
2. A Non-Accredited Calibration Laboratory

Calibration Facility or Laboratory

A calibration facility or laboratory can be any person or organisation who tests and/or calibrates measurement devices or working standards, in a controlled environment to ensure repeatability Documented calibration procedures must be used and documented evidence of the traceability of the standards used must be provided.

A calibration laboratory can be provided by a CAR Part 145 Maintenance Organisation, a CAR Part 148 Manufacturing Organisation or a CAR Part 66 LAME provided the requirements of a calibration facility or laboratory are met.

Acceptable Procedure for Test Equipment

An acceptable procedure is one that has been published or received from the equipment manufacturer. The manufacturer may consider that only certain test equipment is considered as being acceptable to determine the calibration of their equipment. If alternate test equipment is required to be used then either the manufacturer to an appropriate person, qualified in metrology should attest to the use of alternate test equipment.

Procedures based on industry standards may need to be developed, accepted and used by a Calibration Laboratory if the manufacturer's data is not available or sufficient.

Calibration Interval and Labelling

The equipment manufacturer's recommended calibration interval should be used where available.

Where an equipment manufacturer does not specify a calibration interval, an evaluation should be carried out and documented to support the selected interval, utilising the following:

1. Quality of the tool or instrument
2. Operating environment (usage level, where used, storage etc.)
3. Calibration interval for other similar tools or instruments
4. The accuracy of measurement required

The resultant interval is then established as the initial calibration interval and this may be increased or reduced based on the process outlined in the procedure.

The calibration interval should be varied (increased or decreased) based on the reliability of the equipment in maintaining its accuracy as determined from the equipment calibration history. Any interval should be appropriate to the accuracy of measurement to be performed. Any variation from the Manufacturer's recommended interval must be documented and include the justification.

Where a tool is marked "Calibrate Before Use" the transfer standard against which that tool (working standard) is checked should have a log book where each calibration of each tool is recorded. This activity ensures that there is an auditable trail relating to the use of that tool. The policy regarding the use of such tools and reference standards should be highlighted within the Policy and Procedures Manual (or equivalent document).

Calibration of equipment should be performed at certain periods of the equipment life.

Generally calibration should be performed at the following times:

1. Initial purchase, prior to use unless it comes with a calibration certificate
2. After repair
3. Periodic calibration
4. Whenever accuracy is in doubt.

There may be some instances where the aircraft or equipment manufacturer specifies more stringent calibration requirements for a particular piece of equipment than the test equipment manufacturer recommends. This additional requirement must be considered when setting calibration intervals and procedures.

Procedures for variation of intervals

The determination of a calibration interval for a particular item of equipment involves the analysis of the calibration history for the equipment with the data arranged as an observed percentage of intolerance.

Vs. time since a calibration or test. The data should be assembled from recorded results of calibration or testing, organised into a calibration history. A calibration history consists of an unbroken sequence of calibration or testing results accompanied by the date of service against a given serial number.

Description of Calibration Data Management

Continuity

The calibration history record for an item of equipment that requires calibration should be free from missing service actions. If there is a missing service action, then that should be detectable.

Completeness

Each record should provide all information necessary for analysis. This information needs to include as minimum :

1. Identification (serial number, tag number etc.) of the item serviced
2. Any special usage classification of designation.
3. Date of service.
4. Condition as received, prior to adjustment or other corrective service.
5. Service action taken.
6. Condition released (serviceable/unserviceable/limited calibration etc.)
7. Identification of the reference standards used in calibration of the item

Consistency

Each record in the calibration history of a serial numbered item should reflect uniformity with respect to parameters calibrated, tolerances used, procedures used, etc.

Environment (Storage and usage)

The storage and usage of a calibrated item of equipment has a direct relationship to the calibration assessment program. If the location or usage of the equipment changes this needs to be taken into consideration. For example, a torque wrench used daily that has a transit container and is stored on a tool board may have a 6 month calibration interval. If it is transferred for use in a different working environment such as the tarmac, then consideration should be given to reducing its calibration interval.

Out of Tolerance Action

Out of Tolerance Action (OOTA) occurs when a piece of calibrated equipment is found to be out of tolerance. This may occur as a result of a scheduled calibration check or if there is a suspicion of an out of tolerance situation.

An OOTA provides a warning that all aircraft, engines and components whose release-to-service was based on the use that item of calibrated equipment are potentially non-compliant with the required specification. A risk analysis therefore needs to be carried out to determine the extent of any remedial action that may be required on those aircraft, engines or components that are affected by the OOTA associated with the out-of-tolerance item of equipment.

For individual engineers this OOTA action should include a review of all work carried out using the out of tolerance equipment and maintaining a record of any re-work required.

A maintenance organisation and a manufacturing organisation should detail, within its internal quality assurance system, processes that will be applied as a result an OOTA. These procedures should include:

1. A risk assessment of the effect of the OOTA
2. The procedures used to assess the risk.
3. An audit trail to determine what aircraft, engines, components, etc the item of calibrated equipment, (tool inspection or test instrument) was used for certifying a release-to service. A good practice is to detail any item of calibrated equipment used as part of a work package.
4. Procedures for any recall of aircraft etc. that may be determined necessary.
5. Documentation to support the above process.

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.

Steel Rules

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.

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.

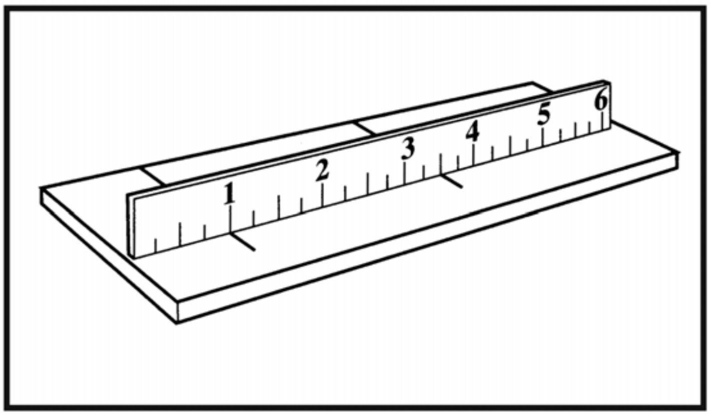


Fig. 2.2, The proper use of a steel scale requires that the end of the scale not be used to make a measurement. Instead, the one inch mark is used as the starting point. However, you must remember to subtract one inch from the final measurement.

Combination Set

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, midwaybetween 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. 2.3, and a few typical applications of it are shown.

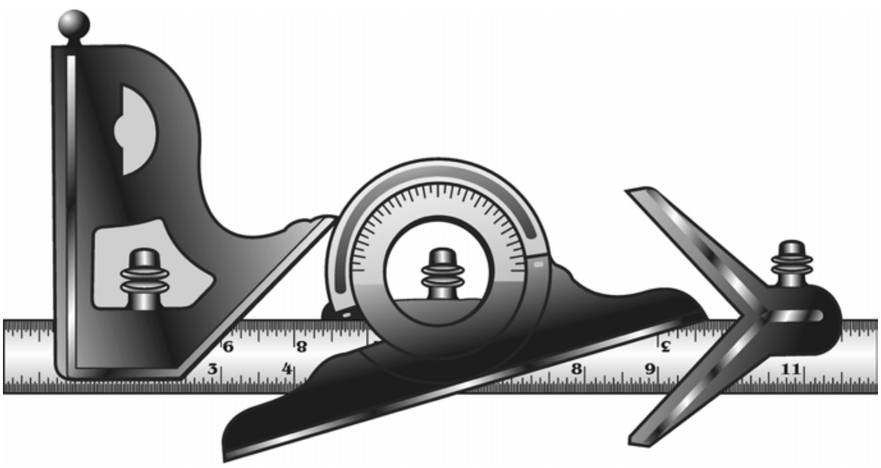


Fig. 2.3, Combination Set

Inside & Outside Calipers

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.

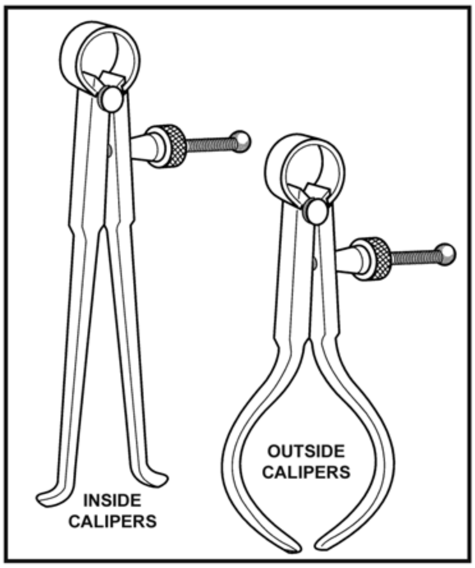


Fig. 2.4 (a), Inside calipers have legs with ends that curve to the outside, whereas outside calipers have legs with ends that curve to the inside.

Scribers

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.

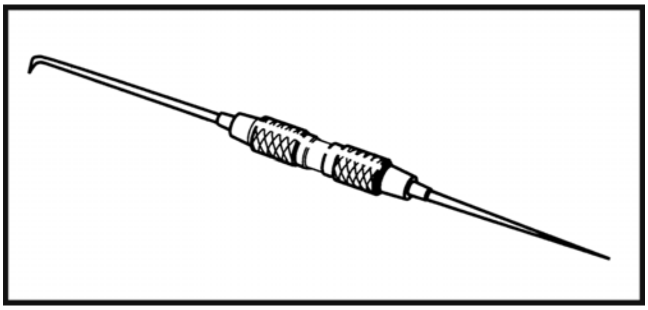


Fig. 2.5, A Scriber is typically used with layout dye to mark reference points on a material. However, scriber marks should never be used for bend lines as they cause stress concentrations that can lead to component failure.

Surface Gauge

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. 2.6. 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. 2.6, Surface Gauge

Dividers

Dividers are veryuseful 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. 2.7. 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.

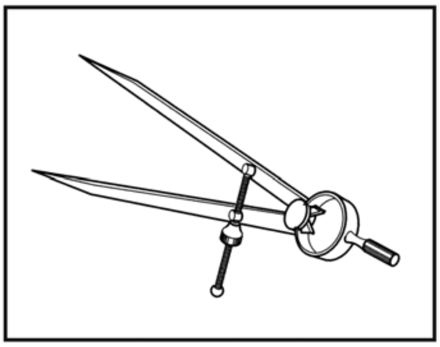


Fig. 2.7, Spring dividers

Trammel

A beam compass is a compass with a beam and sliding sockets or cursors for drawing and dividing circles larger than those made by a regular pair of compasses. The instrument can be as a whole, or made on the sport with individual sockets (called trammel points) and any suitable beam.

Trammel points

Trammels or trammel points are the sockets or cursors that, together with the beam, make up a beam compass. Their relatively small size makes them easy to store or transport. They consist of two separate metal pieces (approx. 2.5” × 5” × ½) that are usually connected by a piece of wood, metal, or pipe. They work like a scratch awl.

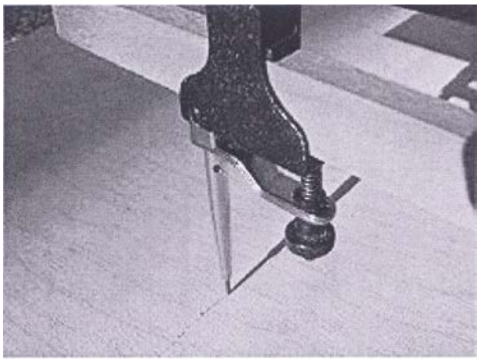


Fig. 2.8

Use

As for any compass, there are two uses.

Scribing a circle

Sharp point used to score a fine line in the birch plywood connected to each other by a piece of 3/4" × 3/8".

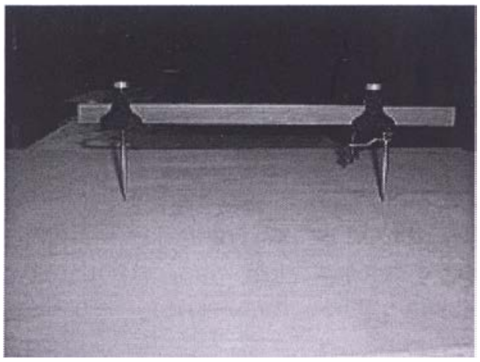


Fig. 2.9

The beam compass is used to scribe a circle. The radius can be adjusted by sliding the metal across the wood (beam) and locking it by turning a knob at the desired location. The threaded machine rod is similar to the bolt. The only limitation is the rigidity of the wood being used. Longer pieces tend to get floppier depending on the species of wood used. Metal can be used as an alternative but also has length limitations. Trammel points score a precise cut out line with the sharp point of the rod. When the circular knob is turned, it micro adjusts the radius of the circle. The spring locks the mechanism at the precise desired location. Turning clockwise decreases the radius while turning counterclockwise increases the radius slightly.

Transferring Measurements

A beam compass can also be used to make a series of repetitious measurements in a precise manner. Each point is rotated 180° and this process is repeated until the desired measurement is reached. The indentation created by the sharp point of the trammel is easily seen and makes a precise point to reference to the next location.

Variants

Circle cutter used to score drywall.

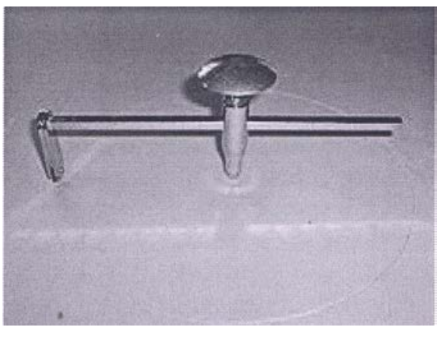


Fig. 2.10

The circle cutter is a basic variation of the beam compass. There are many types of circle cutters. This cutter is used primarily to score a circular pattern in the drywall to fit over recessed lighting in the ceiling. The tool consists of a square shank with a sliding pivot that is locked into the desired location with a turn knob. The shank is graduated into 16 units and each unit is further divided into increments of one quarter. One end of the shank has a fixed cutter wheel that scores a fine line in the drywall.

Bevel Protractor

A bevel protractor (Fig. 2.11) 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.

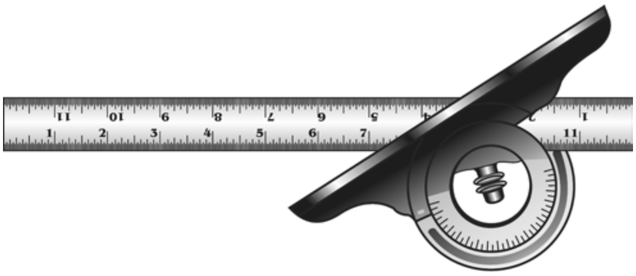


Fig. 2.11, Bevel Protractor

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.

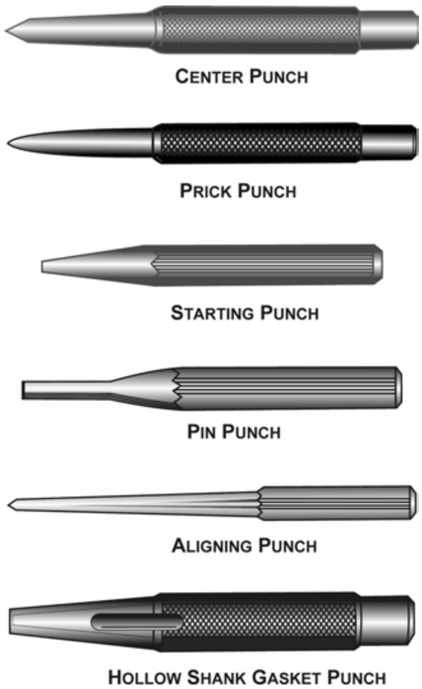


Fig. 2.12, Typical punches

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.

Angle Plates

Are precision tools made of cast iron, tool steel, or granite (Fig. 2.13). 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.

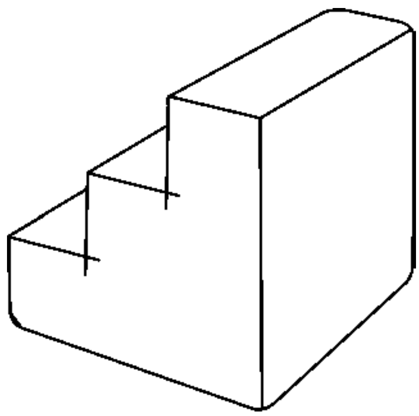


Fig. 2.13, Angle Plates.

Try Square

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. 2.14. 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.

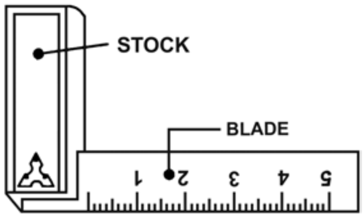


Fig. 2.14. Try square.

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. 2.15 (a), or adjustable, as shown in Fig. 2.15 (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.

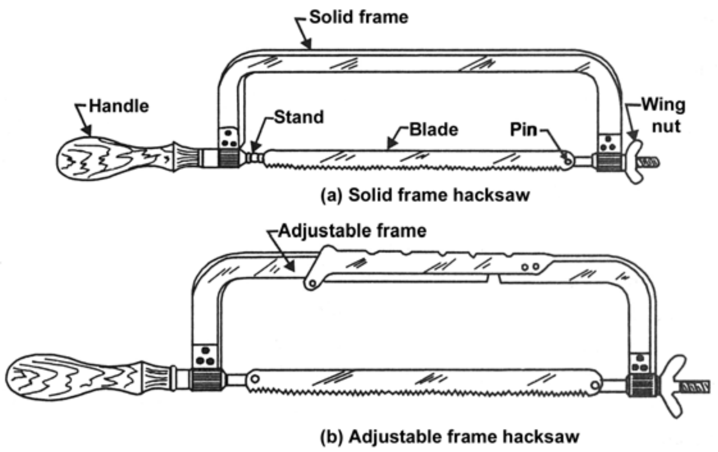


Fig. 2.15, Types of hacksaws.

The points of the teeth are bent, as shown in Fig. 2.16 (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. 2.16 (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.

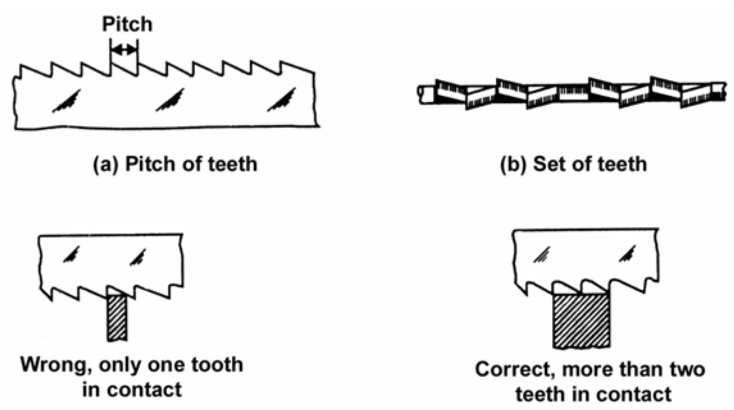


Fig. 2.16, Position of teeth.

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. 2.16 (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. 2.17). 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.

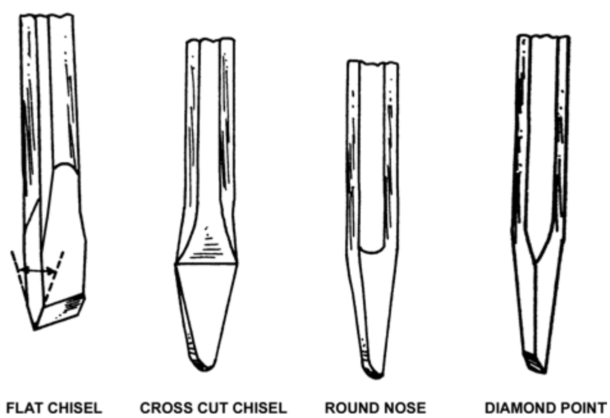


Fig. 2.17, Types of Chisels

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. 2.18. 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.

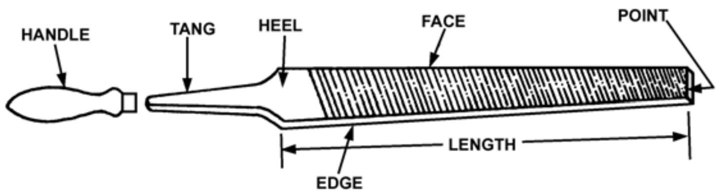


Fig. 2.18, Different parts of File

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. 2.19. 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.

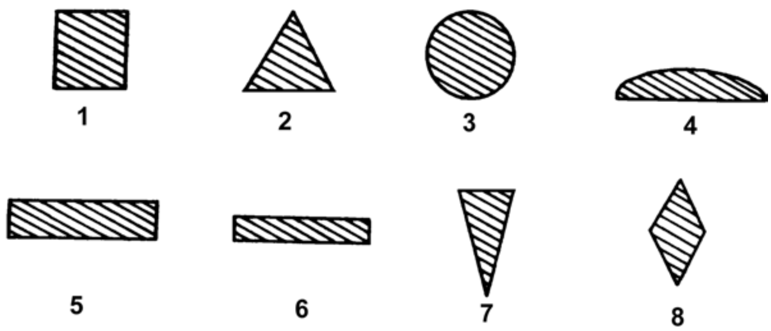


Fig. 2.19, Cross-sections of files.
1. Square 2. Triangular or three square 3. Round 4. Half round
5. Rectangular-1 6. Rectangular-2 7. Knife edge 8. Diamond file.

A round file has a circular cross-section as shown in Fig 2.19 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.

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.

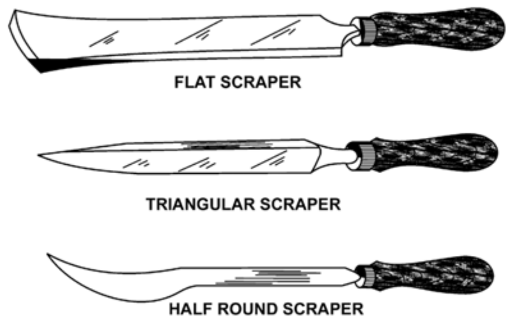


Fig. 2.20, Type of Scrapers

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. 2.21). 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. 2.21, 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.

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 2.22(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 2.22 (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.

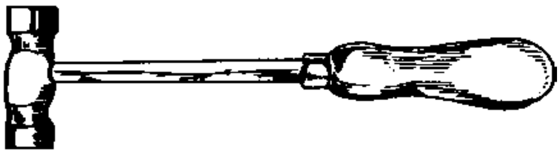


Fig. 2.22 (a), Soft hammers with brass head.

Fig. 2.22 (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 . 2.24). the straight-peen (Fig 2.25). and the cross-peen (Fig 2.23). 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.

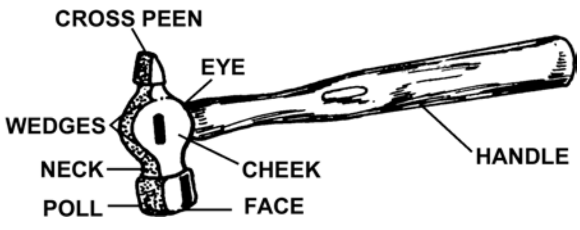


Fig. 2.23, Cross peen hammer

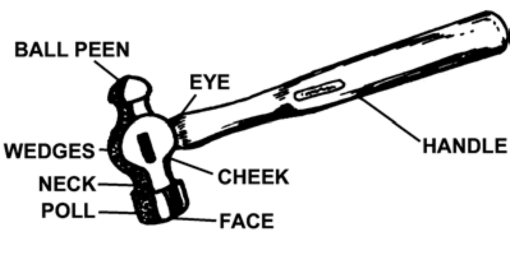


Fig. 2.24, Ball-peen hammer

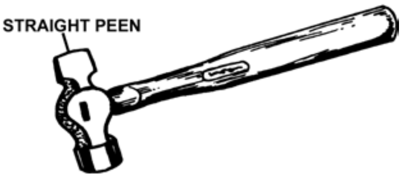


Fig. 2.25, Straight peen hammer

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. 2.26, 2.27 and 2.28 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.

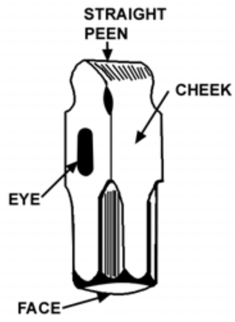


Fig. 2.26, Straight peen sledge hammer.

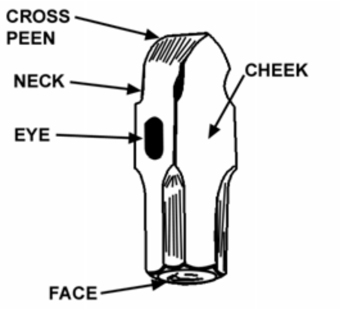


Fig. 2.27, Cross peen sledge hammer.

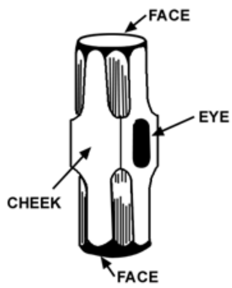


Fig. 2.28, Double faced sledge hammer.

b. Claw hammer

[Fig. 2.29] 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.

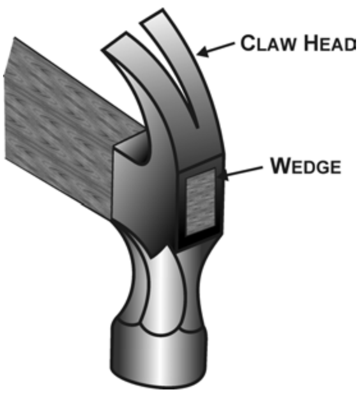


Fig. 2.29, A claw hammer

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. 2.30.

Fig. 2.30, 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. 2.31). 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.

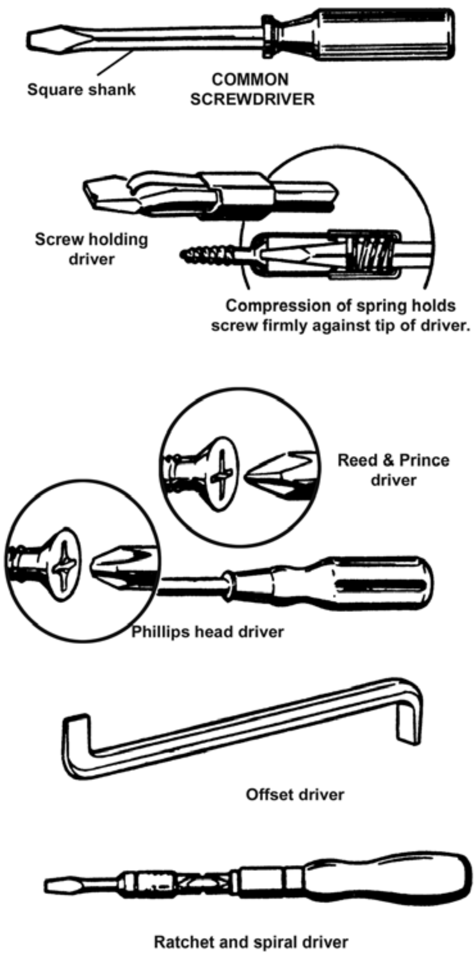


Fig. 2.31, Screwdrivers and their uses.

The two common recessed head screws are **the Phillips** and **the Reed and Prince**. As shown in Fig. 2.31, 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 2.32 shows a set of jewelers' screwdrivers. Fig. 2.33 shows the correct wayto hold this screwdriver. A stubby screwdriver (Fig. 2.34) helps to start screws where space is limited.

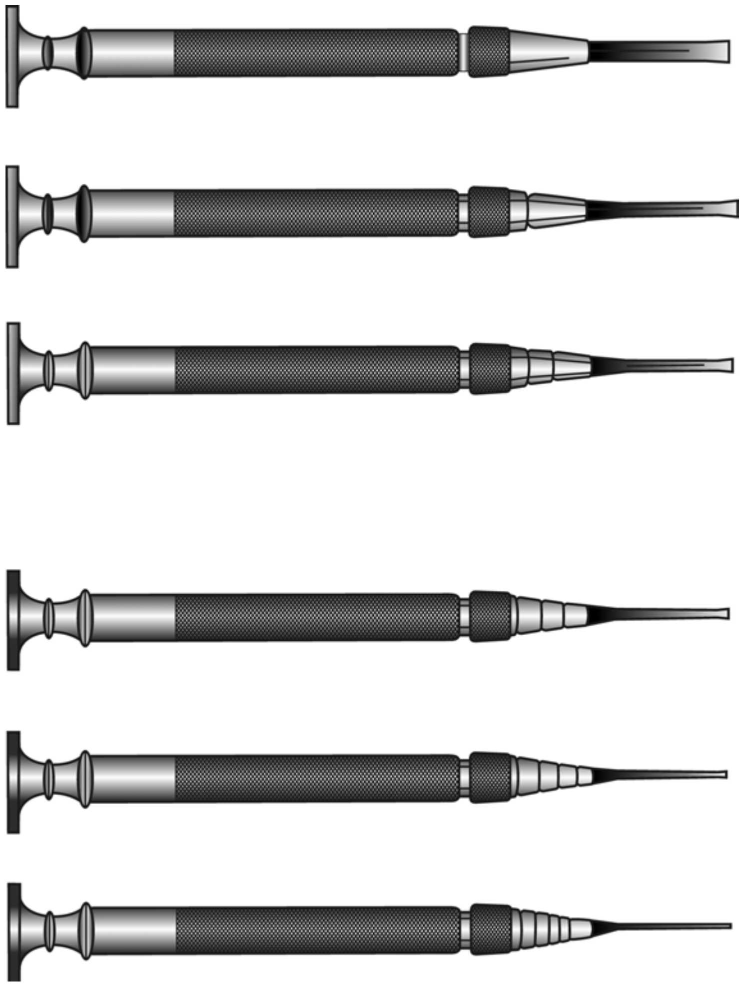


Fig. 2.32, A set of Jewelers' screwdrivers.

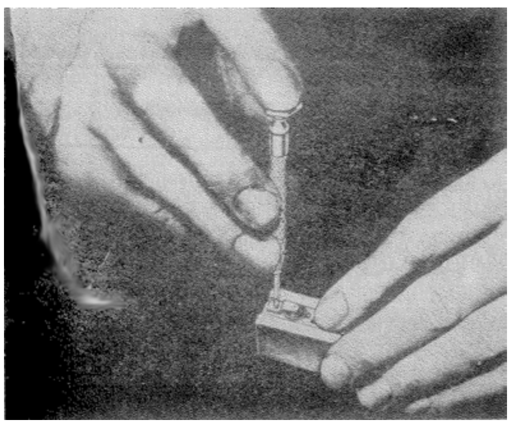


Fig. 2.33, Correct way to use a jewelers' screwdriver.

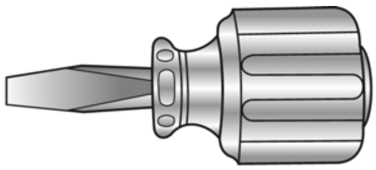


Fig. 2.34, A stubby screwdriver.

A ***heavy-duty screwdriver*** (Fig. 2.35) 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.

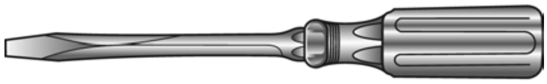


Fig. 2.35, Heavy-duty square-shank screwdriver.

A ***Phillips screwdriver*** (Fig. 2.36) 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.

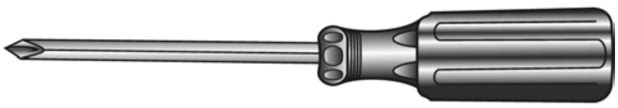


Fig. 2.36, Phillips screwdriver with No. 2.

A ***double-ended offset screwdriver*** (Fig. 2.37) is used for turning screws in awkward places where there is not enough room to use a regular screwdriver.

Fig. 2.37, 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. Alade 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. 2.38a) 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.2.38, 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. 2.38,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.

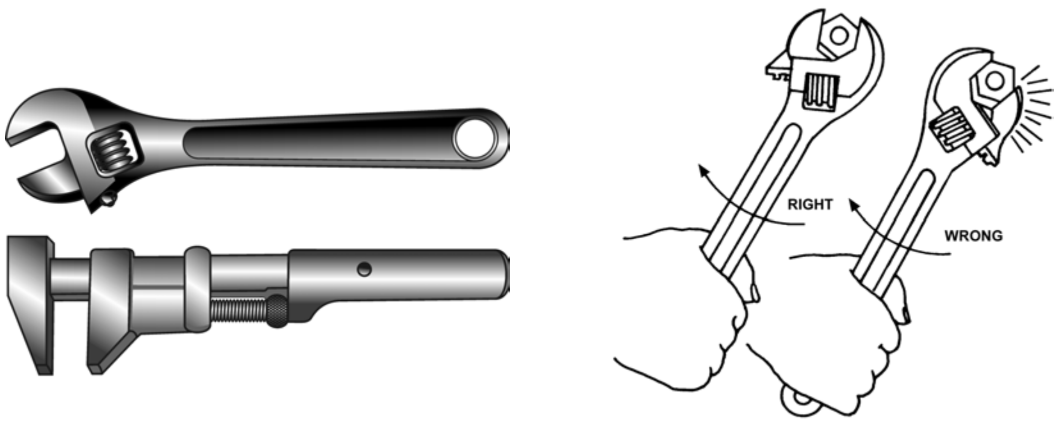
d. Adjustable wrench

(Fig.2.38,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. 2.38, Types of wrenches.

e. Lever-jaw wrench

[Fig 2.39 (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 2.39 (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

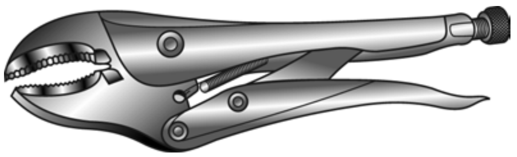
[Fig. 2.39 (g)]. It is a thin, single - ended or double-ended wrench used for turning check or jam nuts. The thinness of these nuts, often used in narrow spaces, requires the use of a thin wrench. These wrenches are not intended for hard use. The openings are offset at an angle of 15^o.

h. Tool-post wrench

[Fig.2.39 (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.

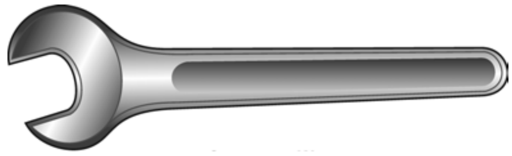
i. Square box wrench

[Fig. 2.39 (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.

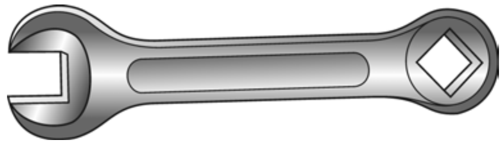


e. Lever Jaw Wrench

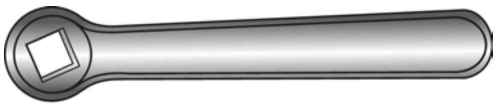
f. Combination Wrench



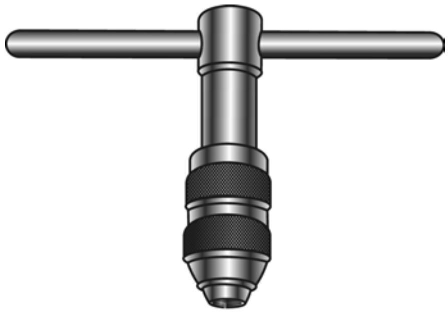
g. Check nut Wrench



h. Tool post wrench



i. Square Box Wrench



j. T-handle Tap Wrench

Fig. 2.39, 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. 2.39(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. 2.40(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.2.40 (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. 2.40(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. 2.40(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. [2.40(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. 2.40(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. 2.40(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.2.40(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.2.40 (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. 2.40(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. 2.40(u)]

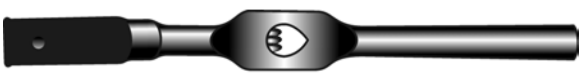
The socket end has an opening with angular notches to fit bolt heads and nuts. This notched opening is made with either 4, 6, 8, or 12 points. The 6 and 12-point sockets are used for hexagon-headbolts and nuts, while the 4- and 8-point sockets are used for square-head bolt and nuts.

v. Ratchet wrench

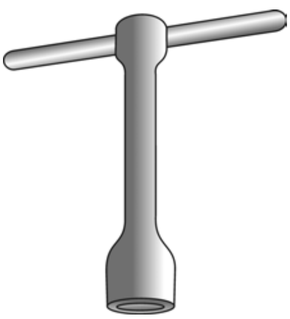
[Fig. 2.40(v)] may be either of the socket type or the open-end type. The handle turns the interchangeable sockets through a ratchet mechanism. This mechanism may be adjusted to operate in the clockwise or the counter clockwise direction so that the ratchet wrench may be used to tighten or loosen nuts 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.

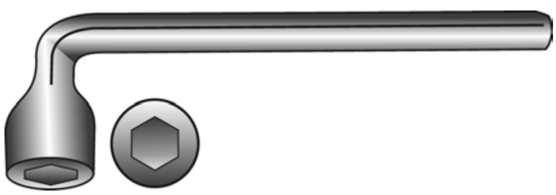
k. 12 point box wrench



l. Adjustable tab wrench

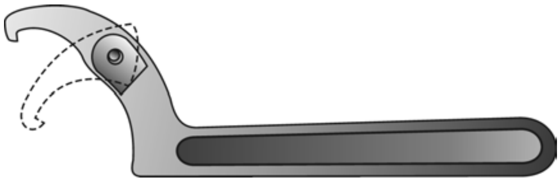


m. T-socket wrench



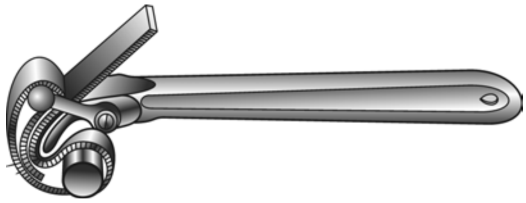
n. Offset socket wrench.

o. Pin hook spanner wrench

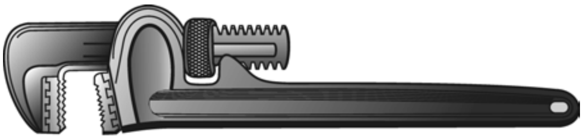


p. Adjustable hook spanner wrench

q. Adjustable pin-face wrench

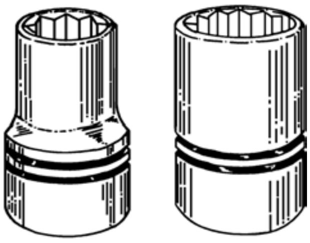


r. Strap wrench



s. Stillson type pipe wrench

t. Hexkey wrench



u. Socket wrench

v. Ratchet wrench.

Fig. 2.40, 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.

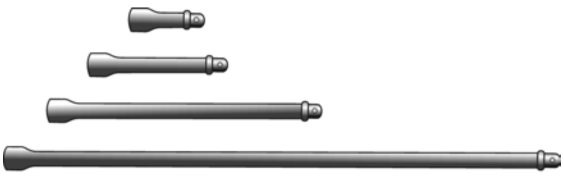


Fig. 2.41 (a) Extension bars

Fig. 2.41 (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).

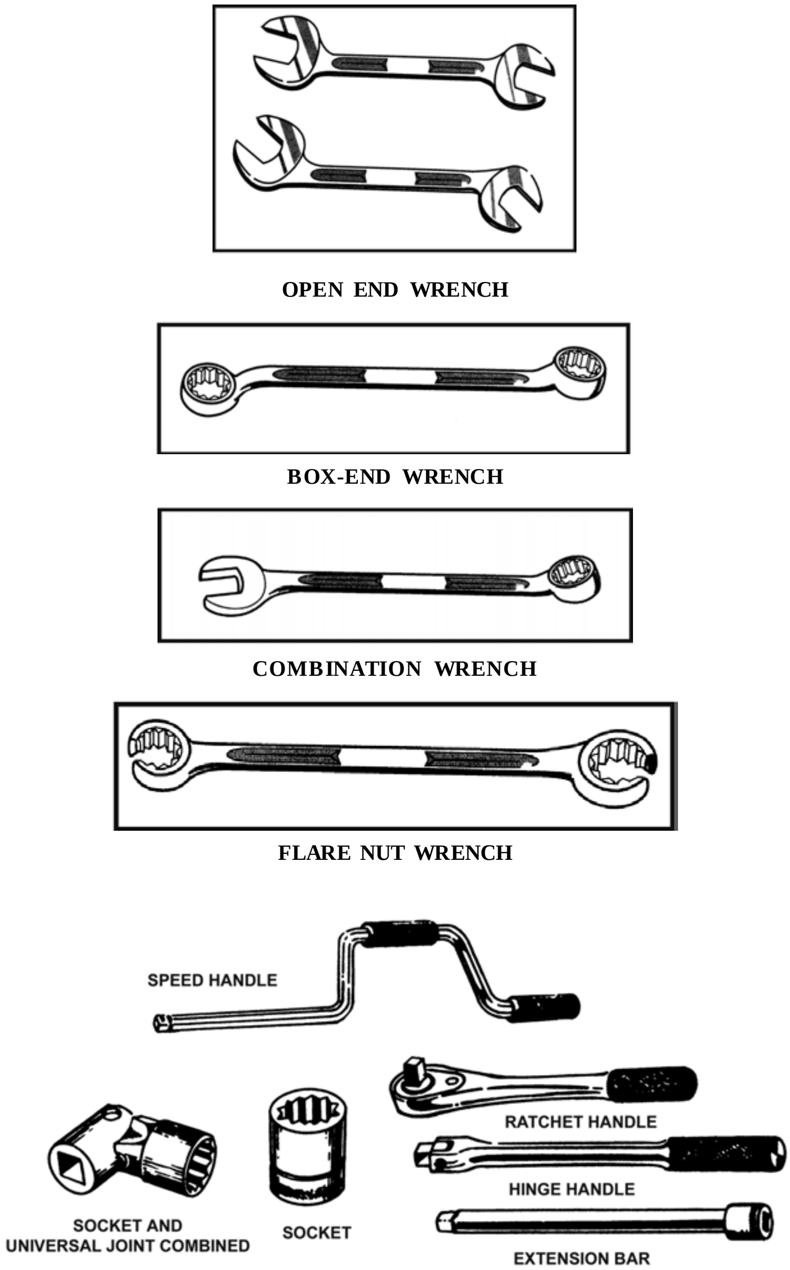


Fig. 2.42, Wrenches and Sockets

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. 2.43 and Fig. 2.44. 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.

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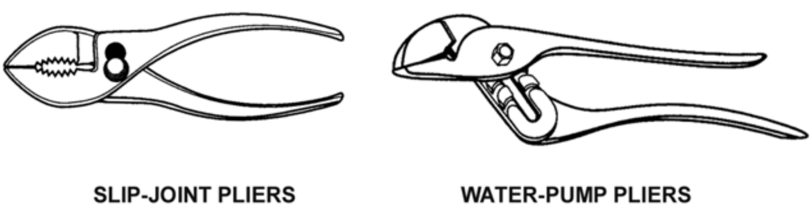


Fig. 2.43, Types of pliers

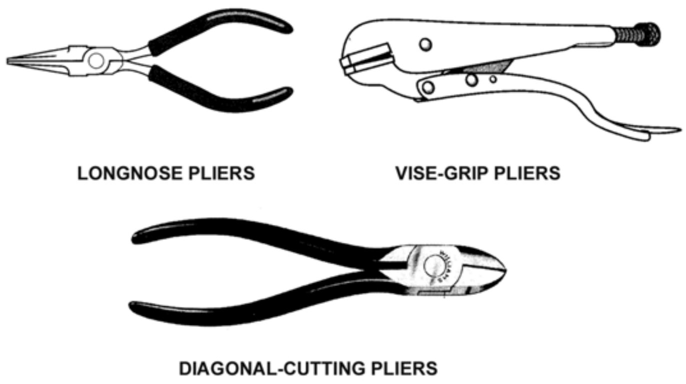


Fig. 2.44, Types of pliers

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. 2.45 (a) has flat jaws with small grooves. It is used for forming and holding work.

Fig. 2.45 (a) Flat Nose Plier

Fig. 2.45 (b) Round Nose Plier

The ***round nose* plier**, as shown in Fig. 2.45 (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. WORK HOLDING TOOLS

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.

Bench Vice

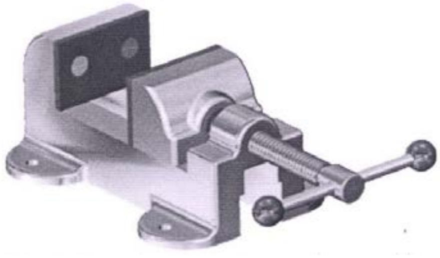
A bench vise, usually swivel-based is the kind most favored for general shop work. It is securely fastened to the bench with bolts. The faces of the jaws are usually lightly serrated and hardened to ensure a firm grip on the work. Finished surfaces should be protected when placed in the vise by using brass or copper jaw caps. It is also used for work holding generally symmetrical work. When it is necessary to hammer a piece of work held in a vise, it is best to support the work by placing a block of wood or metal under it to prevent the work from being driven down through the jaws of teh vise. It is made of iron or steel cast bodywith square threaded screw & nut made of mild steel. One jaw is stationary & other movable by rotating squarethread. Tightening the vise' by hammering on the handle is poor practice.

Banch Vice

Hand Vice

Hand Vice

It is used by toolmakers at the bench for small machining operations such as drilling or tapping. It consists of 2 jaw & hands which are hinged together on a pivot, on the opposite end the work held between the serrated faces of the jaws with a screw & a wing nut.



Machine Vice

Pin Vice

Machine Vice

It is similar to bench vice but used on machines like drilling, milling & grinding machines for holding work & allow machining operations on work. It is made of mild steel. It consists of a body with a solid jaw, a movable jaw, a screw and a handle for the control of movement of movable jaw.

Pin Vice

It is a simple tool for holding small diameter work/tools like drill bits & other tool's such as needle files or sculpting tools like drill bits & other tool'such as needle files or sculpting tools in a collet so that they can be used by hand or machine.

It is consists of a self centering chuck on a handle which may be of wood or metal. The work is gripped between the jaws of the chuck by rotating the handle

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. 2.46. 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.

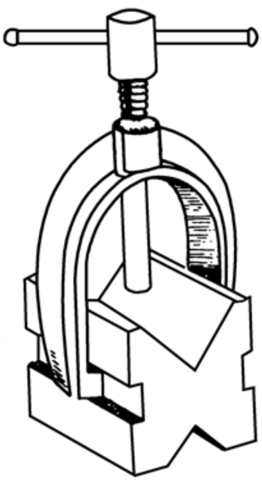


Fig. 2.46. V-Block with 'U' Clamp

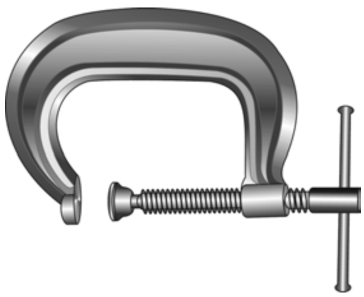


Fig. 2.47, C-clamp.

C-Clamp

A C-clamp (Fig. 2.47) 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.

■■■

CHAPTER-3
PRECISION MEASURMENT TOOLS & GAUGES

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

MICROMETERS

a. Screw Thread Micrometer
The thread micrometer (Fig. 3.1) is used to measure the pitch diameter of threads. The spindle has a 60° conical point, and the anvil has a matching groove.

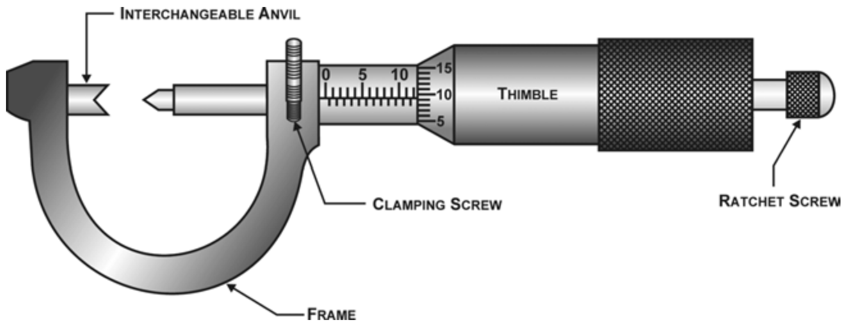


Fig. 3.1, Thread Micrometer.

b. Depth Micrometer
These instruments (Figure 3.2) 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.

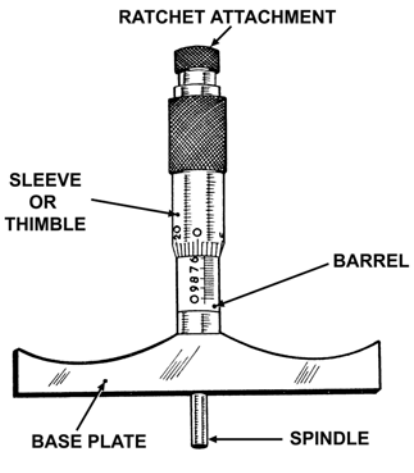


Fig. 3.2, Typical Depth Micrometer.

c. Inside and Outside Micrometer
Figure 3.3 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.

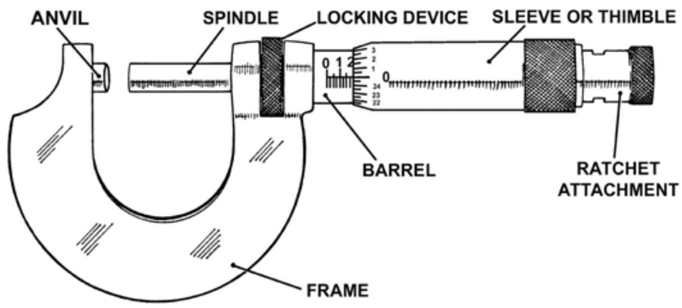


Fig.3.3, Typical Standard External Micrometer.

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.

i. Inside Micrometer

An inside micrometer (Fig. 3.4) 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.

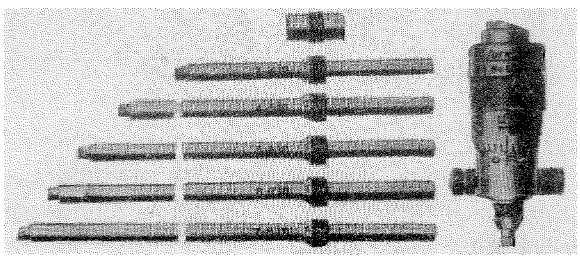


Fig. 3.4, Inside Micrometer.

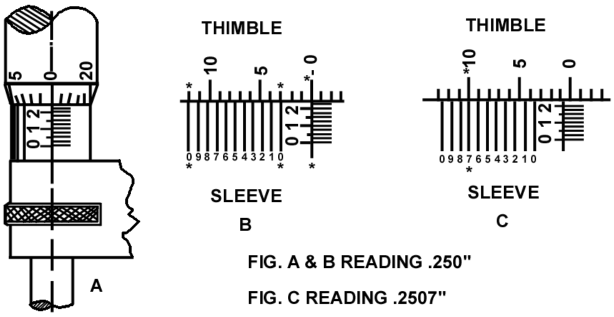


Fig. 3.5, Reading the vernier scale of a micrometer.

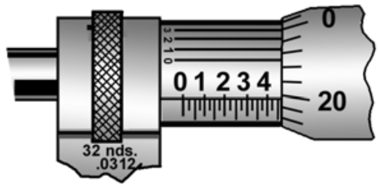


Fig. 3.6, Vernier scale on the sleeve of a micrometer.

d. Vernier Scale Micrometer

Micrometers with an additional scale based on the vernier principle are in common use, and these have a greater degree of measurement accuracy of one ten-thousandth (0.0001) part of an inch. Estimations are unnecessary; the standard thousandth reading is noted and to this id added the coincident vernier scale reading in ten-thousandths (0.0001) of an inch (Figure 3.7).

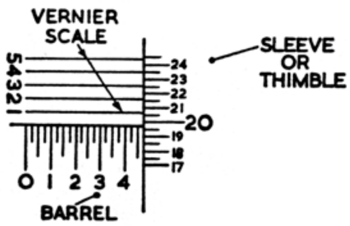


Fig. 3.7, Typical Micrometer Vernier Scale.

Generally, vernier scale micrometer sleeves are graduated into 25 divisions and 25 half divisions. A convenient vernier scale length equal to 9 half-divisions of the sleeve scale is divided equally into 5 vernier scale divisions, and these are engraved on the barrel above and parallel to, and to the full extent of the datum line.

Thus, the vernier scale length is equal to 9 half-divisions on the sleeve (0.0045 in.). It follows that the difference in width between each sleeve division (two half-divisions) and each barrel division is one fifth of a sleeve division. As each sleeve division is representative of 0.005 in., the difference is therefore 0.0001 in.

When a sleeve graduation line does not coincide with the datum line, it is necessary to note the vernier scale division which does coincide, and to add this number of ten-thousandths (0.0001) of an inch to the standard thousandths reading. In Figure 5, for example, the barrel scale shows four tenths and two forthieths (0.4000 + 0.0500), and the sleeve division below the datum line is 0.0190. There is a further half-division on the sleeve below the datum line (0.0005), and the coinciding vernier line is the fourth (0.0004). The micrometer reading is therefore 0.4000 + 0.0500 + 0.0190 + 0.0005 + 0.0004, which equals 0.4699 inches.

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 3.8). 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 3.8), 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 3.8). No attempt must be made to force a locked calliper between two surfaces, otherwise wear or out-of-parallelism may result.

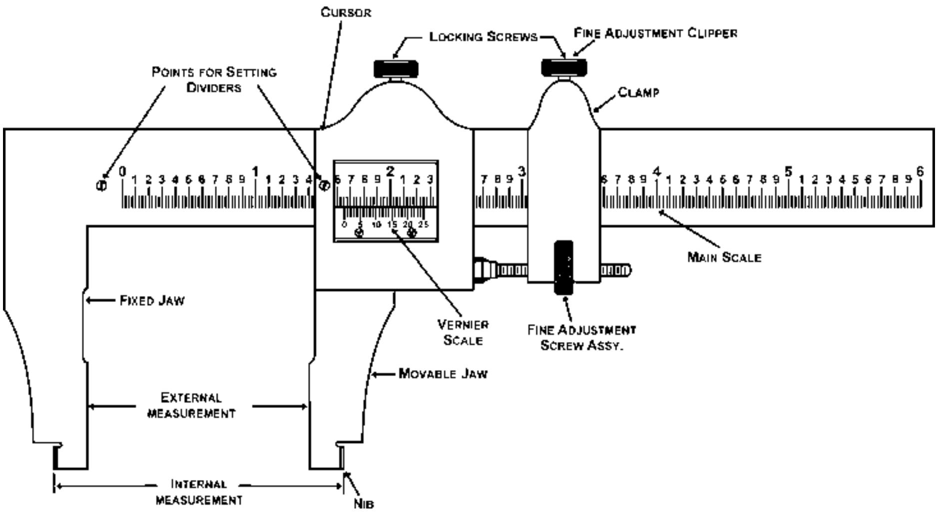


Fig. 3.8, Vernier Calliper.

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.

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 3.9.

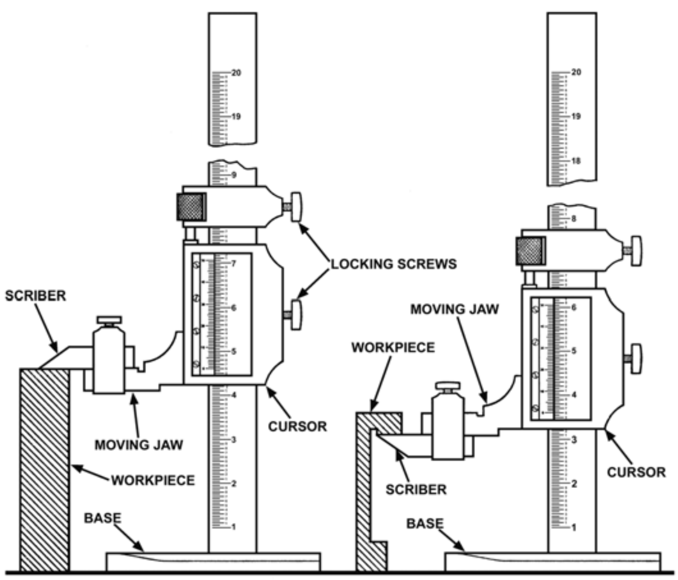


Fig. 3.9 & 3.10, Vernier Height Gauge.

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 3.9).

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 3.10. 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.

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.

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.

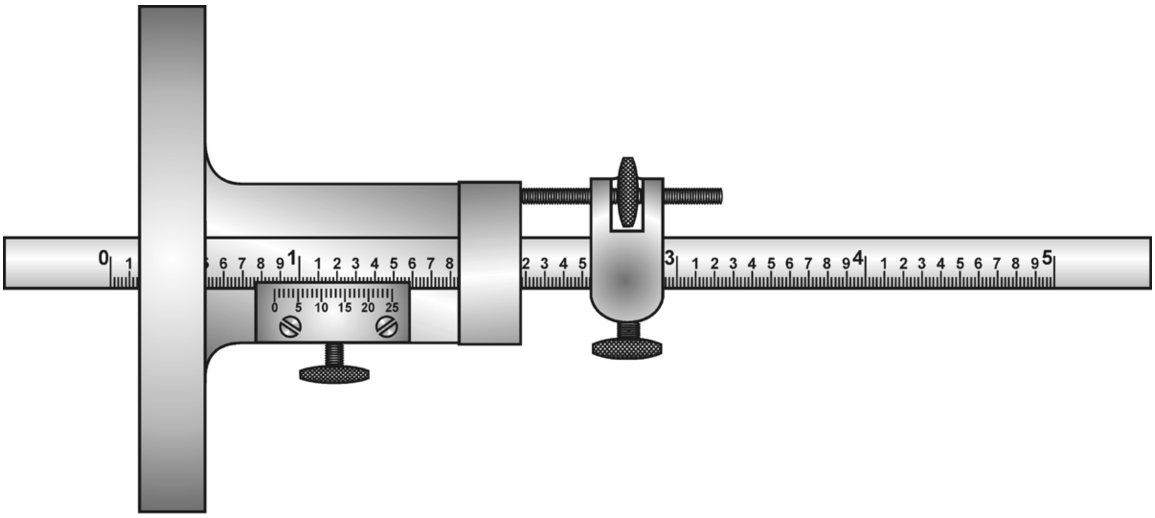


Fig. 3.11, Depth Gauges.

PLUG GAUGE

A plug gage (Fig. 3.12) 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. 3.13) may be conical, as gage A and C; square, as gage D; hexagon, as gage H; or one of the several others shown.

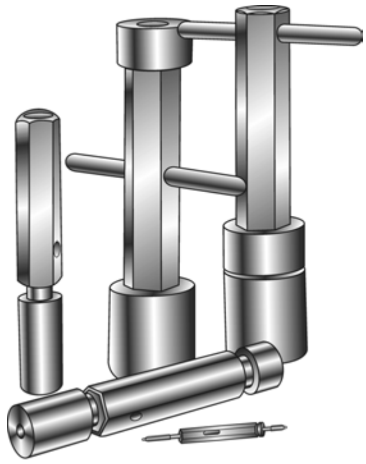


Fig.3.12, Plug Gages

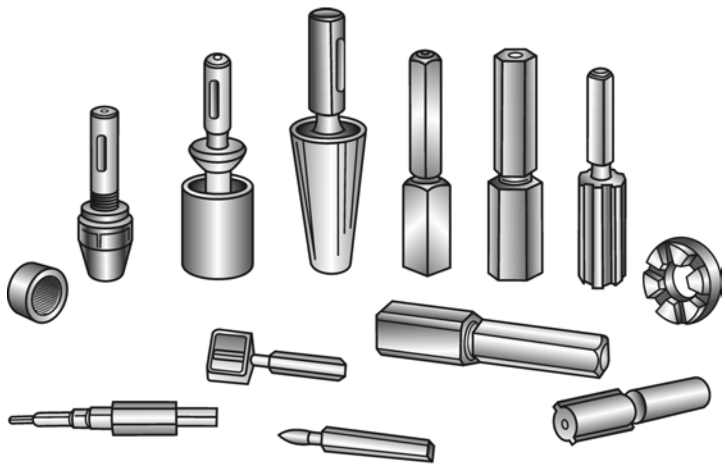


Fig. 3.13, Various shapes of plug gages.

FILLER GAUGE

The filler gauge, as shown in Fig.3.14, 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.

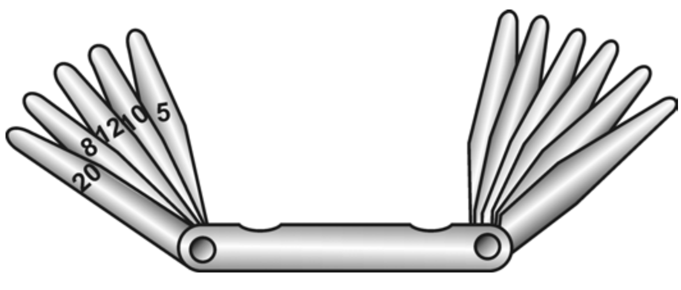


Fig. 3.14, Filler Gauge.

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.

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.

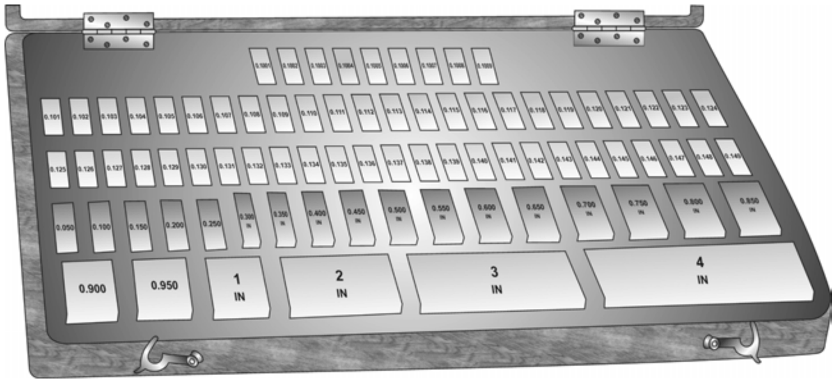


Fig. 3.15, Gauge Block

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, accuracyas 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. 3.16) 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. 3.16, Precision gage-block series.

RADIUS GAUGE

The radius or fillet gauge, as shown in Fig. 3.17, 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.

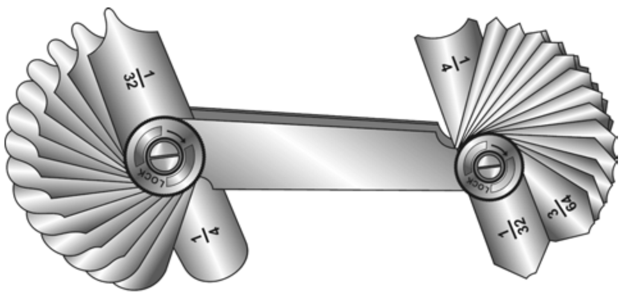


Fig. 3.17, Radius or fillet gauge

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.

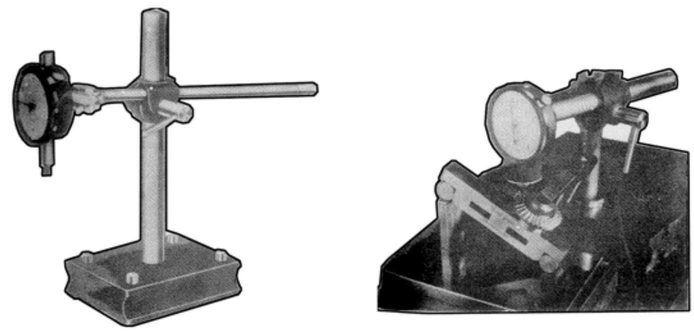
Fig. 3.18, A Wire Gauge

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. 3.19 (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. 3.20. 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. 3.21. 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.



A B

Fig. 3.19, (A) Dial indicator test set. (B) Application of test set.

Fig. 3.20, Dial indicator test set.

Fig. 3.21, Continuous dial with revolution counter and double dial.

SINE BAR

A sine bar (Fig. 3.22) 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. 3.23), 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. 3.24, dimension AB is calculated by multiplying the sine of the required angle by the length of the sine bar.

The sine bar may be used to set a piece of work to a required angle. In Fig. 3.23, 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 3.25 shows four gage blocks being used to set a sine bar.

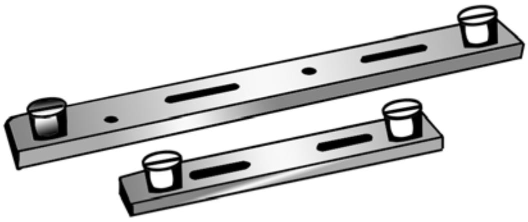


Fig. 3.22, Sine bars.

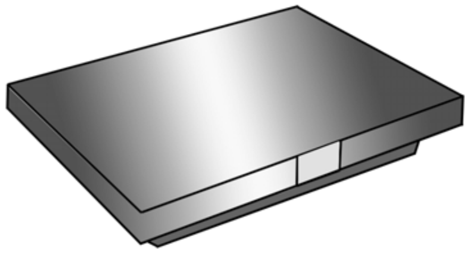


Fig. 3.23, A granite surface plate.

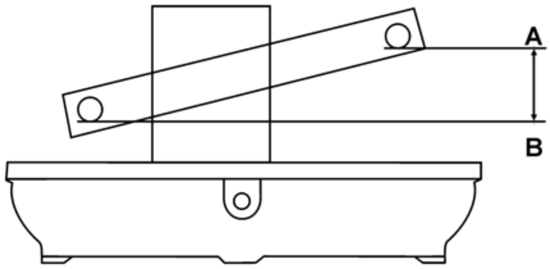


Fig. 3.24, The distance AB is equal to the sine of the angle multiplied by the length of the sine bar.

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. 3.26 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'.

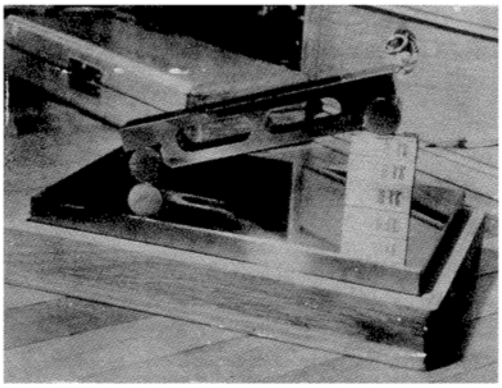


Fig. 3.25, A sine bar may be set to an angle using precision gage blocks.

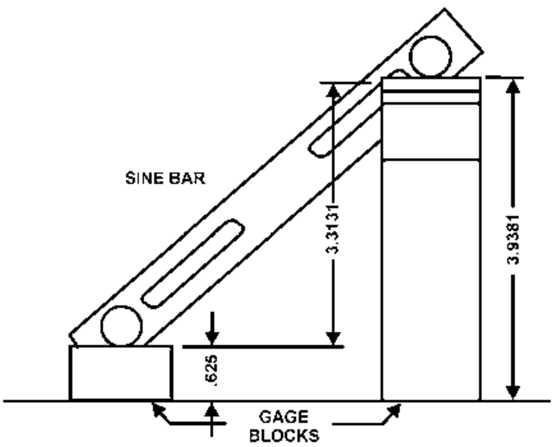


Fig. 3.26, The angle at which a sine bar is set may be determined by the vertical distance between the two plugs of the sine bar.

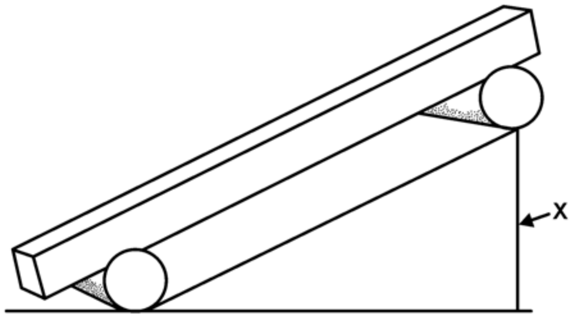


Fig. 3.27, Diagram for sine bar problem.

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. 3.27, 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.

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

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.

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. 3.28. 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.

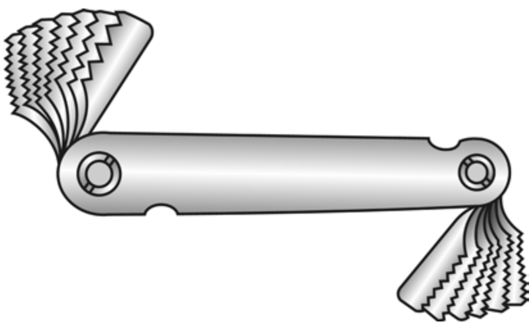


Fig. 3.28, Screw-pitch gauge.

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. 3.29. 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.

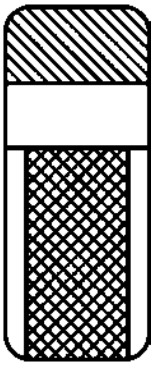


Fig. 3.29, Ring Gauge.

SNAP GAUGE

A snap gage (Fig. 3.30) 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. 3.30. 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.

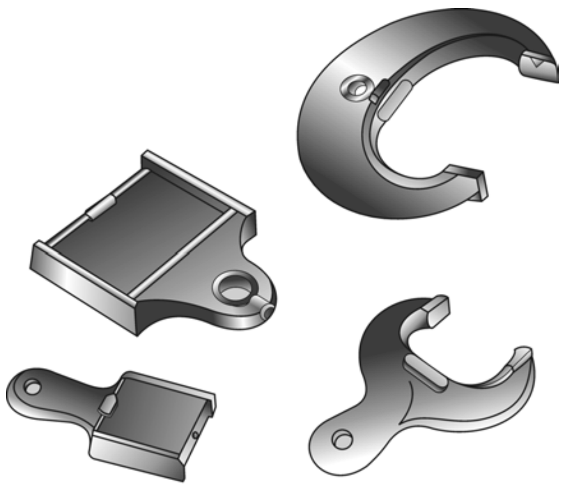


Fig. 3.30, Snap Gauge

■■■

CHAPTER-4
THREAD CUTTING TOOLS

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.

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. 4.1).

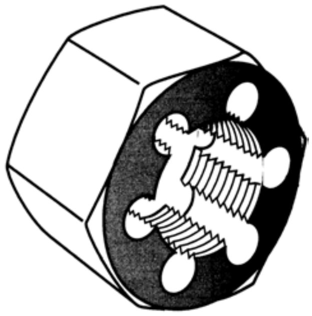


Fig. 4.1, Solid Die

b. Split die

The split dies, as shown in Fig. 4.2 (a), consist of a pair of dies or jaws which fit into the stocks, as shown in Fig. 4.2 (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.

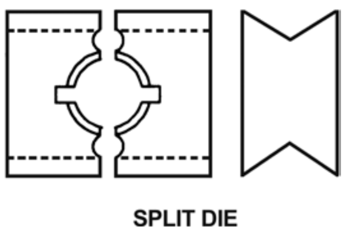


Fig.4.2, (a) Split die

Fig.4.2 (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. 4.3).

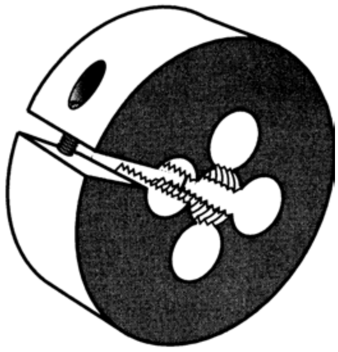


Fig. 4.3 Adjustable die.

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

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. 4.4. 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.

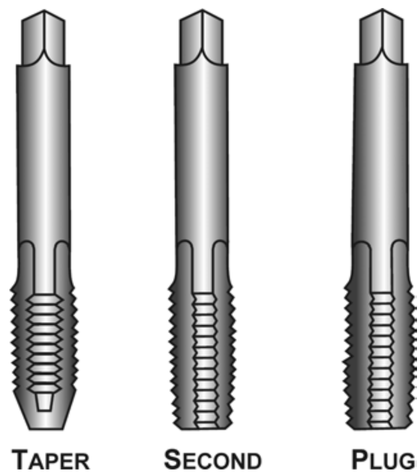


Fig. 4.4, Taps.

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.

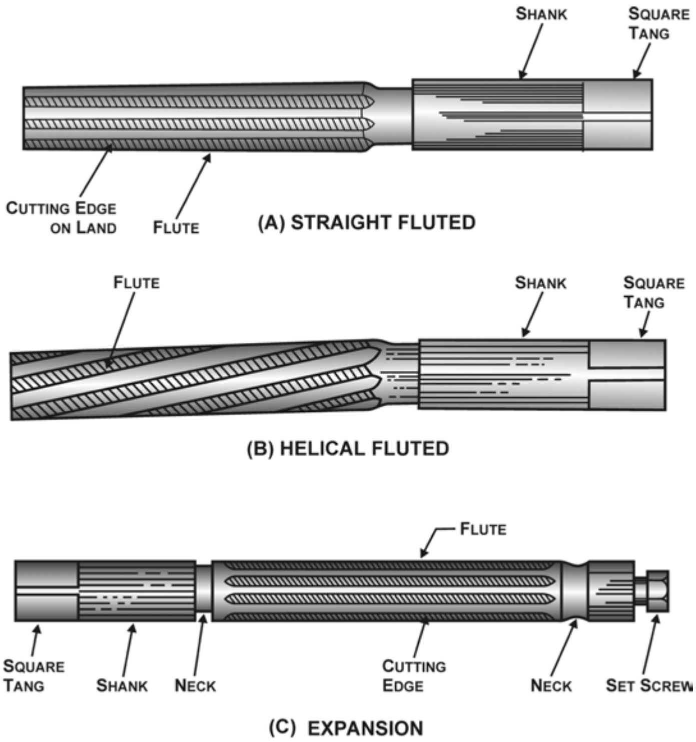


Fig. 4.5, Type of reamers.

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. 4.5 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. 4.5. 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.

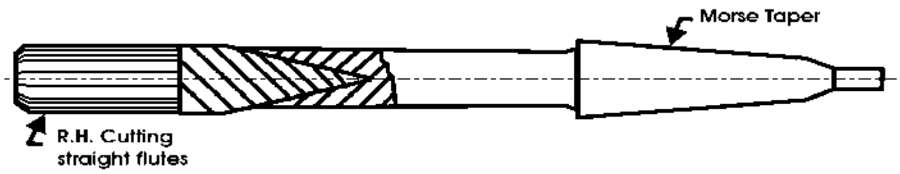


Fig. 4.6, A rose reamer.

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. 4.6 and 4.7 respectively.

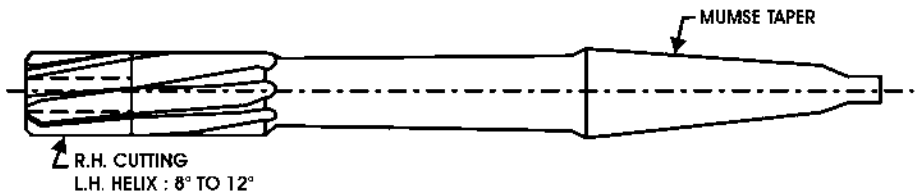


Fig. 4.7, Fluted machine reamer.

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. 4.8).

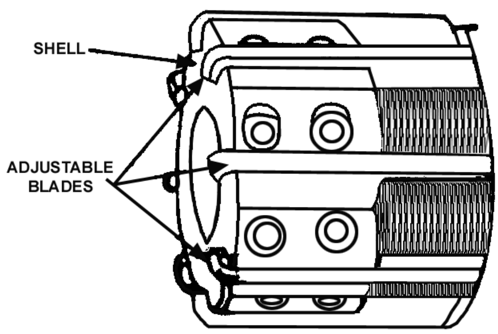


Fig. 4.8, Shell type adjustable reamer.

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. 4.9. 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.

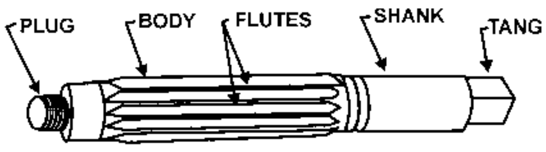


Fig. 4.9, Straight flute expansion reamer.

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. 4.10.

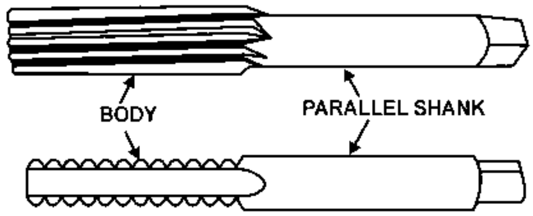


Fig. 4.10, Hand taper reamers.

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. 4.11.

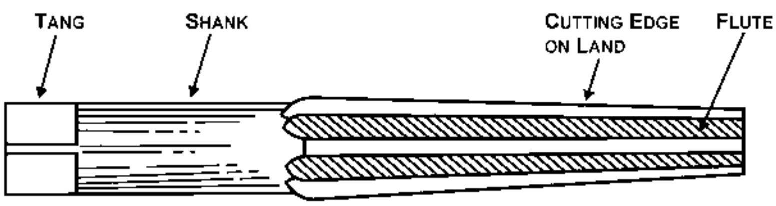


Fig. 4.11, Straight flute taper pin reamer.

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. 4.12.

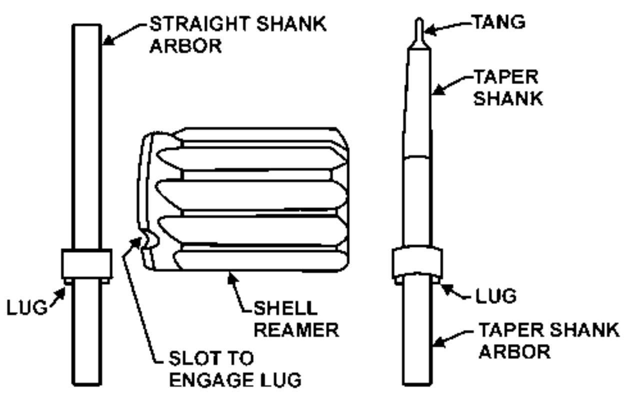


Fig. 4.12, Shell reamer with arbors.

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. 4.13, 4.14 and 4.15.

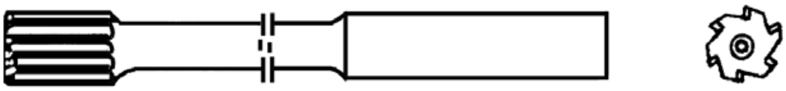


Fig. 4.13, A parallel shank carbide tipped reamer.

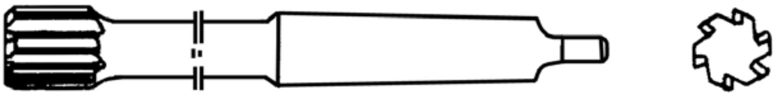


Fig. 4.14, A taper shank carbide tipped reamer.

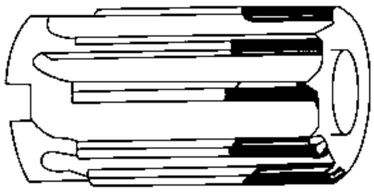


Fig. 4.15, A carbide tipped shell reamer.

IX. Jobber's reamer

A Jobber's Reamer (Fig. 4.16) is a taper-shank machine reamer having flutes about the same length as a hand reamer; it is used as precision finishing reamer.

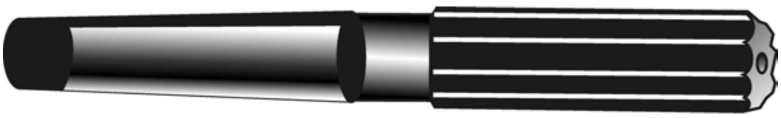


Fig. 4.16, Jobber's reamer

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. 4.17.

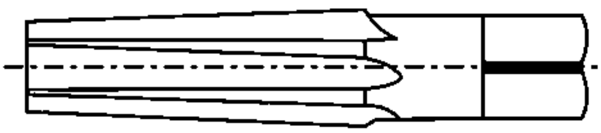


Fig. 4.17, A parallel shank socket reamer for Morse Taper.

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. 4.18 and 4.19 respectively.

Fig. 4.18, A straight fluted machine bridge reamer.

Fig. 4.19, 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. 4.20.

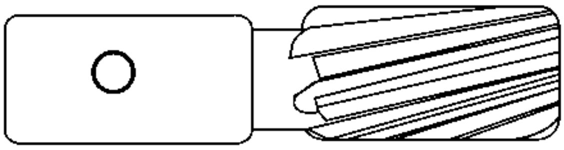


Fig. 4.20, A spiral fluted R.H. cut stub screw machine reamer.

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. 4.21.

Fig. 4.21, 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. 4.22.

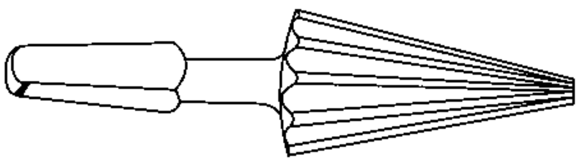


Fig. 4.22, A straight fluted Burring Reamer.

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.

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. 4.23.

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. 4.23.

Twist Drill

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.

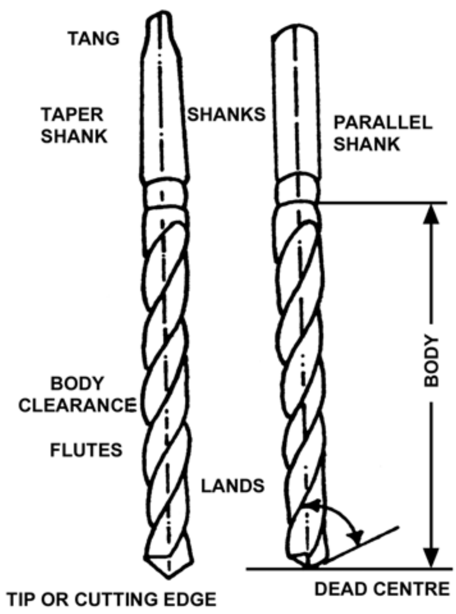


Fig. 4.23, Twist drill

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. 4.24).

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	....	....

Millimeter	Dec. Equiv.	Fractional	Number
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	....

Millimeter	Dec. Equiv.	Fractional	Number
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

Millimeter	Dec. Equiv.	Fractional	Number
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	....	....

Millimeter	Dec. Equiv.	Fractional	Number
....	.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	....

Millimeter	Dec. Equiv.	Fractional	Number
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. 4.24, 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 4.25)

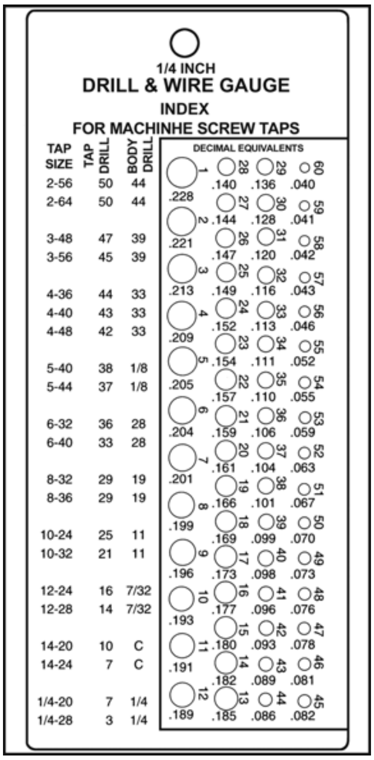


Fig. 4.25, Most drill gauges have holes in which you insert a drill in the appropriate hole. The gauge illustrated above also indicates tap sizes so you can drill the proper size hole for a tap.

Combined Drill & Counter Sunk

A combined drill and countersink (Fig. 4.26), 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. 4.26, Countersink and countersunk hole.

Fig. 4.27, Combined drill and countersink.

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CHAPTER-5
POWER HACKSAW

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.

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 duringhe 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.

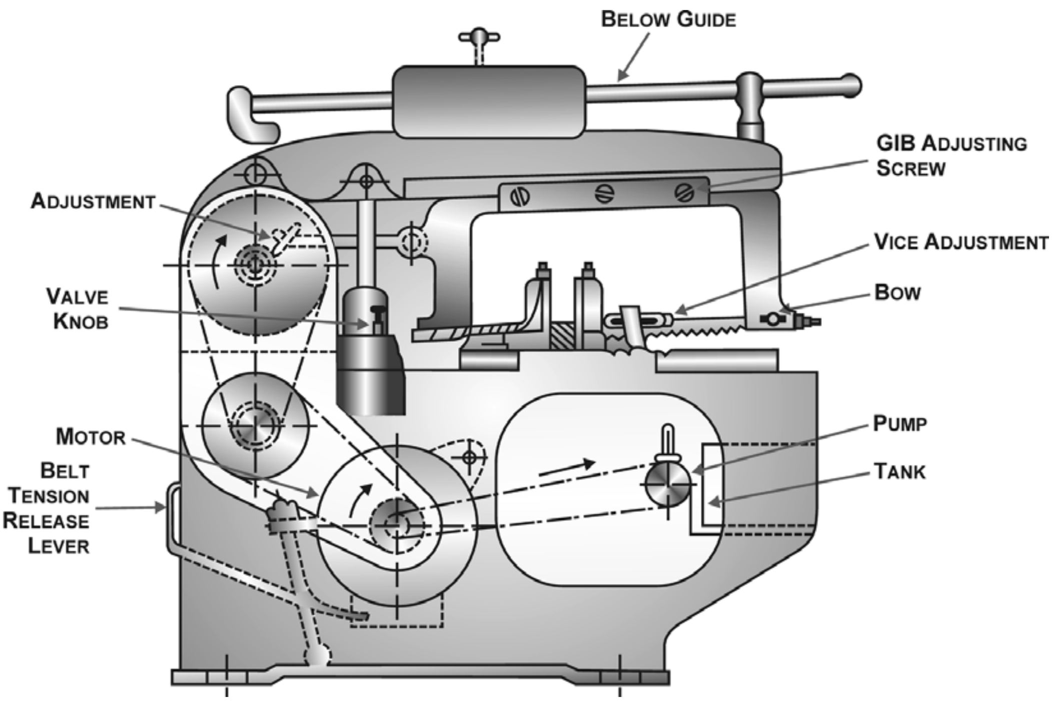

Fig. 5.1, A Power Hacksaw Machine.

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.

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.

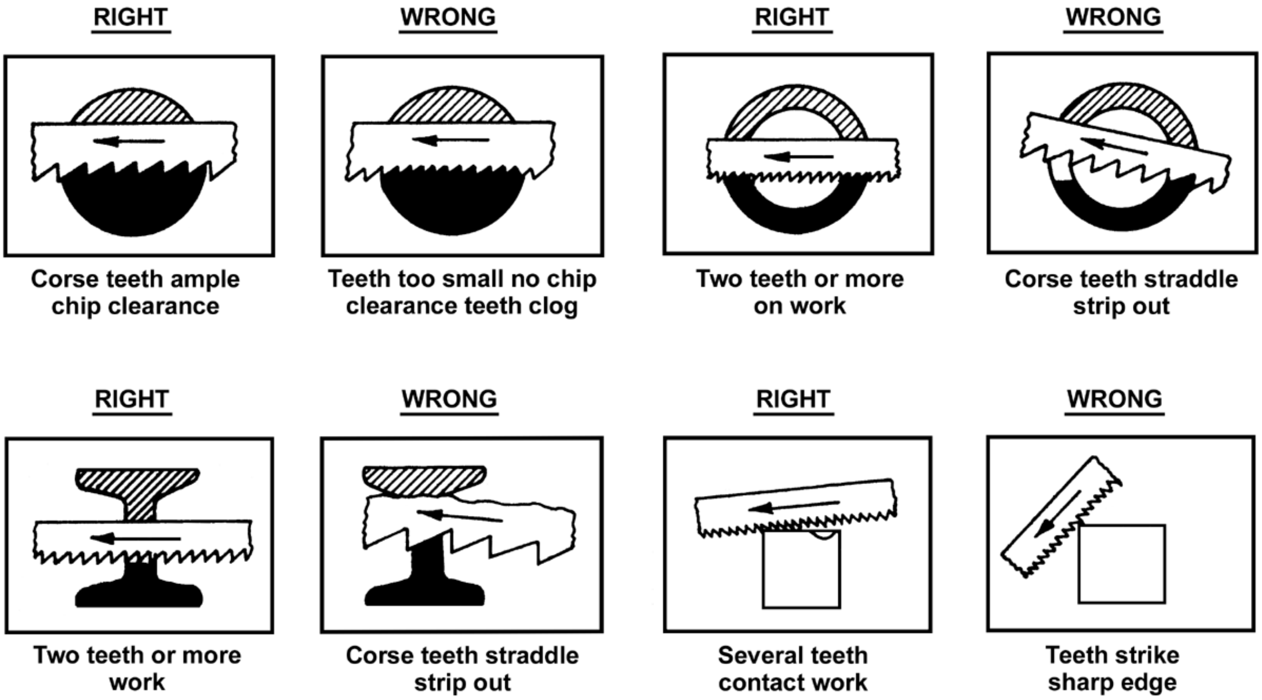

Fig. 5.2, Correct and wrong sawing conditions.

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.

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.

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.

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.

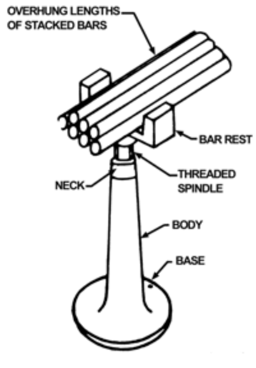

Fig. 5.3, A floor stand to support the overhanging bars.

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.

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CHAPTER-6
LATHE : TYPES OF LATHE

PARTS OF LATHE MACHINE

The lathe carries the following main parts as illustrated by a block diagram in Fig. 6.1 Detailed mechanical features of the lathe are shown in Fig. 6.3.

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. 6.2.

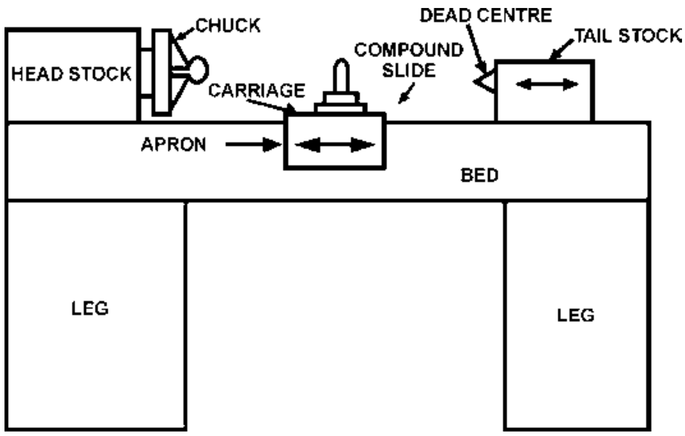


Fig. 6.1, Block Diagram of lathe.

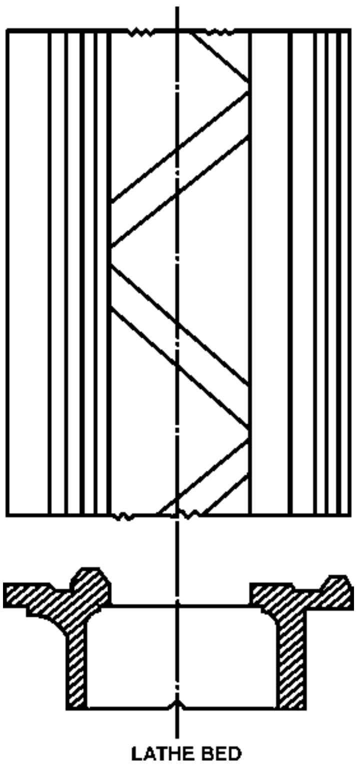


Fig. 6.2, Lathe Bed.

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

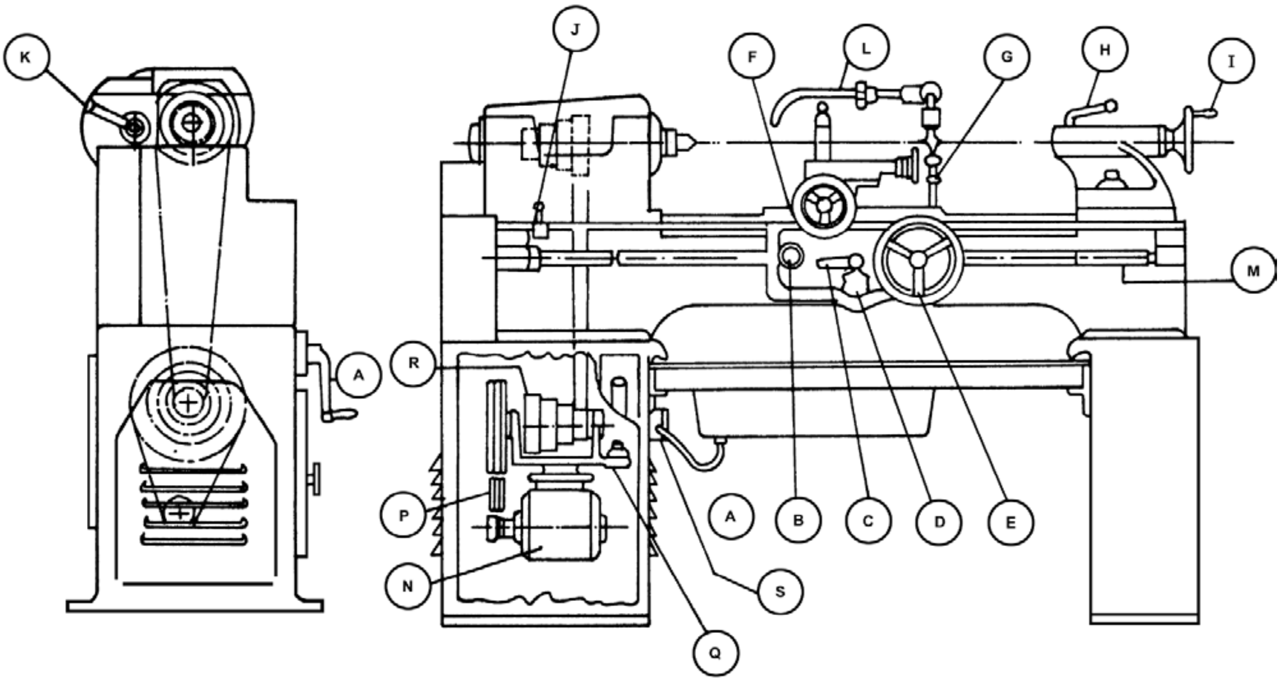
Though it is not a very common practice, some beds are made to have a gap just adjacent to the front of the head stock. Such beds are known as Gap beds. They provide an advantage that the lathe having such a bed is capable of accommodating jobs which are larger in diameter than the provided swing over 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. 6.3, 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. 6.4. 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. 6.4. 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. 6.5. 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.

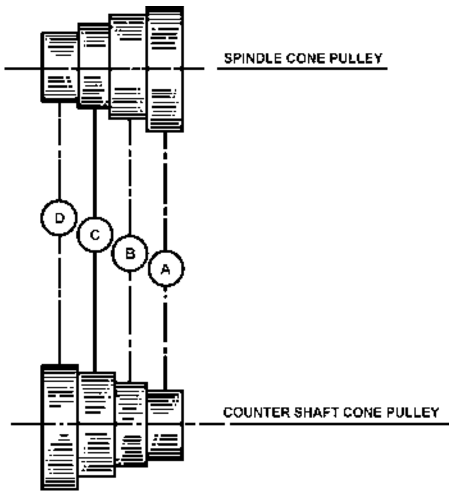


Fig. 6.4, Cone Pulleys.

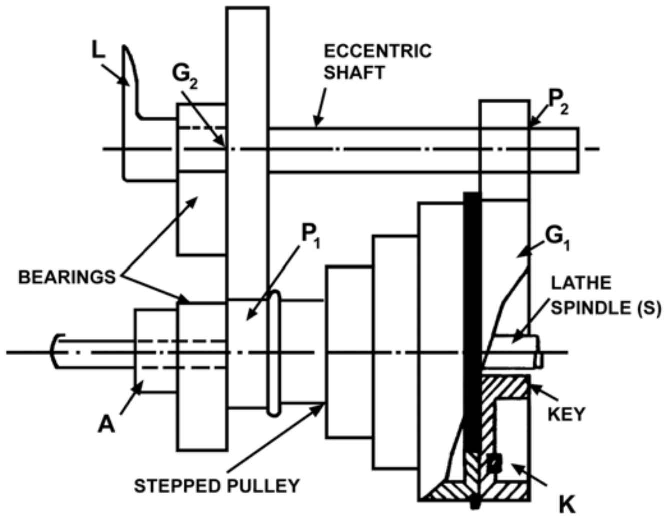


Fig. 6.5, Use of back gears.

Speed Ratios

Let us take a concrete example to illustrate as to how the spindle speeds change with the engagement of back gears. Fig. 6.5. 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.6.6. It will be seen that the motion from the spindle to the lead screw or feed rod is transmitted through this mechanism. Refer Fig.6.6. 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 6.6 (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 6.6 (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.

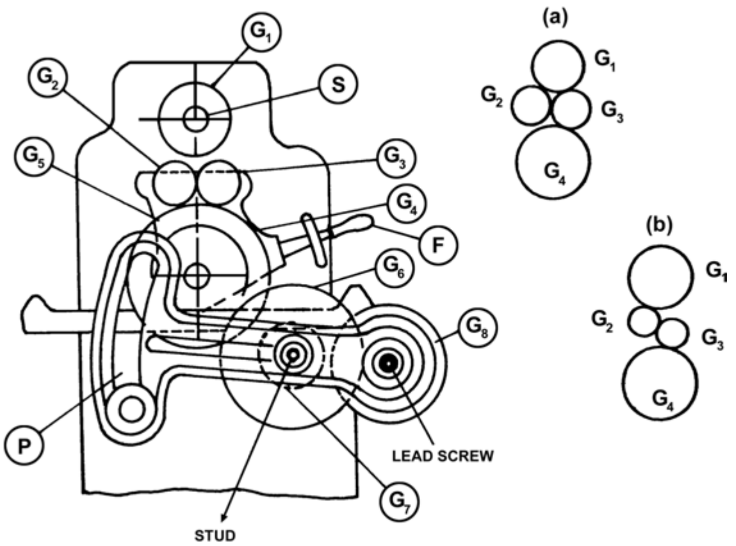


Fig. 6.6, Feed mechanism and change gear.

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 :

$$2^{nd}\text{speed} = SC$$
$$3^{rd}\text{speed} = S.C.C. = SC^2$$
$$n^{th}\text{speed} = SC^{n-1}$$

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

$$N = SC^{n-1}$$

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

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. 6.7. 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.6.7 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.

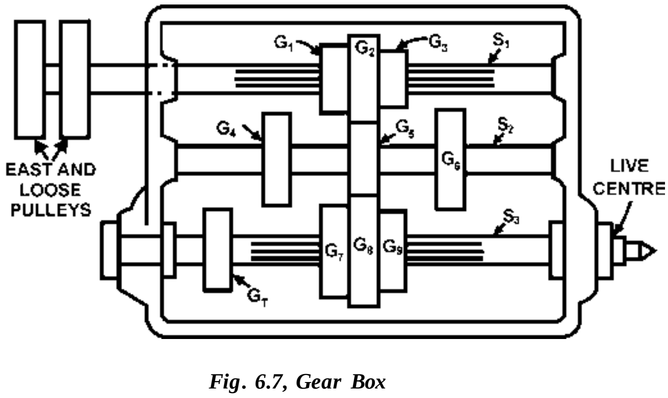


Fig. 6.7, Gear Box

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.

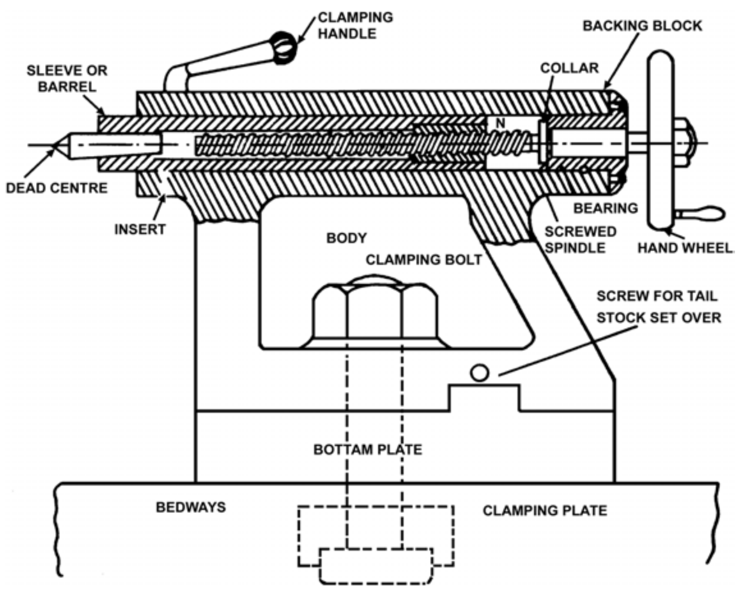


Fig. 6.8, Tail Stock of lathe.

A Simple design of tail stock is shown in Fig. 6.8. 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 6.9). 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.

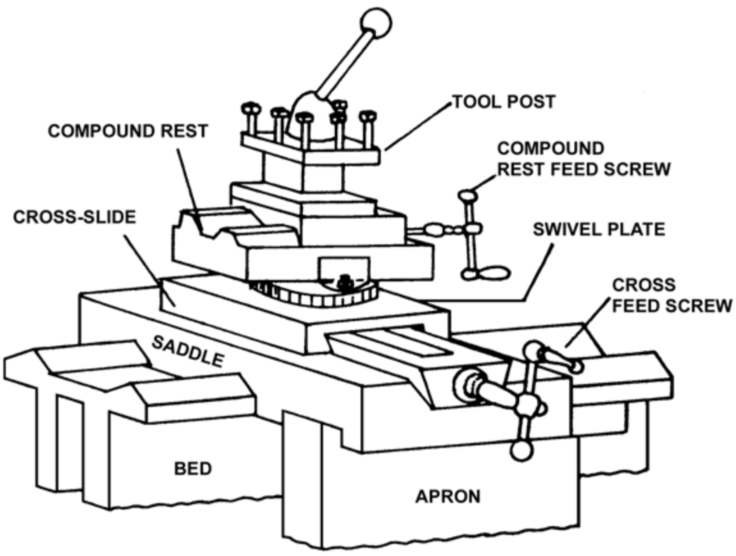


Fig. 6.9, The Carriage.

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.

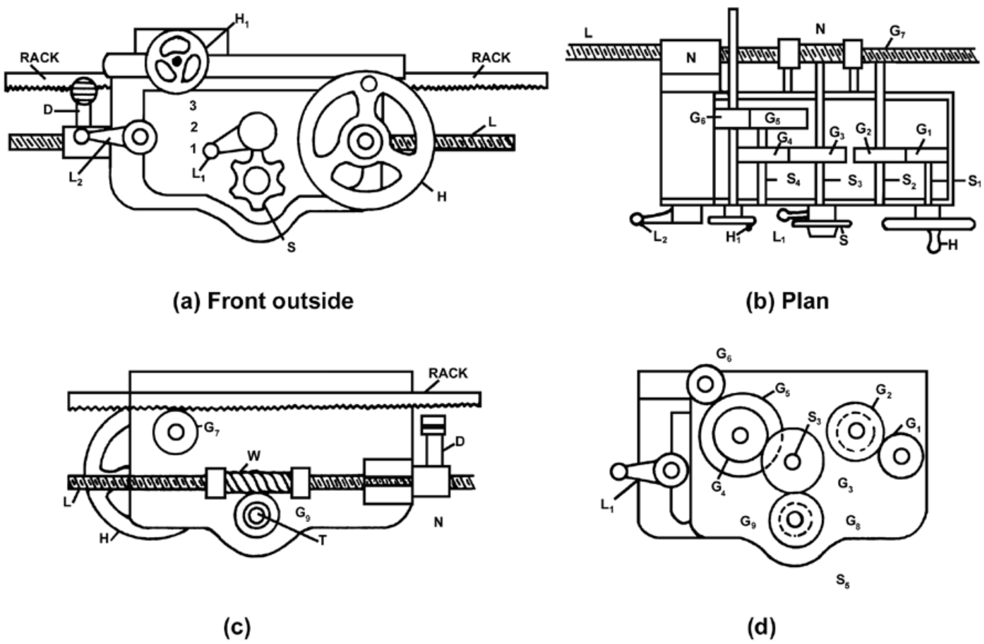
Tool Post
It is topmost part of the carriage and is used for holding the tools holder in position.

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. 6.10 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. 6.10 (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. 6.10, 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. 6.10 (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.6.10 (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 6.10 (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.6.11. 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.

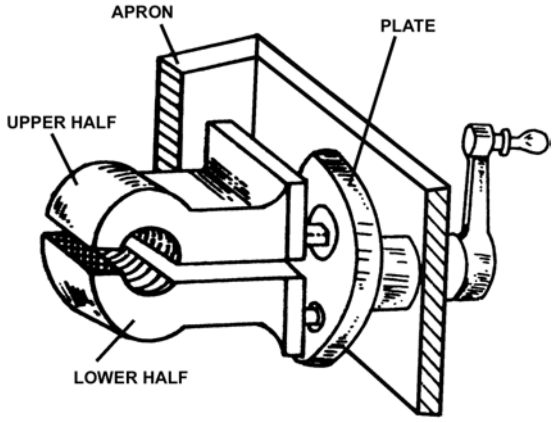


Fig. 6.11, Split half nut.

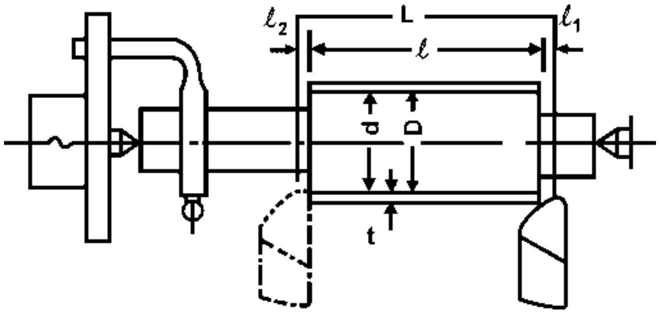


Fig. 6.12

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. 6.13 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 × 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.

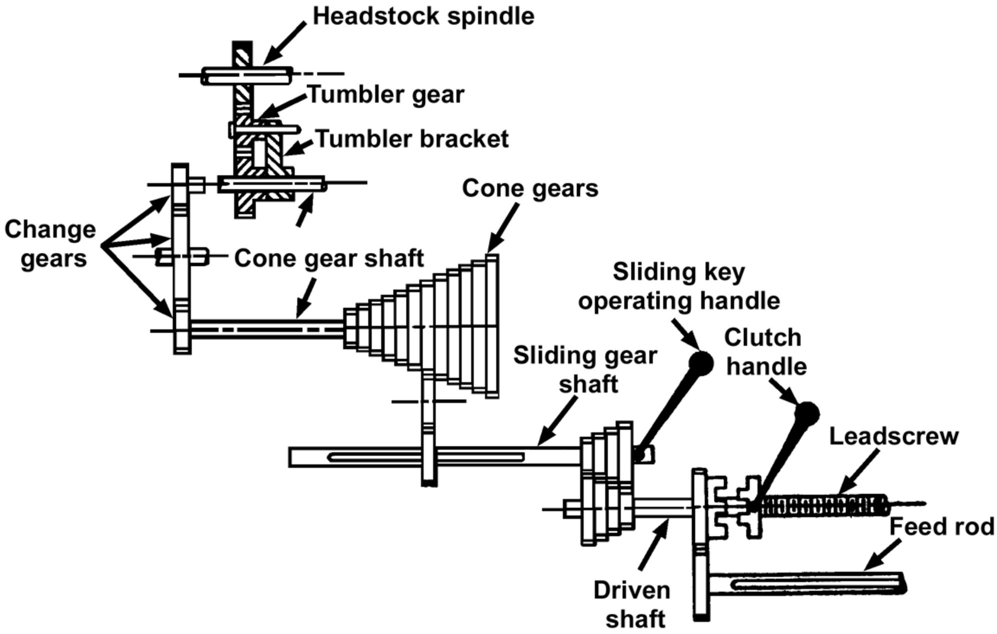


Fig. 6.13, Layout diagram of feed drive.

LATHE OPERATIONS

a. Facing

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.

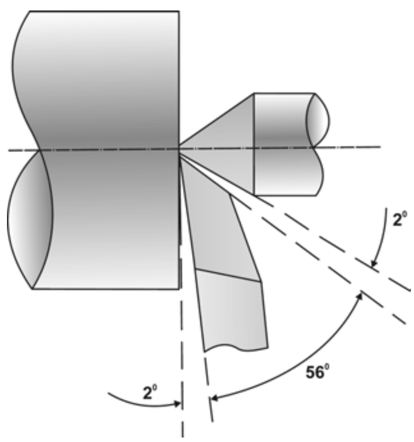


Fig. 6.14, Facing

b. Turning

i. 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.

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

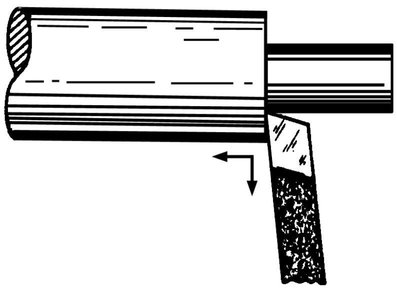


Fig. 6.15, Squaring the corner of a shoulder.

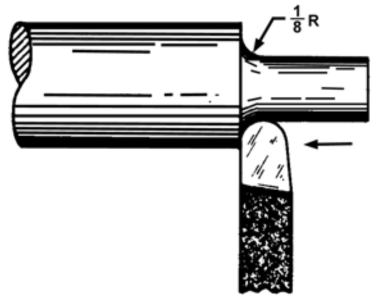


Fig. 6.16, Turning a shoulder radius, or fillet.

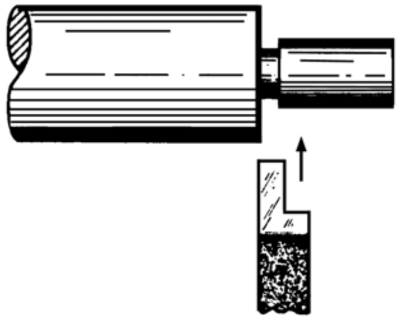


Fig. 6.17, Under cutting, or necking, a shoulder.

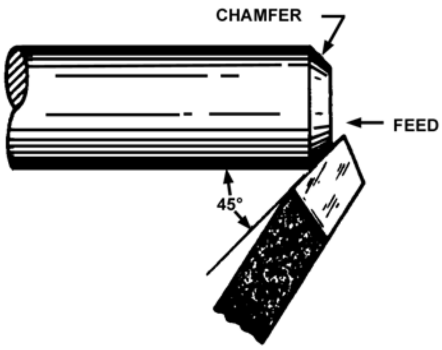


Fig. 6.18, Chamfering with the tool bit set at an angle.

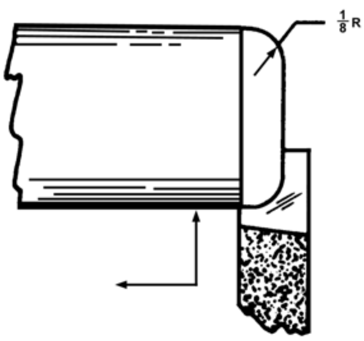


Fig. 6.19, Method of rounding a corner with a form-ground tool bit.

iii. 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.

iv. 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.

c. Step Facing

When a large amount of material is to be removed by facing, it cab be rough machined faster by making a series of deep cuts longitudinally rather than from the centre out. This process is called step facing.

d. Grooving

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. 6.20 (b) and (c)]

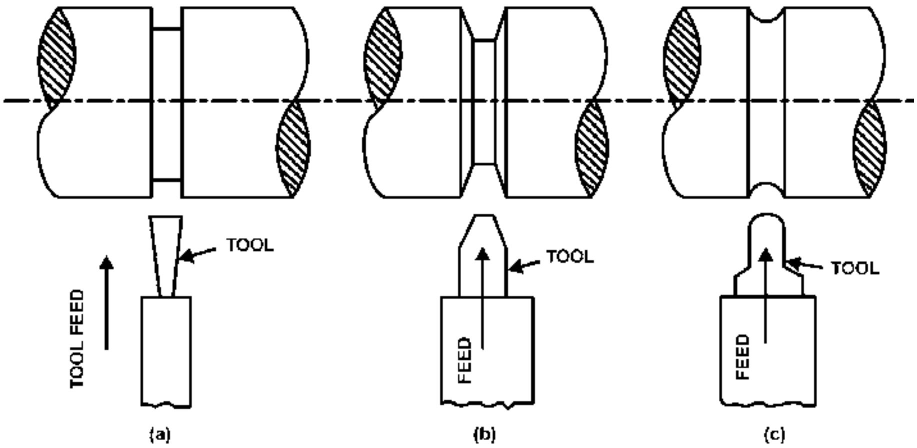


Fig. 6.20, Grooving on lathe (a) Square groove (b) A V-groove (c) A round groove.

e. Knurling

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. 6.21) 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. 6.22 and 6.23).

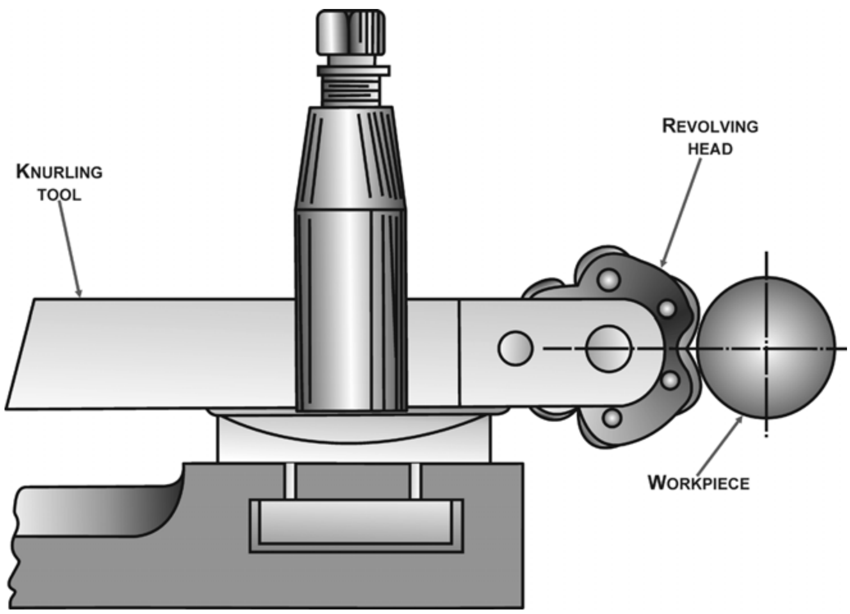


Fig. 6.21, Knurling open

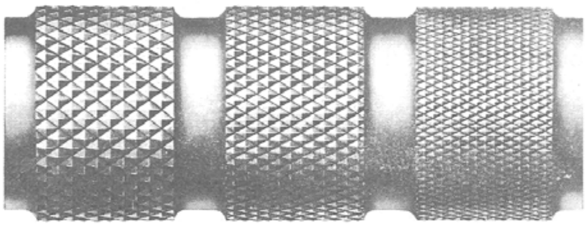


Fig. 6.22, Coarse, medium, and fine diamond pattern knurling.

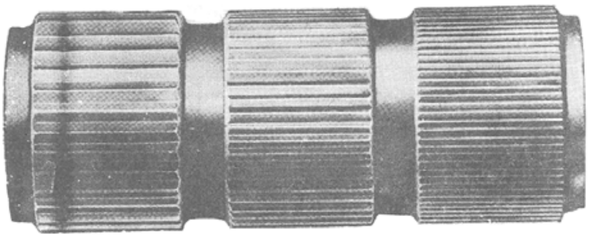


Fig. 6.23, Coarse, medium and fine straight-pattern knurling.

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.

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CHAPTER-7
MILLING MACHINE

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.

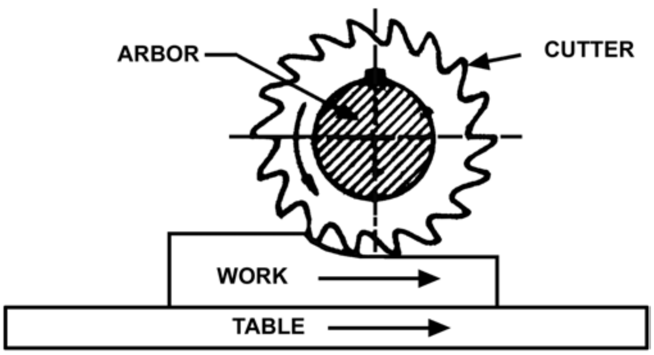


Fig. 7.1, Working principle on a milling machine.

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.

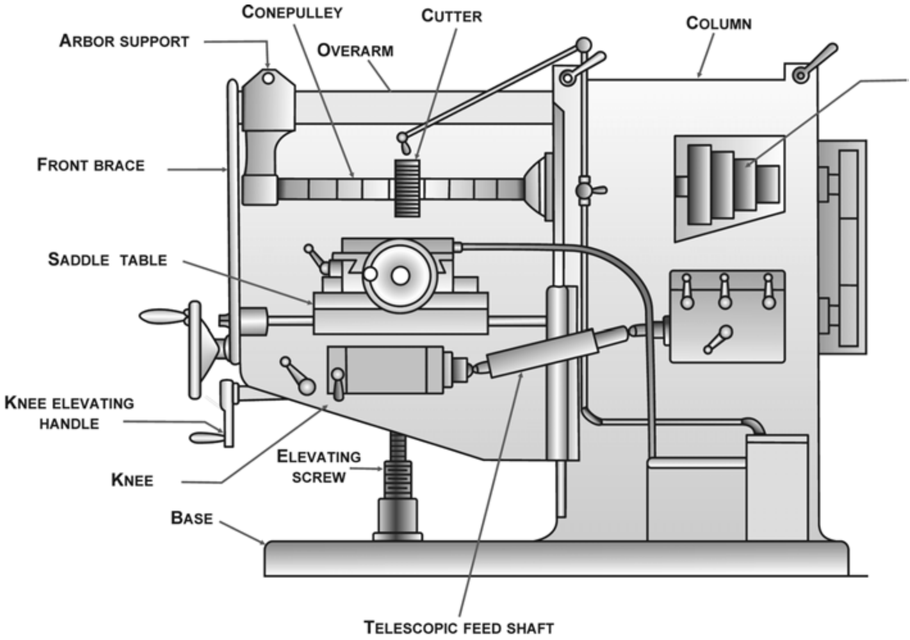


Fig. 7.2, Column and knee type milling machine.

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 dou ble horizontal spindles).
- Triplex head (having two horizontal and one vertical spindle).
- Rise and fall type (for profile milling).

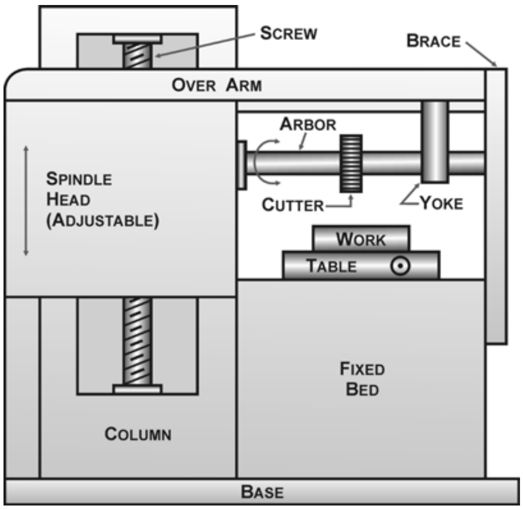


Fig. 7.3, Fixed bed type plain milling machine.

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.

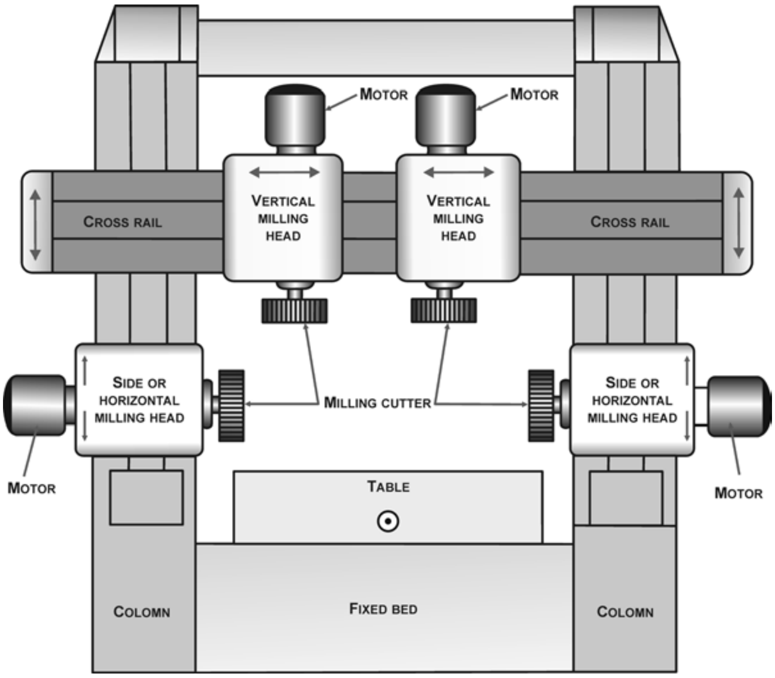
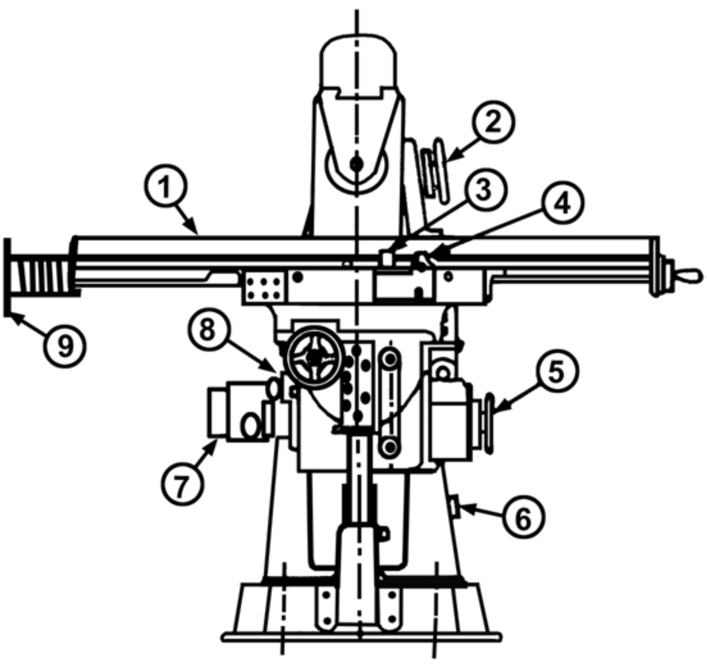
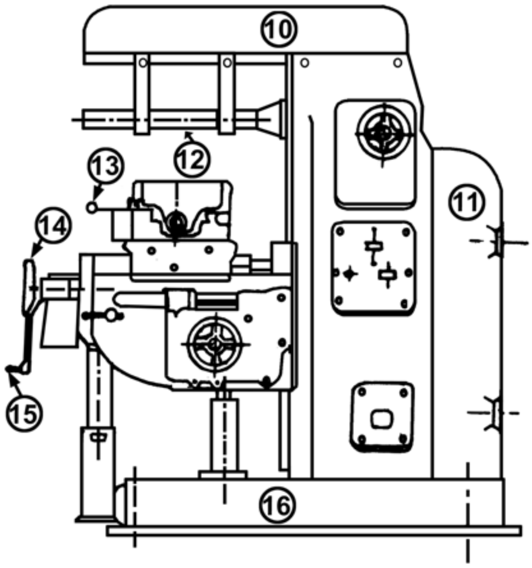


Fig. 7.4, Planer type milling machine or plan mill.

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.

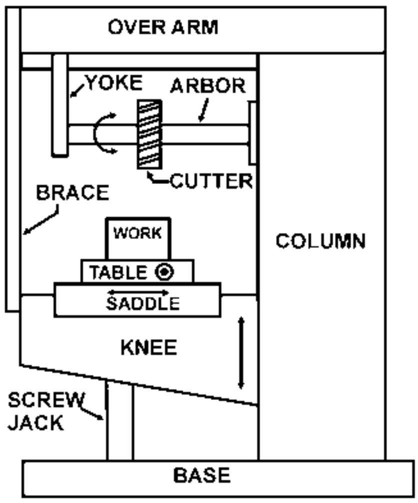


Fig. 7.6, Main parts of a plain milling machine.

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.

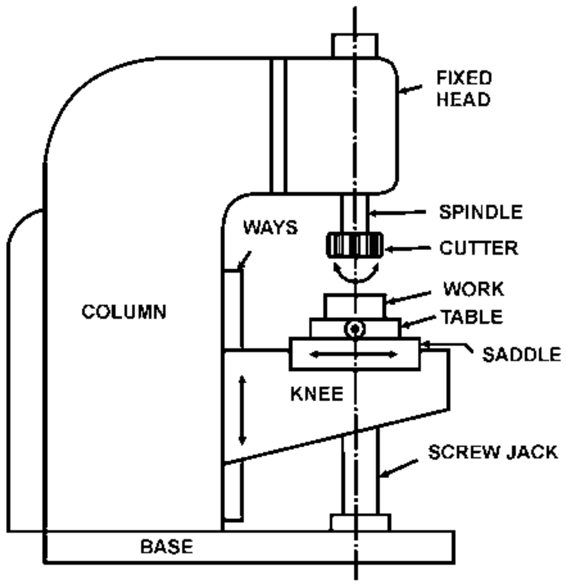


Fig. 7.7, Vertical milling machine with fixed head.

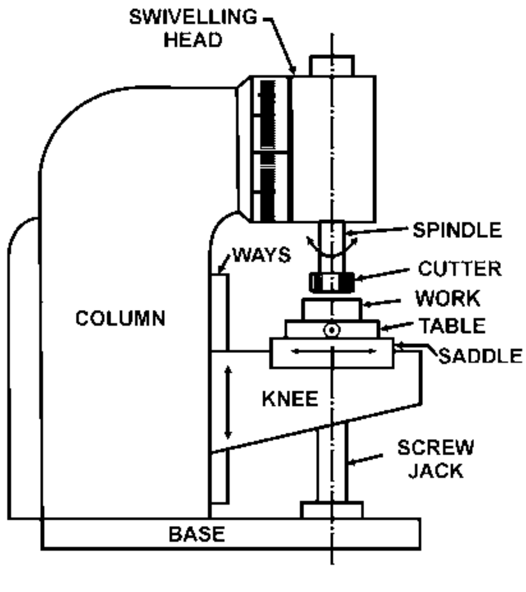


Fig. 7.8, Vertical milling machine with swivelling head.

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.

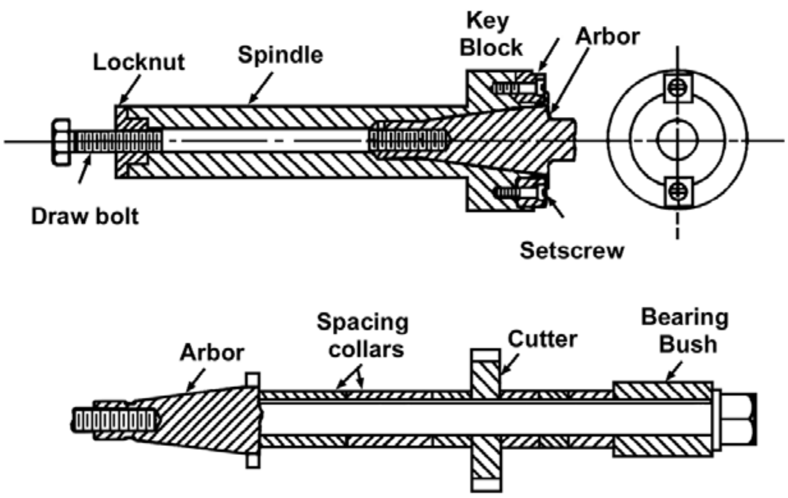


Fig. 7.9, Arbor assembly.

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.

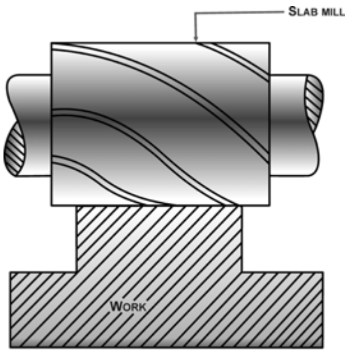


Fig. 7.10, Plain or slab milling

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).

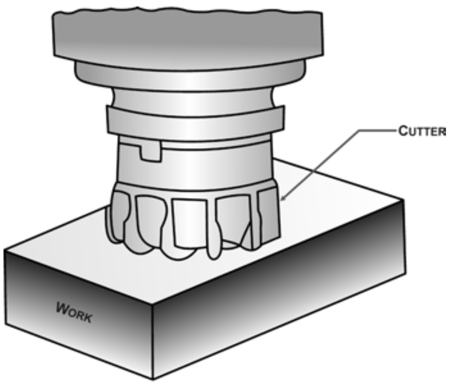


Fig. 7.11, Face milling.

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.

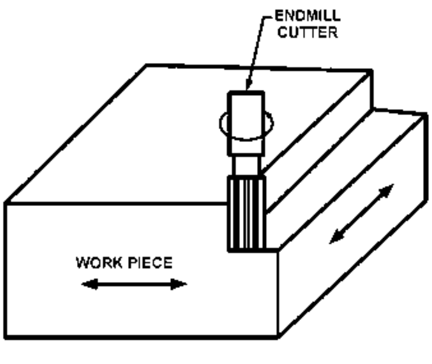


Fig. 7.12, Producing a single flat surface by using an End mill cutter.

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.

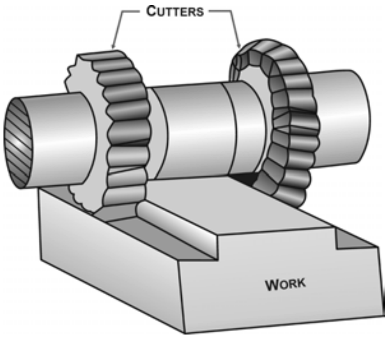


Fig. 7.13, Form milling.

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).

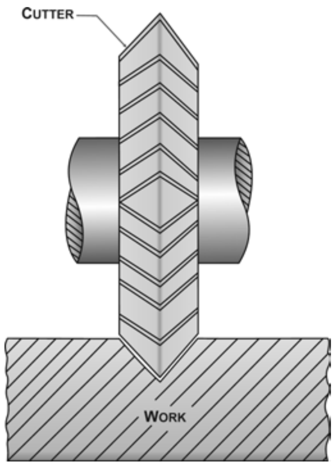


Fig. 7.14, Angular milling

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.

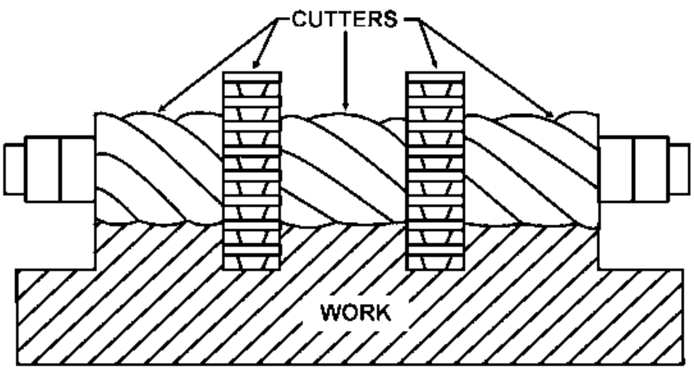


Fig. 7.15, Gang milling

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)

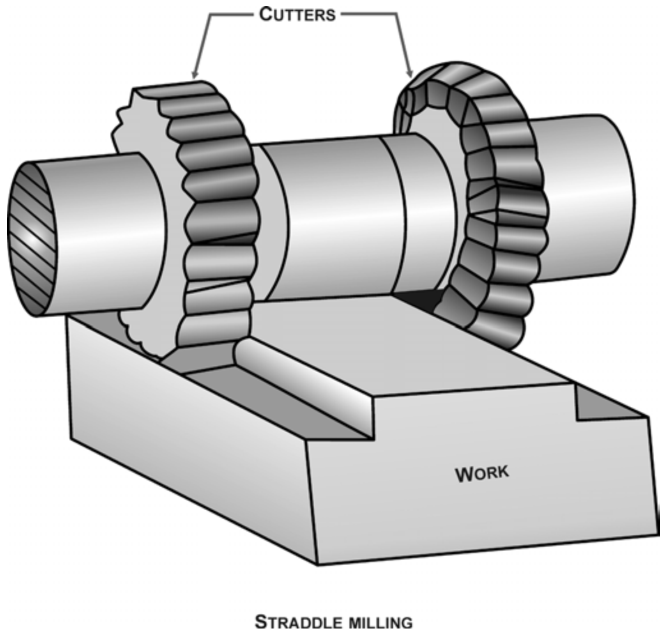


Fig. 7.16, Form milling.

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.

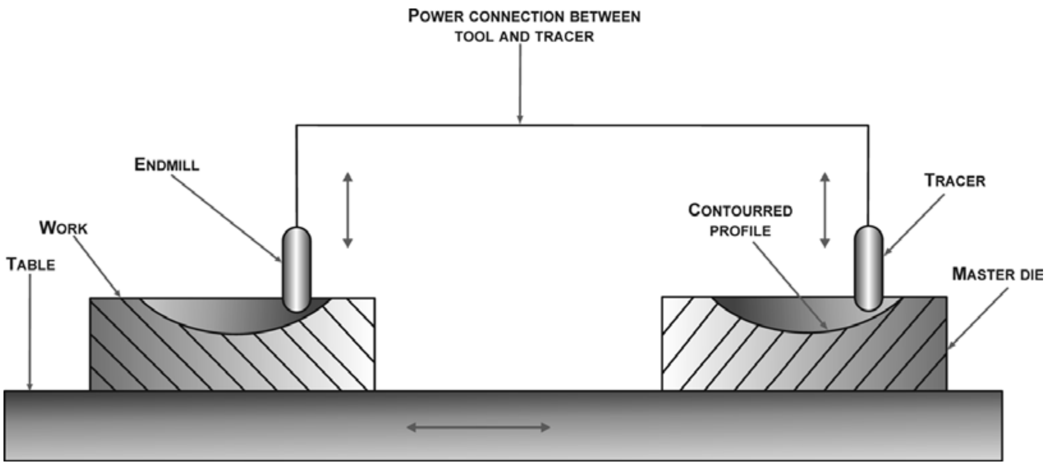


Fig. 7.17, Profile Milling

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 to the 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.

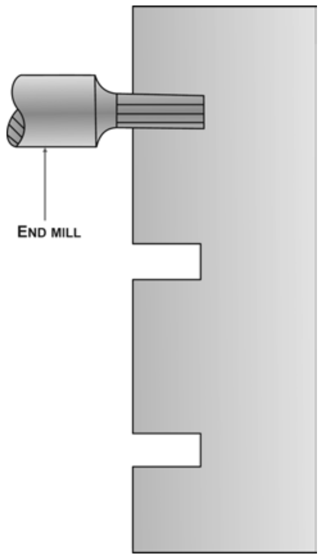


Fig. 7.18, End Milling

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.

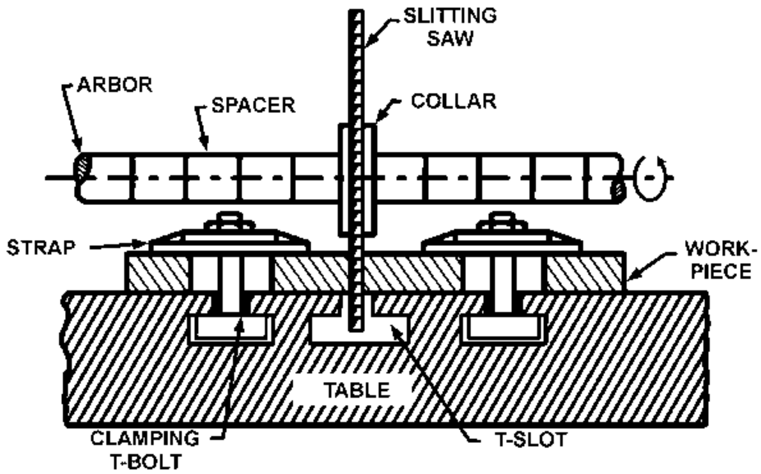


Fig. 7.19, A slitting saw being used for parting off operation.

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.

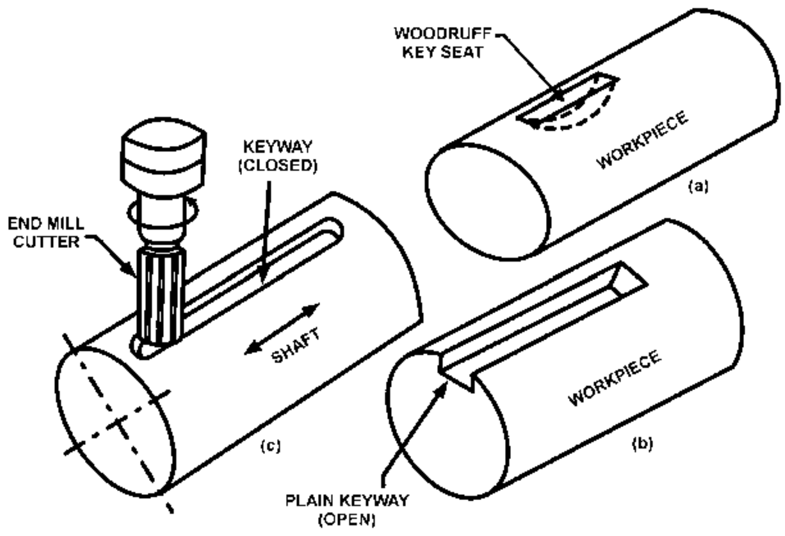


Fig. 7.20, Keyway milling
(a) A woodruff key seat (b) A plain (open) key seat (c) a sunk (closed) key seat.

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).

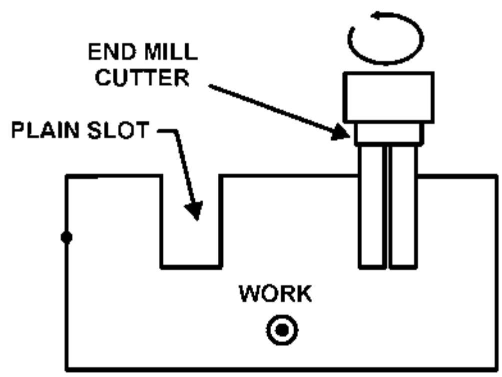


Fig. 7.21, Milling a plain slot by means of an End Mill Cutter.

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.

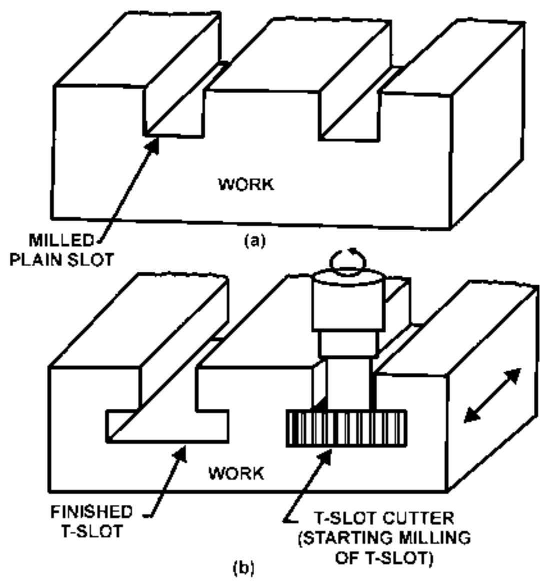


Fig. 7.22, Milling a T-slot, using a T-slot milling cutter
(a) Work having milled plain slots. (b) Milling T-slots with T-slot milling cutter.

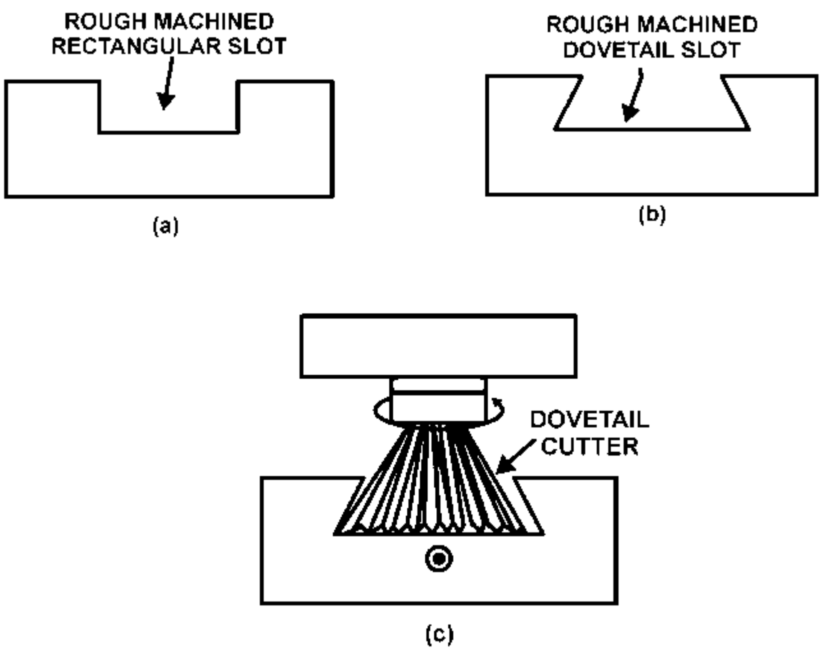


Fig. 7.23, Milling a Dovetail slot. (a) Rough machined rectangular slot, (b) Rough machined dovetail slot
(c) Finish machining the dovetail slot with the help of a dovetail milling cutter.

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.

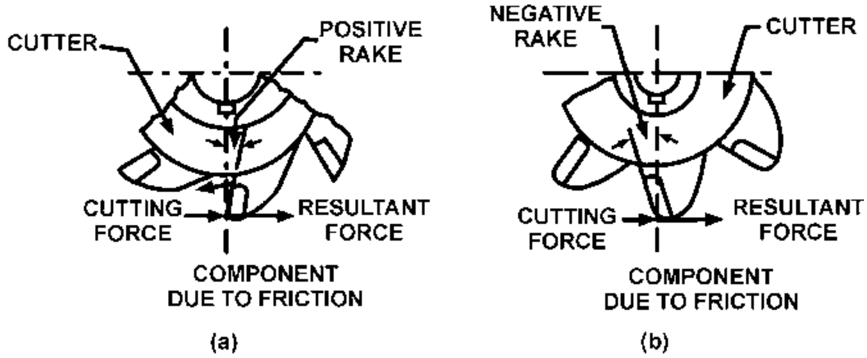


Fig. 7.24, Negative rake milling Vs positive rake milling.

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 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.

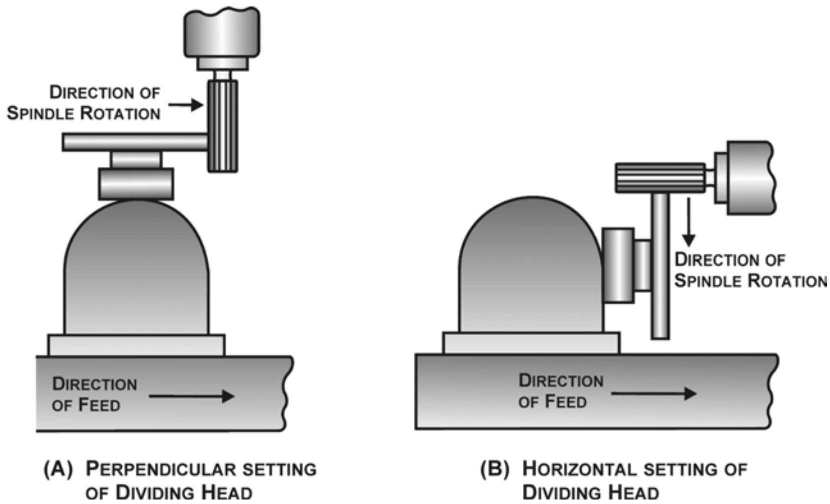


Fig. 7.25, Cam milling - perpendicular and parallel setting.

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.

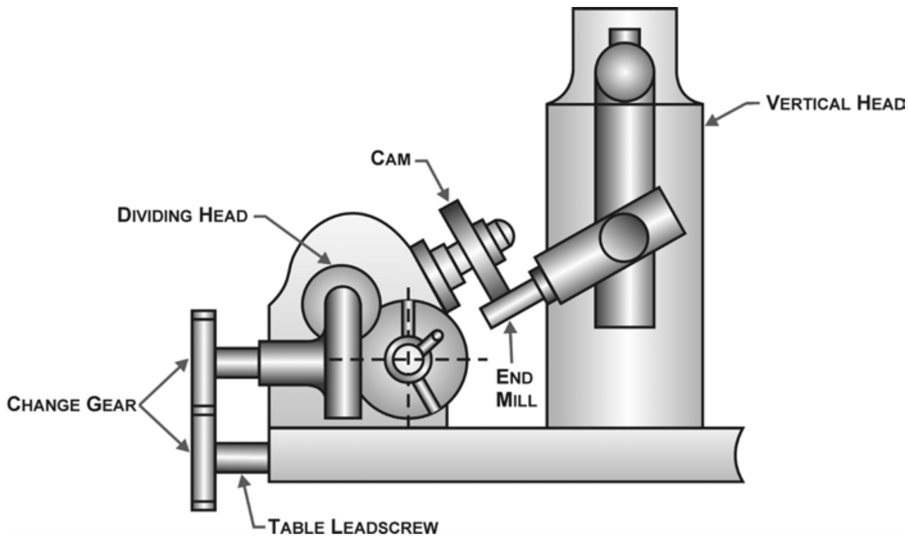


Fig. 7.26, Cam milling - angular setting.

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.

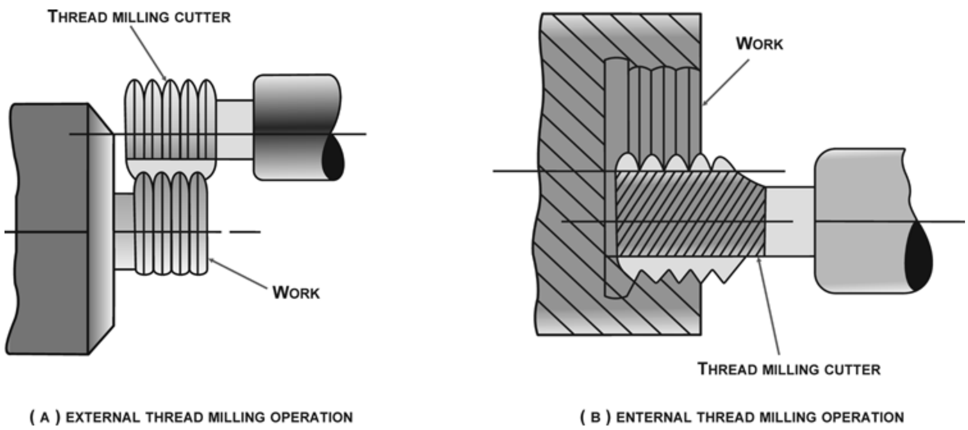


Fig. 7.27, Thread milling operation.

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
LUBRICATION EQUIPMENT & METHODS

OIL

Mineral lubricating oil like all other petroleum grades, are mixtures of hydro carbons of the various types. They are obtained by refining the "lubricating oil distitate drawn from the fractionating column and further refining and blending with other chemicals to obtain the requnced qualities.

The oil can be roughly grouped into two classes. Paraffinic and Naphtemic. Paraffin base oils have olive green cast while napthemic oil have a bluish cast. Mixed base oils are usually bluish green or green.

Concept of Lubrication

Lubrication is a procedure for reducing friction and wear. Friction is the resistance to motion encountered when one surface slides over the other. Wear is any loss or destruction resulting from such sliding.

The purpose of a lubricant is to prevent the surfaces from touching each other and so eliminate friction and wear. This may be brought about under actual working condition in two way :-

i. By fluid lubrication.
ii. By boundary lubrication

Fire Precautions

The fire can cause more damage than any thing else to men and material. Adequate precautions to be taken against fire.

1. Smoking should be strictly prohibited in machine shop.
2. Reciptical control.

METHODS OF LUBRICATION

By Hand

On the bigger surfaces where it is easy to clean and lubricate the surface by hand, greacing is done by hand care should be taken that no dust particles is in contact.

By Grease Gun

The places where restriction is not allowing greasing by hand or greasing is to be done under pressure, between two moving parts or bearing, greasing is to be done by grease Gun, Grease gun is a hollow cylindrical equipment which is filled with grease. It is provided with a hose which is having a nipple at the end. This nipple is connected on the nipple, provided on the part which is to be greased. The Grease gun is provided with a handle, when the handle is operated by hand, the grease is forced under pressure into the part which is to be greased.

Periodicity

Oiling and greasing is done as per recommendation and instructions provided in maintenance manual, may be daily, weely, quaterly, monthly as directed.

Fluid Lubrication

This means there is a thin but definitely measurable and continuous film of oil separating the moving surfaces and preventing metal-to-metal contact. This film may be imagined as a cushion which takes the load, and although very thin (measurable in ten-thousandth of an inch) it compress three distinct layers. The two outer layers cling to their respective surfaces. The central layers consists of particles of oil which are continuously torn apart from each other of sheared. The thinner the oil, the more easily can tins shearing and therefore movement take place.

When an oil thins out excessively the cushion of oil loses the capacity or strength which enables it to resist pressure. It is squeezed out from between the bearing surfaces, and fluid lubrication causes, but before the oil disappears entirely there is an intermediate state known as Boundary Lubrication.

Boundary Lubrication

This can be regarded as the condition bordering on break down, the oil film between the surfaces under load being reduced almost to nothing. The surfaces will continue to slide until such time the very thin smear of oil disappears completely. When boundary lubrication exists the thickness or viscosity of the oil no longer matters, because there is no appreciable film to be sheared. The important factor now is "Oiliness" of the oil, which means its resistance to breakage or vaporization of the boundary film.

Viscosity

The viscosity of a liquid is a measure of its internal friction, or its resistance to flow. A liquid which flows freely is said to have a low viscosity and one which is sluggish a high viscosity.

Viscosity is one of the most important properties of a lubricating oil. Viscosity should not be high as it increases the fluid frictions and due to that heat will be generated. If the viscosity is too less it will affect the fluid film and fluid lubrication.

Determination

Viscosity is expressed in “seconds”. There are various methods of measuring viscosity but in all principle is the same. A certain quantity of oil is taken, out a certain temperature and it is made to pass, through a construction or small jet and the time taken for its flow and expressed in seconds.

Viscosity Index

When oil is heated, it expands, the particles move further apart and its viscosity decreases. The viscosity index is a number which gives a measure of an oils viscosity temperature characteristics. An oil which is very thick at low term and becomes very thin at high term is said to have a low viscosity index or V1. If it changes relatively little in viscosity with term change it is said to have a high viscosity index.

Pour Point

The pour point of an oils is defined as 5°F above that temperature at which the oil ceases to flow when subjected to test. The lubricating oil contains waxy materials which tend to solidify as the oil is cooled. When this cooling takes place, the oil gets and acquires a paste-like structure. This condition would interfere with the free flow of the oil and might cause lubrication failure.

Oiliness

When the oil film separately two surfaces is exceedingly thin, due possibly to high bearing loads, oil starvation or loss of oil pressure of conditions arising during starting, fluid lubrication ceases the exist and is replaced by boundary lubrication conditions. Boundary lubrication is not desirable, but it has been found that under these conditions one lubricating oil reduces friction to a lower value than that given by another oil of the same viscosity the former lubricant is said to have greater oiliness and it is thought that certain fatty acid constituents in the oil combine chemically with the bearing metals, foaming soaps which reduce friction and protect the metals from welding together.

Acidity

Acids are undesirable in a lubricating oil because of the corrosive effects, they will have upon metals. During use, petroleum oils slowly oxidize and may from organic acids, some of which are highly corrosive to lead and lead-bronze. It is essential that the total acidity should not be excessive and therefore a maximum is specified.

Sludge and Varnish

Lubricating oils when new have no tendency to have deposits but in use reaction may take place which results in the formation of in soluble substances. These may settle and cause restriction in the oil pipe-lines which may lead to damage of working parts.

At high temperatures the products of oil oxidation may be deposited in the form of warnish. Detergent or dispersant agents may be added to counteract this. These agents keep the products of deterioration in such a finely dispersed state, that their separation to foam sludge or varnish is prevented.

Carbon Deposits

When oils are heated to temperatures of 675°F and higher, they begin to decomposer or crack rapidly. They break down into low boiling materials which quickly evaporate leaving a carbon deposit. A maximum carbo residue is specified for all oils.

Additives

Additives are substance added in small quantities to an oil to give it some desirable property which it would not otherwise pocess.

Flash Point

The flash point of an oil is the temperature at which in flammable vapours are given off under certain specified conditions. It is found by heating the oil in a special form until the oil vapour flashes i.e. gives off a brief flash when a small flame is brought into contact with its surface.

Saponificatison Number

Of an oil is the measure of the quantity of saponifiable present i.e. patter capable of being turned into soap.

Grades

Lubricating oils are graded by their viscosity and quality. There are various letter coding used to identify these and a few common types are given below for guidance :-

Stores Ref. No. (Old)	Stores Ref. No. (Latest)	Inter Service designation	Nomenclature	Key Letter	Remarks
34 A/32	34A/9100554	OM-270	Aero Engine oil Grade	X	100 seconds viscosity; for piston engine
34 A/116	34A/9100584	OMD-270	Aero engine oil	Z	100 seconds viscosity with additure
34 A/206	34A/9100540	OEP-70	Oil, extreme pressure to D E O-2479/1	V	Turbine engine oil
34 A/266	34A/9100591	OX-38	Oil lubricating synthetic type	S	Turbine engine oil (Synthetic)
34 A/292	34A/9105055	OM-11	Aviation turbine oil	A	Oil, mineral for jet engines
34 A/291	34B/9100593	OX-275	Oil miscellaneous	-	Storage oil for aero engines

Notes :

a. No mixing permitted at all.
b. Avoid water and exposure to moisture.
c. Do not mix up cans.
d. Keep cans and containers clearly marked.
e. Funnels are to be separated and used for a particular grade only.

Greases

(a) Composition

Greases are not solidified oils but are cooked product of one or more types of soaps and lubricating oil, which has a property to "Gee" (pronounced as jee). Additives and detergents are also added as in the case of lubricating oils to improve their quality.

(b) Purpose

Greases are employed as lubricants. Where oils fail to maintain the film due to extreme pressures, temperatures, or speed. Greases are also preferred under the following conditions.

i. Where there is possibility of oil leaking away.
ii. Inaccessible places.
iii. Where temperatures are critical.
iv. Where dirt and moisture are to be avoided to prevent corrosion.

(c) Manufacture

Greases are manufactured by cocking sodium (soda-base), calcium (lime-base) and other bases like aluminium, lithium, clay and graphite with fatty acids and oils. These impart excellent lubricating qualities to greases.

(d) Classification

Greases are mainly classified into three general groups.

i. Limn Base Greases

Which has a low melting point, used on control surfaces.

ii. **Soda Base Grease**

For high water resistance and high temperature range.

iii. Metallic or aluminium base grease

For high or extreme pressures where high tacky qualities are required e.g. prop. splines and places where very heavy loads are experienced with low speeds.

8. **Uses**

Greases are used to wet the surfaces and to maintain a separating film between to working surfaces, unlike lubricating oil, which apart from lubricating the surfaces, also carries away a certain amount of heat, produced by friction. Greases are preferred over oil where there are chances of corrosion as the metallic soap present in grease is an excellent corrosion preventive.

MAINTAINING THE STORED PARTS BY OIL/GREASE

When the parts or components are stored for long period they are to be protected against corrosion/rust. A thin layer of oil or grease is applied to these parts/components to protect them against corrosion or rust. Before applying grease or oil the parts must be cleaned properly.

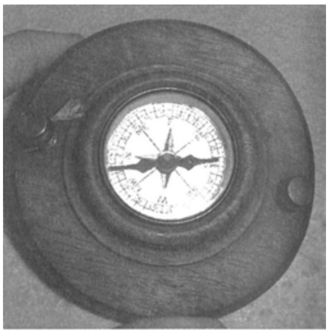
■■■

CHAPTER-9
OPERATION, FUNCTION & USE OF ELECTRICAL GENERAL TEST EQUIPMENT

OPERATION FUNCTION AND USE OF ELECTRICAL GENERAL TEST EQUIPMENT

Absolute and secondary instruments

The various electrical instruments may, in a very broad sense, be divided into (i) absolute instruments and (ii) secondary instruments. Absolute instruments are those which give the value of the quantity to be measured in terms of the constant of the instruments and their deflection only. No previous calibration or comparison is necessary in thier case. The example of such an instrument is tangent galvanometer which gives the value of current in terms of the tangent of deflection produced by the current and of the radius and number of turns of wire used and the horizontal component of earth's field.



An absolute instrument

Secondary instruments are those in which the value of electrical quantity to be measured can be determined from the deflection of the instruments only when they have been pre-calibrated by comparison with an absolute instrument. Without calibration, the deflection of such instruments is meaningless.

It is the secondary instruments which are most generally used in everyday work, the use of the absolute instruments being merely confined within laboratories as standardizing instruments.

Electrical Principles of Operation

All electrical measuring instruments depend for their action on one of the many physical effects of an electric current or potential and are generally classified according to which of these effects is utilized in their operation. The effects generally utilized are :

1. Magnetic effect - for ammeters and voltmeters usually.
2. Electrodynamic effect - for ammeters and voltmeters usually.
3. Electromagnetic effect - for ammeters, voltmeters, wattmeters and watthour meters.
4. Thermal effect - for ammeters and voltmeters.
5. Chemical effect - for d.c. ampere-hour meters.
6. Electrostatic effect - for voltmeters only.

Another way to classify secondary instruments is to divide them into (i) indicating instruments (ii) recording instruments and (iii) integrating instruments.

Indicating instruments are those which indicate the instantaneous value of the electrical quantity being measured at the time at which it is being measured. Their indications, are given by pointers moving over calibrated dials. Ordinary ammeters, voltmeters and wattmeters belong to this class.

Recording instruments are those which, instead of indicating by means of a pointer and a scale the instantaneous value of an electrical quantity, give a continuous record of the variations of such a quantity over a selected period of time. The moving system of the instrument carries an inked-pen which rests lightly on a chart or graph that is moved at a uniform and low speed, in a direction perpendicular to that of the deflection of the pen. The path traced out by the pen presents a continuous record of the variations in the deflection of the instruments.

Integrating instruments are those which measure and register by a set of dials and pointer either the total quantity of electricity (in ampere-hours) or the total amount of electrical energy (in watt-hours or kWh) supplied to a circuit in a given time. Their summation gives the product of time and the electrical quantity but gives no direct indication as to the rate at which the quantity or energy is being supplied because their registrations are independent of this rate provided the current flowing through the instrument is sufficient to operate it.

Essential of Indicating Instruments

As defined above, indicating instruments are those which indicate the value of the quantity that is being measured at the time at which it is measured. Such instruments consist essentially of a pointer which moves over a calibrated scale and which is attached to a moving system pivoted in jewelled bearings. The moving system is subjected to the following three torques :

1. A deflecting (or operating) torque
2. A controlling (or restoring) torque
3. A damping torque

Deflecting Torque

The deflecting or operating torque (T_d) is produced by utilizing one or other effects mentioned in para 4 as Electrical principle of operation i.e. magnetic, electrostatic, electrodynamic, thermal or chemical etc. The actual method of torque production depends on the type of instrument and will be discussed in the succeeding paragraphs. This deflecting torque cause the moving system (and hence the pointer attached to it) to move from its 'zero' position i.e. its position when the instrument is disconnected from the supply.

Controlling Torque

The deflection of the moving system would be indefinite if there were no controlling or restoring torque. This torque opposes the deflecting torque and increases with the deflection of the moving system. The pointer is brought to rest at a position where the two opposing torques are numerically equal. The deflecting torque ensures that currents of different magnitudes shall produce deflections of the moving system in proportion to their size. Without such a torque, the pointer would swing over to the maximum deflected position irrespective of the magnitude of the current to be measured. Moreover, in the absence of a restoring torque, the pointer once deflected, would not return to its zero position on removing the current. The controlling or restoring or balancing torque in indicating instruments is either obtained by a spring or by gravity as described below.

a. Spring Control

A hair-spring, usually of phosphor-bronze, is attached to the moving system of the instrument as shown in Fig. 9.1 (a). With the deflection of the pointer, the spring is twisted in the opposite direction. This twist in the spring produces restoring torque which is directly proportional to the angle of deflection of the moving system. The pointer comes to a position of rest (or equilibrium) when the deflecting torque (T_d) and controlling torque (T_c) are equal. For example, in permanent-magnet moving-coil type of instruments, the deflecting torque is proportional to the current passing through them.

$\therefore T_d \alpha I$ and for spring control $T_c \ \alpha \theta$

As $T_c = T_d$ $\therefore \theta \alpha I$

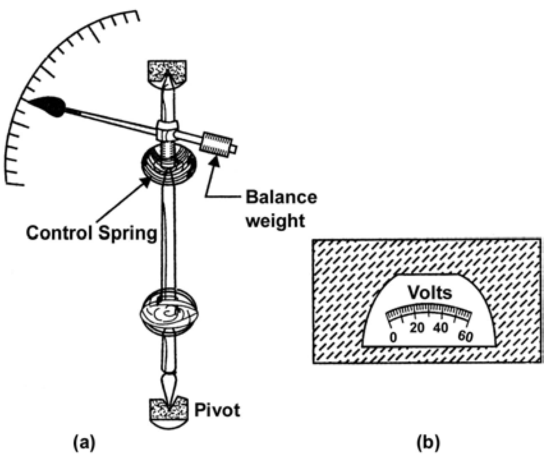


Fig. 9.1.

Since deflection θ is directly proportional to current I, the spring-controlled instruments have a uniform or equally-spaced scales over the whole of their ranges as shown in Fig. 9.1 (b).

To ensure that controlling torque is proportional to the angle of deflection, the spring should have a fairly large number of turns so that angular deformation per unit length, on full-scale deflection, is small. Moreover, the stress in the spring should be restricted to such a value that it does not produce a permanent set in it.

Springs are made of such materials which
1. are non-magnetic.
2. are not subject to much fatigue.
3. have low specific resistance-especially in cases where they are used for leading the current in or out of the instrument.
4. have low temperature-resistance coefficient.

b. Gravity Control
Gravity control is obtained by attaching a small adjustable weight to some part of the moving system such that the two exert torques are in the opposite directions. The usual arrangement is shown in Fig. 9.2 (a).

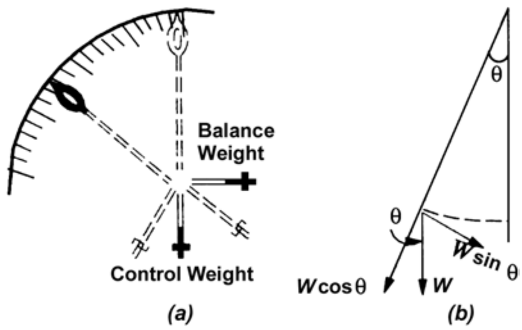


Fig. 9.2.

It is seen from Fig. 9.2 (b) that the controlling or restoring torque is proportional to the sine of the angle of deflection i.e. $T_e \alpha \sin\theta$. The degree of control is adjusted by screwing the weight up or down the carrying system.

As compared to spring control, the disadvantages of gravity control are :
i. it gives cramped scale
ii. the instrument has to be kept vertical.

However, gravity control has the following advantages :
i. it is cheap
ii. it is unaffected by temperature
iii. it is not subjected to fatigue or deterioration with time
iv. have low temperature - resistance co - efficient.

The exact expression for controlling torque is $T_C = CQ$

where C is spring constant. Its value is given by $C = \frac{Ebt^3}{L}$ N - m/rad. The angle 'Q' is in radians.

Damping Torque
A damping force is one which acts on the moving system of the instrument only when it is moving and always opposes its motion. Such a stabilizing or damping force is necessary to bring the pointer to rest quickly, otherwise due to inertia of the moving system, the pointer will oscillate about its final deflected position quite for sometime before coming to rest in the steady position. The degree of damping should be adjusted to a value which is sufficient to enable the pointer to rise quickly to its deflected position without overshooting. In that case, the instrument is said to be dead-beat. Any increase of damping above this limit i.e. overdamping will make the instrument slow and lethargic. In (Fig. 9.3) is shown the effect of damping on the variation of position, with time, of the moving system of an instrument.

The damping force can be provided by (i) air friction (ii) eddy currents and (iii) fluid-friction (used occasionally).

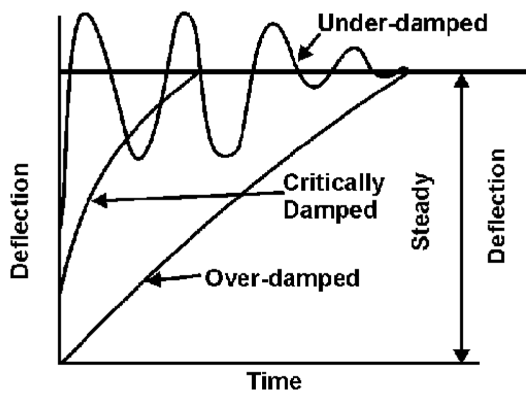


Fig. 9.3

Two methods of air-friction damping are shown in Fig. 9.4 (a) and Fig. 9.4 (b). In Fig. 9.4 (a), the light aluminium piston attached to the moving system of the instrument is arranged to travel with a very small clearance, in a fixed air chamber closed at one end. The cross-section of the chamber is either circular or rectangular. Damping of the oscillations is affected by the compression and suction actions of the piston on the air enclosed in the chamber. Such a system of damping is not much favoured these days, those shown in Fig. 9.4 (b) and Fig. 9.4 (c) being preferred. In the latter method, one or two light aluminium vanes are mounted on the spindle of the moving system which moves in a closed sector-shaped box as shown.

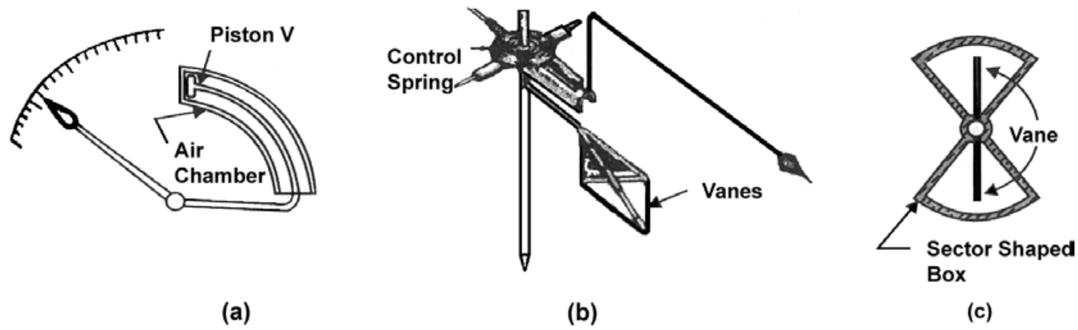


Fig. 9.4.

Fluid friction is similar in action to the air friction. Due to greater viscosity of oil, the damping is more effective. However, oil damping is not much used because of several disadvantages such as objectionable creeping of oil, the necessity of using the instrument always in the vertical position and its obvious unsuitability for use in portable instruments.

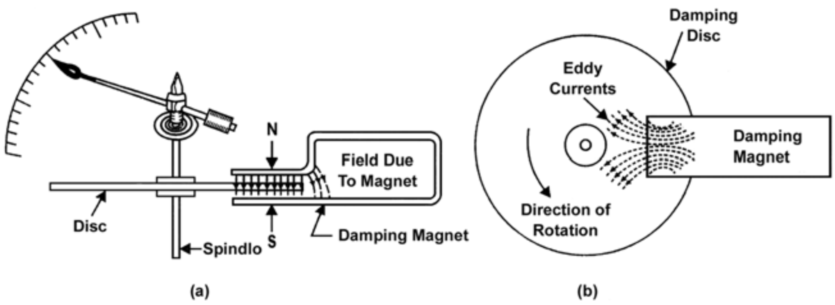


Fig. 9.5.

The eddy-current form of damping is the most efficient of the three. The two forms of such a damping are shown in (Fig. 9.5) and (Fig. 9.6). In Fig. 9.5 (a) is shown a thin disc of a conducting but nonmagnetic material like copper or aluminium mounted on the spindle which carries the moving system and the pointer of the instrument. The disc is so positioned that its edge, when in rotation, cuts the magnetic flux between the poles of a permanent magnet. Hence, eddy currents are produced in the disc which flow and so produce a damping force in such a direction as to oppose the very cause producing them as per (Lenz's Law Art). Since the cause producing them is the rotation of the disc, these eddy currents retard the motion of the disc and the moving system as a whole.

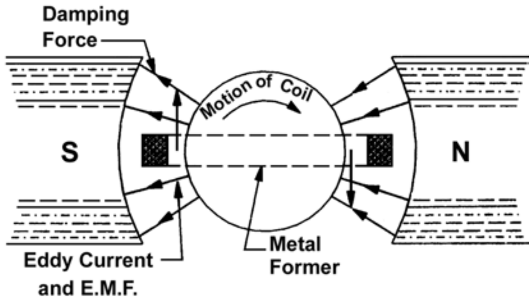


Fig. 9.6.

In (Fig. 9.6) is shown the second type of eddy-current damping generally employed in permanent-magnet moving-coil instruments. The coil is wound on a thin light aluminium former in which eddy currents are produced when the coil moves in the field of the permanent magnet. The directions of the induced currents and of the damping force produced by them are shown in the figure given above.

D'Arsonval Meter

The basic d.c. meter movement is known as the D'Arsonval meter movement because it was first employed by the French scientist, D' Arsonval, in making electrical measurement. This type of meter movement is a current-measuring device which is used in the ammeter, voltmeter, and ohmmeter. Basically, both the ammeter and the voltmeter are current-measuring instruments, the principal difference being the method in which they are connected in a circuit. While an ohmmeter is also basically a current-measuring instrument, it differs from the ammeter and voltmeter in that it provides its own source of power and contains auxiliary circuits.

DC MEASURING INSTRUMENTS

MULTIMETERS

Ammeters are commonly incorporated in multiple-purpose instruments such as multimeter or volt-ohm-milliammeters. These instruments vary somewhat according to the design used by different manufacturers, but most incorporate the functions of an ammeter, a voltmeter, and an ohmmeter in one unit. A typical multimeter is shown in (Fig. 9.7). This multimeter has two selector switches : a function switch and a range switch. Since a multimeter is actually three meters in one case, the function switch must be placed in proper position for the type of measurement to be made. In (Fig. 9.7), the function swhich is shown in the ammeter position to measure d.c. milliamperes and the range switch is set at 1000. Set in this manner, the ammeter can measure up to 1,000 milliamperes or 1 ampere.

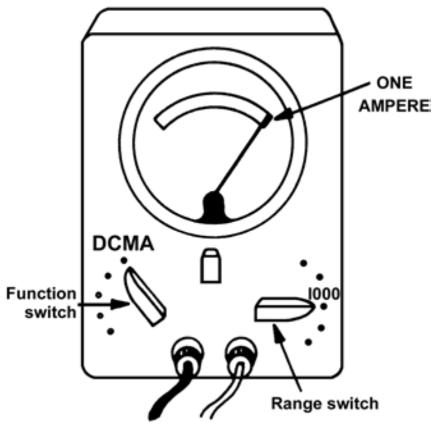


Fig. 9.7. A multimeter set to measure one ampere.

Multimeters have several scales, and the one used should correspond properly to the position of the range switch. If current of unknown value is to be measured, always select the highest possible range to avoid damage to the meter. The test leads should always be connected to the meter in the manner prescribed by the manufacturer. Usually the red lead is positive and the black lead is negative, or common. Many multimeters employ color coded jacks as an aid in connecting the meter into the circuit to be tested. In (Fig. 9.8), a multimeter properly set to measure current flow is connected into a circuit.

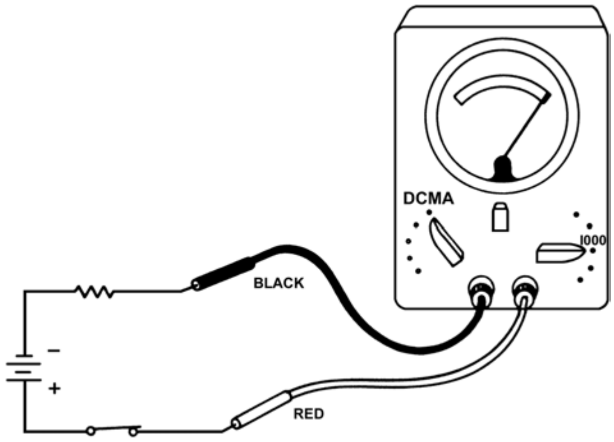


Fig. 9.8. A multimeter set to measure current flow.

The precautions to be observed when using all ammeter are summarized as follows :

1. Always connect an ammeter in series with the element through which the current flow is to be measured.
2. Never connect an ammeter across a source of voltage, such as a battery or generator. Remember that the resistance of an ammeter, particularly on the higher ranges, is extremely low and that any voltage, even a volt or so, can cause very high current to flow through the meter, causing damage to it.
3. Use a range large enough to keep the deflection less than full scale. Before measuring a current, form some idea of its magnitude. Then switch to a large enough scale or start with the highest range and work down until the appropriate scale is reached. The most accurate readings are obtained at approximately scale is reached. The most accurate readings are obtained at approximately half-scale deflection. Many milliammeters have been ruined by attempts to measure amperes. Therefore, be sure to read the lettering either on the dial or on the switch positions and choose proper scale before connecting the meter in the circuit.
4. Observe proper polarity in connecting the meter in the circuit. Current must flow through the coil in a definite direction in order to move the indicator needle up-scale. Current reversal because of incorrect connection in the circuit results in a reversed meter deflection and frequently causes bending of the meter needle. Avoid improper meter connections by observing the polarity markings on the meter.

VOLTMETER

The D' Arsonval meter movement can be used either as an ammeter or a voltmeter (Fig. 9.9). Thus, an ammeter can be converted to a voltmeter by placing a resistance in series with the meter coil and measuring the current flowing through it. In other words, a voltmeter is a current-measuring instrument, designed to indicate voltage by measuring the current flow through a resistance of known value. Various voltage ranges can be obtained by adding resistors in series with the meter coil. For low-range instruments, this resistance is mounted inside the case with the D' Arsonval movement and usually consists of resistance wire having a low temperature coefficient which is wound either on spools or card frames. For higher voltage ranges, the series resistance may be connected externally. When this is done, the unit containing the resistance is commonly called a multiplier.

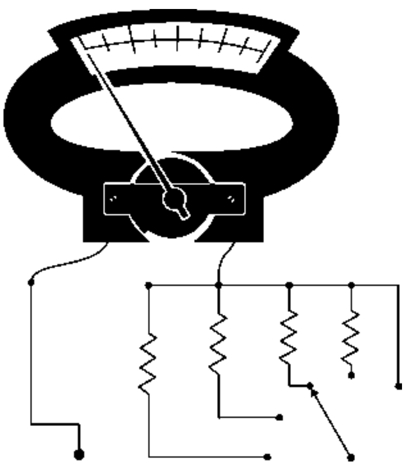


Fig. 9.9. Simplified diagram of a voltmeter.

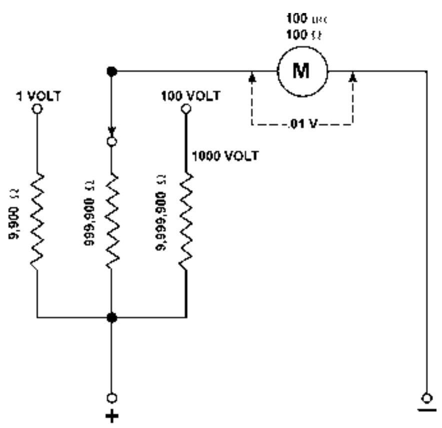


Fig. 9.10. Multirange voltmeter schematic.

Extending the Voltmeter Range

The value of the necessary series resistance is determined by the current required for full-scale deflection of the meter and by the range of voltage to be measured. Because the current through the meter circuit is directly proportional to the applied voltage, the meter scale can be calibrated directly in volts for a fixed series resistance.

For example, assume that the basic meter (microammeter) is to be made into a voltmeter with a full-scale reading of 1 volt. The coil resistance of the basic meter is 100 ohms, and 0.0001 ampere (100 microamperes) cause a full-scale deflection. The total resistance, R, of the meter coil and the series resistance is

$$R = \frac{E}{I} = \frac{1}{0.0001} = 10{,}000\,\text{ohms},$$

and the series resistance alone is
$R_s = 10{,}000 - 100 = 9{,}900$ ohms.

Multirange voltmeters utilize one meter movement with the required resistances connected in series with the meter by a convenient switching arrangement. A multirange voltmeter circuit with three ranges is shown in (Fig. 9.10). The total circuit resistance for each of the three ranges beginning with the 1-volt range is :

$$R = \frac{E}{I} = \frac{1}{100} = 0.01\,\text{megohm}$$

$$\frac{100}{100} = 1\,\text{megohm}$$

$$\frac{1{,}000}{100} = 10\,\text{megohms.}$$

Multirange voltmeters, like multirange a meters, meters are used frequently. They are physically very similar to ammeters, and their multipliers are usually located inside the meter with suitable switches or sets of terminals on the outside of the meter for selecting ranges (see Fig. 9.11).

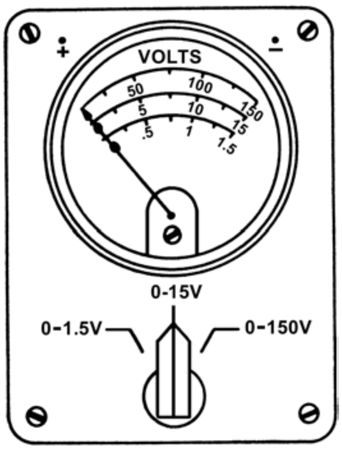


Fig. 9.11. Typical multirange voltmeter.

Voltage-measuring instruments are connected across (in parallel with) a circuit. If the approximate value of the voltage to be measured is not known, it is best, as in using the ammeter, to start with the highest range of the voltmeter and progressively lower the range until a suitable reading is obtained.

In many cases, the voltmeter is not a central-zero indicating instrument. Thus, it is necessary to observe the proper polarity when connecting the instrument to the circuit, as is the case when connecting the d.c. ammeter. The positive terminal of the voltmeter is always connected to the positive terminal of the source, and the negative terminal to the negative terminal of the source, when the source voltage is being measured. In any case, the voltmeter is connected so that electrons will flow into the negative terminal and out of the positive terminal of the meter. In (Fig. 9.12) a multimeter is properly connected to a circuit to measure the voltage drop across a resistor. The function switch is set at the d.c. volts position and the range switch is placed in the 50-volt position and the range switch is placed in the 50-volt position.

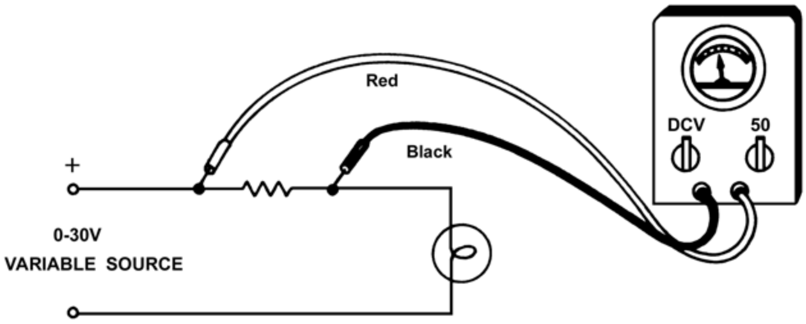


Fig. 9.12. A multimeter connected to measure a circuit voltage drop.

The function of a voltmeter is to indicate the potential difference between two points in a circuit. When the voltmeter is connected across a circuit, it shunts the circuit. If the voltmeter has low resistance, it will draw an appreciable amount of current. The effective resistance of the circuit will be lowered, and the voltage reading will consequently be lowered.

When voltage measurements are made in high-resistance circuits, it is necessary to use a high-resistance voltmeter to prevent the shunting action of the meter. The effect is less noticeable in low-resistance circuits because the shunting effect is less.

Voltmeter Sensitivity

The sensitivity of a voltmeter is given in ohms per volt (Ω/E) and is determined by dividing the resistance (R_m) of the meter plus the series resistance (R_s) by the full-scale reading in volts.
Thus,

$$\text{sensitivity} = \frac{R_m + R_s}{E}$$

This is the same as saying that the sensitivity is equal to the reciprocal of the current (in amperes); that is

$$\text{Sensitivity} = \frac{\text{ohms}}{\text{volts}} = \frac{1}{\frac{\text{volts}}{\text{ohms}}} = \frac{1}{\text{amperes}}$$

Thus, the sensitivity of a 100-microampere movement is the reciprocal of 0.0001 ampere, or 10,000 ohms per volt.

The sensitivity of a voltmeter can be increased by increasing the strength of the permanent magnet, by using lighter weight materials for the moving element (consistent with increased number of turns on the coil), and by using sapphire jewel bearings to support the moving coil.

Voltmeter Accuracy

The accuracy of a meter is generally expressed in percent. For example, a meter with an accuracy of 1 percent will indicate a value within a percent of the correct value. The statement means that, if the correct value is 100 units, the meter indication may be anywhere within the range of 99 to 101 units.

Ammeter

The D'Arsonval ammeter is an instrument designed for measuring direct current flowing in an electrical circuit and consists of the following parts : a permanent magnet, a moving element mounting, bearings, and a case which includes terminals, a dial, and screws. Each part and its function are described in the discussion which follows.

The permanent magnet furnishes a magnetic field which will react with the magnetic field set up by the moving element.

The moving element is mounted so that it is free to rotate when energized by the current to be measured. A pointer which moves across a calibrated scale is attached to this element. A moving-coil mechanism is shown in (Fig. 9.13). The controlling element is a spring, or springs, whose main function is to provide a counter or restoring force. The strength of this force increases with the turning of the moving element and brings the pointer to rest at some point on the scale. Two springs are generally used; they are wound in opposite directions to compensate for the expansion and contraction of the spring material due to temperature variation. The springs are made of nonmagnetic material and conduct current to and from the moving coil in some meters.

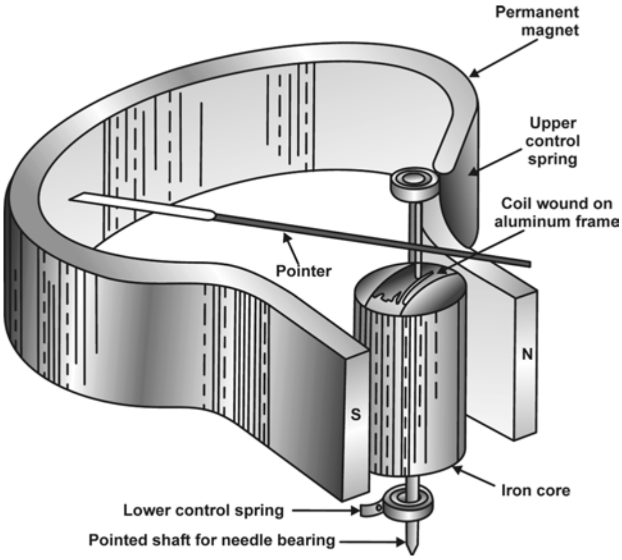


Fig. 9.13. Moving-coil element with pointer and springs.

The moving element consists of a shaft with very hard pivot points to carry the moving coil or other movable element (Fig. 9.13). The pivot points are so fitted into highly polished jewels or very hard glass bearings that the moving element can rotate with very little friction. Another type of mounting has been designed in which the pivot points are reversed and the bearings are inside the moving-coil assembly. A method of mounting moving elements is shown in (Fig. 9.14).

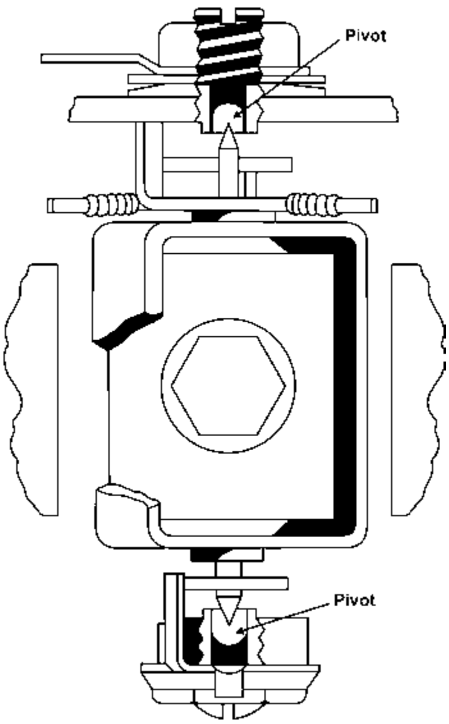


Fig. 9.14. Method of mounting moving elements.

The bearings are highly polished jewels such as sapphire, synthetic jewels, or very hard glass. These are usually round and have a conical depression in which the pivots rotate. They are set in threaded nuts which allow adjustment. The radius of the depression in the jewel is greater than the radius of the pivot point. This limits the area of contact surfaces and provides a bearing which, when operated dry, probably has the lowest constant friction value of any known type of bearing.

The case houses the instrument movement and protects it from mechanical injury and exposure. It also has a window for viewing the movement of the pointer across a calibrated scale. The dial has printed on it pertinent information such as the scale, units of measurement, and meter uses. The terminals are made of materials having very low electrical resistance. Their function is to conduct the required current into and away from the meter.

Operation of the Meter Movement

The major units are mounted in their relationship to one another (Fig. 9.15). Note that the coil portion of the moving element is in the magnetic field of the permanent magnet.

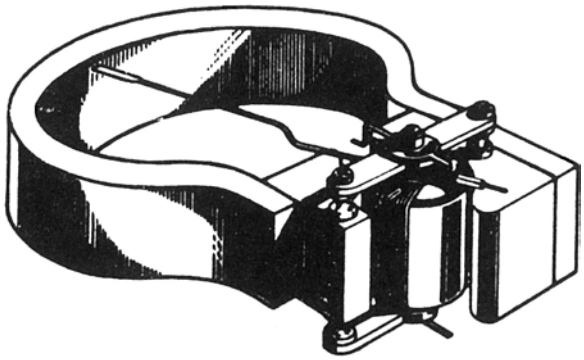


Fig. 9.15. D'Arsonval meter movement.

In order to understand how the meter works, assume that the coil of the moving element is placed in a magnetic field as shown in(Fig. 9.16).

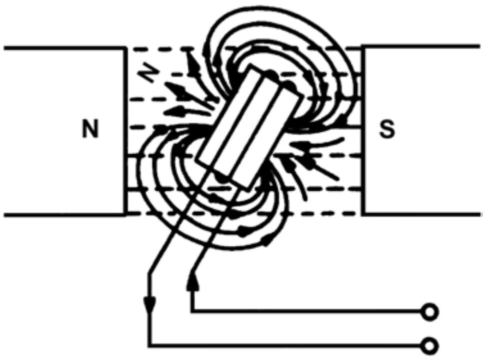


Fig. 9.16. Effect of a coil in a magnetic field.

The coil is pivoted so that it is able to rotate back and forth within the magnetic field set up by the magnet. When the coil is connected in a circuit, current flows through the coil in the direction indicated by the arrows and sets up a magnetic field within the coil. This field has the same polarity as the adjacent poles of the magnet. The interaction of the two fields causes the coil to rotate to a position so that the two magnetic fields are aligned. This force of rotation (torque) is proportional to the interaction between the like poles of the coil and the magnet and, therefore, to the amount of current flow in the coil. As a result, a pointer attached to the coil will indicate the amount of current flowing in the circuit as it moves across a graduated scale.

In the arrangement just discussed, note that any torque sufficient to overcome the inertia and friction of moving parts causes the coil to rotate until the fields align. This uncontrolled movement would cause inaccurate current readings. There fore, the turning motion of the coil is opposed by two springs. The value of the current flowing through the coil determines the turning force of the coil. When the turning force is equal to the opposition of the springs, the coil stops moving and the pointer indicates the current reading on a calibrated scale. In some meters the springs are made of conducting material and conduct current to and from the coil. The pole pieces of the magnet form a circular air gap within which the coil is pivoted.

To obtain a clockwise rotation, the north pole of the permanent magnet and that of the coil must be adjacent. The current flowing through the coil must, therefore, always be in the same direction. The D'Arsonval movement can be used only for d.c. measurements and the correct polarity must be observed. If the current is allowed to flow in the wrong direction through the coil, the coil will rotate counterclock wise and the pointer will be damaged. Since the movement of the coil is directly proportional to the current through the coil, the scale is normally a linear scale.

Meter Sensitivity

The sensitivity of a meter movement is usually expressed as the amount of current required to give full-scale deflection. In addition, the sensitivity may be expressed as the number of millivolts across the meter when full-scale current flows through it. This voltage drop is obtained by multiplying the full-scale current by the resistance of the meter movement. A meter movement, whose resistance is 50 ohms and which requires 1 milliampere (ma.) for full-scale reading, may be described as a 50-milli volt 0-1 milli ammeter.

Extending the Range of an Ammeter

A 0-1 milli ammeter movement may be used to measure currents greater than 1 ma. by connecting a resistor is called a shunt because it bypasses a portion of the current around the movement, extending the range of the ammeter. A schematic drawing of a meter movement with a shunt connected across it to extend its range is shown in (Fig. 9.17).

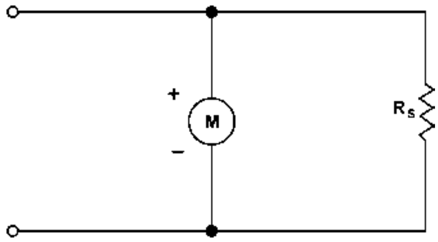


Fig. 9.17. Meter movement with shunt.

Determining the Value of a Shunt

The value of a shunt resistor can be computed by applying the basic rules for parallel circuits. If a 50 millivolt 0-1 milliammeter is to be used to measure values of current up to 10 ma., the following procedure can be used : The first step involves drawing a schematic of the meter shunted by a resistor labelled R_S (shunt resistor), as shown in (Fig. 9.18).

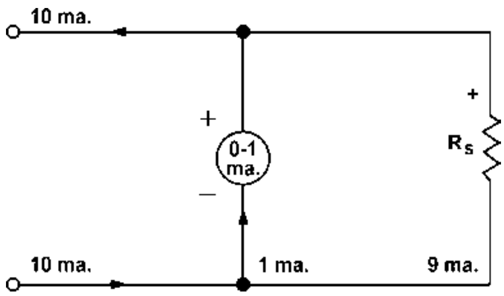


Fig. 9.18. Circuit schematic for shunt resistor.

Since the sensitivity of the meter is known, the meter resistance can be computed. The circuit is then redrawn as shown in (Fig. 9.19), and the branch currents can be computed, since a maximum of 1 ma. can flow through the meter. The voltage drop across R_S is the same as that across the meter, R_m :

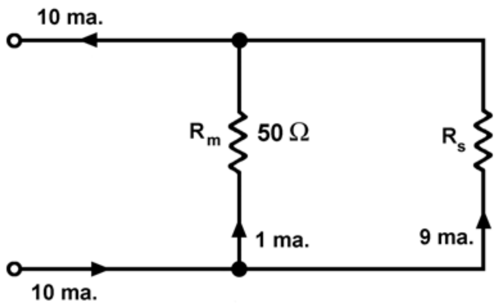


Fig. 9.19. Equivalent meter circuit.

$$E = I R$$
$$= 0.001 \times 50$$
$$= 0.050 \text{ volt.}$$

R_s can be found by applying Ohm's law :

$$R_s = \frac{E_{rs}}{I_{rs}}$$

$$= \frac{0.050}{0.009}$$

$$= 5.55 \text{ ohms.}$$

The value of the shunt resistor (5.55 Ω) is very small, but this value is critical. Resistors used as shunts musts have close tolerances, usually 1 percent.

Universal Ammeter Shunt

The schematic drawing in (Fig. 9.20), the universal shunt, shows an arrangement whereby two or more ranges are provided by tapping the shunt resistor at the proper points. In this arrangement, a 0-5 ma. movement with a resistance of 20 ohms is shunted to provide a 0-25 ma. range and a 0-50 ma. range.

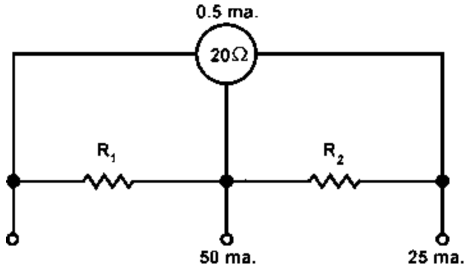


Fig. 9.20. Universal ammeter shunt.

Ammeters having a number of internal shunts are called multirange ammeters. A scale for each range is provided on the meter face (Fig. 9.21). Some multimeters avoid internal switching through the use of external shunts. Changing ammeter ranges involves the selection and installation on the meter case of the proper size shunt.

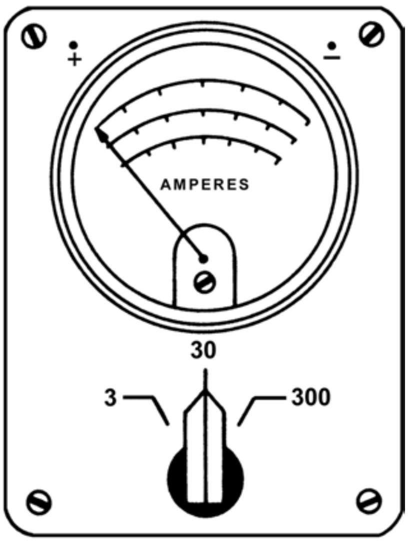


Fig. 9.21. A multirange ammeter.

A.C. MEASURING INSTRUMENTS

A d.c. meter, such as an ammeter, connected in an a.c. circuit will indicate zero, because the moving ammeter coil that carries the current to be measured is located in a permanent magnet field. Since the field of a permanent magnet remains constant and in the same direction at all times, the moving coil follows the polarity of the current. The coil attempts to move in one direction during half of the a.c. cycle and in the reverse direction during the other half when the current reverses.

The current reverses direction too rapidly for the coil to follow, causing the coil to assume an average position. Since the current is equal and opposite during each half of the a.c. cycle, the direct current meter indicates zero, which is the average value. Thus, a meter with a permanent magnet cannot be used to measure alternating voltage and current. However, the permanent magnet D' Arsonval meter may be used to measure alternating current or voltage if the current that passes through the meter is first rectified - that is, changed from alternating current to direct current.

Rectifier A.C. Meters

Copper-oxide rectifiers are generally used with D' Arsonval d.c. meter movements to measure alternating currents and voltages; however, there are many types of rectifiers which may be used, some of which are included in the discussion of alternator systems.

A copper-oxide rectifier allows current to flow through a meter in only one direction. As shown in (Fig. 9.22), the copper-oxide rectifier consists of copper-oxide disks separated alternately by copper disks and fastened together as a single unit. Current flows more readily from copper to copper oxide than from copper to copper. When a.c. is applied, therefore, current flows in only one direction, yielding a pulsating d.c. output as shown by the output wave shapes in (Fig. 9.23). This current can then be measured as it flows through the meter movement.

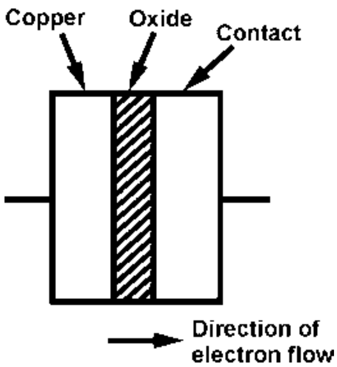


Fig. 9.22. Copper-oxide rectifier.

In some a.c. meters, selenium or vacuum tube rectifiers are used in place of the copper-oxide rectifier. The principle of operation, however, is the same in all meters employing rectifiers.

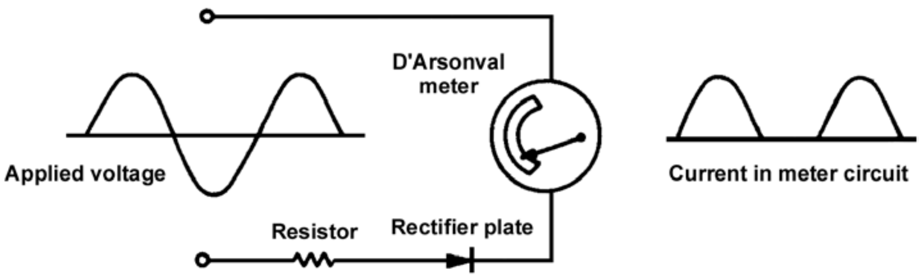


Fig. 9.23. A half-wave rectifier circuit.

Electrodynamometer Meter Movement

The electrodynamometer meter can be used to measure alternating or direct voltage and current. It operates on the same principles as the permanent magnet moving-coil meter, except that the permanent magnet is replaced by an air-core electromagnet. The field of the electrodynamometer meter is developed by the same current that flows through the moving coil (see Fig. 9.24).

In the electrodynamometer meter, two stationary field coils are connected in series with the movable coil. The movable coil is attached to the central shaft and rotates inside the two stationary field coils. The spiral springs provide the restraining force for the meter and also a means of introducing current to the movable coil.

When current flows through field coils A and B and movable coil C, coil C rotates in opposition to the springs and places itself parallel to the field coils. The more current flowing through the coils, the more the moving coil overcomes the opposition of the springs and the farther the pointer moves across the scale. If the scale is properly calibrated and the proper shunts or multipliers are used, the dynamometer movement will indicate current or voltage.

Although electrodynamometer meters are very accurate, they do not have the sensitivity of D'Arsonval meters and, for this reason, are not widely used outside the laboratory.

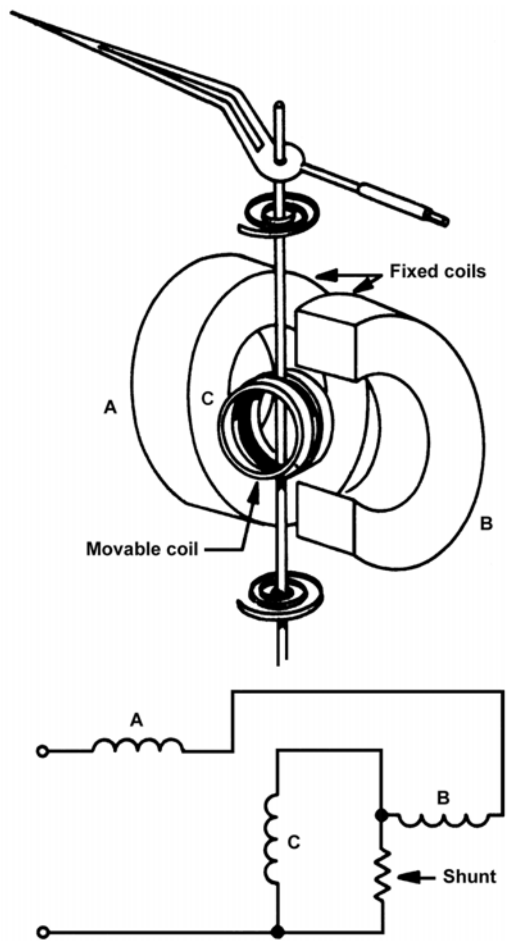


Fig. 9.24. Simplified diagram of an electrodynamometer movement.

Electrodynamometer Ammeter

In the electrodynamometer ammeter, low resistance coils produce only a small voltage drop in the circuit measured. An inductive shunt is connected in series with the field coils. This shunt, similar to the resistor shunt used in d.c. ammeters, permits only part of the current being measured to flow through the coils. As in the d.c. ammeter, most of the current in the circuit flows through the shunt; but the scale is calibrated accordingly, and the meter the total current. An a.c. ammeter, like a d.c. ammeter, is connected in series with the circuit in which current is measured. Effective values are indicated by the meter. A schematic diagram of an electrodynamometer ammeter circuit is shown in (Fig. 9.25).

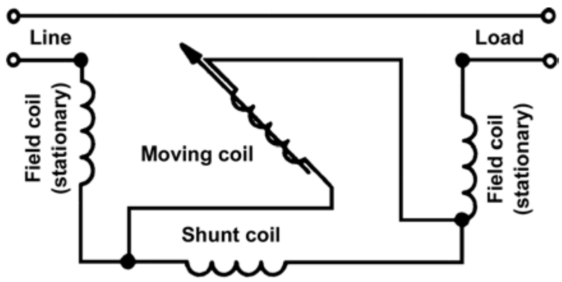


Fig. 9.25. Electrodynamometer ammeter circuit.

Electrodynamometer Voltmeter

In the electrodynamometer voltmeter, field coils are wound with many turns of small wire. Approximately 0.01 ampere of current flow through both coils is required to operate the meter. Resistors of a non-inductive material, connected in series with the coils, provide for different voltage ranges. Voltmeters are connected in parallel across the unit in which voltage is to be measured. The values of voltages indicated are effective values. A schematic diagram of an electrodynamometer voltmeter is shown in (Fig. 9.26).

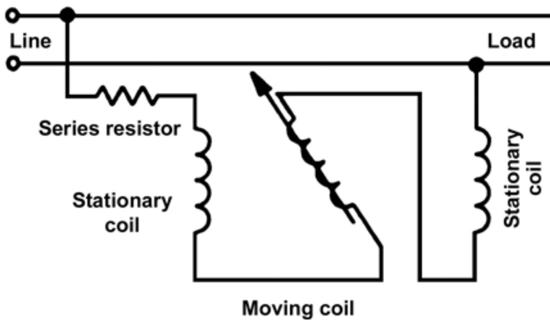


Fig. 9.26. Electrodynamometer voltmeter circuit.

Moving Iron-Vane Meter

The moving iron-vane meter is another basic type of meter. It can be used to measure either a.c. or d.c. Unlike the D'Arsonval meter, which employs permanent magnets, it depends on induced magnetism for its operation. It depends on induced magnetism for its operation. It utilizes the principle of repulsion between two concentric iron vanes, one fixed and one movable, placed inside a solenoid, as shown in (Fig. 9.27). A pointer is attached to the movable vane.

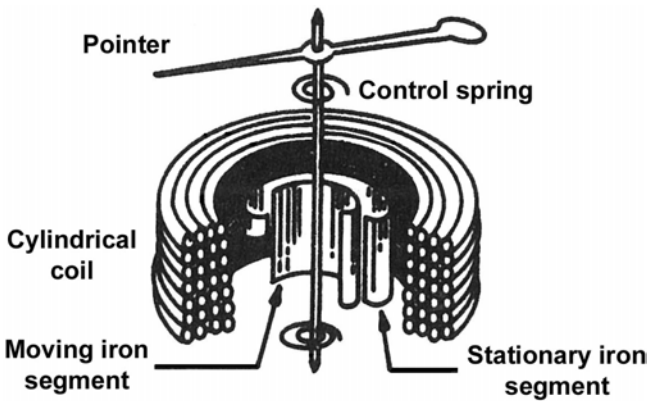


Fig. 9.27. Moving iron-vane meter.

When current flows through the coil, the two iron vanes become magnetized with north poles at their upper ends and south poles at their lower ends for one direction of current through the coil. Because like poles repel, the unbalanced component of force, tangent to the movable element, causes it to turn against the force exerted by the springs.

The movable vane is rectangular in shape and the fixed vane is tapered. The design permits the use of a relatively uniform scale.

When no current flows through the coil, the movable vane is positioned so that it is opposite the larger portion of the tapered fixed vane, and the scale reading is zero. The amount of magnetization of the vanes depends on the strength of the field, which, in turn, depends on the amount of current flowing through the coil. The force of repulsion is greater opposite the large end of the fixed vane than it is nearer the smaller end. Therefore, the movable vane moves toward the smaller end through an angle that is proportional to the magnitude of the coil current. The movement ceases when the force of repulsion is balanced by the restraining force of the spring.

Because the repulsion is always in the same direction (toward the smaller end of the fixed vane), regardless of the direction of current flow through the coil, the moving iron-vane instrument operates on either d.c. or a.c. circuits.

Mechanical damping in this type of instrument can be obtained by the use of an aluminium vane attached to the shaft so that, as the shaft moves, the vane moves in a restricted air space.

When the moving iron-vane meter is designed to be used as an ammeter, the coil is wound with relatively few turns of large wire in order to carry the rated current.

When the moving iron-vane meter is designed to be used as a voltmeter, the solenoid is wound with many turns of small wire. Portable voltmeters are made with self-contained series resistance for ranges up to 750 volts. Higher ranges are obtained by the use of additional external multipliers.

The moving iron-vane instrument may be used to measure direct current but has an error due to residual magnetism in the vanes. The error may be minimized by reversing the meter connections and averaging the readings. When used on a.c. circuits the instrument has an accuracy of 0.5 percent. Because of its simplicity, its relatively low cost, and the fact that no current is conducted to the moving element, this type of movement is used extensively to measure current and voltage in a.c. power circuits. However, because the reluctance of the magnetic circuit is high, the moving iron-vane meter requires much more power to produce full-scale deflection than is required by a D' Arsonval meter of the same range. Therefore, the moving iron-vane meter is seldom used in high-resistance low-power circuits.

Inclined-Coil Iron-Vane Meter

The principle of the moving iron-vane mechanism is applied to the inclined-coil type of meter, which can be used to measure both a.c. and d.c. The inclined-coil, iron-vane meter has a coil mounted at an angle to the shaft. Attached obliquely to the shaft, and located inside the coil, are two soft-iron vanes. When no current flows through the coil, a control spring holds the pointer at zero, and the iron vanes lie in planes parallel to the plane of the coil. When current flows through the coil, the vanes tend to line up with magnetic lines passing through the center of the coil at right angles to the plane of the coil. Thus, the vanes rotate against the spring action to move the pointer over the scale.

The iron vanes tend to line up with the magnetic lines regardless of the direction of current flow through the coil. Therefore, the inclined-coil, iron-vane meter can be used to measure either alternating current or direct current. The aluminium disk and the drag magnets provide electromagnetic damping.

Like the moving iron-vane meter, the inclined coil type requires a relatively large amount of current for full-scale deflection and is seldom used in high-resistance low-power circuits.

As in the moving iron-vane instruments, the inclined-coil instrument is wound with few turns of relatively large wire when use as an ammeter and with many turns of small wire when used as a voltmeter.

Thermocouple Meter

If the ends of two dissimilar metals are welded together and this junction is heated, a d.c. voltage is developed across the two open ends. The voltage developed depends on the material of which the wires are made and on the difference in temperature between the heated junction and the open ends.

In one type of instrument, the junction is heated electrically by the flow of current through a heater element. It does not matter whether the current is alternating or direct because the heating effect is independent of current direction. The maximum current that can be measured depends on the current rating of the heater, the heat that the thermocouple can stand without being damaged, and on the current rating of the meter used with the thermocouple. Voltage can also be measured if a suitable resistor is placed in series with the heater. In meter applications, a D' Arsonval meter is used with a resistance wire heater, as shown in (Fig. 9.28).

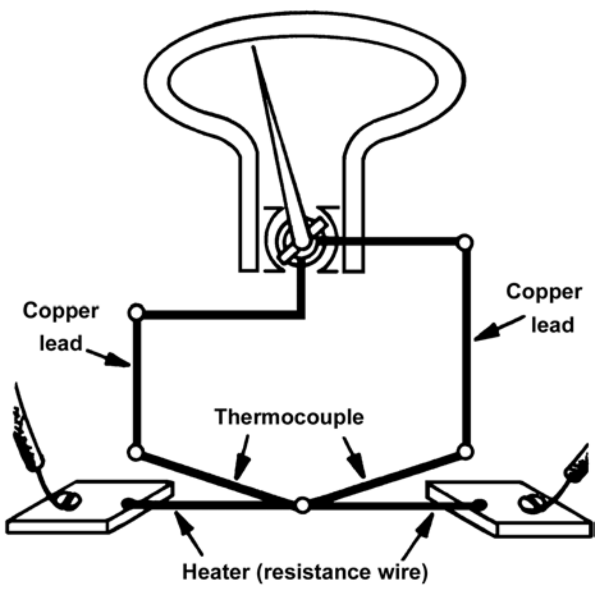


Fig. 9.28. Simplified diagram of a thermocouple meter.

As current flows through the resistance wire, the heat developed is transferred to the contact point and develops an e.m.f. which causes current to flow through the meter. The coil rotates and causes the pointer to move over a calibrated scale. The amount of coil movement is dependent on the amount of heat, which varies as the square of the current. Thermocouple meters are used extensively in a.c. measurements.

Disc Ammeter with Split-phase Windings

In this arrangement, the windings on the two laminated a.c. magnets P_1 and P_2 are connected in series. But the winding of P_2 is shunted by a resistance R with the result that the current in this winding lags with respect to the total line current. In this way, the necessary phase angle α is produced between two fluxes Φ_1 produced by P_1 and P_2 respectively. This angle is of the order of 60^o. If the hysteresis effects etc. are neglected, then each flux will be proportional to the current to be measured i.e. line current I.

FREQUENCY METER

Alternating-current electrical equipment is designed to operate within a given frequency range. In some instances the equipment is designed to operate at one particular frequency, as are electric clocks and time switches. For example, electric clocks are commonly designed to operate at 60 c.p.s. If the supply frequency is reduced 59 c.p.s., the clock will lose one minute every hour.

Transformers and a.c. machinery are designed to operate at a specified frequency. If the supply frequency falls more than 10 percent from the rated value, the equipment may draw excessive current, and dangerous overheating will result. It is, therefore, necessary to control the frequency of electric power systems. Frequency meters are employed to indicate the frequency so that corrective measures can be taken if the frequency varies beyond the prescribed limits.

Frequency meters are designed so that they will not be affected by changes in voltage. Because a.c. systems are designed to operate normally at one particular frequency, the range of the frequency meter may be restricted to a few cycles on either side of the normal frequency. There are several types of frequency meters, including the vibrating-reed type, and the resonant-circuit type. Of these types, the vibrating-reed frequency meter is used most often in aircraft systems, and is discussed in some detail.

Vibrating-Reed Frequency Meter

The vibrating-reed type of frequency meter is one of the simplest devices for indicating the frequency of an a.c. source. A simplified diagram of one type of vibrating-reed frequency meter is shown in (Fig. 9.29).

The current whose frequency is to be measured flows through the coil and exerts maximum attraction on the soft-iron armature twice during each cycle (A of Fig. 9.29). The armature is attached to the bar, which is mounted on a flexible support. Reeds of suitable dimensions to have natural vibration frequencies of 110, 112, 114, and so forth up to 130 c.p.s. are mounted on the bar (B of Fig. 9.29). The reed having a frequency of 110 c.p.s. is marked "55" cycles; the one having a frequency of 130 c.p.s. is marked "65" c.p.s.; the one having a frequency of 120 c.p.s. is marked "60" c.p.s., and so forth.

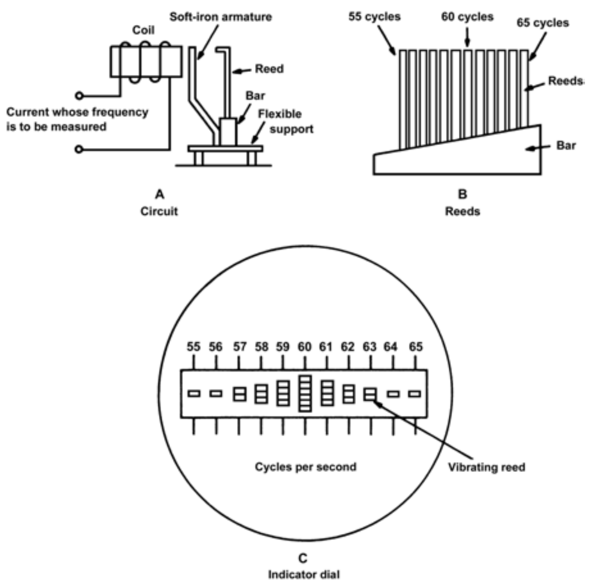


Fig. 9.29. Simplified diagram of a vibrating-reed frequency meter.

In some instruments the reeds are the same lengths, but are weighted by different amounts at the top so that they will have different natural rates of vibration.

When the coil is energized with a current having a frequency between 55 and 65 c.p.s., all the reeds are vibrated slightly; but the reed having a natural frequency closest to that of the energizing current (whose frequency is to be measured) vibrates through a larger amplitude. The frequency is read from the scale value opposite the reed having the greatest amplitude of vibration.

An end view of the reeds is shown in the indicator dial (C of Fig. 9.29). If the energizing current has a frequency of 60 c.p.s., the reed marked "60" c.ps. will vibrate the greatest amount, as shown.

These instruments form part of the metering system required for main a.c. power generating systems, and in some aircraft, they may also be employed in secondary a.c. generating systems utilizing inverters. The dial presentation and circuit diagram of a typical meter are shown in (Fig. 9.30). The indicating element, which is used in a mutual inductance circuit, is of the standard electrodynamometer pattern consisting essentially of a moving coil and a fixed field coil. The inductor circuit includes a nickel-iron core loading inductance, a dual fixed capacitor unit, four current-limiting resistors connected in series-parallel, and two other parallel-connected resistors which provide for temperature compensation. The electrical values of all the inductor circuit components are fixed.

The instrument also incorporates a circuit which is used for the initial calibration of the scale. The circuit is comprised of a resistor, used to govern the total length of the arc over which the pointer travels between the minimum and maximum frequencies, and a variable inductor system which governs the position of the centre of the arc of pointer travel relative to the mid-point of the instrument scale.

In operation the potential determined by the supply voltage and frequency is impressed on the field coil, which in turn sets up a main magnetic field in the area occupied by the moving coil. A second potential, whose value is also dependent on the supply voltage and frequency, is impressed on the moving coil, via the controlling springs. Thus, a second magnetic field is produced which interacts with the main magnetic field and also produces a torque causing the moving coil to rotate in the same manner as a conventional moving coil indicator. Rotation of the coil continues until the voltage produced in this winding by the main field is equal and opposite to the impressed potential at the given frequency. The total current in the moving coil and the resulting torque are therefore reduced to zero and the coil and pointer remain stationary at the point on the scale which corresponds to the frequency impressed on the two coils.

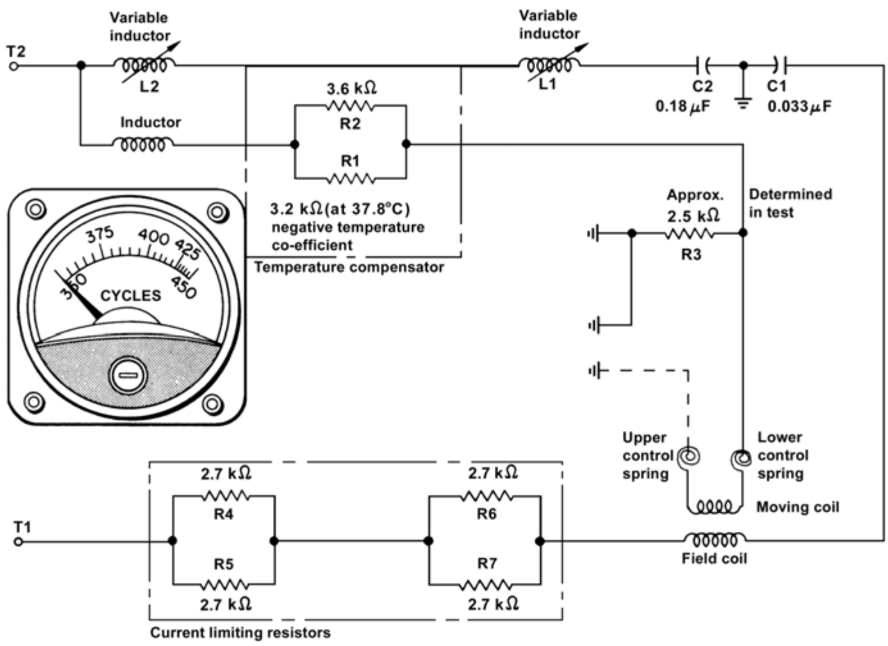


Fig. 9.30. Circuit arrangements of a frequency meter.

Ampere-hour Mercury Motor Meter

It is one of the best and most popular form of mercury Ammeter used for d.c. work.

Construction

It consists of a thin Copper disc D, mounted at the base of a spindle working in jewelled cup bearing and revolving between a pair of permanent magnets M_1 and M_2. One of the two magnets i.e. M_2 is used for driving purpose whereas M_1 is used for braking. In between the poles of M_1 and M_2 is a hollow circular box B in which rotates the Cu disc and the rest of the space is filled up with mercury which exerts a considerable upward thrust on the disc, thereby reducing the pressure on the bearings. The spindle is so weighted that it just sinks in the mercury bath. A worm cut in the spindle at its top engages the gear wheels of the recording mechanism as shown in (Fig. 9.31) and (Fig. 9.32).

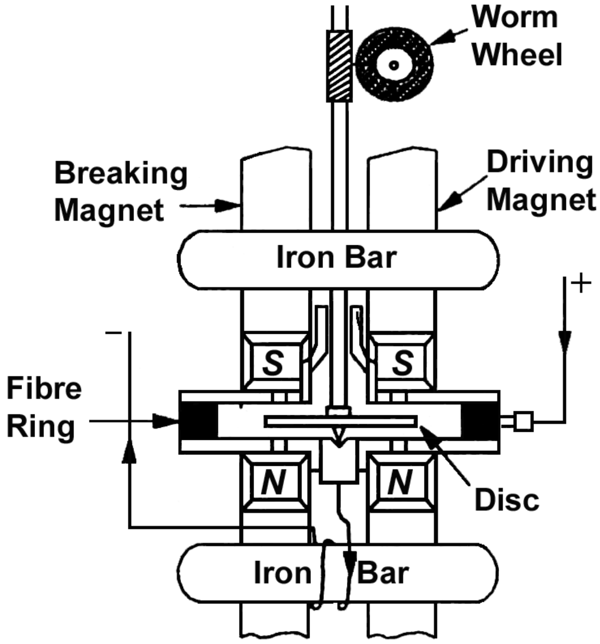


Fig. 9.31

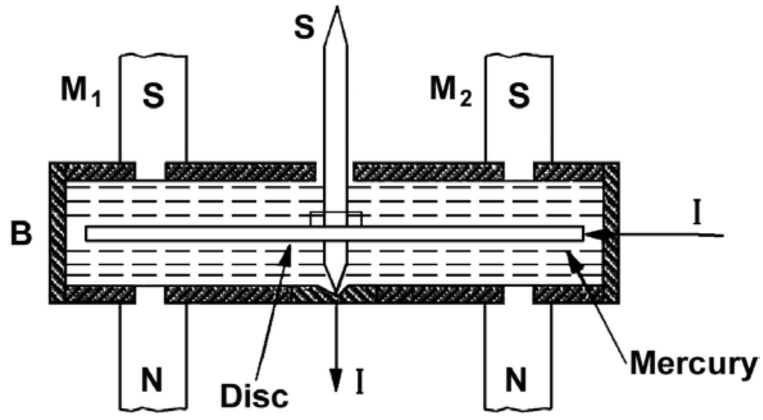


Fig. 9.32

Principle of Action

Its principle of action can be understood from (Fig. 9.33) which shows a separate line drawing of the motor element. The current to be measured is led in the disc through the mercury, at a point at its circumference on the right-hand side. As shown by arrows, it flows radially to the centre of the disc where it passes out to the external circuit through the spindle and its bearings. It is worth noting that current flow takes place only under the right-hand side magnet M_2 and not under the left-hand side magnet M_1. The field of M_2 will, therefore, exert a force on the right-side portion of the disc which carries the current (motor action). The direction of the force, as found by Fleming's Left-hand rule, is as shown by the arrow. The magnitude of the force depends on the flux density and current ($\because$ F=BIl). The driving or motoring torque

T_d so produced is given by the product of the force and the distance from the spindle at which this force acts. When the disc rotates under the influence of this torque, it cuts through the field of left-hand side magnet M_1 and hence eddy currents are produced in it which results in the production of braking torque. The magnitude of the retarding or braking torque is proportional to the speed of rotation of the disc.

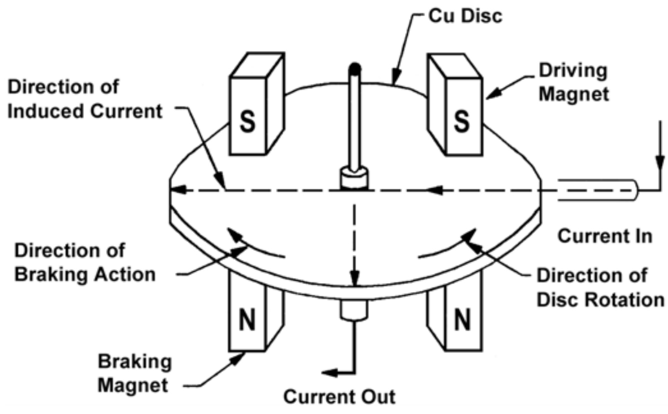


Fig. 9.33.

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CHAPTER-10
AVIONIC GENERAL TEST EQUIPMENT

MULTIMETERS
The most versatile electrical measuring instrument used by the aircraft technician is the multimeter. This handy tool has a single meter movement and a selector switch which may be used to select any of a number of circuits.

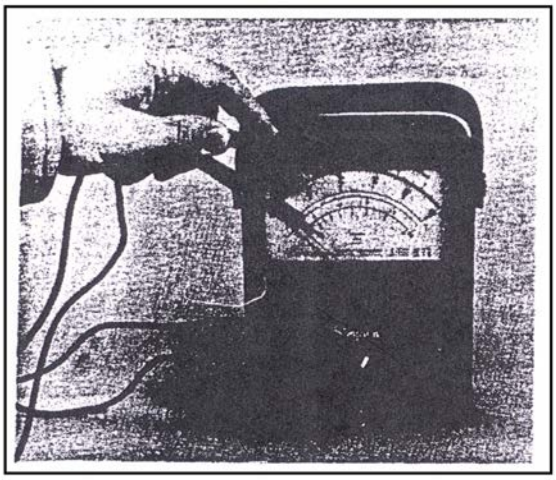


Fig. 10.1, The multimeter is one of the most useful electrical measuring instruments used by the A & P technician.

1. Analog Multimeters
Analog multimeters have voltage ranges from 0 to 2.5, 10, 50, 2501,000 and 5,000 volts for both AC and DC. They can measure direct current in ranges of 100 microamperes, 10, 100, and 500 milliamps and 10 amps. Resistance can be measured in ranges from 0-2,000 ohms, 0-200,000 ohms and 0-20 megohms. The meter has a sensitivity of 20,000 ohms per volt for measuring DC, but because of the rectifier circuit, its sensitivity for AC is 1,000 ohms per volt.

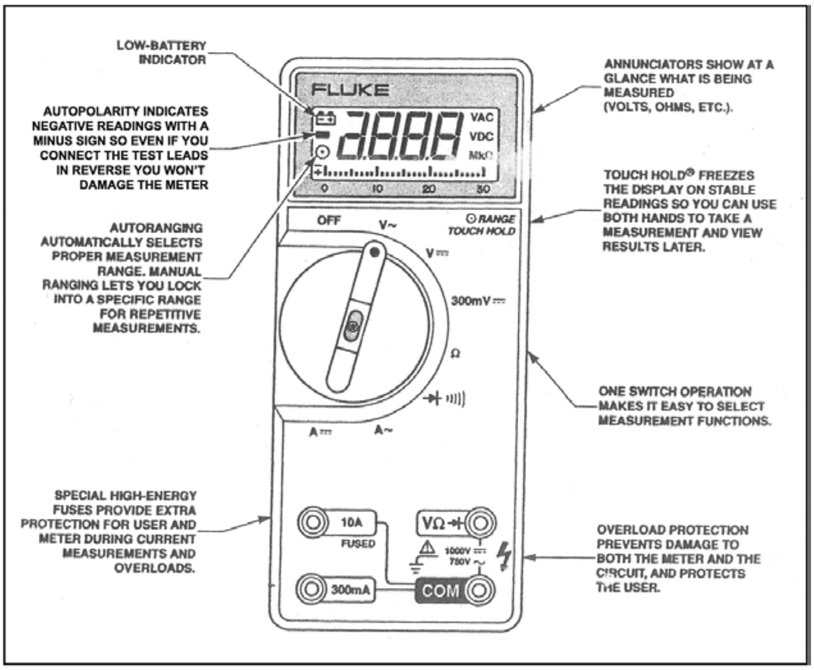


Fig. 10.2, A DMM can have a great many special features that differ from an analog multimeter.

All analog multimeters have a "zero adjust" knob to reset the scale as the internal battery discharges with time and usage.

2. Digital Multimeters

A digital multimeter (DMM) is simply an electronic ruler for making electrical measurements. It may have any number of special features, but mainly, a DMM measures volts, ohms, and amperes.

a. Resolution, Digits and Counts

Resolution refers to how small or fine a measurement the meter can make. By knowing the resolution of a DMM, you can determine whether the meter could measure down to only a volt or a millivolt (1/1.000 of a volt).

The terms bits and counts are used to describe a meter's resolution. DMMs are grouped by the number of counts or digits they display.

A 3-½ digit meter, for example can display three full digits ranging from 0 to 9, and one "half" digit which displays only a one or is left blank. A 3-½ digit meter will display up to 1,000 counts of resolution.

It is more precise to describe a meter by counts or resolution than by digits. Today's 3-½ digit meters may have enhanced resolution of up to 3,200 or 4,000 counts.

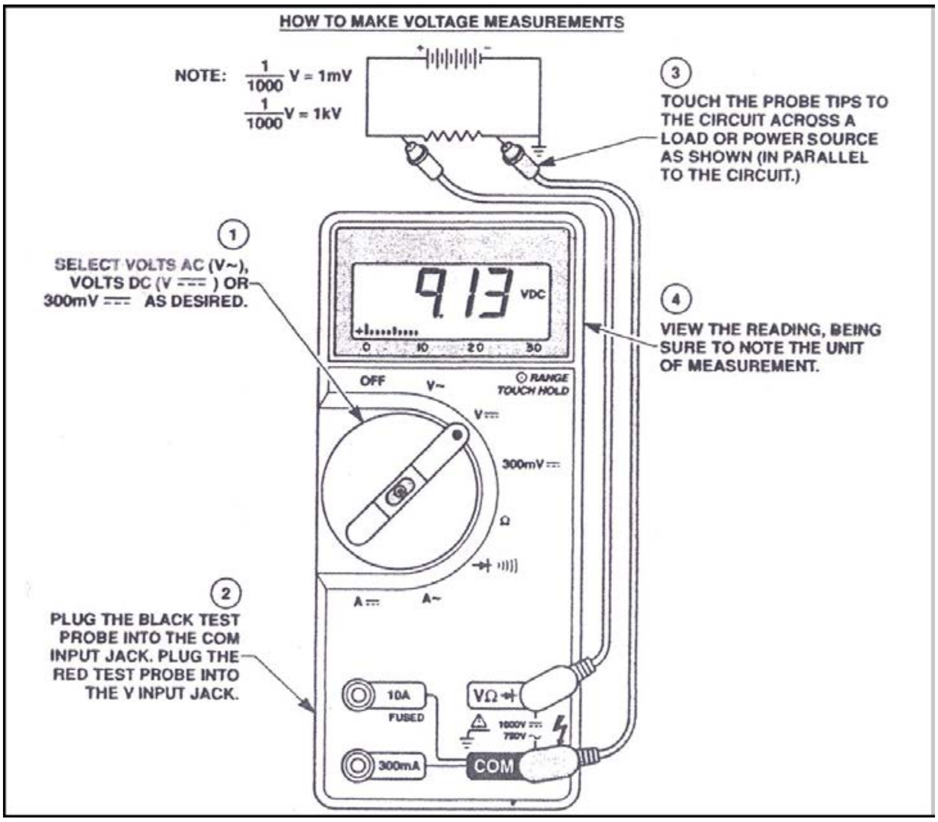


Fig. 10.3, For DC readings of the correct polarity (+/-), touch the red test probe to the positive side of the circuit and the black probe to the negative side or to the circuit ground. If you reverse the connections, a DMM with auto polarity will merely display a minus sign indicating negative polarity. With an analog meter you risk damaging the meter.

b. Accuracy

Accuracy is the largest allowable error that will occur under specific operating conditions. In other words, it is an indication of how close the DMMs displayed measurement is to the actual value of the signal being measured.

Accuracy for a DMM is usually expressed as a percent of reading. An accuracy of $\pm$ 1% of reading means that for a displayed reading of 100.0 volts, the actual value of the voltage could be anywhere between 99.0V and 101.0 V.S

Specifications may also include a range of digits added to the base accuracy specification. This indicates how many counts the digit to the extreme right of the display may vary. So the accuracy example above might be stated as $\pm$ 1% + 2. Therefore, a display reading of 100.0 volts could actually represent a voltage between 98.8 volts and 101.2 volts.

For high accuracy and resolution, the digital display excels, displaying three or more digits for each measurement. The analog needle display is less accurate and has lower effective resolution, since you have to estimate values between the lines.

Some DMMs have a bar graph display. A bar graph shows changes and trends in a signal just like an analog needle, but is more durable and less prone to damage.

c. Measuring Voltage

One of the most basic tasks of a DMM is measuring voltage. A typical DC voltage source is a battery, like the one used in you car. The wall outlets in your home are common sources for AC voltage.

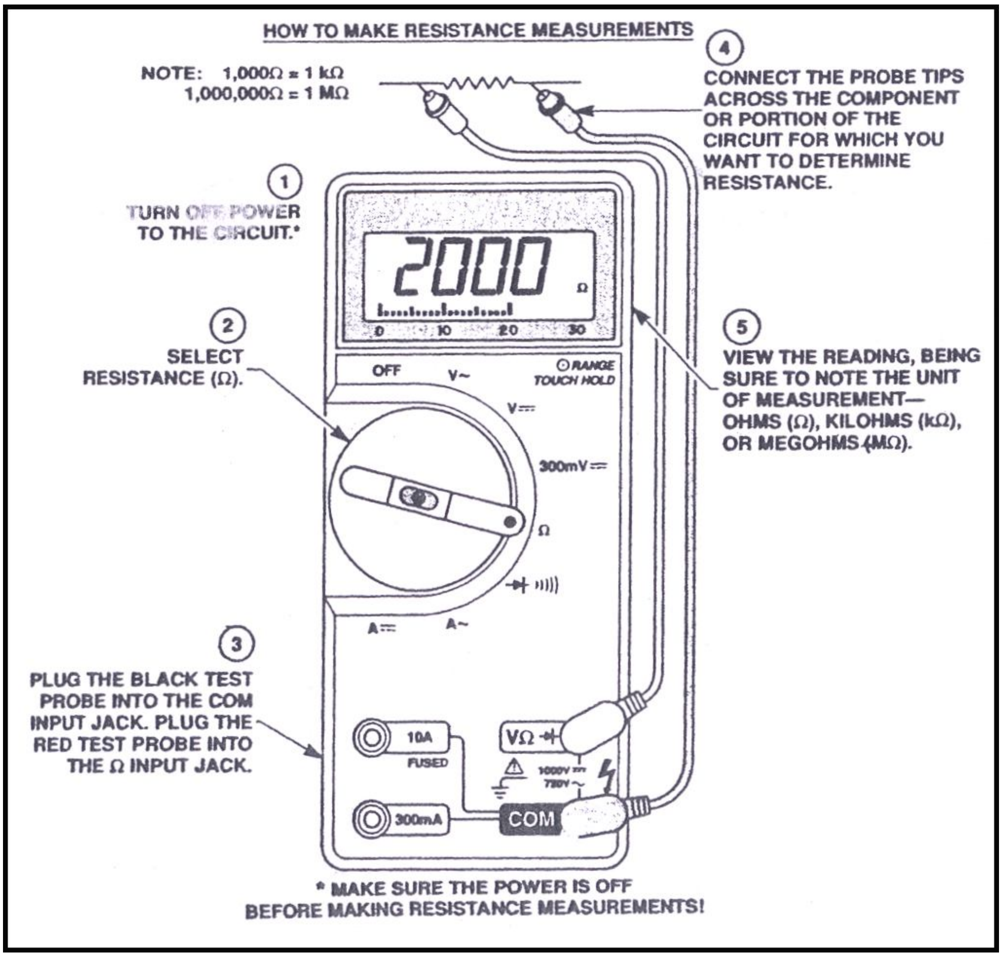


Fig. 10.4, Using a DMM, resistance measurements should never be made with the circuit energized. Damage to the meter is not only possible, but probable.

Some devices convert AC to DC. For example, electronic equipment such as TVs, stereos, VCRs and computers that you plug into the wall outlet use devices called rectifiers to convert AC into DC. This DC voltage is used to power the electronic circuits in these devices.

Testing for proper supply voltage is usually the first thing measured when troubleshooting a circuit. If there is no voltage present, or if it is too high or too low, the voltage problem should be corrected before investigating further.

The waveforms associated with AC voltages are either sinusoidal (sine waves) or non-sinusoidal (sawtooth, square, ripple, etc.). DMMs display the root-mean-square (RMS) value of these voltage waveforms. The RMS value is the effective or equivalent DC value of the AC voltage.

Most meters, called" average responding", give accurate RMS readings if the AC voltage signal is a pure sine wave. Averaging meters are not capable of measuring non-sinusoidal signals accurately. Special DMMs called "true-RMS" meters will accurately measure the correct RMS value, regardless of the waveform.

A DMM's ability to measure AC voltage can be limited by the frequenc of the signal. Most DMMs can accurately measure AC voltages with frequencies from 50 Hz to 500 Hz. DMM accuracy specifications for AC voltage and AC current should state the frequency range of a signal that the meter can accurately measure.

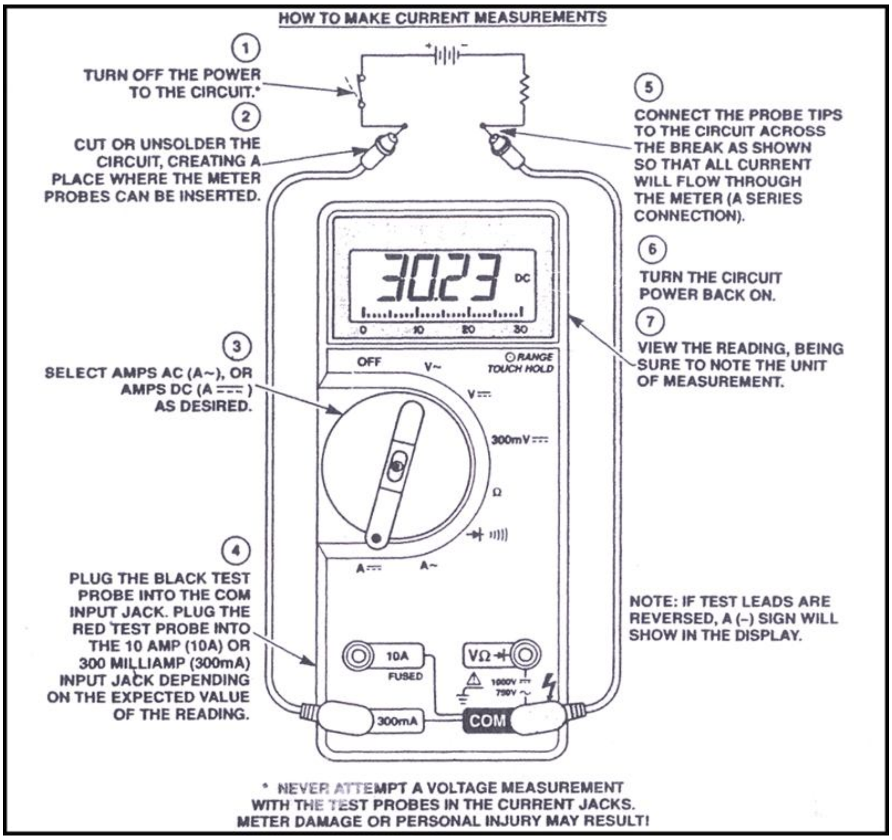


Fig. 10.5, Always make sure the power is off before cutting or unsoldering the circuit and inserting the DMM for current measurement. Even small amounts of current can be dangerous.

d. Measuring Resistance

Resistance is measured in ohms. Resistance values may vary from a few milli ohms for contact resistance to billions of ohms for insulators. Most DMMs measure as little as 0.1 ohm, and may measure as high as 300 Megohms. Infinite resistance is read as "OL" on some displays, and means that the resistance is greater than the meter can measure. Open circuits will also read OL on some meter displays. For accurate low resistance measurements, resistance in the test leads must be subtracted from the total resistance measurement.

Resistance measurements must e made with the circuit power off, otherwise damage to the meter and the circuit may result. Some DMMs provide protection in the ohms mode in case of accidental contact with voltages. The level of protection may vary greatly between different makes and models of meter.

If the DMM supplies less than 0.3 volts DC test voltage for measuring resistances, it will be able to measure the values of resistors that are isolated in a circuit by diodes from semiconductor junctions. This often allows you to test resistors on a circuit board without unsoldering them.

e. Continuity

Continuity is a quick go/no-go resistance test that distinguishes between an open and closed circuit.

A DMM with a continuity beeper allows you to complete many continuity tests quickly and easily. The meter beeps when is detects a closed circuit, so you don't have to look at the meter as you test. The level of resistance required to trigger the beeper varies from model to model.

f. Measuring Current

Current measurements are different from other measurements made with a DMM. Current measurements are made with the meter connected in series with the circuit. The entire current being measured flows through the meter. Also, the test leads must be plugged into a different set of input jacks on the meter.

ELECTRODYNAMOMETER

Electrodynamometer Wattmeter

An electrodynamometer operates in a manner similar to a D'Arsonval meter, except that an electromagnet is used instead of the permanent magnet for the fixed field.

A large coil having a few turns of heavy wire is connected in series with the load, and the strength of the magnetic field is proportional to the amount of current flowing through the load. The movable voltage coil is connected across the load, and its magnetic strength is proportional to the amount of voltage dropped across the load, and its magnetic strength is proportional to the amount of voltage dropped across the load. The magnetic fields caused by the current and the voltage react with each other to move the pointer an amount that is proportional to the power dissipated by the load.

Electrodynamometer wattmeters may be used in either DC or AC circuits. In an AC circuit, they measure the true power, because if the current and voltage are out of phase in the circuit, they will also be out of phase with each other in the coils of the instrument, and the resultant field will cause the pointer to deflect an amount proportional to the true power rather than the apparent power.

The apparent power in an AC circuit may be found by measuring the current with an AC ammeter and the voltage with an AC voltmeter. The product of these two values is the apparent power.

$$\text{Apparent Power (volt - amps)} = \text{volts amps}$$

The power factor of the circuit can be found as the quotient of the true power divided by the apparent power.

$$\text{Power factor} = \frac{\text{True power (watts)}}{\text{Appaent power (volt - amps)}}$$

ANALOG MULTIMETER

A multimeter may be implemented with a galvanometer meter movement, or with a bar-graph or simulated pointer such as an LCD or vacuum fluorescent display. Analog multimeters are common; a quality analog instrument will cost about the same as a DMM. Analog multimeters have the precision and reading accuracy limitations described above, and so are not built to provide the same accuracy as digital instruments.

Analog meters, with needle able to move rapidly, are sometimes considered better for detecting the rate of change of a reading; some digital multimeter include a fast-responding bar-graph display for this purpose. A typical example is a simple "good/no good" test of an electolytic capacitor, which is quicker and easier to read on an analog meter. The ARRL handbook also says that analog multimeters, with no electronic circuitry, are less sceptible to radio frequency interference.

DIGITAL MULTIMETER

Modern multimeters are often digital due to their accuracy, durability and extra features. In a digital multimeter the signal under test is converted to a voltage and an amplifier with electronically controlled gain preconditions the signal. A digital multimeter displays the quantity measured as a number, which eliminates parallax errors.

Modern digital multimeters may have an embedded computer, which provides a wealth of convenience features. Measurement enhancements available include :

- **Auto-ranging**, which selects the correct range for the quantity under test so that the most significant digits are shown. For example, a four-digit multimeter would automatically select an appropriate range to display 1.234 instead of 0.012, or overloading. Auto-ranging meters usually include a facility to 'freeze' the meter to a particular range, because a measurement that causes frequent range changes is distracting to the user. Other factors being equal, an auto-ranging meter will have more circuitry than an equivalent, non-auto-ranging meter, and so will be more costly, but will be more convenient to use.
- **Auto-polarity** for direct-current readings, shows if the applied voltage is positive (agrees with meter lead labels) or negative (opposite polarity to meter leads).
- **Sample and hold,** which will latch the most recent reading for examination after the instrument is removed from the circuit under test.
- Current-limited tests for voltage drop across semiconductor junctions. While not a replacement for a transistor tester, this facilitates testing diodes and a variety of transistor types.
- A **graphic representation** of the quantity under test, as a bar graph. This makes go/no-go testing easy, and also allows spotting of fast-moving trends.
- A low-bandwidth **oscilloscope.**
- Automatic circuit testers, including tests for automotive timing and dwell signals.

- Simple data acquisition features to record maximum and minimum readings over a given period, or to take a number of samples at fixed intervals.
- Integration with tweezers for surface-mount technology.
- A combined LCR meter for small-size SMD and through-hole components.

Modern meters may be interfaced with a personal computer by IrDA links, RS-232 connections, USB, or an instrument bus such as IEEE-488. The interface allows the computer to record measurements as they are made. Some DMMs can store measurements and upload them to a computer.

The first digital multimeter was manufactured in 1955 by Non Linear Systems.

Digital

The resolution of a multimeter is often specified in "digits" of resolution. For example, the term 5½ digits refers to the number of digits displayed on the readout of a multimeter.

By convention, a half digit an display either a zero or a one, while a three-quarters digit can display a numeral higher than a one but not nine. Commonly, a three-quarters digit refers to a maximum value of 3 or 5. The fractional digit is always the most significant digit in the displayed value. A 5½ digit multimeter would have five full digits that display values from 0 to 9 and one half digit that could only display 0 or 1. Such a meter could show positive or negative values from to 199, 999. A 3 3/4 digit meter can display a quantity from 0 to 3,999 or 5,999, depending on the manufacturer.

While a digital display can easily be extended in precision, the extra digits are of no value if not accompanied by care in the design and calibration of the analog portions of the multimeter. Meaningful high-resolution measurements require a good understanding of the instrument specifications, good control of the measurement conditions, and traceability of the calibration of the instrument.

Specifying "display counts" is another way to specify the resolution. Display counts give the largest number, or the largest number plus one (so the count number looks nicer) the multimeter' display can show, ignoring a decimal separator. For example, a 5½ digit multimeter can also be specified as a 199999 display count or 200000 display count multimeter. Often the display count is just called the count in multimeter specifications.

INSULATION TESTER [MEGGER (MEGOHMMETER)]

The megger, or megohmmeter, is a high-range ohmmeter containing a hand-operated generator. It is used to measure insulation resistance and other high resistance values. It is also used for ground, continuity, and short-circuit testing of electrical power systems. The chief advantage of the megger over an ohmmeter is its capacity to measure resistance with a high potential, or "breakdown" voltage. This type of testing ensures that insulation or a dielectric material will not short or leak under potential electrical stress.

The megger (Fig. 10.6) consists of two primary elements, both of which are provided with individual magnetic fields from a common permanent magnet : (1) A hand-driven d.c. generator, G, which supplies the necessary current for making the measurement and (2) the instrument portion, which indicates the value of the resistance being measured. The instrument portion is of the opposed-coil type. Coils A and B are mounted on the movable member with a fixed angular relationship to each other and are free to turn as a unit in a magnetic field. Coil B tends to move the pointer counterclockwise and coil A, clockwise. The coils are mounted on a light, movable frame that is pivoted in jewel bearings and free to move about axis 0.

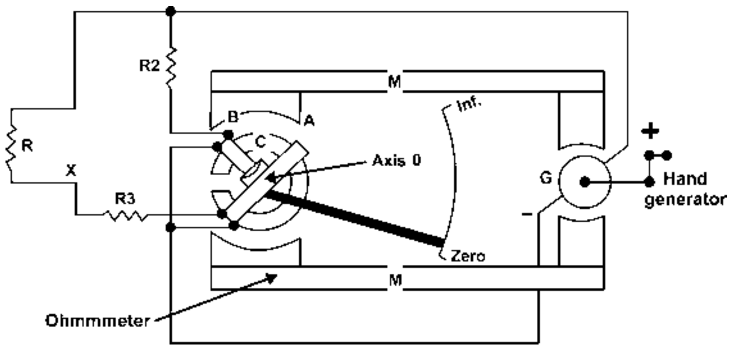


Fig. 10.6. Simplified megger circuit.

Coil A is connected in series with R3 and the unknown resistance, R_x, to be measured. The series combination of coil A, R3 and R_x is connected between the + and - brushes of the d.c. generator. Coil B is connected in series with R2 and this combination is also connected across the generator. There are no restraining springs on the movable member of the instrument portion of the megger. When the generator is not in operation, the pointer floats freely and may come to rest at any position on the scale.

If the terminals are open-circuited, no current flows in coil A, and the current in coil B alone controls the movement of the moving element. Coil B takes a position opposite the gap in the core (since the core cannot move and coil B can), and the pointer indicates infinity on the scale. When a resistance is connected between the terminals, current flows in coil A, tending to move the pointer clockwise. At the same time, coil B tends to move the pointer counterclockwise. Therefore, the moving element, composed of both coils and the pointer, comes to rest at a position at which the two forces are balanced. This position depends upon the value of the external resistance, which controls the relative magnitude of current of coil A. Because changes in voltage affect both coil A and B in the same proportion, the position of the moving element is independent of the voltage. If the terminals are short-circuited, the pointer rests at zero because the current in A is relatively large. The instrument is not damaged under these circumstances because the current is limited by R3.

There are two types of hand-driven megger: the variable type and the constant-pressure type. The speed of the variable-pressure type. The speed of the variable-pressure megger is dependent on how fast the hand crank is turned. The constant-pressure megger utilizes a centrifugal governor, or slip clutch. The governor becomes effective only when the megger is operated at a speed above its slip speed, at which speed its voltage remains constant.

BONDING
Bonding is the electrical interconnection of metallic aircraft parts (normally at earth potential) for the safe distribution of electrical charges and currents.

Bond Testing
Special test equipment, comprising a meter and two cables each of specific length, is required for checking the resistance of an ohmmeter operating on the current ratio principle, and a single 1.2 volt nickel alkaline cell housed in a wooden carrying case. The associated cables are 60 feet and 6 feet in length, and are fitted with a single-spike probe and a double-spike probe respectively. Plug and socket connectors provide for quick-action connection of the cables to the instrument.

Prior to carrying out a bonding test, a check should be made on the state of the nickel-alkaline cell of the tester by observing.

a. That a full-scale deflection of pointer of the meter is obtained when the two spikes of the 6-foot cable probe are shorted by a suitable conductor; and
b. That the meter reads zero when the two spikes of the 6-foot cable probe are shorted with the single spike cable probe.

The 60-feet lead of the test equipment should be connected to the main earth (also known as the bond datum point) at the terminal points which are usually shown diagrammatically in the relevant Aircraft Maintenance Manual. Since the length of a standard bonding tester lead is 60 feet, the measurement between extremities of the larger types of aircraft may have to be done by selecting one or more main earth points successively, in which event the resistance value between the maim earth points chosen should be checked before proceeding to check the remote point.

NOTE : When connecting the 60-feet lead to an earthing point, any protective treatment (e.g. stripable lacquer) should be removed at the point of contact.

The 6-foot test lead should be used to check the resistance between selected points ; these are usually specified in the bonding test schedule or the Maintenance Manual for the aircraft concerned. When the two spikes of the test lead probe are brought into contact with the aircraft part, the test-meter will indicate, in ohms, the resistance of the bond.

As an alternative to the above, the four terminal method of resistance measurement may be adopted with the appropriate milliammeter (see Fig.10.7). With this type of instrument, a test current (approximately 2 amps) is supplied bythe internal batteries and passed through the resistance via cables C1 and C2. The voltage drop across the resistance is measured (P1 and P2) and compared with the current flowing. The resultant value is then displayed (normally digitally) on the meter. The test leads may be in the form of duplex spikes (see Fig.10.8) or when used in association with crocodile type test leads, single spikes. In order to check that the instrument is functioning correctly, the two hand spikes should be placed on a low resistance conductor with the potential spikes (P1 and P2) closely together (see Fig.10.9). The result of this test should be a zero reading on the meter.

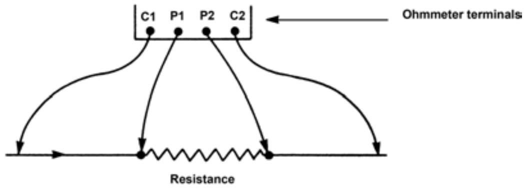


Fig. 10.7. Four terminal resistance measurement.

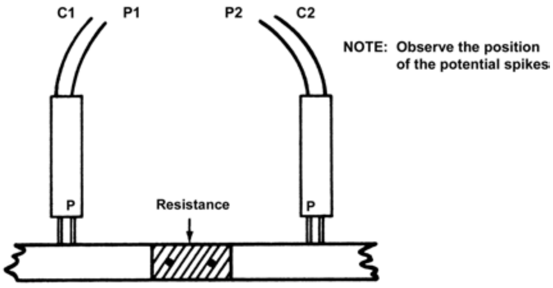


Fig. 10.8. Duplex hand spikes.

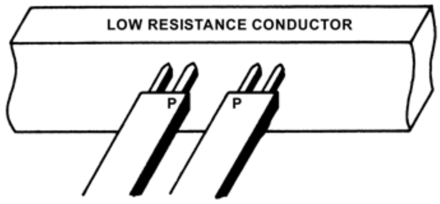


Fig. 10.9. Test position of hand spikes.

To ensure good electrical contact at the probe spikes, it may be necessary to penetrate or remove a small area of a non-conducting protective coating. Therefore, after test, any damage to the protective coating must be restored.

If the resistance at a bond connection is excessive, rectification action will depend on the type of connection. The following action should be taken for the more common types of connections:-

a. In the case of bonding jumpers, the connecting tag or lug should be removed and the contacting faces thoroughly cleaned, using a slight abrasive if necessary. The bare metal thus exposed should be only just large enough to accept the palm of the tag or lug. The connecting area should be sealed and treated with antioxidant as specified in the relevant drawing and specification.

NOTE : When an abrasive has been used it is important to ensure that all traces of it are removed.

b. Where equipment is bonded through a holding bolt, the bolt should be removed and the area under the bolt-head, or nut, thoroughly cleaned and protected as recommended in paragraph 3.10.7 (a). The correct washer (both with regard to size and material) should be fitted before the bolt is replaced and tightened.

c. Where the required bond value cannot be obtained at a structural joint the advice of the manufacturer should be sought.

NOTE : Corrosion tends to form at a bonding or earth connection and is often the cause of excessive resistance.

The resistance between the man in earth system and a metal plate on which the earthing device (e.g. tyre) is resting should be measured and should not exceed 10 megohms when measured with a 250 volt or 500 volt resistance tester, as specified in the test schedule.

NOTE : After carrying out tests, all areas where the protective coating has been removed should be re-protected using the appropriate scheme.

BONDING TESTER SERVICING

A tester requires little in the way of servicing, a part from periodic attention to the alkaline cell, which should be removed at prescribed intervals for routine servicing. When replacing the cell, it is most important that the polarity of connection is correct. The ohmmeter is normally sealed in its case and no attempt should be made to open it; if a fault should develop, then the complete instrument should be withdrawn from use and overhauled.

The leads are an integral part of the tester, and being carefully matched to the meter unit must not be modified or altered in any way. All contact surfaces of plug pins and probes must be kept scrupulously clean, and the points of the probe spikes should be reasonably sharp to give effective penetration of protective finishes, etc., on metal surfaces.

The accuracy of the tester should be checked periodically by using it to measure the resistance of standard test resistors. Normally, three such resistors are supplied for testing purposes and the readings obtained should be within 10% of the standard ohmic values.

SCREENING

Screening performs a similar function to bonding in that it provides a low resistance path for voltages producing unwanted radio frequency interference. However, whereas a bonding system is a conducting link for voltages produced by the build up of static charges, the voltages to be conducted by a screening system are those stray ones due to the coupling of external fields originating from certain items of electrical equipment, and circuits when in operation. Typical examples are " d.c.generator, engine ignition systems, d.c. motors, time switches and similar apparatus designed for making and breaking circuits at a controlled rate.

The methods adopted for screening are generally of three main types governed principally by the equipment or circuit radiating the interference fields. In equipment such as generators, motors and time switches several capacitors, which provide a low resistance path, are interconnected across the interference source, i.e. brushes, commutators and contacts, to form a self-contained unit known as a suppressor. The other methods adopted are the enclosing of equipment and circuits in metal cases and the enclosure of cables in a metal braided sheath, a method used for screening the cables of ignition systems. The suppressors and metal screens are connected to the main earth or ground system of an aircraft.

EARTHING OR GROUNDING

In the literal sense, earthing or grounding as it is often termed, refers to the return of current to the conducting mass of the earth, or ground, itself. If considered as a single body, the earth is so large that any transfer of electrons between it and another body fails to produce any perceptible change in its state of electrification. It can therefore be regarded as electrically neutral and as a zero reference point for judging the state of electrification of other bodies. For example, if two charged bodies, A and B, both have positive potentials relative to earth, but the potential of A is more positive than that of B, then the potential of B may be described as negative to that of A by the appropriate amount.

As we have already learned, the positive outputs of aircraft power supplies and the positive input terminals of consumer components are all connected to busbars which are insulated from the aircraft structure. Since in most aircraft the structure is of metal and of sufficient mass to remain electrically neutral, then it too can function as an earth or " negative busbar' and so provide the return path of current. Thus, power supply and consumer circuits can be completed by coupling all negative connections to the structure at various 'earth stations', the number and locations of which are predicted in a manner appropriate to the particular type of aircraft. As this results in the bulk of cable required for the circuits being on the positive side only, then such an electrical installation is designated as a 'single' wire, or single-pole, earth-return system", For a.c. power supply circuits the airframe also services as a connection for the neutral point.

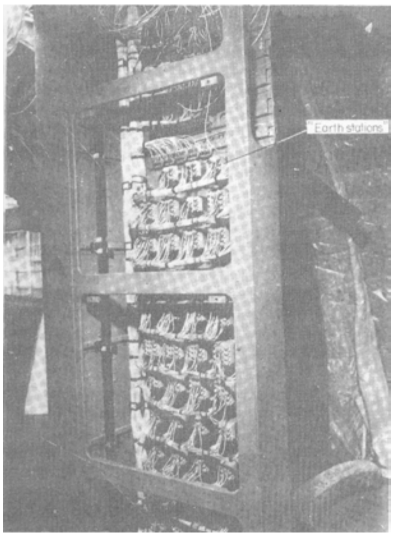


Fig. 10.10. Open looms.

The selection of types of connection for earth return cables is based on such important factors as mechanical strength, current to be carried, corrosive effects, and ease with which connections can be made. As a result, they can vary in form; some typical arrangements being a single bolt passing through and secured directly to a structural member, and either a single bolt or a cluster of bolts secured to an earthing plate designed for riveting or bolting to a structural member. In order to ensure good electrical contact and minimum resistance between an earthing bolt or plate and the structure, protective film is removed from the contacting surfacing before assembly. Protection against corrosion is provided by coating the surfaces with an anti-corrosion and solvent resistant compound to the edges of the joint. An example of a cluster arrangement with a corrosion plate is illustration in (Fig.10.10).

Earth-return cables are connected to earthing bolts by means of crimped ring type connectors, each bolt accommodating cables from several circuits. For some circuits, however, it is necessary to connect cables separately and this applies particularly to those of the sensitive low current-carrying type, e.g. resistance type temperature indicators in which erros can arise from varying earth return currents of other circuits.

In aircraft in which the primary structure is of non-metallic construction, a separate continuous main earth and bonding system is provided. It consists of four or more soft copper strip-type conductors extending the whole length of the fuselage and disposed so that they are not more than six feet apart as measured around the periphery of the fuselage at the position of greatest cross-sectional area. The fuselage earthing strips are connected to further strips which follow the leading and trailing edges from root to tip of each wing and horizontal stabilizer, and also to strip located on or near the leading edge of the vertical stabilizer. Earthing strips are provided in the trailing edges of the rudder, elevators and ailerons, and are connected to the fuselage and wing systems via the outer hinges of the control surfaces. The strips are arranged to run with as few bends as possible and are connected to each other by means of screwed or riveted joints.

Lightning strike plates, extending round the tips of each wing, horizontal and vertical stabilizers, fuselage nose and tail, are also provided. They consist of copper strips and are mounted on the exterior of the structure.

CLAMP METER

In electrical and electronic engineering, a current clamp or current probe is an electrical device having two jaws which open to allow clamping around an electrical conductor. This allows properties of the electric current in the conductor to be measured, without having to make physical contact with it, or to disconnect it for insertion through the probe. Current clamps are usually used to read the magnitude of a sinusoidal current (as invariable used in alternating current (AC) power distribution systems), but in conjunction with more advanced instrumentation the phase and waveform are available. Very high alternating currents (1000 A and more) are easily read with an appropriate meter; direct currents, and very low AC currents (milliamps) are more difficult to measure.

Pushing the large button at the bottom opens the lower jaw of the clamp, allowing the clamp to be placed around a conductor.

An electrical meter with integral AC current clamp is known as a clamp meter, clamp-on ammeter or tong tester.

In order to use a clamp meter, only one conductor is normally passed through the probe; if more than one conductor is passed through then the measurement would be the vector sum of the currents flowing in the conductors and would depend on the phase relationship of the currents. In particular if the clamp is closed around a 2-conductor cable carrying power to equipment the same current flows down one conductor and up the other, with a net current of zero. Clamp meters are often sold with a device that is plugged in between the power outlet and the device to be tested. The device is essentially a short extension cord with the two conductors separated, so that the clamp can be placed around only one conductor.

The reading produced by a conductor carrying a very low current can be increased by winding the conductor around the clamp several times; the meter reading divided by the number of turns is the current, with some loss of accuracy due to inductive effects.

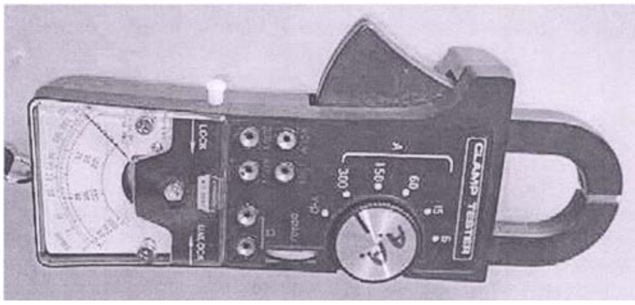


Fig. 10.11, A multimeter with built in clamp

Clamp meters are used by electricians, sometimes with the clamp incorporated into a general purpose multimeter.

It is simple to measure very high currents (hundreds of amperes) with the appropriate current transformer. Accurate measurement of low currents (a few milliamps) with a current transformer clamp is more difficult.

Fig. 10.12, An iron vane type clamp-on ammeter

Less-expensive clamp meters use a rectifier circuit which actually reads mean current, but is calibrated to display the RMS current corresponding to the measured mean, giving a correct RMS reading only if the current is a sone wave. For other waveforms readings will be incorrect; when these simpler meters are used with non-sinusoidal loads such as the ballasts used with fluorescent lamps or high-intensity discharge lamps or most modern computer and electronic equipment, readings can be quite inaccurate. Meters which respond to true RMS rather than mean current are described as "true RMS".

Typical hand-held Hall effect units can read currents as low as 200mA, and units that can read down to 1mA are available.

The Columbia tong test ammeter, manufactured by Weschler Instruments, is an example of the iron vane type, used for measuring large AC currents up to 1000 amps. The iron jaws of the meter direct the magnetic field surrounding the conductor to an iron vane that is attached.

The meter movement in a moving pointer analog multimeter is practically always a moving-coil galvanometer of the d'Arsonval type, using either jeweled pivots or taut bands to support the moving coil. In a basic analog multimeter the current to deflect the coil and pointer is drawn from the circuit being measured; it is usually an advantage to minimize the current drawn from the circuit. The sensitivity of an analog multimeter is given in units of ohms per volt. For example, an inexpensive multimeter would have a sensitivity of 1000 ohms per volt and would draw 1 milliampere from a circuit at the full scale measured voltage. More expensive, (and mechanically more delicate) multimeters would have sensitivities of 20,000 ohms per volt or higher, with a 50,000 ohms per volt meter (drawing 20 microamperes at full scales) being about the upper limit for a portable, general purpose, nonamplified analog multimeter.

To avoid the loading of the measured circuit by the current drawn by the meter movement, some analog multimeters use an amplifier inserted between the measured circuit and the meter movement. While this increased the expense and complexity of the meter and required a power supply to operate the amplifier, by use of vacuum tubes or field effect transistors the input resistance can be made very high and independent of the current required to operate the meter movement coil. Such amplified multimeters are called VTVMs (vacuum tube voltmeters), TVMs (transistor volt meters), FET-VOMs, and similar names.

CRO (CATHODE RAY OSCILLOSCOPE)

The cathode-ray oscilloscope (CRO) is a common laboratory instrument that provides accurate time and amplitude measurements of voltage signals over a wide range of frequencies. Its reliability, stability, and ease of operation make it suitable as a general purpose laboratory instrument. The heart of the CRO is a cathode-ray tube shown schematically in Fig. 10.13.

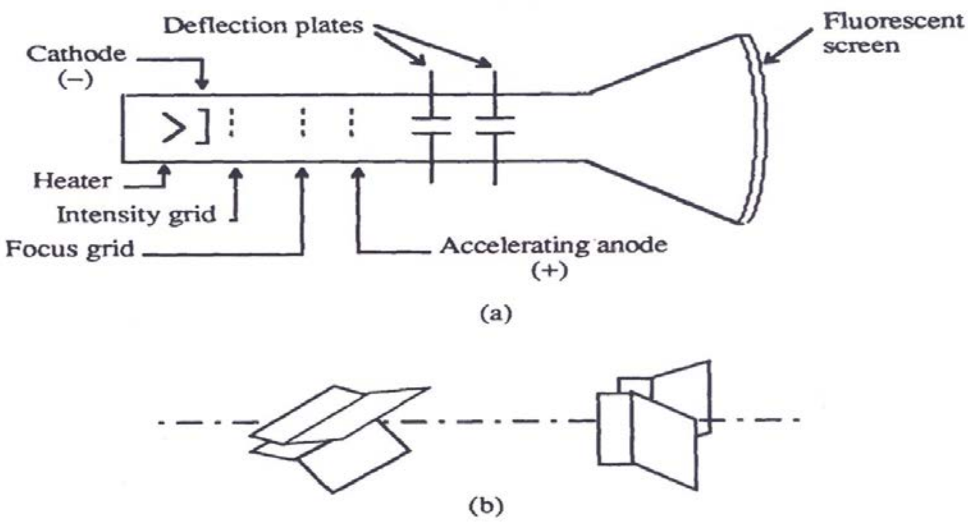


Fig. 10.13, Cathode-ray tube : (a) schematic, (b) detail of the deflection plates

The cathode ray is a beam of electrons which are emitted by the heated cathode (negative electrode) and accelerated toward the fluorescent screen. The assembly of the cathode, intensity grid, focus grid, and accelerating anode (positive electrode) is called an electron gun. Its purpose is to generate the electron beam and control its intensity and focus. Between the electron gun and the fluorescent screen are two pair of metal plates - one oriented to provide horizontal deflection of the beam and one pair oriented to give vertical deflection to the beam. These plates are thus referred to as the horizontal and vertical defection plates. The combination of these two deflections allows the beam to reach any portion of the fluorescent screen. Wherever the electron beam hits the screen, the phosphor is excited and light is emitted from that point. This conversion of electron energy into light allows us to write with points or lines of light on an otherwise darkened screen.

In the most common use of the oscilloscope the signal to be studied is first amplified and then applied to the vertical (deflection) plates to deflect the beam vertically and at the same time a voltage that increases linearly with time is applied to the horizontal (deflection) plates thus causing the beam to be deflected horizontally at a uniform (constant > rate). The signal applied to the vertical plates is thus displayed on the screen as a function of time. The horizontal axis serves as a uniform time scale.

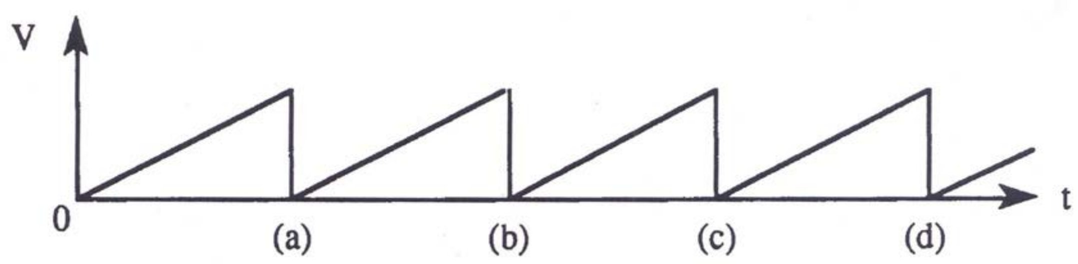


Fig. 10.14, Voltage difference V between horizontal plates as a function of time t.

The linear deflection or sweep off the bream horizontally is accomplished by use of a sweep generator that is incorporated in the oscilloscope circuitry. The voltage output of such a generator is that of a sawtooth wave as shown in Fig. 10.14. Application of one cycle of this voltage difference, which increases linearly with time, to the horizontal plates causes the beam to be deflected linearly with time across the tube face. When the voltage suddenly falls to zero, as at points (a) (b) (c), etc., the end of each sweep - the beam flies back to its initial position. The horizontal deflection of the beam is repeated periodically, the frequency of this periodicity is adjustable by external controls.

To obtain steady traces on the tube face, an internal number of cycles of the unknown signal that is applied to the vertical plates must be associated with each cycle of the sweep generator. Thus, with such a matching of synchronization of the two deflections, the pattern on the tube face repeats itself and hence appears to remain stationary. The persistence of vision in the human eye and of the glow of the fluorescent screen aids in producing a stationary pattern. In addition, the electron beam is cut off (blanked) during flyback so that the retrace sweep is not observed.

CRO Operation : In general, the instrument is operated in the following manner. The signal to be displayed is amplified by the vertical amplifier and applied to the vertical deflection plates of the CRT. A portion of the signal in the vertical amplifier is applied to the sweep trigger as a triggering signal. The sweep trigger then generates a pulse coincident with a selected point in the cycle of the triggering signal. This pulse turns on the sweep generator, initiating the sawtooth wave form. The sawtooth wave is amplified by the horizontal amplifier and applied to the horizontal deflection plates. Usually, additional provisions signal are made for applying an external triggering signal or utilizing the 60 Hz line for triggering. Also the sweep generator may be bypassed and an external signal applied directly to the horizontal amplifier.

■■■

CHAPTER-11
ENGINEERING DRAWINGS, DIAGRAMS & STANDARDS

INTRODUCTION IMPORTANCE OF ENGINEERING DRAWING IN AVIATION

The exchange of ideas is essential to everyone, regardless of his vocation or position. Usually, this exchange is carried on by the oral or written word; but under some conditions the use of these alone is impractical. Industry discovered that it could not depend entirely upon written or spoken words for the exchange of ideas because misunderstanding and misinterpretation acrose frequently. A written description of an object can be changed in meaning just by misplacing a comma; the meaning of an oral description can be completely changed by the use of a wrong word. To avoid these possible errors, industry uses drawings to describe objects. For this reason, drawing is called the Draftsman's Language.

Drawing, as we use it, is a method of conveying ideas concerning the construction or assembly of objects. This is done with the help of lines, notes, abbreviations, and symbols. It is very important that the aviation mechanic who is to make or assemble the object understand the meaning of the different lines, notes, abbreviations, and symbols that are used in a drawing.

Prints are the link between the engineers who design an aircraft and the men who build, maintain, and repair it. A print may be a copy of a working drawing for an aircraft part or group of parts, or for a design of a system or group of systems. They are made by placing a tracing of the drawing over a sheet of chemically treated paper and exposing it to a strong light for a short period of time. When the exposed paper is developed, it turns blue where the light has penetrated the transparent tracing. The inked lines of the tracing, having blocked out the light, show as white lines on a blue background. Other types of sensitized paper have been developed; prints may have a white background with colored lines or a colored background with white lines.

A print shows the various steps required in building anything from a simple component to a complete aircraft.

CARE AND USE OF DRAWINGS

Drawings are both expensive and valuable; consequently, they should be handled carefully. Open drawings slowly and carefully to prevent tearing the paper. When the drawing is open, smooth out the fold lines instead of bending them backward.

To protect drawings from damage, never spread them on the floor or lay them on a surface covered with tools or other objects that may make holes in the paper. Hands should be free of oil, grease, or other unclean matter than can soil or smudge the print.

Never make notes or marks on a print, as they may confuse other persons and lead to incorrect work. Only authorized persons are permitted to make notes or changes on prints, and they must sign and date any changes they make.

When finished with a drawing, fold and return it to its proper place. Prints are folded originally in a proper size for filing, and care should be taken so that the original folds are always used.

Care of Drawing Instruments

Good drawing instruments are expensive precision tools. Reasonable care given to them during their use and storage will prolong their service life.

T-squares, triangles, and scales should not be used, or placed, where their surfaces or edges may be damaged. Use a drawing board only for its intended purpose, and not in a manner that will mar the working surface.

Compasses, dividers, and pens will provide better results with less annoyance, if they are correctly shaped and sharpened, and they are not damaged by careless handling.

Store drawing instruments in a place where they are not likely to be damaged by contact with other tools or equipment. Protect compass and divider points by inserting them into a piece of soft rubber or similar material. Never store ink pens without first cleaning and drying them thoroughly.

WORKING DRAWINGS

Working drawings must give such information as size of the object and all of its parts, its shape and that of all of its parts, specifications as to the material to be used, how the material is to be finished, how the parts are to be assembled, and any other information essential to making and assembling the particular object.

TYPES OF ENGINEERING DRAWINGS

Working drawings may be divided into three classes :

1. Detail drawings
2. Assembly drawings, and
3. Installation drawings.

a. Production Drawings

Production drawings show how to manufacture the product. In a medium or large sized organisation there will typically be a production engineering department. Production engineers take the engineering drawings and decide how best to manufacture the product described by the drawings in their factory. They produce a set of production drawings that detail the task to be performed, the equipment to be used, the order tasks are to be performed in and the procedures to be followed.

These drawings are used by the shop-floor workers in their day-to day activities. Machine operatives, production line workers and supervisors all use the production drawings as a reference for how to go about manufacturing the product.

For example, if the engineering drawings called for a screw to be tightened to a particular torque, the production drawings would typically detail which tool is to be used to tighten the screw, and how it should be calibrated. If the screw is in an awkward place the drawings might also specify that this tightening is to be done early in the assembly procedure before access becomes restricted.

b. Assembly Drawing

An assembly drawing is a description of an object made up of two or more parts. Examine the assembly drawing in the center of figure 11-1. It describes the object by giving, in a general way, the size and shape. Its primary purpose is to show the relationship of the various parts. An assembly drawing is usually more complex than a detail drawing, and is often accompanied by detail drawings of various parts.

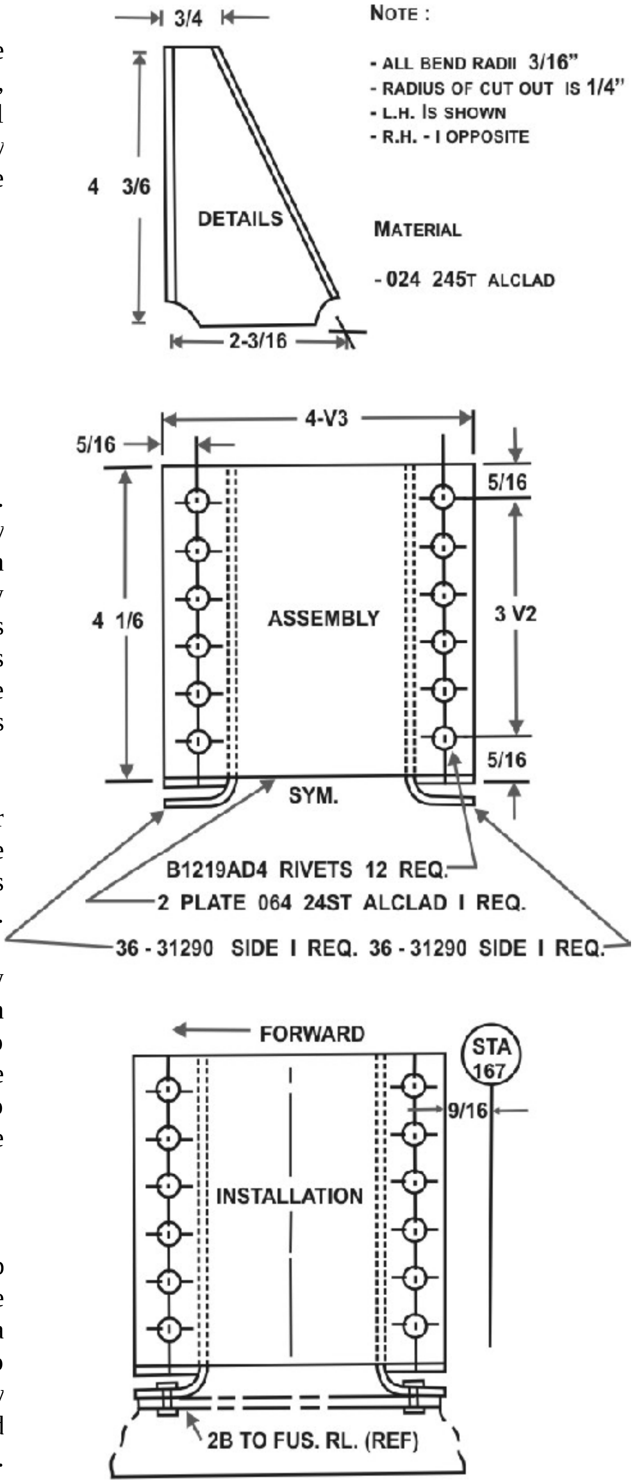


Fig. 11.1 Working drawings.

c. Exploded view assembly Drawing

An exploded view assembly drawing is a diagram, picture or technical drawing of an object, that shows the relationship or order of assembly of various parts.

It shows the components of an object slightly separated by distance, or suspended in surrounding space in the case of a three-dimensional exploded diagram. An object is represented as if there had been a small controlled explosion emanating from the middle of the object, causing the object's parts to be separated an equal distance away from their original locations.

The exploded view drawing is used in parts catalogs, assembly and maintenance manuals and other instructional material.

Usually, the projection of an exploded view is normally shown from above and slightly in diagonal from the left or right side of the drawing.

An exploded view drawing is a type of drawing, that shows the intended assembly of mechanical or other parts. It shows all parts of the assembly and how they fit together. In mechanical systems usually the component closest to the center are assembled first, or is the main part in which the other parts get assembled. This drawing can also help to represent the disassembly of parts, where the parts on the outside normally get removed first.

Exploded diagrams are common in descriptive manuals showing parts placement, or parts contained in an assembly or sub-assembly. Usually such diagrams have the part identification number and a label indicating which part fills the particular position in the diagram. Many spreadsheet applications can automatically create exploded pie charts.

In patent drawings in an exploded views the separated parts should be embraced by a bracket, to show the relationship or order of assembly of various parts are permissible, see image. When an exploded view is shown in a figure that is on the same sheet as another figure, the exploded view should be placed in brackets.
Exploded views can also be used in architectural drawing, for example in the presentation of landscape design. An exploded view can create an image in which the elements are flying through the air above the architectural plan, almost like a cubist painting. The locations can be shadowed or dotted in the siteplan of the elements.

d. Installation Drawing

An installation drawing is one which includes all necessary information for a part or an assembly of parts in the final position in the aircraft. It shows the dimensions necessary for the location of specific parts with relation to the other parts and reference dimensions that are helpfully in later work in the shop.

2. LETTER WRITING

Technical lettering is the process of forming letters, numerals, and other characters in technical drawing. It is used to describe, or provide detailed specifications for, an object. With the goals of legibility and uniformity, styles are standardized and lettering ability has little relationship to normal writing ability. Engineering drawings use a Gothic sans-serif script, formed by a series of short strokes. Lower case letters are rare in most drawings of machines.

FITTING ON AIRCRAFTS

Aircraft drawings seldom show more than two principal, or complete, views of an object. Instead, generally there will be one complete view and one of more detail views or sectional vies.

Detail View

A detail view shows only a part of the object but in greater detail and to a larger scale than the principle view. The part that is shown in detail elsewhere on the drawing is usually encircled by a heavy line on the principal view. Figure 11.2 is an example of the use of detail views. The principal view shows the complete control wheel, while the detail view is an enlarged drawing of a portion of the control wheel.

Sectional Views

A section or sectional view is obtained by cutting away part of an object to show the shape and construction at the cutting plane. The part or parts cut away are shown by the use of section (cross-hatching) lines.

Sectional views are used when the interior construction or hidden features of an object cannot be shown clearly by exterior vies. For example, figure 11.3, a sectional view of a coaxial cable connector, shows the internal construction of the connector. This is known as full section. Other types of sections are described in the following paragraphs.

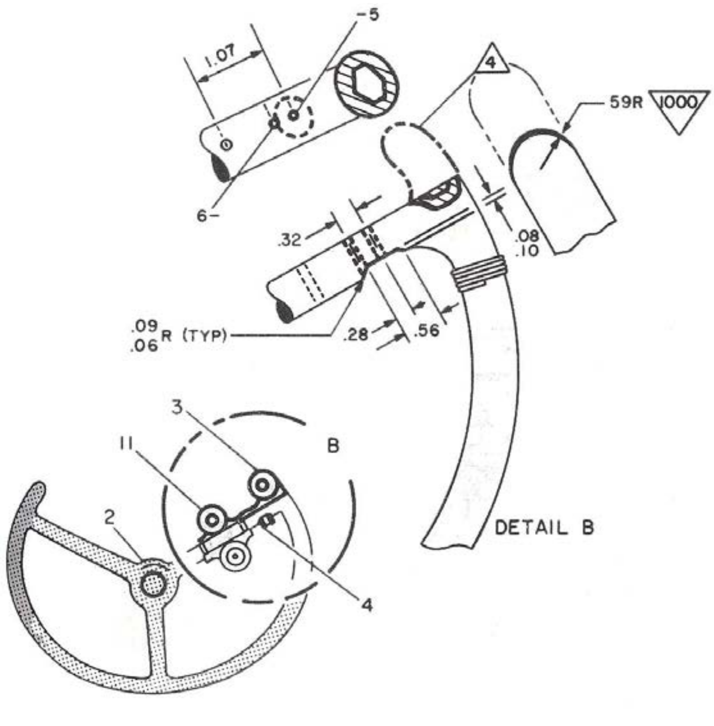


Fig. 11.2 Detail View

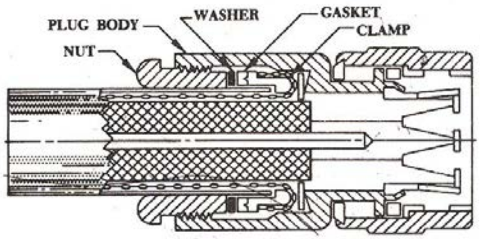


Fig. 11.3, Sectional view of a cable connector.

Half Sections

In a half section, the cutting plane extends only halfway across the object, leaving the other half of the object as an exterior view. Half sections are used to advantage with symmetrical objects to show both the interior and exterior.

Figure 11.4 is a half-sectional view of a quick disconnect used in aircraft fluid systems.

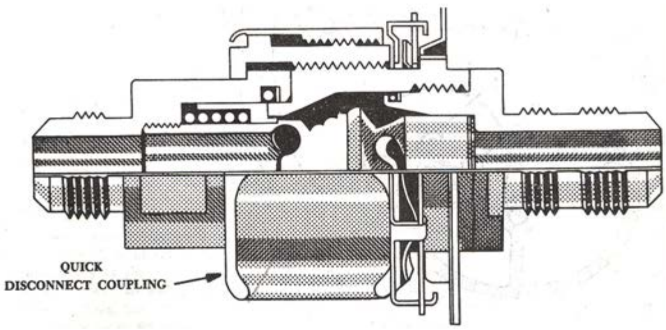


Fig. 11.4 Half section.

Revolved Sections

A revolved section drawn directly on the exterior view shows the shape of the cross section of a part, such as the spoke of a wheel. An example of a revolved section is shown in figure 11.5.

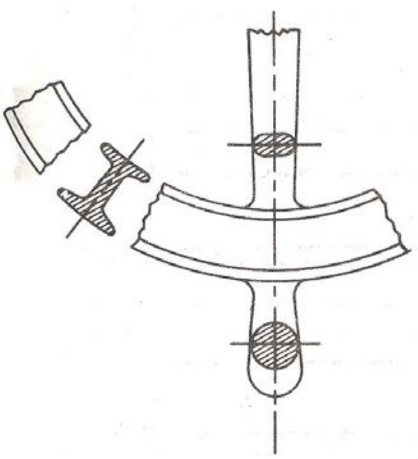


Fig. 11.5, Revolved sections

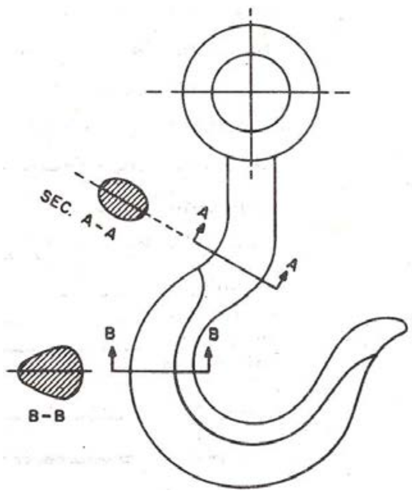


Fig.11.6 Removed section

Removed Sections

Removed sections illustrate particular parts of an object. They are drawn like revolved sections, except that they are placed at one side and, to bring out pertinent details, are often drawn to a larger scale than the view on which they are indicated.

Figure 11.6 is an illustration of removed sections. Section A-A shows the cross sectional shape of the object at cutting plane line A-A. Section B-B shows the cross-sectional shape at cutting plane line A-A. Section B-B shows the cross-sectional shape at cutting plane line B-B. These sectional views are drawn to the same scale as the principal view; however, as already mentioned, they are often drawn to a larger scale to bring out pertinent details.

CONVENTION FOR ELECTRICAL COMPONENTS

Electrical Symbols

Electrical symbols (figure 11.7) represent various electrical devices rather than an actual drawing of the units. Having learned what the various symbols indicate, it becomes relatively simple to look at an electrical diagram and determine what each unit is, what function it serves, and how it is connected in the system.

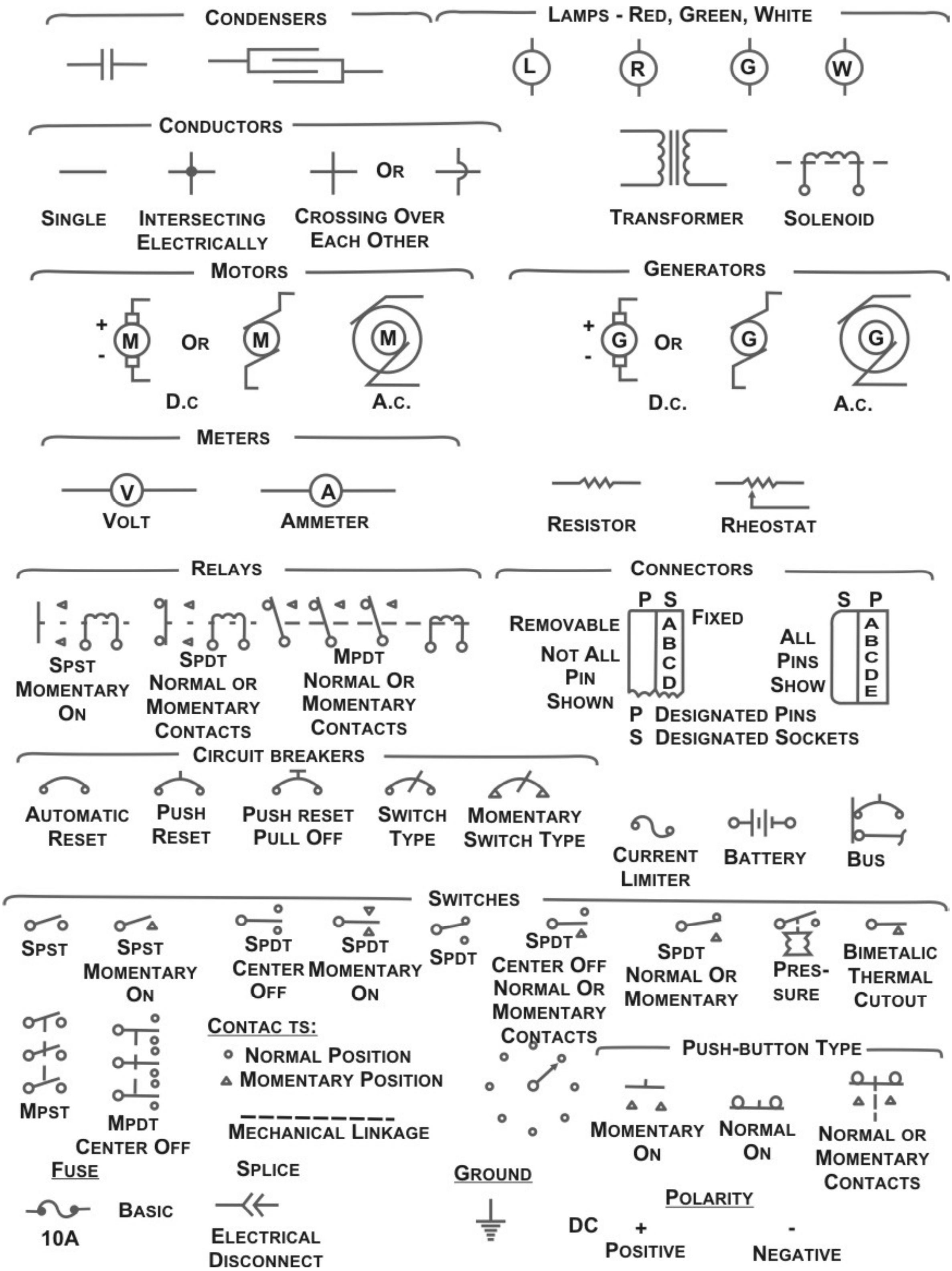


Fig. 11.7, Electrical symbols

STANDARD MATERIAL AND SHAPE SYMBOLS

Drawing Symbols

The drawings for a component are composed largely of symbols and conventions representing its shape and material. Symbols are the shorthand of drawing. They graphically portray the characteristics of a component, with a minimum amount of drawing.

Material Symbols

Section-line symbols show the kind of material from which the part is to be constructed. The material may not be indicated symbolically when its exact specification must also be shown elsewhere on the drawing. In this case, the more easily drawn symbol for cast iron is used for the sectioning, and the material specification is listed in the bill of materials or indicated in a note. Figure 11.8 illustrates a few standard material symbols.

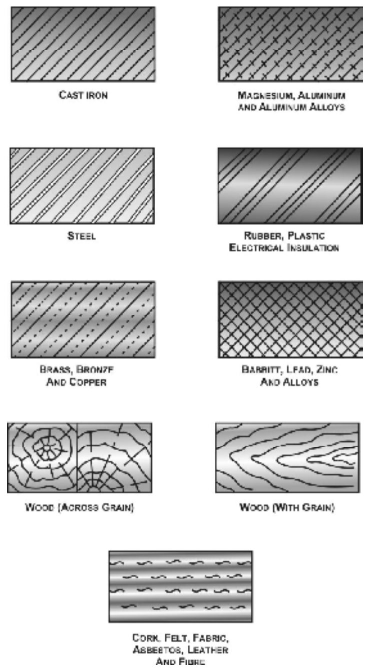


Fig. 11.8. Material symbols

Shape Symbols

Symbols can be used to excellent advantage, when it is desired to show the shape of an object. Typical shape symbols used on aircraft drawings are shown in figure 11.9. Shape symbols are usually shown on a drawing as a revolved or removed section.

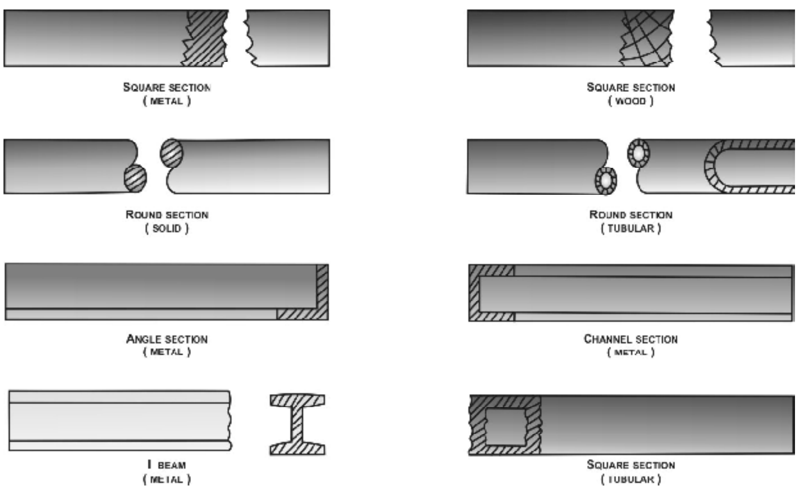


Fig. 11.9. Shape symbols

THEORETICAL CIRCUIT AND WIRING DIAGRAMS

Theoretical Circuit Diagrams

Design staff will prepare theoretical circuit diagrams where all the necessary connections for the correct operation of the system are included. Different sections of industry freely use other terms, such as schematics, sequence diagrams and flow charts (see Fig. 11.10).

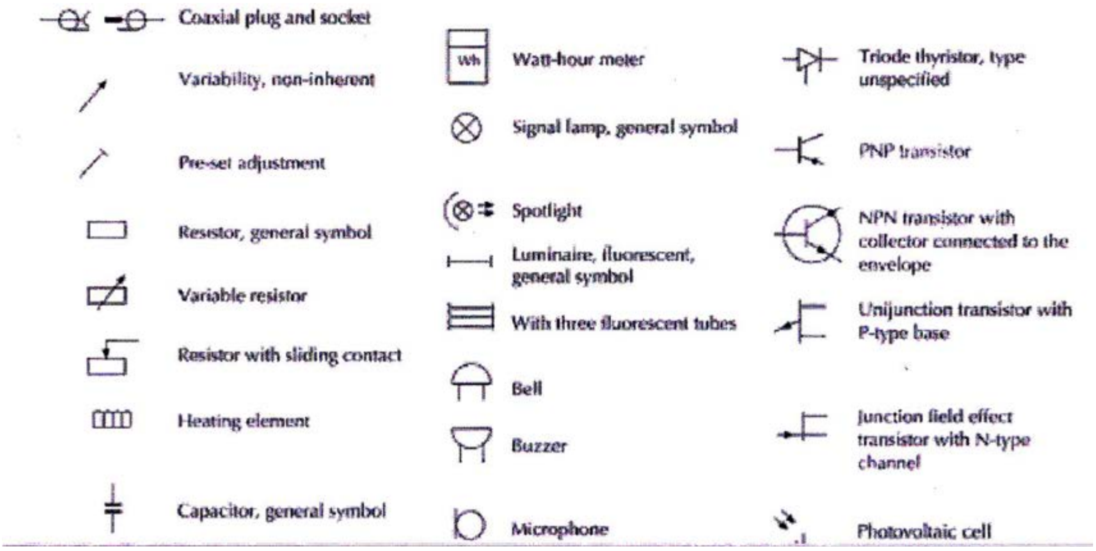


Fig. 11.10

One of the conventions with this type of diagram is that components should be arranged so that the sequence of events can be read from left to right, or top to bottom, or perhaps a combination of both.

The diagram does not differentiate between the physical sizes of the separate components. The actual component shape may not be reflected in the standardized symbols and the arrangement on the diagram will not attempt to indicate the true layout of all the items.

Basic engineering practice follows where specification will be produced for all parts of the system covering, for example, the components in detail, materials, manufacturing processes, relevant standards, inspection procedures, delivery dates and costs. The customer needs to know exactly what is being supplied, and details of financial arrangements. Contracts will be exchanged when supplier and client are satisfied. Obviously failure of any aspect of an agreement may involve either party in financial loss and litigation could follow. It is of course in nobody's interest that this should occur.

Circuit Diagrams

The term circuit suggests electrical components wire together but this need not be the only case. The circuit could show parts of a central beating system connected by water piping or units in an air conditioning system joined together by fabricated ductwork.

Wiring Diagram

A wiring diagram is a simplified conventional pictorial representation of an electrical circuit. It shows the components of the circuit as simplified shapes, and the power and signal connections between the devices. A wiring diagram usually gives more information about the relative position and arrangement of devices and terminals on the devices, as an aid in construction the device. This is unlike a schematic diagram where the arrangement of the components interconnections on the diagram does not correspond to their physical locations in the finished device. A pictorial diagram would show more detail of the physical appearance, whereas a wiring diagram uses a more symbolic notation to emphasize interconnections over physical appearance.

A wiring diagram is used to troubleshoot problems and to make sure that all the connections have been made and that everything is present.

Architectural Wiring Diagrams

Architectural wiring diagrams show the approximate locations and interconnection of receptacles, lighting, and permanent electrical services in a building. Interconnecting wire routes may be shown approximately, where particular

receptacles or fixtures must be on a common circuit.
Wiring diagrams use standard symbols for wiring devices, usually different from those used on schematic diagrams. The electrical symbols not only show where something is to be installed, but also what type of device is being installed. For example, a surface ceiling light is shown by one symbol, a recessed ceiling light has a different symbol, and a surface fluorescent light has another symbol. Each type of switch has a different symbol and so do the various outlets. There are symbols that show the location of smoke detectors, the doorbell chime, and thermostat. On large projects symbols may be numbered to show, for example, the panel board and circuit to which the device connects, and also to identify which of several types of fixture are to be installed at that location.

A set of wiring diagrams may be required by the electrical inspection authority to approve connection of the residence to the public electrical supply system.

Wiring diagrams will also include panel schedules for circuit breaker panel boards, and riser diagrams for special services such as fire alarm or closed circuit television or other special services.

DIMENSIONS

All dimensions necessary for the manufacture of the part or assembly are given on the drawing; it should be necessary to deduce any dimension from other dimensions. To avoid confusion, dimensions are normally given once only. The units of measurement used are usually stated on the drawing, to avoid repetition, but any dimension to which this general statement does not apply will be suitably annoted. Dimensions are placed so that they may be read from the bottom or right hand side of the drawing.

When dimensions are given from a common datum, one of the methods shown in Figure 11.11 is normally used. Chain dimensioning, i.e. dimensioning between adjacent holes, is not often used, since it allows a build up of tolerances, which may not be acceptable. An alternative method, used with riveted joints, is to locate the end holes and add a note such as ‘11 rivets equally spaced’; this method is useful on curved surfaces.

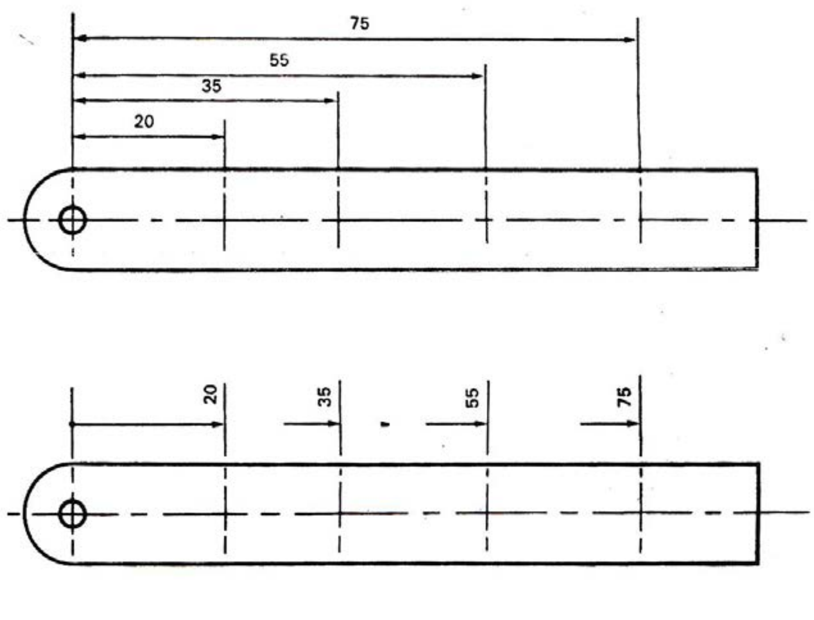


Fig.11.11 Dimensioning from a Common Datum

Machined components are usually measured by a system of functional and non-functional dimensions. The functional dimensions are those which directly affect the function of the component, e.g. the length of the plain portion of a shouldered bolt. A non-functional dimension would be the depth of the bolt head, and other dimensions chosen to suit production or inspection. Auxiliary dimensions may also be given, without tolerances, for information.

Dimensioning of Curved Profiles. Items the profiles of which are curved, are where practicable, dimensioned by means of radii, as shown in Figure 11.12. Where a radius is very large, and the centre of the arc could not be shown on the drawing, the method shown for the R150 dimension; the portion of the radius which touches the arc being in line with the true centre. Where this method cannot be employed, a system of ordinates may be used, as shown in Figure 11.13. The radii method is usually preferred, since accurate arcs can be produced; whereas with the ordinate system, deviations from the required curve may occur as a result of connecting the plotted points.

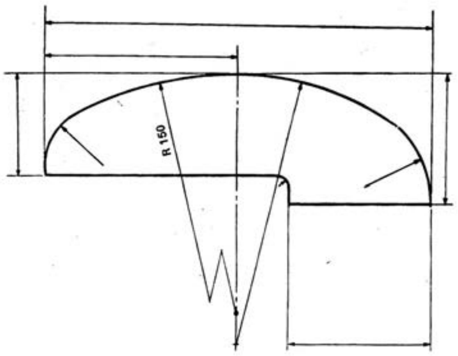


Fig.11.12 Dimension Profile by Radii

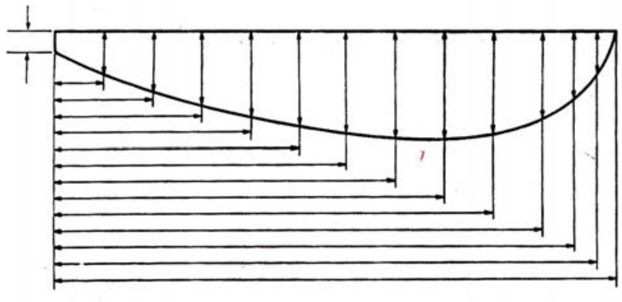


Fig.11.13 Dimension Profile by Ordinates

Dimensional and Angular Tolerances.

A general tolerance is usually given for all dimensions on a drawing, and may be found in the appropriate box on the printed layout. Where the general tolerance is inadequate or restrictive, an individual tolerance may be given to t a dimension.

RULES, TYPES AND METHODS

Drawing Sketches

A sketch is a simple, rough drawing that is made rapidly and without much detail. Sketches may take many forms-from a simple pictorial presentation to a multiview orthographic projection.

A sketch is frequently drawn for use in manufacturing a replacement part. Such a sketch must provide all necessary information to those persons who must manufacture the part.

A mechanic need not be an accomplished artist. However, in many situations, he will need to prepare a drawing to present an idea for a new design, a modification, or a repair method. The medium of sketching is an excellent way of accomplishing this.

The rules and conventional practices for making mechanical drawings are followed to the extent that all views needed to portray an object accurately are shown in their proper relationship. It is also necessary to observe the rules for correct line use and dimensioning.

To make a sketch, first determine what views are necessary to portray the object; then block in the views, using light construction lines. Next, complete the details, darken the object outline, and sketch extension and dimension lines. Complete the drawing by adding notes, dimensions, title, date and, when necessary, the sketcher's name. The steps in making a sketch of an object are illustrated in figure 11.14.

The degree to which a sketch is complete will depend on its intended use. Obviously, a sketch used only to represent an object pictorially need not be dimensioned. If a part is to be manufactured from the sketch, it should show all the necessary construction details.

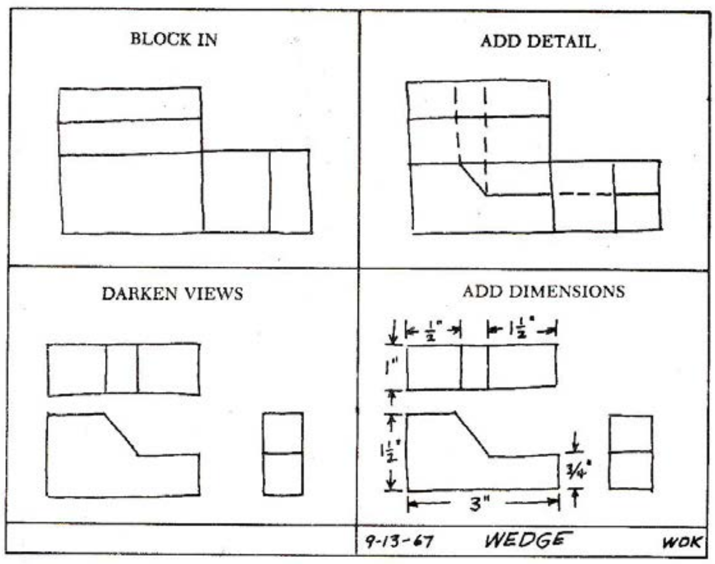


Fig. 11.14. Steps in sketching.

LIMITS, FITS AND TOLERANCES

Tolerances

When a given dimension on a print shows an allowable variation, the plus (+) figure indicates the maximum, and the minus (-) figure the minimum, allowable variation. The sum of the plus and minus allowance figures is called tolerance. For example, using .225 + .0025 - .00005, the plus and minus figures indicate the part will be acceptable if it is not more than .0005 smaller than the 0225 dimension. Tolerance in this example is .0030 (.0025 max. plus .005 min.).

If the plus and minus allowances are the same, you will find them presented as .224 $\pm$ .0025. The tolerance would then be .0050 Allowance can be indicated in either fractional or decimal form. When very accurate dimensions are necessary, decimal allowances are used. Fractional allowances are sufficient when close dimensions are not required. Standard tolerances of -.010 or 1/32 may be given in the title block of many drawings, to apply throughout the drawing.

Limits Fits Tolerance

The dimensions given for fits signify the amount of clearance allowable between moving parts. A positive allowance is indicated for a part that is to slide or revolve upon another part. A negative allowance is one given for a force fit. Whenever possible, the tolerance and allowances for desired fits conform to those set up in the American Standard for Tolerances, Allowances, and Gages for Metal Fits. The classes of fits specified in the standard may be indicated on assembly drawings.

Types of Fits

Type of Fit	Symbol	Examples of application
Clearance fit		
Precision sliding fit	H7/h6	Sealing rings, bearing covers, milling cutters on milling mandrels
Close running fit	H7/g6	Sleeve shafts, clutches, movable gears in change gear trains.
Normal running fit	H7/f7	Sleeve bearings with high revolution, bearings on machine tool spindles.
Easy running fit	H8/e8	Sleeve bearings with medium revolution, grease lubricated bearings of wheel boxes, gear sliding on shafts and sliding blocks.
Loose running fit	H8/d9	Sleeve bearing with low revolution.
Slack running fit	H8/c11	Oil seals with metal housings, multi-spline shafts.
	H11/a11	Large clearance and widely used
Transition fit		
Light press fit	H7/n6	Gears and bearing bushes, shaft and wheel assembly fixed by feather key
Force fit	H7/m6	Parts of machine tools that must be dismantled without damage e.g. gears belt pulleys, couplings, fit bolts, inner ring of ball bearings.
Push fit	H7/k6	Belt pulleys, brake pulleys, gears and couplings as well as inner rings of ball bearings on shafts for average loading conditions.
Easy push fit	H7/j6	Parts which are frequently dismantled, but are secured by keys, e.g. pulleys, hand wheels, bushes, bearing shells, piston on piston rods, change gear trains.
Interference Fit		
Sharing fit	H8/u8	Wheel steel tyres, bronze crowns on worm wheel hubs, couplings etc.
Heavy drive fit	H7/s6	
Press Fit	H7/r6	Coupling of shaft ends, bearing bushing in hubs, valve seats, gear wheels
Medium press fit	H7/p6	

PROJECTIONS - TYPES OF PROJECTIONS

Projections

The majority of drawings produced for aircraft purposes show the parts in third angle orthographic projection, but a number of older drawings may have been produced in first angle orthographic projection. Both systems show objects as they actually are, both in size (unless for convenience the drawing is scaled up or down) and shape, when viewed in the vertical and horizontal planes. The projection used for a drawing must be clearly stated, and the appropriate international projection symbol must be placed in a prominent position on the drawing. Any views not complying with the projection stipulated, e.g. a view showing the true shape of an inclined face, are generally marked with an arrow, and suitably annotated.

Orthographic

In order to show the exact size and shape of all the parts of complex objects, a number of views are necessary. This is the system used in orthographic projection.

In orthographic projection there are six possible views of an object, because all objects have six sides - front, top. bottom, rear, right side, and left side. Figure 11.15(a) shows an object placed in a transparent box, hinged at the edges. The projections on the sides of the box are the views as seen looking straight at the object through each side. If the outlines of the object are drawn on each surface and the box opened as shown in (b), then laid flat as shown in (c), the result is a six-view orthographic projection.

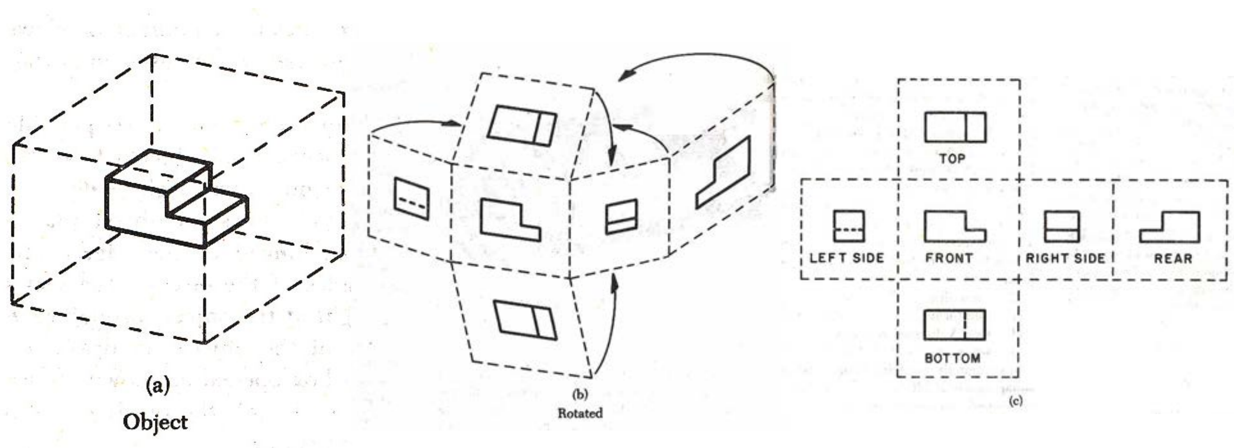
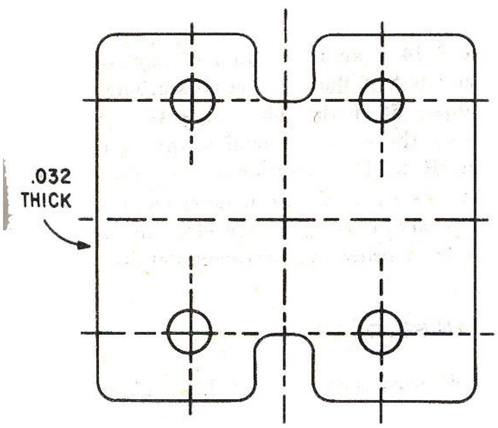


Fig.11.15 Orthographic projection.

It is seldom necessary to show all six vies to portray an object clearly; therefore, only those views necessary to illustrate the required characteristics of the object are drawn. One-view, two-view, and three-view drawings are the most common. Regardless of the number of views used, with the front view being the principal one. If the right-side view is shown, it will be to the right of the front view. If the left-side view is shown, it will be to the left of the front view. The top and bottom views, if included, will be shown in their respective positions relative to the front view.

One-view drawings are commonly used for objects of uniform thickness, such as gaskets, shims, and plates. A dimensional note gives the thickness as shown in figure 11.16. One-view drawings are also commonly used for [illegible]e view.



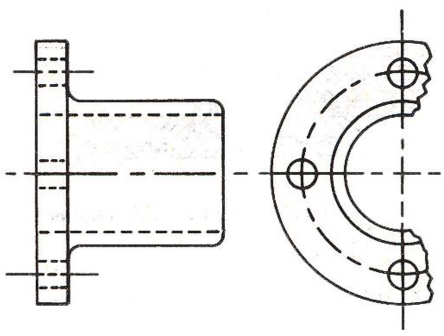


Fig.11.16. One view drawing.

Fig.11.17. Symmetrical object with exterior half view.

When space is limited and two views must be shown, symmetrical objects are often represented by half views, as illustrated in figure 11.17.

Isometric Projections

These are pictorial views of an object, which are drawn with the three axes inclined, usually at an angle of 30°, to the plane of projection. The central drawing in Figure 2 and 3, is an isometric projection. Isometrics views are sometimes used in drawing to indicate the position that the component occupies in the aircraft, or as a guide to understanding a complicated drawing.

Oblique Projection

An oblique projection is a simple type of graphical projection used for producing pictorial, two-dimensional images of three-dimensional objects :

- It projects an image by intersecting parallel rays (projectors)
- From the three-dimensional source object with the drawing surface (projection plan).

In both oblique projection and orthographic projection, parallel lines of the source object produce parallel line sin the projected images.

Perspective

Perspective is an approximate representation on a plat surface, of an image as it is perceived by the eye. The two most characteristic features of perspective are that objects are drawn :

- Smaller as their distance from the observer increases
- Foreshortened : the size of an object's dimensions along the line of sight are relatively shorter than dimensions across the line of sight.

Section Views

Projected views (either Auxiliary or Orthographic) which show a cross section of the source object along the specified cut plane. These views are commonly used to show internal features with more clarity than maybe available using regular projections or hidden lines. In assembly drawings, hardware components (e.g. nuts, screws, washers) are typically not sectioned.

THEORY OF ORTHOGRAPHIC PROJECTIONS

Orthographic Projection Drawings

Ref. to PROJECTIONS

PROJECTION PLANES

First Angle Projection

The principle of first angle projection is shown in Figure 11.18 . Each view represents the side of the object remote from it in the adjacent view.

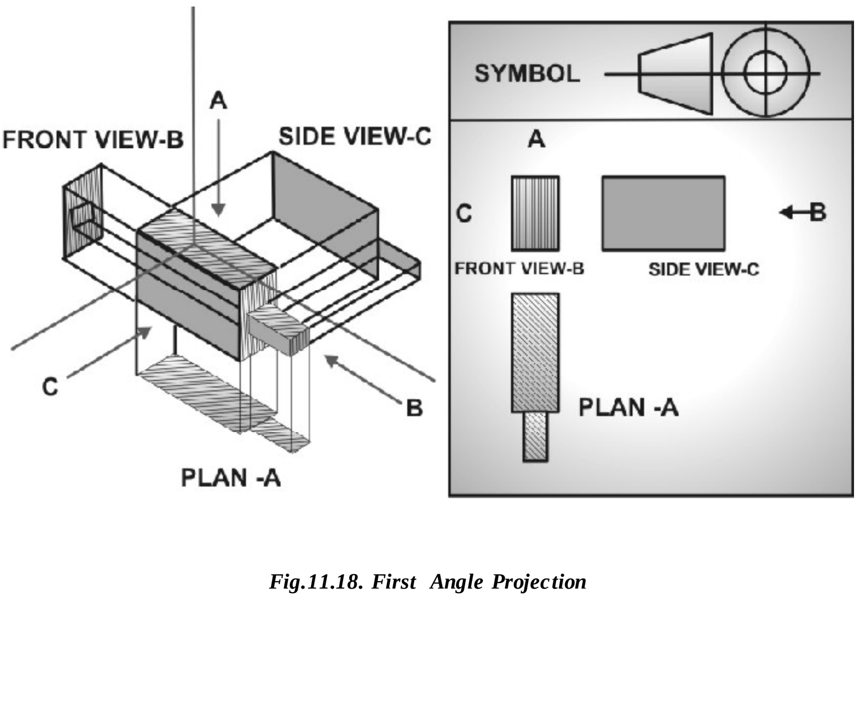


Fig.11.18. First Angle Projection

Third Angle Projection.

The Principle of third angle projection is shown in Figure 11.19. Each view represents the side of the object nearest to it in the adjacent view.

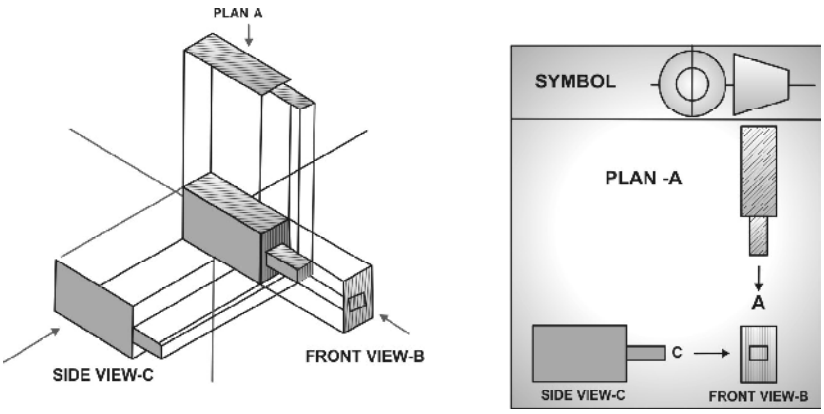


Fig.11.19. Third Angle Projection

Pictorial Drawings

A Pictorial drawing, figure 11.20, is similar to a photograph. It shows an object as it appears to the eye, but it is not satisfactory for showing complex forms and shapes. Pictorial drawings are useful in showing the general appearance of an object and are used extensively with orthographic projection drawings. Pictorial drawing are used in maintenance, overhaul, and part numbers.

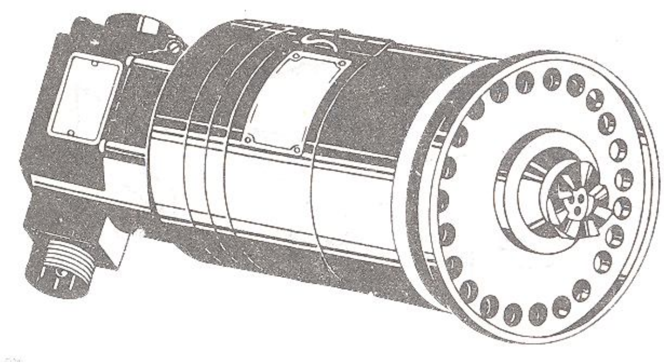


Fig.11.20 Pictorial drawing.

GENERAL SHEET LAYOUT MARGINS, TITLE BLOCK, REVISION BLOCK, BILL OF MATERIALS, GRID SYSTEM

GENERAL SHEET LAYOUT

Drawing Systems

Section A of BCAR, prescribes that each drawing must bear a descriptive title, drawing number, issue number, and the date of issue, it also prescribes that all alterations to drawings shall be made in accordance with a drawing amendment system which will ensure amendment to design records. If an alteration is made, a new issue number and date must be allocated to the drawing. To comply with the requirements, procedures must be introduced to progressively amend the total definition of the product in terms of its associated list of drawings at specific issues. Each particular variant of a product, and its state of modification, must be identifiable in relation to the appropriate list of drawings. The following paragraphs amplify these procedures, and explain the purposes of various parts of a drawing, together with the systems used and the methods of presentation

The Drawing Number

No two drawings should bear identical numbers, and a design office should maintain a register of all drawings issued. The drawing number has three features, the project identity (A2 in Figure 11.21). TS 88 describes an acceptable numbering method, but considerable discretion is allowed for particular design office requirements. In Figure 11.21, A2 indicates the aircraft type R indicates a repair, 21 indicates the front fuselage, and 29 indicates the register number in this group of drawings. Except for repair drawings, the drawing number is also, generally, the part number of the item.

Handed Parts

Drawings of handed parts usually have the left hand (port), upper, inner, or forward part drawn, this item taking the odd number, and the opposite hand the consecutive even number. Parts which are not handed have an odd drawing number. The drawing sheet bears the legend 'AS DRAWN' and 'OPP HAND' in the item quantity column. Where necessary the handed condition is indicated by a local scrap view or annotation.

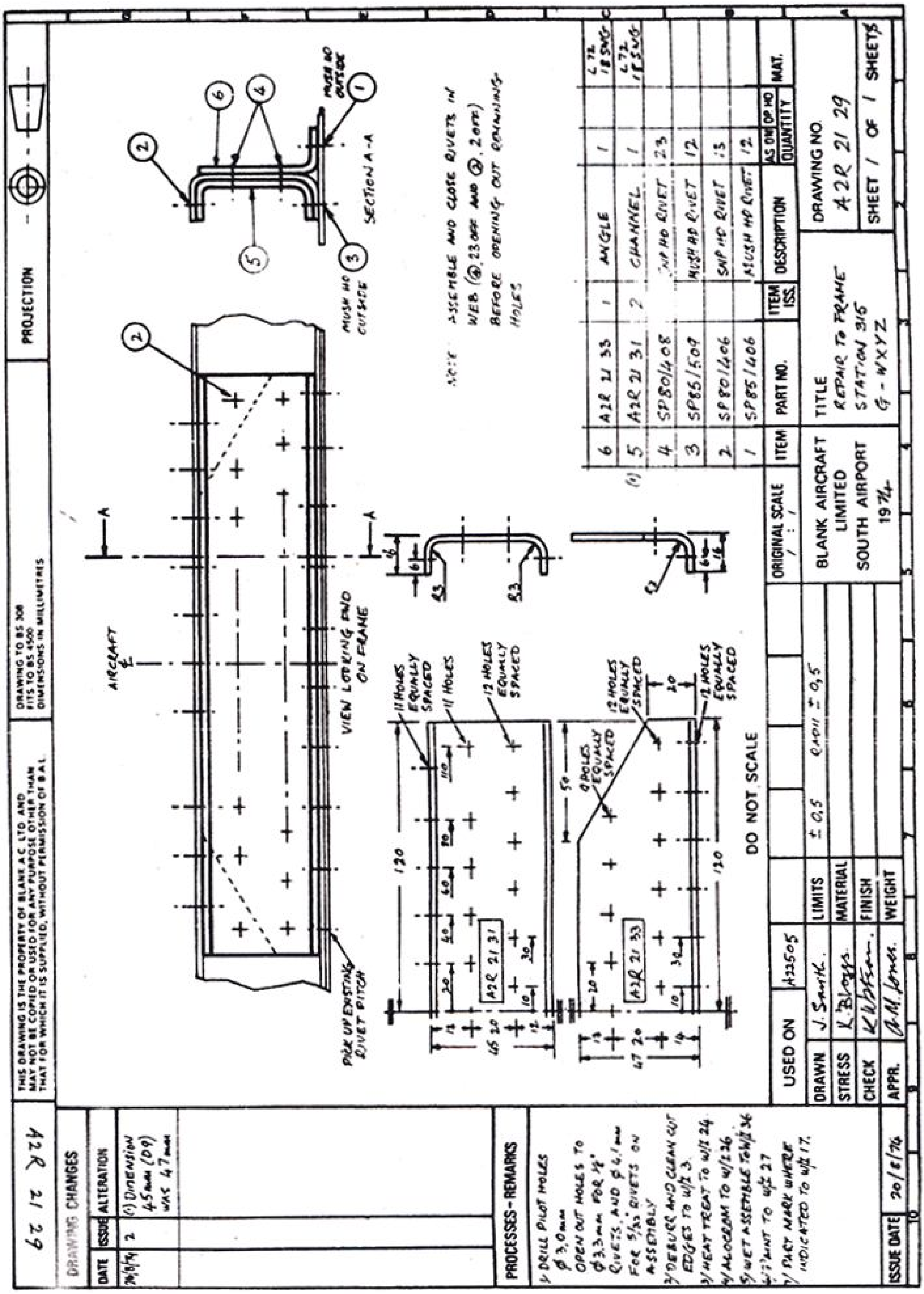


Fig. 11.21 Typical Engineering Drawing

Sheet Numbers

Where a complete drawing cannot be contained on a single sheet, successive sheets are used. The first sheet is identified as 'SHEET 1 or X SHEETS', as applicable, and subsequent sheets by the appropriate sheet number. Where a schedule or parts applicable to all sheets, is required, it appears on Sheet 1.

Drawing Changes
Any change to a design drawing, other than the correction of minor clerical errors, must be accompanied by a new issue number and date. New parts added to the drawing, or 'drawn on' parts affected by the change, take the new issue number, and parts which are not affected retain the original issue number. In all cases where interchangeability is affected, a new drawing number and part number are allocated.

Details of the drawing changes are recorded in the appropriate column on the drawing, or recorded separately on an 'Alteration Sheet', which is referenced on the drawing. Changes are related to the change number quoted in the change of issue columns on the drawing, and the marginal grid reference is given to identify the altered features.

The issue 'number' may sometimes be represented by a letter. Some organisations are alphabetical issues for prototype aircraft drawings, and numerical issues for production aircraft drawings; thus all drawings of a prototype aircraft become 'Issue 1' when production commences.

An alteration to a single part drawing may also result in changes to associated drawings; in addition, it ay be necessary to halt manufacture or assembly of the product. The drawing office system usually makes provision for the proper recording of drawing changes, by publishing, concurrently with the re-issued drawing, an instruction detailing the effects these will have on other drawings, on work in progress, and on existing stock. As a further safeguard, some organisations publish Drawing Master Reference Lists, which give details of the current issues of all drawings which are associated with a particular component or assembly.

Part Referencing
Every item called up on a drawing is given an item number, which is shown in a balloon' on the face of the drawing, as illustrated in Figure1. No other information is given in or adjacent to the balloon, with the exception of information necessary for manufacture or assembly, such as 'equally spaced', 'snap head inside', or the symbol 'ND', which indicates that no separate drawing exists for the part.

A schedule of parts is usually given in the manner shown in Figure1, or on a separate sheet of the drawing.

As an alternative to the system described above, grid references may be given in the list of parts; in such instances the actual part numbers appear in the balloons. Where a part occurs a number of times on a drawing, e.g. as may be the case with rivets, bolts, etc, it may be impractical to list all grid references, in which case this column is left blank. In instances where ND parts are shown as items on a drawing, the part number of such items may be that drawing number, followed by the drawing item number. Alternatively the part may be given its own part number, but will be identified as an ND part, e.g. 'Al 31 101 ND'. The information required for the manufacture of an ND part is contained in the description and material columns of the drawing, but reference may also be made to other drawings, where necessary.

Materials such as locking wire and shimming, which are available in rolls and sheets, will be detailed by specification number in the 'Part No' column, and the quantity will be entered as 'As Required', or 'A/R'. Standard parts to BS and SBAC Specifications will be detailed by the appropriate part numbers, but will not be drawn separately.

Drawing Queries
Drawing queries may arise through mistakes in draftsmanship, through ambiguity or through inability to purchase, manufacture, or assemble the items as drawn. Design Office procedures must be introduced which cater both for raising queries, and for providing satisfactory answers to those queries.

Drawing queries are usually raised on Drawing Query Form, which is passed to the Design Office for action. The answer to the query may be an immediate Provisional one, detailed on the query form; a temporary, fully approved answer, issued by means of a Drawing Office Instruction, and having the same authority as the drawing to which it refers; or a permanent answer provided by means of a new or re-issued drawing.

Drawing Query Forms and Drawing Office Instructions should be suitable identified, and should be referenced on the amended drawing. The effect on other drawings, on existing stock, and on work in progress, should be included in the answer to the query.

The number of Drawing Query Forms or Drawing Office Instructions permitted on a drawing, should be limited, and a new or re-issued drawing should be completed as soon as possible.

Title Blocks

Every print must have some means of identification. This is provided by a title block (see figure 11.22). The title block consists of a drawing number and certain other data concerning the drawing and the object it represents. This information is grouped in a prominent place on the print, usually in the lower right-hand corner. Sometimes the title block is in the form of a strip extending almost the entire distance across the bottom of the sheet.

Although title blocks do not follow a standard form, insofar as layout is concerned, all of them will present essentially the following information:

1. A drawing number to identify the print for filing purposes and to prevent confusing it with any other print.
2. The name of the part or assembly
3. The scale to which it is drawn.
4. The date
5. The name of the firm
6. The name of the draftsmen, the checker, and the person approving the drawing.

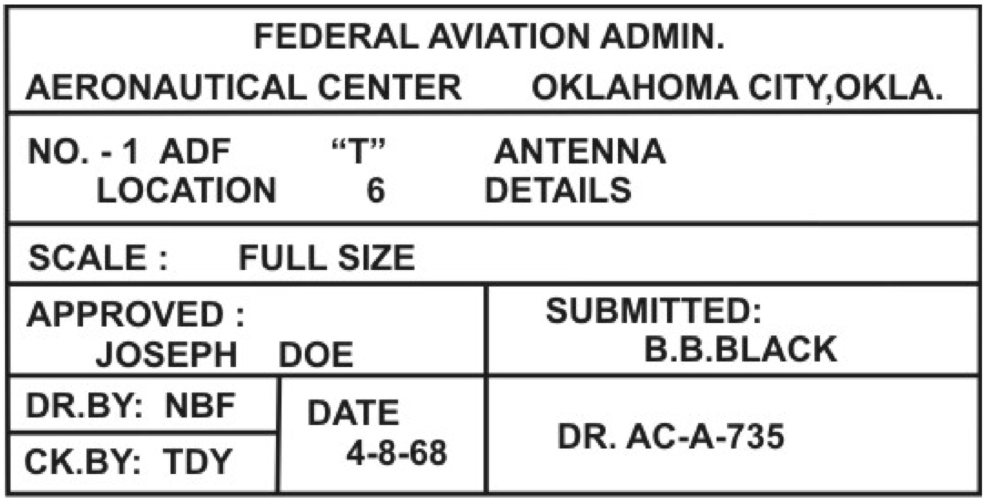


Fig.11.22. Title Block

Revision Block

Revision to a drawing are necessitated by changes in dimensions, design, or materials. The changes are usually listed in ruled columns either adjacent to the title block or at one corner of the drawing. All changes to approved drawings must be carefully noted on all existing prints of the drawing.

2	CHANGED PART NO.5	E.O.I	2/3/70	B.K.
1	REVISED DIMENSIONS	J.L.M.	7/1/69	E.K.P.
No.	REVISION	AUTH.	DATE	SIGN.

Fig.11.23. Revision blocks

When drawings contain such corrections, attention is directed to the changes by lettering or numbering them and listing those changes against the symbol in a revision block (figure 11.23). The revision block contains the identification symbol, the date, the nature of the revision, the authority for the change, and the name of the draftsman who made the change.

To distinguish the corrected drawing from its previous version, many firms are including, as part of the title block, a space for entering the appropriate symbol to designate that the drawing has been changed or revised.

Bill of Material

A list of the materials and parts necessary for the fabrication or assembly of a component or system is often included on the drawing. The list usually will be in ruled columns in which are listed the part number, name of the part, material from which the part is to be constructed, the quantity required, and the source of the part or material. A typical bill of material is shown in figure 11.24. On drawings that do not have a bill of material, the data may be indicated directly on the drawing.

BILL OF MATERIAL			
ITEM	**PART NO.**	**REQUIRE-D**	**SOURCE**
CONNECT-OR	**UG-21D/U**	**2**	**STOCK**

Fig.11.24. A typical bill of material

On assembly drawings, each item is identified by a number in a circle or square. An arrow connecting the number with the item assists in locating it in the bill of material.

Drawing or Print Numbers

All prints are identified by a number, which appears in a number block in the lower right-hand corner of the title block. It may also be shown in other places - such as near the top border line, in the upper right-hand corner, or on the reverse side of the print at both ends - so that the number will show when the print is folded or rolled. The purpose of the number is for quick identification of a print. If a print has more than one sheet and each sheet has the same number, this information is included in the number block, indicating the sheet number and the number of sheets in the series.

Reference and Dash Numbers

Reference numbers that appear in the title block refer a person to the numbers of other prints. When more than one detail is shown on a drawing, dash numbers are used. Both parts would have the same drawing number plus an individual number, such as 40267-1 and 40267-2.

In addition to appearing in the title block, dash numbers may appear on the face of the drawing near the parts they identify. Dash numbers are also used to identify right-hand and left-hand parts.

In aircraft, many parts on the left side are like the corresponding parts on the right side but in reverse. The left-hand part is always shown in the drawing. The right-hand part is called for in the title block. Above the title block will be found a notation such as : 470204-1LH shown ; 470204-2RH opposite. Both parts carry the same number, but the part called for is distinguished by a dash number. Some prints have odd numbers for left-hand parts and even numbers for right-hand parts.

Universal Numbering System

The universal numbering system provides a means of identifying standard drawing sizes. In the universal numbering system, each drawing number consists of six or seven digits. The first digit is always 1, 2, 4, or 5 (figure 11.25), and indicates the size of the drawing. The remaining digits identify the drawing. Many firms have modified this basic system to conform to their particular needs. Letters may be used instead of numbers. The letter or number depicting the standard drawing size may be prefixed to the number, separated from it by a dash. Other numbering systems provide a separate box preceding the drawing number for the drawing size identifier. In other modification of this system the part number of the depicted assembly is assigned as the drawing number.

SIZE	1	2	4	5
LENGTH	11"	17"	22"	INDEFINITE (ROLL)
WIDTH	8-1/2"	11"	17"	17, 22, 25, 50, 34, and 36 inches

Fig.11.25. Standard blueprint paper sizes

Notes

Notes are added to drawings for various reasons. Some of these notes refer to methods of attachment or construction. Others give alternatives, so that the drawing can be used for different styles of the same object. Still others list modifications that are available.

Notes amy be found alongside the item to which they refer. If the notes are lengthy, they may be placed elsewhere on the drawing and identified by letters or numbers. Notes are used only when the information cannot be conveyed in the conventional manner or when it is desirable to avoid crowding the drawing. Figure 11-1 illustrates one method of depicting notes.

When the note refers to a specific part, a light line with an arrowhead leads from the note to the part. If it applies to more than one part, the note is so worded that no mistake can be made as to the parts to which it pertains. When there are several notes, they are generally grouped together and numbered consecutively.

Zone Numbers

Zone numbers on drawings are similar to the numbers and letters printed on the borders of a map. They are there to help locate a particular point. To find a point, mentally draw horizontal and vertical lines from the letters and numerals specified; the point where these lines would intersect is the area sought.

Use the same method to locate parts, sections, and views on large drawings, particularly assembly drawings. Parts numbered in the title block can be located on the drawing by finding the numbers in squares along the lower border. Zone numbers read from right to left.

Station Numbers

A numbering system is used on large assemblies for aircraft to locate stations such as fuselage frames. Fuselage Frame-STA 185 indicates that the frame is 185 inches from the datum of the aircraft. The measurement is usually taken from the nose or zero station, but in some instances it may be taken from the fire wall or some other point chosen by the manufacturer.

The same station numbering system is used for wing and stabilizer frames. The measurement is taken from the center line or zero station of the aircraft.

Finish Marks

Finish marks are used to indicate the surface that must be machine finished. Such finished surfaces have better appearance and allow a closer fit with adjoining parts. During the finishing process the required limits and tolerances must be observed. Do not confuse machined finishes with those of paint, enamel, chromium plating, and similar coating.

TYPES OF LINES USED IN ENGINEERING DRAWING

The Meaning of Lines / Types of Line

Every drawing is composed of lines. Lines mark the boundaries, edges, and intersection of surfaces. Lines are used to show dimensions and hidden surfaces, and to indicate centers. Obviously, if the same kind of line is used to show all of these things, a drawing becomes a meaningless collection of lines. For this reason, various kinds of standardized lines are used on aircraft drawings. These are illustrated in figure 11.26, and their correct uses are shown in figure 11.27.

Most drawings use three widths, or intensities, of lines : thin, medium, or thick. These lines may vary somewhat on different drawings, but there will always be a noticeable difference between a thin and a thick line, with the width of the medium line somewhere between the two.

Center Lines

Center lines are made up of alternate long and short dashes. They indicate the center of an object or part of an object. Where center lines cross, the short dashes intersect symmetrically. In the case of very small circles, the center lines may be shown unbroken.

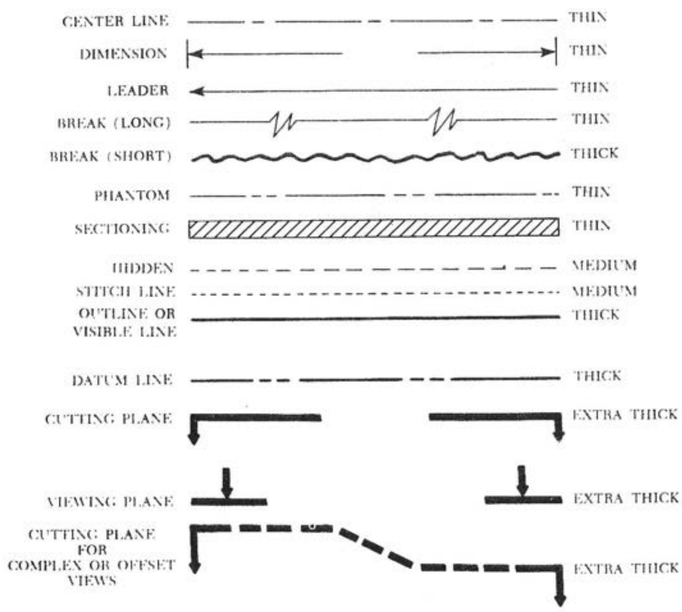


Fig.11.26. The meaning of Lines.

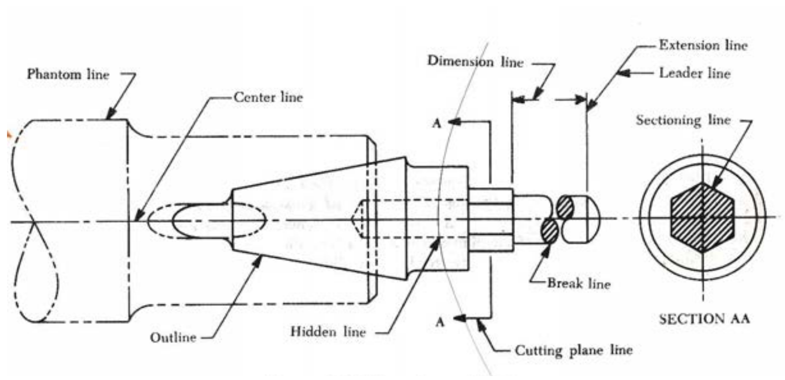


Fig.11.27. Correct uses of lines.

Dimension Lines

A dimension line is a light solid line, broken at the midpoint for insertion of measurement indications, and having opposite pointing arrowheads at each end to show origin and termination of a measurement. They are generally parallel to the line for which the dimension is given, and are usually placed outside the outline of the object and between views if more than one view is shown.

All dimensions and lettering are placed so that they will read from left to right. The dimension of an angle is indicated by placing the degree of the angle in its arc. The dimensions of circular parts are always given in terms of the diameter of the circle and are usually marked with the letter D or the abbreviation DIA following the dimension. The dimension of an arc is given in terms of its radius and is marked with the letter R following the dimension. Parallel dimensions are placed so that the longest dimension is farthest from the outline and the shortest dimension is closest to the outline of the object. On a drawing showing several vies, the dimensions will be placed upon each view to show its details to the best advantage.

In dimensioning distances between holes in an object, dimensions are usually given from center to center rather than from outside to outside of the holes. When a number of holes of various sizes are shown, the desired diameters are given on a leader followed by notes indicating the machining operations for each hole. If a part is to have three holes of equal size, equally spaced, this information is given. For precision work, sizes are given in decimals. Diameters and depths are given for counterbored holes. For countersunk are given for counterbored holes. For countersunk holes the angle of countersinking and the diameters are given. Study the examples shown in figure 11.28.

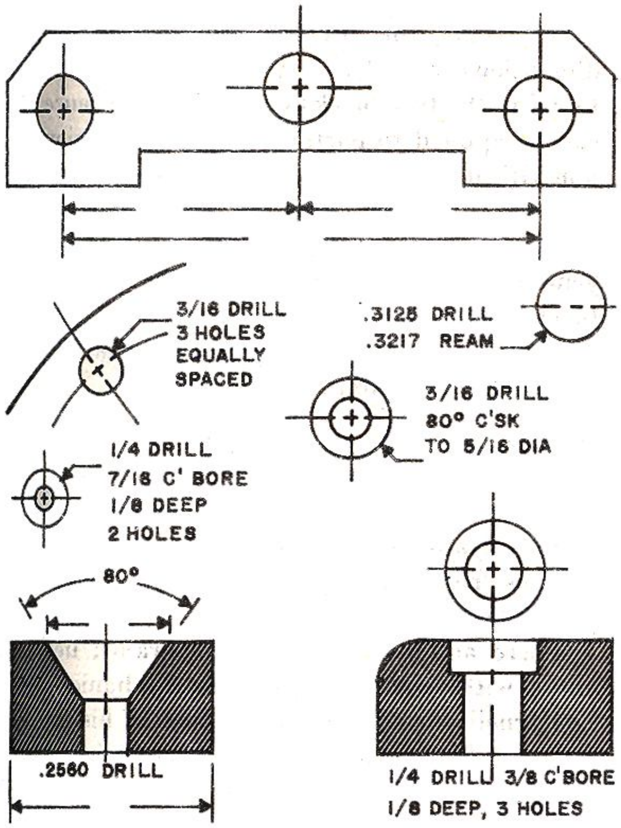


Fig.11.28. Dimensioning holes.

LeaderLines

Leaders are solid lines with one arrowhead and indicate a part or portion to which a note, number, or other reference applies.

Break Lines

Break lines indicate that a portion of the object is not shown on the drawing. Short breaks are made by solid, free hand lines. For long breaks, solid ruled lines with zigzags are used. Shafts, rods, tubes, and other such parts which have a portion of their length broken out, have the ends of the break drawn as indicated in figure 11.27.

Phantom Lines

Phantom lines indicate the alternate position of parts of the object or the relative position of a missing part. Phantom lines are composed of one long and two short evenly spaced dashes.

Sectioning Lines

Sectioning lines indicate the exposed surfaces of an object in sectional view. They are generally thin, full lines, but may vary with the kind of material shown in section.

Hidden Lines

Hidden lines indicate invisible edges or contours. Hidden lines consist of short dashes evenly spaced and are frequently referred to as dash lines.

Outline or Visible Lines

The outline or visible line is used for all lines on the drawing representing visible lines on the object.

Stitch Lines
Stitch lines indicate stitching or sewing lines and consist of a series of evenly spaced dashes.

Cutting Plane and Viewing Plane Lines
Cutting plane lines indicate the plane in which a sectional view of the object is taken. In figure 11.27, plane line A-A indicates the plane in which section A-A is taken.

Viewing plane lines indicate the plane from which a surface is viewed.

Standard Engineering Drawing Line Types
A variety of line styles graphically represent physical objects. Types of lines include the following :
Visible : are continuous lines used to depict edges directly visible from a particular angle.

Hidden - are short-dashed lines that may be used to represent edges that are not directly visible.

Center :- are alternately long-and short-dashed lines that may be used to represent the axes of circular features.

Cutting plane :- are thin, medium-dashed lines, or thick alternately long - and double short dashed that may be used to define sections for section views.

Section :- are thin lines in a pattern (pattern determined by the material being "cut" or "sectioned") used to indicate surfaces in section views resulting from "cutting." Section lines are commonly referred to as "cross-hatching."

Phantom :- (not shown) are alternately long - and double short-dashed thin lines used to represent a feature or component that is not part of the specified part or assembly. E.g. billet ends that maybe used for testing, or the machined product that is the focus of a tooling drawing.

Lines can also be classified by a letter classification in which each line is given a letter.

Type A lines show the outline of the feature of an object. They are the thickest lines on a drawing and done with a pencil softer than HB.

Type B lines are dimension lines and are used for dimensioning, projecting, extending, or leaders. A harder pencil should be used, such as a 2H.

Type C lines are used for breaks when the whole object is not shown. They are free hand drawn and only for short breaks. 2H pencil.

Type D lines are similar to Type C, except they are zigzagged and only for longer breaks. 2H pencil.

Type E lines indicate hidden outlines of internal features of an object. They are dotted lines. 2 H pencil.

Type F lines are type F [typo] lines, except they are used for drawings in electro technology. 2H pencil.

Type G lines are used for centre lines. They are dotted lines, but a long line of 10-20 mm, then a gap, then a small line of 2 mm. 2H pencil.

Type H lines are the same as Type G, except that every second long line is thicker. They indicate the cutting plane of an object. 2H pencil.

Type K lines indicate the alternate positions of an object and the line taken by that object. They are drawn with a long line of 10-20 mm, then a small gap, then a small line of 2mm, then a gap, then another small line. 2H pencil.

PRESENTATION METHODS

a. Microfilms
The practice of recording drawings, parts catalogs, and maintenance and overhaul manuals on microfilms was introduced in recent years. Microfilm is regular 16-mm. or 35-mm. film. Since 35-mm. film is larger, it provides a better reproduction of drawings. Depending on the size of the drawing to be reproduced, a varying number of drawings can be photographed on the reel of 35-mm. film. To view or read drawings or manuals on a reel of film, you need either a portable 35-mm. film projector or a microfilm reader or viewer.

The advantage of microfilm is that several reels, which represent perhaps hundreds of drawings, require only a small amount of storage space. Too, a person working on an aircraft may need to refer to a specific dimension. He can place the reel of microfilm in a projector, locate the drawing or desired information, and read the dimension. If he has to study a detail of the drawing, or work with the drawing for a long period of time, an enlarged photographic reproduction can be made, using the microfilm as a negative.

Microfilm of drawings has many other uses and advantages. However, microfilm is not intended to replace the need for original drawings, especially where the originals are modified and kept current over a long period of time. When drawings are filmed on continuous reels, corrections can be made by cutting out superseded drawings and splicing in the revised ones. When these corrections become numerous, the procedure becomes impractical and is discarded in favor of again filming all the related drawings.

A method that allows corrections to be made easily is to photograph the drawings and then cut up the film into individual slides. This has one a disadvantage; it requires considerable time to convert the film into slides, insert them into transparent protective envelopes, and arrange them in sequence so that desired drawings can be located quickly.

A 70-mm. microfilm has become available very recently. With it, larger size drawings can be reproduced as individual frames or slides, and these can be inserted in regular paper envelopes and kept in an ordinary file. When held to the light, this large microfilm can be read with the naked eye.

b. Microfiches

A microfiche is a flat film 105 × 148 mm in size, that is ISO A6. It carries a matrix of micro images. All microfiche are read with text parallel to the long side of the fiche. Frames may be landscape or portrait. Along the top of the fiche a title may be recorded for visual identification. The most commonly used format is a portrait image of about 10 × 14 mm. Office size papers or magazine pages require a reduction of 24 or 25. Microfiche are stored in open top envelopes which are put in drawers or boxes as file cards, or fitted into pockets in purpose made books.

Microforms are any form, either films or paper, containing micro reproductions of documents for transmission, storage, reading, and printing. Microform images are commonly reduced about 25 times from the original document size. For special purposes, greater optical reductions may be used.

All microform images may be provided as positives or negatives, more often the latter.

Three formats are common : microfilm (reels), aperture cards and microfiche (flat sheets). Microcards, a format no longer produced, were similar to microfiche, but printed on cardboard rather than photographic film.

Uses

Systems that mount microfilm images in punched cards have been widely used for archival storage of engineering information.

For example, when airlines demand archival engineering drawings to support purchased equipment (in case the vendor goes out of business, for example), they normally specified punch-card-mounted microfilm with an industry-standard indexing system punched into the card. This permits automated reproduction, as well as permitting mechanical card-sorting equipment to sort and select microfilm drawings.

Aperture card mounted microfilm is roughly 3% of the size and space of conventional paper or vellum engineering drawings. Some military contracts around 1980 began to specify digital storage of engineering and maintenance data because the expenses were even lower than microfilm, but these programs are now finding it difficult to purchase new readers for the old formats.

Microfilm first saw military use during the Franco-Prussian War of 1870-71. During the Siege of Paris, the only way for the provincial government in Tours to communicate with Paris was by pigeon post. As the pigeons could not carry paper dispatches, the Tours government turned to microfilm. Using a microphotography unit evacuated from Paris before the siege, clerks in Tours photographed paper dispatches and compressed them to microfilm, which were carried by homing pigeons into Paris and projected by magic lantern while clerks copied the dispatches onto paper.

Additionally, the US Victory mail, and the British “Alirgraph” system it was based on, were used for delivering mail between those at home and troops serving overseas during World War II. The systems worked by photographing large amounts of censored mail reduced to thumb-nail size onto reels of microfilm, which weighed much less than the originals would have. The film reels were shipped by priority air flight to and from the home fronts, sent to their prescribed destinations for enlarging at receiving stations near the recipients, and printed out on lightweight photo paper. These facsimiles of the letter-sheets were reproduced about one-quarter the original size and the miniature mails were then delivered to the addressee. Use of these microfilm systems saved significant volumes of cargo capacity needed for vital war supplies. An additional benefit was that the small, lightweight reels of microfilm were almost always transported by air, and as such were much quicker than any surface mail services.

Libraries began using microfilm in the mid-20th century as a preservation strategy for deteriorating newspaper collections. Books and newspapers that were deemed in danger of decay could be preserved on film and thus access and use could be increased. Microfilming was also a space-saving measure. In his 1945 book, "The Scholar and the Future of the Research Library," Fremont Rider calculated that research libraries were doubling in space every sixteen years. His suggested solution was microfilming, specifically with his invention, the microcard. Once items were put onto film, they could be removed from circulation and additional shelf space would be made available for rapidly expanding collections. The microcard was superseded by microfiche. By the 1960s, microfilming had become standard policy.

Visa and National City use microfilm to store bank statements, and produce microfilm, from digital records, that is placed into storage.

Advantages

The medium has numerous advantages :

- It enables libraries to greatly expand access to collections without putting rare, fragile, or valuable items at risk of theft or damage.
- It is compact, with far smaller storage costs than paper documents. Normally 98 document size pages fit on one fiche, reducing to about 0.25% original material. When compared to filing paper, microforms can reduce space storage requirements by up to 95%.
- It is cheaper to distribute than paper copy. Most microfiche services get a bulk discount on reproduction rights, and have lower reproduction and carriage costs than a comparable amount of printed paper.
- It is a stable archival form when properly processed and stored. Preservation standard microfilms use the silver halide process, creating silver images in hard gelatin emulsion on a polyester base. With appropriate storage conditions, this film has a life expectancy of 500 years. Unfortunately, in tropical climates with high humidity, fungus eats the gelatin used to bind the silver halide. Thus, diazo-based systems with lower archival lives (20 years) which have polyester or epoxy surfaces are used.
- Since it is analog (an actual image of the original data), it is easy to view. Unlike digital media, the format requires no software to decode the data stored thereon. It is instantly comprehensible to persons literate in the language; the only equipment that is needed is a simple magnifying glass. This eliminates the problem of software obsolescence.
- It is virtually impossible to mutilate. Users cannot tear pages from or deface microforms.
- It has low intrinsic value and does not attract thieves. Few heavily-used microform collections suffer any losses due to theft.
- Prints from microfilm are accepted in legal proceedings as substitutes for original documents.

Disadvantages

- The principal disadvantage of microforms is that the image is (usually) too small to read with the naked eye. Libraries must use either special readers that project full-size images on a ground-glass or frosted acrylic screen or a modern Viewer/Scanner which converts the image from analog to digital-see section below on Digital Conversion.
- Reader machines used to view microfilm are often difficult to use, requiring users to carefully wind and rewind until they have arrived at the point where the data they are looking for is stored.
- Photographic illustrations reproduce poorly in microform format, with loss of clarity and halftones. However the latest electronic digital viewer/scanners have the ability to scan in gray shade which greatly increases the quality of photographs, but they still can not duplicate the nuances of true gray shade photographs- due to the inherent bi-tonal nature of microfilm.

- Reader-printers are not always available, limiting the user's ability to make copies for their own purposes. Conventional photocopy machines cannot be used.
- Color microform is extremely expensive, thus discouraging most libraries supplying color films. Color photographic dyes also tend to degrade over the long term. This results in the loss of information, as color materials are usually photographed using black and white film.
- When stored in the highest-density drawers, it is easy to misfile a fiche, which is thereafter unavailable. As a result, some libraries store microfiche in a restricted area and retrieve it on demand. Some fiche services use lower-density drawers with labeled pockets for each card.
- Like all analog media formats, microfiche is lacking in features enjoyed by users of digital media. Analog copies degrade with each generation, while digital copies have much higher copying fidelity. Digital data can also be indexed and searched easily.
- Reading microfilms on a machine for some time may cause headache and/or eyestrains.

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CHAPTER-12
SPECIFICATION 100 OF AIR TRANSPORT ASSOCIATION (ATA) OF AMERICA

FAMILIARISATION WITH ATA -100

A.T.A. Specification N0100

The Air Transport Association of America (A.T.A.) issued the specifications for Manufacturers Technical Data June 1, 1956.

Quote : "This specification establishes a standard for the presentation of technical data, by an aircraft, aircraft accessory, or component manufacturer required for their respective products."

What is ATA - 100

"In order to standardize the treatment of subject matter and to simplify the user's problem in locating instructions, a uniform method of arranging material in all publications has been developed.

How to refer it

The A.T.A. Specification 100 has the aircraft divided into systems such as electrical which covers the basic electrical system (ATA-2400). Numbering in each major system provides an arrangement for breaking the system down into several subsystems. Late model aircraft, both over and under the 12,500 dividing line, have their parts manuals and maintenance manuals arranged according to the A.T.A. coded system.

The following table of A.T.A System, subsystem, and Title is included for familiarization purposes.

ATA SPEC.100 -Systems

Sys.	Sub	Title
21		**AIR CONDITIONING**
	00	General
	10	Compression
	20	Distribution
	30	Pressurization Control
	40	Heating
	50	Cooling
	60	Temperature Control
	70	Moisture/ Air Contaminate Control
22		**AUTO FLIGHT**
	00	General
	10	Autopilot
	20	Speed-Attitude Correction
	30	Auto Throttle
	40	System Monitor
23		**COMMUNICATIONS**
	00	General
	10	High Frequency (HF)
	20	VHF/UHF
	30	Passenger Address and Entertainment
	40	Interphone
	50	Audio Integrating
	60	Static Discharging
	70	Audio and Video Monitoring
24		**ELECTRICAL POWER**
	00	General
	10	Generator Drive
	20	AC Generation
	30	DC Generation
	40	External Power
	50	Electrical Load Distribution

Sys.	Sub	Title
25		**EQUIPMENT/FURNISHINGS**
	00	General
	10	Flight Compartment
	20	Passenger Compartment
	30	Buffet/Galley
	40	Lavatories
	50	Cargo Compartments /AG Spray Apparatus
	60	Emergency
	70	Accessory Compartments
26		**FIRE PROTECTION**
	00	General
	10	Detection
	20	Extinguishing
	30	Explosion Suppression
27		**FLIGHT CONTROLS**
	00	General
	10	Aileron and Tab
	20	Rudder/Ruddervator and Tab
	30	Elevator and Tab
	40	Horizontal Stabilizers/Stabilator
	50	Flaps
	60	Spoiler, Drag Devices & Variable Aerodynamic Fairings
	70	Gust Lock and Dampener
	80	Lift Augmenting
28		**FUEL**
	00	General
	10	Storage
	20	Distribution/ Drain Valves
	30	Dump
	40	Indicating

Sys.	Sub	Title
29		**HYDRAULIC POWER**
	00	General
	10	Main
	20	Auxiliary
	30	Indicating
30		**ICE AND RAIN PROTECTION**
	00	General
	10	Airfoil
	20	Air Intakes
	30	Pilot and Static
	40	Windows and Windshields
	50	Antennas and Radomes
	60	Propellers/ Rotors
	70	Water Lines
	80	Detection
31		**INDICATING/RECORDING SYSTEMS**
	00	General
	10	Unassigned
	20	Unassigned
	30	Recorders
	40	Central Computers
	50	Central Warning System
32		**LANDING GEAR**
	00	General
	10	Main Gear
	20	Nose Gear/Tail Gear
	30	Extension & Retraction, Level Switch
	40	Wheels and Brakes
	50	Steering
	60	Position, Warning & Ground Safety Switch
	70	Supplementary Gear/Skis/Floats
33		**LIGHTS**
	00	General
	10	Flight Compartment & Annunciator Panels
	20	Passenger Compartments
	30	Cargo and Service Compartments
	40	Exterior Lighting
	50	Emergency Lighting
34		**NAVIGATION**
	00	General
	10	Flight Environment Data
	20	Attitude and Direction
	30	Landing and Taxiing Aids
	40	Independent Position Determining
	50	Dependent Position Determining
	60	Position Computing
35		**OXYGEN**
	00	General
	10	Crew
	20	Passenger
	30	Portable
36		**PNEUMATIC**
	00	General
	10	Distribution
	20	Indicating
37		**PNEUMATIC**
	00	General
	10	Distribution
	20	Indicating

Sys.	Sub	Title
37		**VACUUM/PRESSURE**
	00	General
	10	Distribution
	20	Indicating
38		**WATER/WASTE**
	00	General
	10	Potable
	20	Wash
	30	Waste Disposal
	40	Air Supply
39		**ELECTRICAL/ELECTRONIC PANEL AND MULTIPURPOSE COMPONENTS**
	00	General
	10	Instrument & Control Panels
	20	Electrical & Electronic Equipment Racks
	30	Electrical & Electronic Junction Boxes
	40	Multipurpose Electronic Components
	50	Integrated Circuits
	60	Printed Circuit Card Assemblies
49		**AIRBORNE AUXILIARY POWER**
	00	General
	10	Power Plant
	20	Engine
	30	Engine Fuel and Control
	40	Ignition/Starting
	50	Air
	60	Engine Controls
	70	Indicating
	80	Exhaust
	90	Oil
51		**STRUCTURES**
	00	General
52		**DOORS**
	00	General
	10	Passenger/Crew
	20	Emergency Exit
	30	Cargo
	40	Service
	50	Fixed Interior
	60	Entrance Stairs
	70	Door Warning
	80	Landing Gear
53		**FUSELAGE**
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Aerodynamic Fairings
54		**FUSELAGE**
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Fillets/Fairings

Sys.	Sub	Title
55		**STABILIZERS**
	00	General
	10	Horizontal Stabilizers/Stabilator
	20	Elevator/Elevon
	30	Vertical Stabilizer
	40	Rudder/Ruddervator
	50	Attach Fittings
56		**WINDOWS**
	00	General
	10	Flight Compartment
	20	Cabin
	30	Door
	40	Inspection and Observation
57		**WINGS**
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plate/Skin
	40	Attach Fittings
	50	Flight Surfaces
61		**PROPELLERS**
	00	General
	10	Propeller Assembly
	20	Controlling
	30	Breaking
	40	Indicating
65		**ROTORS**
	00	General
	10	Main Rotor
	20	Anti-torque Rotor Assembly
	30	Accessory Driving
	40	Controlling
	50	Braking
	60	Indicating
71		**POWERPLANT**
	00	General
	10	Cowling
	20	Mounts
	30	Fireseals & Shrouds
	40	Attach Fittings
	50	Electrical Harness
	60	Engine Air Intakes
	70	Engine Drains
72		**(T) TURBINE/TURBOPROP**
	00	General
	10	Reduction Gear & Shaft Section
	20	Air Inlet Section
	30	Compressor Section
	40	Combustion Section
	50	Turbine Section
	60	Accessory Drives
	70	By-pass Section
72		**(R) ENGINE RECIPROCATING**
	00	General
	10	Front Section
	20	Power Section
	30	Cylinder Section
	40	Supercharger Section
	50	Lubrication
73		**ENGINE FUEL & CONTROL**
	00	General
	10	Distribution
	20	Controlling/Governing
	30	Indicating
74		**IGNITION**
	00	General
	10	Electrical Power Supply
	20	Distribution
	30	Switching
75		**BLEED AIR**
	00	General
	10	Engine Anti-Icing
	20	Accessory Cooling
	30	Compressor Control
	40	Indicating
76		**ENGINE CONTROL**
	00	General
	10	Power Control
	20	Emergency Shutdown
77		**ENGINE INDICATING**
	00	General
	10	Power
	20	Temperature
	30	Analyzers
78		**ENGINE EXHAUST**
	00	General
	10	Collector/Nozzle
	20	Noise Suppressor
	30	Thrust Reverser
	40	Supplementary Air
79		**ENGINE OIL**
	00	General
	10	Storage (Dry Sump)
	20	Distribution
	30	Indicating
80		**STARTING**
	00	General
	10	Cranking
81		**TURBINES (RECIPROCATING ENG)**
	00	General
	10	Power Recovery
	20	Turbo-Supercharger
82		**WATER INJECTION**
	00	General
	10	Storage
	20	Distribution
	30	Dumping & Purging
	40	Indicating
83		**REMOTE GEAR BOXES (ENG DR)**
	00	General
	10	Drive Shaft Section
	20	Gearbox Section

CHAPTER-13
AERONAUTICAL & OTHER APPLICABLE STANDARDS INCLUDING ISO, AN, MS, NAS & MIL

INTRODUCTION TO THE FOLLOWING STANDARD SYSTEM RELATED TO AVIATION

ISO

The International Organization for Standardization (Organisation international de normalisation), widely known as ISO, is an international-standard-setting body composed of representatives from various national standards organizations.

ISO 9000 is a family of standards for quality management systems. ISO 9000 is maintained by ISO, the International Organization for Standardization and is administered by accreditation and certification bodies. The rules are updated, as the requirements motivate changes over time. Some of the requirements in ISO 9001:2008 (which is one of the standards in the ISO 9000.

- a set of procedures that cover all key processes in the business;
- monitoring processes to ensure they are effective;
- keeping adequate records;
- checking output for defects, with appropriate and corrective action where necessary;
- regularly reviewing individual process and the quality itself for effectiveness; and
- facilitating continual improvement

A company or organization that has been independently audited and certified to be in conformance with ISO 9001 may publicly state that it is “ISO 9001 certified” or “ISO 9001 registered”. Certification to an ISO 9001 standard does not guarantee any quality of end products and services; rather, it certifies that formalized business processes are being applied.

Although the standards originated in manufacturing, they are now employed across several types of organizations. A”product”, in ISO vocabulary, can mean a physical object, services, or software.

ISO 9001

Aviation System Standards has three, separate, production processes, each containing an ISO 9001:2008 or AS9110:2003 quality management policy:

1. Business and Planning Services (BPS)
“We continually improve our products and services to make it happen for our customer”.

2. Aviation System Standards’ production processes for Instrument Flight Procedures (IFP) “Aviation System Standards provides our customers **safe**, **timely**, and **continually improved** Instrument Flight Procedures that enable efficient use of the National Airspace System.”

3. Aircraft Maintenance and Engineering Group (AMEG) processes “We continually improve our processes to provide **airworthy**, **safe** and **reliable** aircraft.

ISO 14001

The Aviation System Standards’ Environmental Management Policy is:

Aviation System Standards is a worldwide leader in aviation. Consistent with our mission to develop and certify procedures and systems for the global aviation community, Aviation System Standards shall minimize environmental impacts of its operations through the design and deployment of an organization-wide environmental management system (EMS) confront with ISO 14001 by:

- Pollution Prevention to cost effectively reduce waste.
- Integration of environmental management with our mission and other systems.
- Communication of this environmental policy to our employees and all interested external parties.
- Compliance with legal and other requirements to which we subscribe.
- Continual improvement of our environmental management system.

AN & MS

Specification and Standards

Before the Federal Aviation Administration issues a type certificate for an aircraft the manufacturers must demonstrate that the aircraft conforms to all airworthiness requirements. These requirements pertain not only to performance, but to structural strength and integrity as well. To meet these requirements, each individual aircraft produced frame a given design must meet the same standards. To accomplish this, all materials and hardware must be manufactured to a standard of quality, specification and standard for aircraft hardware are generally identified by the organization originating them. Some of the most common are -

AMS - Aeronautical Material Specification

AN - Airforce Navy Specification

MS - Military Standard

NAS- National Aerospace Standard etc.

AN - Airforce/Navy (Specification) -/ MS-Military Standard (Specification)

Standard aircraft fasteners, Nuts and bolts in America are manufactured in accordance with Government, military and civil specifications. These specification provide for a range of fasteners/ equipments with unified threads (UNC, UNF, UNIF series, extreme care is necessary when matching up nuts with screws or bolts in these series if not properly identified, then thread gauges must be used to check the threads AN, MS or Nas are various standard for identification. For identification Purposes AN number is used to indicate 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 locking wire or collar pin (split pin) holes. It should be noted that the AN series has to a large extent been replaced by MS (MILITARY STANDARD), and NAS (NATIONAL AEROSPACE STANDARD) components.

NAS

The National Academy of Sciences (NAS) is an honorific of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare.

The NAS was established by an Act of Congress that was signed by President Abraham Lincoln on March 3, 1863, at the height of the Civil War, which calls upon the NAS to "investigate, experiment, and report upon any subject of science or art" whenever called upon to do so by any department of the government. Scientific issues would become more complex in the years following the war, and to expand the expertise available to it in its advisory service to the government, the NAS created the National Research Council under its charter in 1916. To keep pace with the growing roles that science and technology would play in public life. The National Academy of Engineering was established under the NSA charter in 1964, and the Institute of Medicine followed in 1970.

Since 1863, the nation's leaders have turned to these non-profit organizations for advice on the technological issues that frequently pervade policy decisions. Most of the institution's science policy and technical work is conducted by its operating arm, the National Research Council (NRC), which was created expressly for this purpose and which provides a public service by working outside the framework of government to ensure independent advice on matters of science, technology, and medicine. The NRC enlists committees of the nation's top scientists, engineers, and other experts, all of whom volunteer their time to study specific concerns. The results of their deliberations have inspired some of America's most significant and lasting efforts to improve the health, education, and welfare of the population. The Academy's service to government has become so essential that Congress and the White House have issued legislation and executive orders over the years that reaffirm its unique role.

The Academy membership is composed of approximately 2,100 members and 380 foreign associates, of whom nearly 200 have won Noble Prizes. Members and foreign associates of the Academy are elected in recognition of their distinguished and continuing achievements in original research; election to the Academy is considered one of the highest honours that can be accorded a scientist or engineer. The Academy is governed by a Council consisting of twelve members (councilors) and five officers, elected from among the Academy membership Dr.Ralph J. Cicirone is the president of the National Academy of Sciences.

MIL

A mil is a standard measurement of a round conductor's cross sectional area. One mil is equivalent to .001 inches. Thus, a wire that has a diameter of .125, is expressed as 125 mils. To find out the cross sectional area of a conductor in circular mils, square the conductor's diameter. For example if a round wire has a diameter of 3/8" or 375 mils, its circular area is 1,40,625 circular mils (375×345=1,40,625).

The **square mil** is the unit of measure for square or rectangular conductors such as bus bars. To determine the cross-sectional area of a conductor in square mils, multiply the conductor's length by its width. For example, the cross sectional area of a strip of copper that is 400 mils thick and 500 mils wide is 2,00,000 square mils.

It should be noted that one circular mil is. 7854 of one square mil. Therefore, to convert a circular mil area to a square mil area, multiply the are in circular mils by .7854 mil. Conversely, to convert a square mil area to a circular area, divide the area in square mils by .7854 (Fig.13.1)

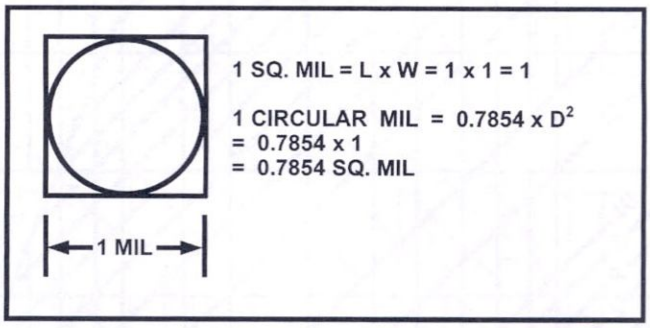

Fig. 13.1. The area of a round conductor is measured in circular mils.

AERONAUTICAL PUBLICATIONS

Aeronautical publications are the sources of information for guiding aviation mechanics in the operation and maintenance of aircraft and related equipment. The proper use of these publications will greatly aid in the efficient operation and maintenance of all aircraft. These include manufacturers' service bulletins, manuals, and catalogs, as well as FAA regulations, airworthiness directives, advisory circulars, and aircraft, engine and propeller specifications.

MANUFACTURERS SERVICE BULLETINS/MANUALS

Bulletins

Service bulletins are one of several types of publications issued by airframe, engine and component manufacturers. The bulletins may include: (1) The purpose for issuing the publication; (2) the name of the applicable airframe, engine, or component; (3) detailed instructions for service, adjustment, modification or inspection, and source of parts, if required; and (4) the estimated number of man-hours required to accomplish the job.

MANUALS

Maintenance Manual

The aircraft maintenance manual provided by the manufacturer contains complete instructions for maintenance of all systems and components installed in the aircraft. It contains information for the mechanic who normally works on units, assemblies, and systems, while they are installed in the aircraft, and not for the overhaul mechanic. A typical aircraft maintenance manual contains:

(1) A description of the systems such as electrical, hydraulic, fuel, control, etc.;
(2) lubrication instructions setting forth the frequency and the lubricants and fluids which are to be used in the various systems;
(3) pressures and electrical loads applicable to the various systems;
(4) tolerances and adjustments necessary to proper functioning of the airplane;
(5) methods of balancing control surfaces;
(6) methods of balancing control surfaces;
(7) identification of primary and secondary structures;
(8) frequency and extent of inspections necessary to the proper operation of the airplanes ;
(9) special repair methods applicable to the airplane;
(10) special inspection techniques requiring X-ray, ultrasonic, or magnetic particle inspection; and
(11) a list of special book

Overhaul Manual

The manufacturer's overhaul manual contains brief descriptive information and detailed step-by-step instructions covering work normally performed on a unit away from the aircraft. Simple, inexpensive items, such as switches and relays, on which overhaul is uneconomical, are not covered in the overhaul manual.

Structural Repair Manual

This manual contains information and specific instructions from the manufacturer for repairing primary and secondary structure. Typical skin, frame, rib, and stringer repairs are covered in this manual. Also included are material and fastener substitutions and special repair techniques.

Illustrated Parts Catalog

This catalog presents component breakdowns of structure and equipment in disassembly sequence. Also included are exploded views or cutaway illustrations for all parts and equipment manufactured by the aircraft manufacturer.

Federal Aviation Regulations (FAR)

Federal Aviation Regulations were established by law to provide for the safe and orderly conduct of flight operations and to prescribe airmen privileges and limitations. A knowledge of the FARs is necessary during the performance of maintenance, since all work done on aircraft must comply with FAR provisions.

Aircraft Logs

"Aircraft logs" as used in this handbook is an inclusive term which applies to the aircraft log-book and all supplemental records concerned with the aircraft. The logs and records provide a history of maintenance and operation, control of maintenance schedules, and data for time replacements of components or accessories.

The aircraft logbook is the record in which all data concerning the aircraft is recorded. Information gathered in this log is used to determine the aircraft condition, date of inspections, time on airframe and engines. It reflects a history of all significant events occurring to the aircraft, its components, and accessories, and provides a place for indicating compliance with FAA Airworthiness Directives or manufacturers' service bulletins.

Airworthiness Directives

A primary safety function of the Federal Aviation Administration is to require correction or unsafe conditions found in an aircraft, aircraft engine, propeller, or appliance when such conditions exist and are likely to exist or develop in other products of the same design. The unsafe condition may exist because of a design defect, maintenance, or other causes. FAR Part 39, Airworthiness Directives, defines the authority and responsibility of the administrator for requiring the necessary corrective action. The Airworthiness Directives (AD) are the media used to notify aircraft owners and other interested persons of unsafe conditions and to prescribe the conditions under which the product may continue to be operated.

Airworthiness Directives are Federal Aviation Regulations and must be complied with, unless specific exemption is granted.

Airworthiness Directives may be divided into two categories: (1) Those of an emergency nature requiring immediate compliance upon receipt and (2) those of a less urgent nature requiring compliance within a relatively longer period of time.

The contents of Ads include the aircraft, engine, propeller, or appliance model and serial numbers affected. Also included are the compliance time or period, a description of the difficulty experienced, and the necessary corrective action.

Type Certificate Data sheets

The type certificate data sheet describe the type design and sets forth the limitations prescribed by the applicable Federal Aviation Regulations. It also include any other limitations and information found necessary for type certification of a particular model aircraft.

Type certificate data sheets are numbered in the upper right-hand corner of each page. This number is the same as the type certificate number. The name of the type certificate holder, together with all of the approved models, appears immediately below the type certificate number. The issue date completes this group, which is enclosed in a box to set it off.

The data sheet is separated into one or more sections. Each section is identified by a Roman numeral followed by the model designation of the aircraft to which the section pertains. The category or categories in which the aircraft can be certificated are shown in parentheses following the model number. Also included is the approval date shown on the type certificate.

The data sheet contains information regarding:

1. Model designation for all engines for which the aircraft manufacturer obtained approval for use with this model aircraft.
2. Minimum fuel grade to be used.
3. Maximum continuous and takeoff ratings of the approved engines, including manifold pressure (when used), r.p.m., and horse-power (hp).
4. Name of the manufacturer and model designation for each propeller for which the aircraft manufacturer obtained approval will be shown together with the propeller limits and any operating restrictions peculiar to the propeller or propeller-engine combination.
5. Airspeed limits in both m.p.h. and knots.

6. Center of gravity range for the extreme loading conditions of the aircraft is given in inches from the datum. The range may also be stated in percent of MAC (Mean Aerodynamic Chord) for transport category aircraft.
7. Empty weight c.g. range (when established) will be given as fore and aft limits in inches from the datum. If no range exists, the word “none” will be shown following the heading on the data sheet.
8. Location of the datum.
9. Means provided for leveling the aircraft.
10. All pertinent maximum weights.
11. Number of seats and their moment arms.
12. Oil and fuel capacity.
13. Control surface movements.
14. Required equipment.
15. Additional or special equipment found necessary for certification.
16. Information concerning required placards.

It is not within the scope of this handbook to list all the items that can be shown on the type certificate data sheets. Those items listed above are merely to acquaint aviation mechanics with the type of information generally included on the data sheets.

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CHAPTER-14
SCHEMATIC DIAGRAMS &WIRING DIAGRAMS

SCHEMATIC DIAGRAM

Schematic diagrams do not indicate the location of individual components in the aircraft, but do locate components with respect to each other within the system. Figure 14.1 illustrates a schematic diagram of an aircraft hydraulic system. The hydraulic pressure gage is not necessarily located above the landing gear selector valve in the aircraft; however, it is connected to the pressure line that leads to the selector valve.

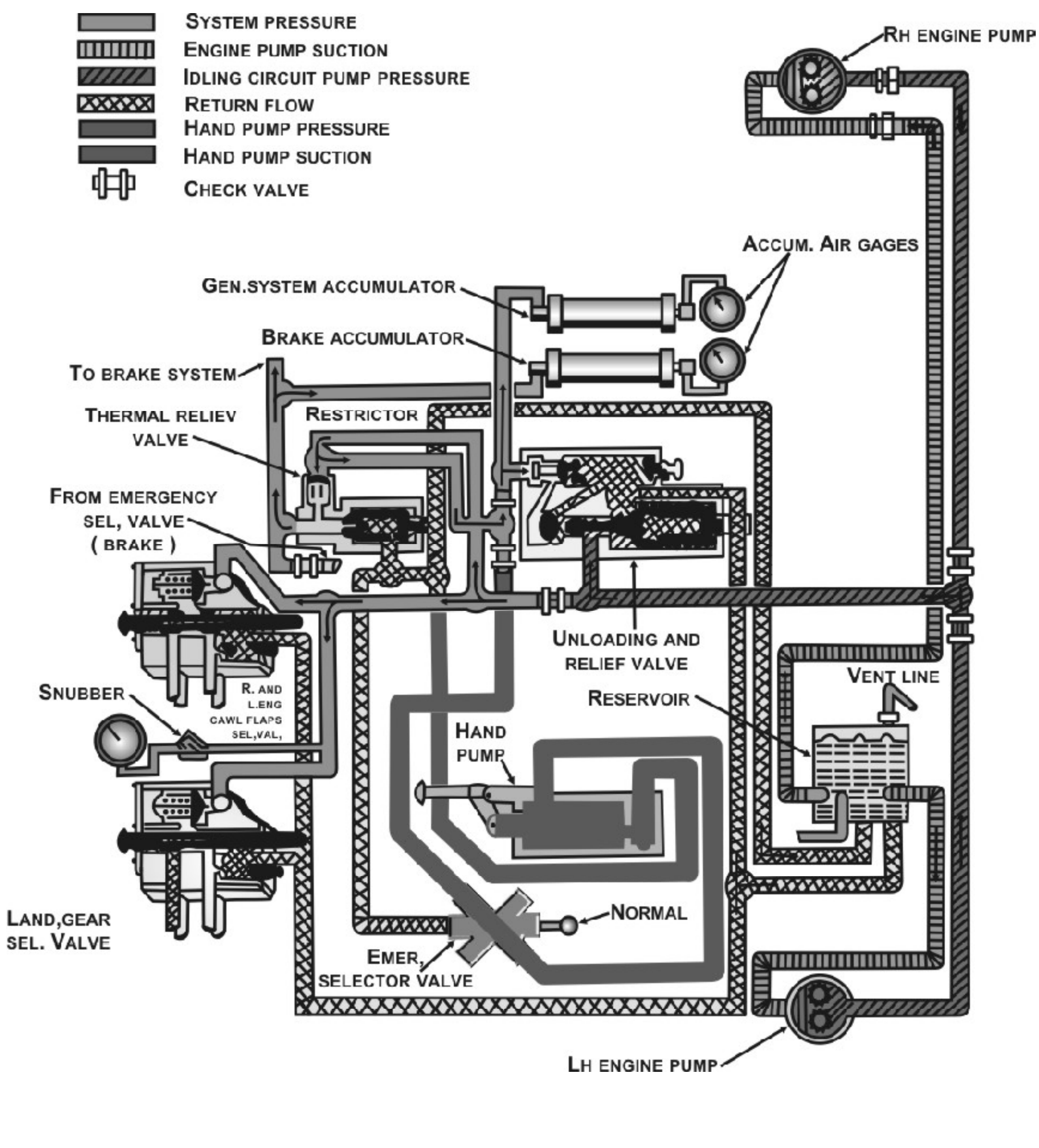

Fig. 14.1. Aircraft hydraulic system schematic

Schematic diagrams of this type are used mainly in trouble-shooting. Note that each line is coded for ease of reading and tracing the flow. Each component is identified by name, and its location within the system can be ascertained by noting the lines that lead into and out of the unit.

In tracing the flow of fluid through the system, it can be seen that the engine-driven pumps receive a supply of fluid from the reservoir. One-way check valves are installed in both left and right pump pressure lines so that failure of one pump will not render the pressure from the other pump ineffective. Fluid flows to the relief side of the unloading and relief valve, and through the check valve, which will hold pressure built up beyond this point. Pressure is then directed through all lines leading to each selector valve, where it is checked if no units are being operated.
Pressure builds up in the line routed to the control port of the unloading valve and begins to charge the system accumulator. Pressure to charge the brake accumulator is routed through a check valve incorporated in the thermal relief valve; this prevents the pressure from returning to the general system.

Although the general system accumulator starts charging at the same time, it will not charge as fast, because the fluid passes through a restrictor valve. The general system pressure will bleed into the brake system whenever the brake pressure drops below system pressure.

As soon as the pressure reaches the relief valve setting, the valve will open slightly. General system pressure increases until it reaches the value established as the system operating pressure. At this point, through the line leading to the control part of the unloading valve, the pressure will force the unloading and relief valve completely open. The pressure trapped in the system by the one-way check valve holds the value open to create an idling circuit, which prevails until some unit of the hydraulic system is operated.

Schematic diagrams, like installation diagrams, are used extensively in aircraft manuals.

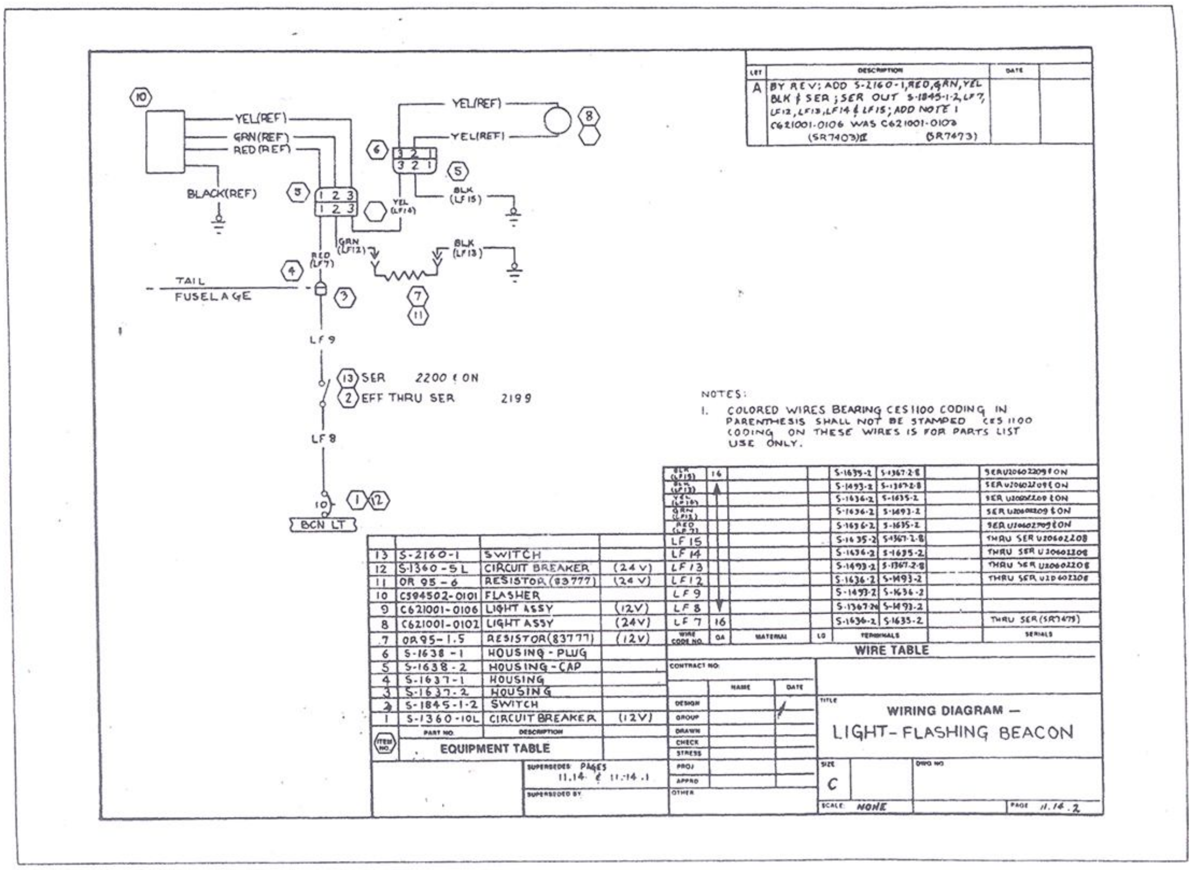

Fig.14.2. A schematic diagram of a portion of an aircraft electrical system.

This is the type of wiring diagram that is of most importance to us as aircraft maintenance technicians. From a schematic diagram, we can get the information needed to troubleshoot and service the equipment, and since this type of diagram is used in the manufacturer's maintenance manuals, they are FAA-approved data. In the typical diagram of figure 14.2, we have the information we need to service this particular flashing beacon light. In the equipment table, we can find the part number of each of the components, and in the wire table, we have the wire gage and a list of the various electrical connectors. The symbols used for aircraft schematics vary somewhat from one manufacturer to the next, but the symbols shown in figure 8.4 are typical of the ones you are most likely to encounter.

WIRING DIAGRAMS

There are a number of different types of electrical diagrams available to help us understand the electrical systems we are called upon to service. These include the block diagram, the pictorial diagram, and the schematic diagram. We will take a brief look at each of these types.

1. Block Diagrams

The block diagram uses very few component symbols, but rather uses blocks to tell us how a particular portion of the system operates. In figure14.3, we have a block diagram of the power system of a Boeing 727 aircraft. From this diagram, we can tell nothing about the wires required or the types of components, but the interrelation between the parts of the system is clear. We can tell what each generator does, and visualize the way each of the relays and breakers tie the system together, and the way in which we can isolate portions of the circuit. A block diagram gives us an overview of a system in the simplest way.

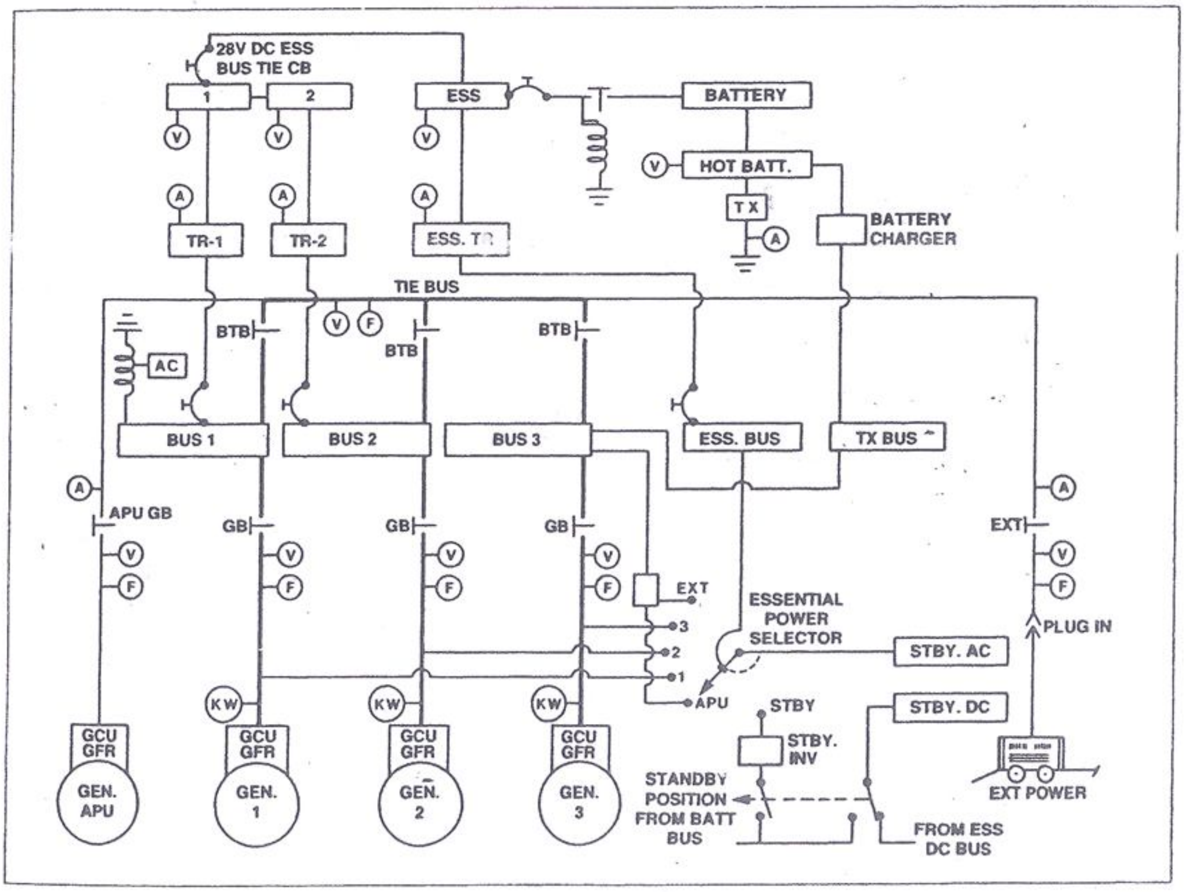

Fig. 14.3. Block diagram of the electrical system of a Boeing 727 jet transport aircraft.

2. PICTORIAL DIAGRAMS

The symbols used on an electrical schematic are actually a language of their own and are often unintelligible to persons not schooled inn their use. In figure 14.4, we have a pictorial diagram of the electrical system used in a popular single-engine aircraft. You will notice that this is a sort of mixture of a block diagram and schematic. You can identify such components as the alternator, the starter, the battery, and the ignition switch, but you do not know the wire sizes needed, or part numbers of any of the components. This type of drawing is extremely helpful for understanding the operation of a system, and of seeing the interrelationship between parts.

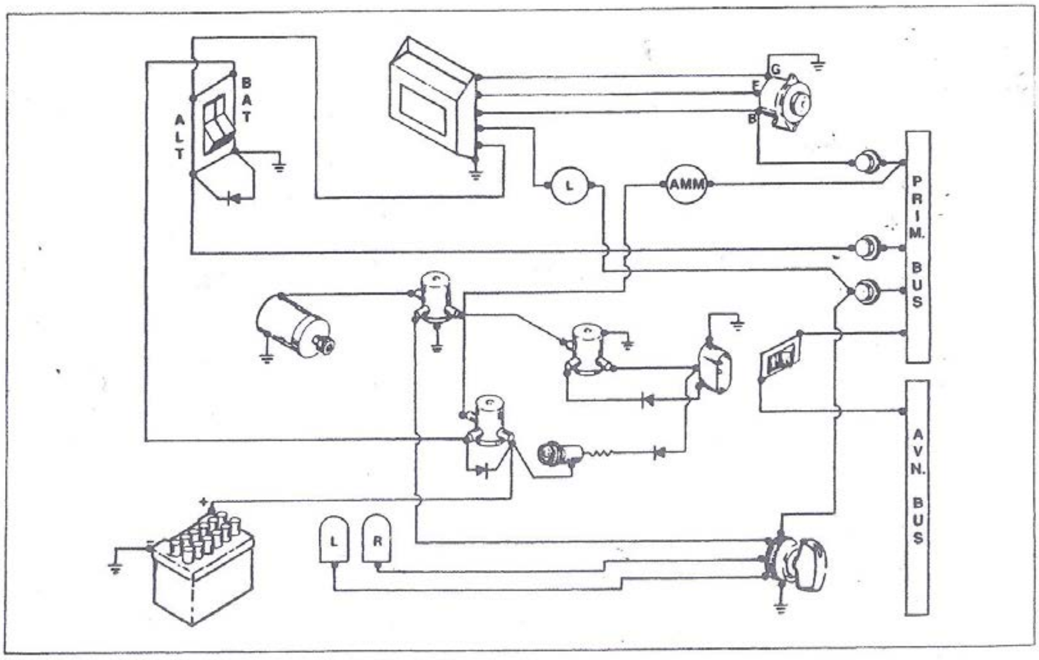

Fig.14.4. A Pictorial diagram of an aircraft electrical system.

■■■

CHAPTER-15
FITS AND CLEARANCES

FITS AND CLEARANCE

1. For ease of manufacture and case of replacement it is essential that the components of similar mechanisms should be interchangeable. For this reason limit systems are now in general use. For this reason limit systems limit are now in general use. These ensure that if any two mating parts are manufactured to the limits called for on the drawing, they will assemble without any hard fitting. Various limit systems have been devised. Many manufacturers of air frames, engines and armament, work to systems of their own, but for general engineering use the two principal systems employed are the Newall and the British Standard.

2. Both Newall and British Standard systems are devised are devised on the "Hole" basis, that is made as near to the nominal size as the limits workmanship demand while the different types of fits are obtained by varying the size of shaft. (The term "shaft" is here used to include bolt, pins, etc.). There are two grades of holes used in the Newall System, Class A and Class B, the former being machined to finer limits than the latter. In the British Standard there are four grades for bilateral holes (K.X.Y.Z.) and four grades for unilateral (B.U.V.W.) the letters in each case being arranged in decreasing order of limit fineness.

CLASS OF FITS

There are three principal types of fits, "Interference" in which the shaft is larger than the hole. "Transition" where the shaft and hole are approximately the same size, and 'Clearance" where the hole is larger than the shaft. These are shown diagrammatically as follows.

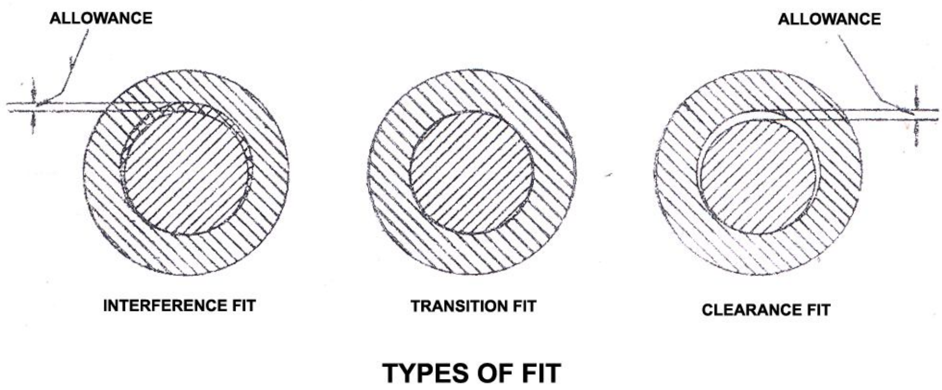

Fig.15.1

Type of Hit	Class of Fit	Shaft Required	Remarks
Clearance	**Running**	(X) (Y) (Z)	Suitable for various types of moving parts.
Transition	**Push**	(P)	Slight manual effort is required to assemble the parts. Suitable for detachable or locating parts but not for moving parts.
Interference	**Driving**	(D)	These are a little less tight than Force Fits, and one part can be driven into the other.
	Force	(F)	Mechanical pressure is required for assembly and once assembled no dismantling is likely to be required.

DRILL SIZES

These are three methods used to indicated 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.15.2)

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	....	....

Millimeter	Dec. Equiv.	Fractional	Number
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	....

Millimeter	Dec. Equiv.	Fractional	Number
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

Millimeter	Dec. Equiv.	Fractional	Number
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	....	....

Millimeter	Dec. Equiv.	Fractional	Number
....	.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	....

Millimeter	Dec. Equiv.	Fractional	Number
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. 15.2, Drill sizes 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 to tell the exact size of a given drill there are several commercially produced gauges available that simplify this task. (Figure 15.3)

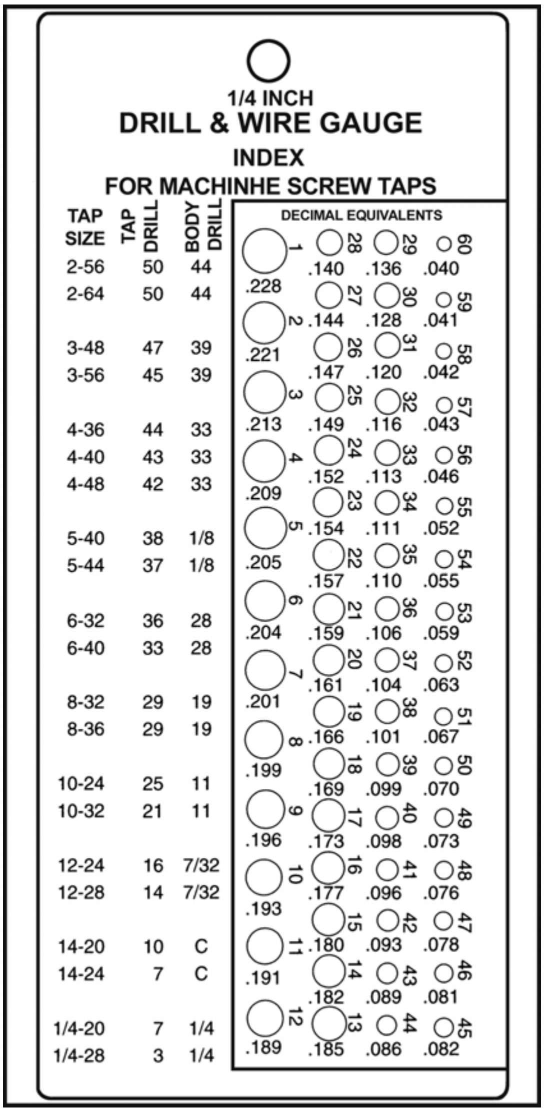

Fig. 15.3, Most drill gauges have holes in which you insert a drill in the appropriate hole. The gauge illustrated above also indicates tap sizes so you can drill the proper size hole for a tap.

Twist Drill Sizes

The size of a drill is usually marked on its shank. To ensure uniformity between manufacturers and the British Standards Institution has formulated specification for all twist drill of British Origin. These specifications indicate, among other features, the diameter of drills in all their different ranges. Details of the ranges used in service are as follows:-

Letter Series : "A" (0.234") to "Z" (0.413")

Number Series: No.60(0.40") to No.1: (0.028").

Fractional Series: The minimum size is 1/64 in diameter, proceeding by steps of 1/64 in. to 1 in. diameter; then by steps of 1/32 in. to $1^{7/16}$ in diameter; then by steps of 1/16" to $1^{3/4}$".

Schedule of Fits and Clearances For Aircraft & Engine

A Schedule of Fits and clearances is issued for each mechanism used on aircraft, e.g.. airframe aero-engine and armament components, etc. The specimen page illustrated, extracted, refers to parts of a hydraulic component. The schedule shows dimensions for each part under four headings:-

Dimension, New	Clearance, New
Permissible Worn Dimension	Permissible Worn Clearance

The "Diagram Ref. No." refers to a drawing to show exact details of the part referred to.

Parts and description		Dimension New	Permissible worm dimension	Clearance New	Permissible worm clearance	Remarks
Shaft collars in transfer plates	Transfer plate, bore	0.750 0.752	0.756	0.002 0.006	0.008	Shaft collars and end bushes are selected for with in accordance with repair schedule.
	Shaft collar, 0/dia.	0.746 0.748	0.742			
End bush in rear cover	End cover, bore	0.750 0.752	0.754	0.002 0.006	0.006	
	End bush, 0/dia	0.746 0.748	0.744			
Shaft bush in mounting and cover	End cover, bore	0.750 0.752	0.754	0.002 0.006	0.006	
	Shaft bush, 0/dia	0.746 0.748	0.744			

Limits for Bow/ Twist

When taper or ovality is found in measuring a shaft, the minimum size anywhere along the shaft must be taken to ensure that it is not derical bore, the maximum size must not exceed the permissible worm dimension.

A method of guaging the depth of such a depression is by mounting a dial test indicator on a special adaptor block as illustrated in Figure 15.4. The bottom edge of the block should be straight and reduced to about 1.2 mm (0.05 in), and the dial test indicator (DTI) stem should be at right angles to this edge. The point of the conical anvil should be lightly stoned to avoid scratching the surface of the depression.

When gauging the depth of a depression, a reading should first be taken at two points, adjacent to but unaffected by the depression (such as A and B in Figure 15.4), then the maximum depth reading (D) should be taken. By subtracting the average of the two point readings $\frac{A+B}{2}$ from the depth reading (D) the actual depth of the depression will be obtained thus: depth of depression= $D-\frac{A+B}{2}$.

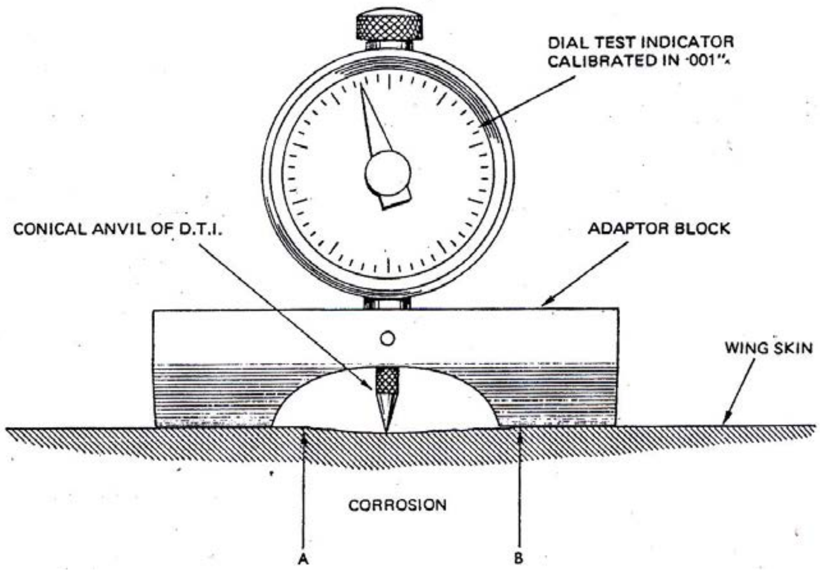

Fig. 15.4 Measurement of Surface Damage

Bowing Limits. To measure the amount of bow in a structural member (e.g. a strut), a straight edge and a set of feeler gauges can be used, providing the part to be measured is free from protruding fittings and the straight edge can be applied directly along the surface of the member. The straight edge should be placed along the entire length of the member and parallel to its axis, then by inserting feeler gauges at the point of maximum clearance the amount of bow can be calculated by the formula:- $Bow = \frac{Clearance\ mearsured\ by\ feeler\ gauges}{Length\ of\ member}$

For example, if the length of the member is 2 ft and the clearance measured by the feeler gauge is 0.040 in, the amount of bow is:

$$Bow = \frac{0.040}{24.0} = \frac{4}{2400} = \frac{1}{600} \text{ or 1 in 600}$$

NOTE : In general a maximum bow of 1 in 600 is normally acceptable unless otherwise stated in the Repair Manual. However, in some instances the manual may permit tolerances for bow greater than this figure.

To measure a member which has protruding fittings, a trammel fitted with three pointers can be used to bridge the fittings. The three pointers can be used to bridge the fittings. The three points should be checked for truth against a straight edge or surface table and adjusted if necessary. The outer points should be placed at the ends of the member and any clearance between the member and the centre point checked with a feeler gauge, the amount of bow being calculated as in paragraph.
For more accurate measurement the central trammel point can be replaced by a depth gauge in which case the neutral reading on the depth gauge in relation to the outer points should be carefully noted by checking on a surface table.

Curved Sections. When checking the maximum depth of a depression in a curved surface (e.g. a leading edge), the adaptor block or the trammel must be placed over a line at right-angles to the curvature of the part, i.e. parallel to the longitudinal axis of the curve.

Limits for -Wear

(a) **Dimension New**. This is the size of the part when new, showing the tolerance. The outside diameter of the shaft collar when new must be between the low limit of 0.746 in., and the high limit of 0.748 in, (tolerance 0.002 in.).

(b) **Permissible worn Dimension.** This is the size to which a part may wear before it must be rejected as unserviceable. Thus the shaft collar diameter may be worn to 0.742 in (wear of 0.004 in on the low limit size) before being rejected. Parts which are worn beyond this dimension can be used again provided a suitable mating part is chosen to keep the clearance within the permissible figure; this will frequently involve choosing a new part to mate with the worn part.

(c) **Clearance New.** This is the desired clearance limit form. eg. Shaft Collar in transfer plate-low limit. 0.002 in.

clearance-high limit 0.006 in. clearance. Interference fits are quoted as negative clearances.

(d) **Permissible Worn Clearance.** This is the maximum allowable clearance when re-assembling the component.

LUBRICATION

Adequate lubrication is essential for all types of rolling bearings. The purpose 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 bearing 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; these bearings cannot normally be re-packed with grease, and when un serviceable, must be rejected. Wheel bearings are normally tapered roller bearing, 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 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 ensure 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, 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. Bearing 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.

INSPECTION AFTER REMOVAL

After removal and cleaning, bearings should be inspected for corrosion, pitting, fracture, chip, discoloration and excessive internal clearances. With self-aligning bearing 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 raceway 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 housing 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 redial loads in either direction. The outer 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

Bearing 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-16
ELECTRICAL CABLES AND CONNECTORS

TYPES OF WIRES AND CABLES

Wires and cables are designed and manufactured for duties under specific environmental conditions and are selected on this basis. This ensures functioning of distribution and consumer systems, and also helps to minimize risk for fire and structural damage in the event of failure of any kind. Table 16.1 gives details of some commonly used general service wires and cables of U.K. manufacture, while typical constructional features are illustrated in (Fig 16.1).

The names adopted for the various types are derived from contractions of the names of the various insulating materials used. For example, "NYVIN" is derived from "Nylon" and from polyVINyl-chloride (P.V.C.); and "TERSIL" is derived from polyester and Silicone. Cables may also be further classified by prefixes and suffixes relating to the number of cores and any additional protective covering. For example, "TRINYVIN" would denote a cable made up of three single Nyvin cables, and if suffixed by "METSGEATH" the name would further denote that the cable is enclosed in a metal braided sheath.

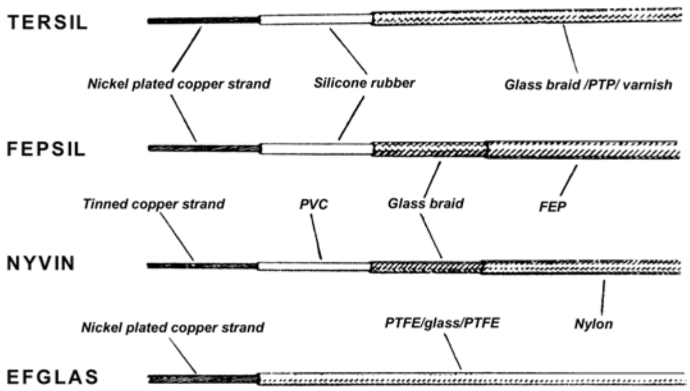

Fig. 16.1. Constructional features of some typical cables.

It will be noted from the Table that only two metals are used for conductors, i.e. copper (which may also be tinned, nickel-plated or silver-plated depending on cable application) and aluminium. Copper has a very low specific resistance and is adopted for all but cables of large cross-sectional areas. An aluminium conductor having the same resistance as a copper conductor, has only two-thirds of the weight but twice the cross-sectional area of the copper conductor. This has an advantage where low-resistance short-term circuits are concerned; for example, in power supply circuits of engine starter motor systems.

The insulation materials used for wires and cables must conform to a number of rigid requirements such as, toughness and flexibility over a fairly wide temperature range, resistance to fuels, lubricants and hydraulic fluids, ease of stripping for terminating, non-flammability and minimum weight. These requirements, which are set out in standard specifications, are met by the materials listed and in the selection of the correct cable for a specific duty and environmental condition.

To ensure proper identification of cables, standard specification also require that cable manufacturers comply with a code and mark outer protective coverings accordingly. Such a coding scheme usually signifies, in sequence, the type of cable, country of origin ("G" for U.K. manufacturers) manufacturer's code letter, year of manufacture also by a letter, and its wire gauge size, thus, NYVIN G-AN 22. A colour code scheme is also adopted particularly as a means of tracing the individual cores of multicore cables to and from their respective terminal points. In such cases it is usual for the insulation of each core to be produced in a different colour and in accordance with the appropriate specification. Another method of coding, and one used for cables in three-phase circuits of some types of aircraft, is the weaving of a coloured trace into the outer covering of each core; thus red-(phase A); yellow - (phase B); blue - (phase C). The code may also be applied to certain single-core cables by using a coloured outer covering.

CONNECTORS

Connectors (plugs and receptacles) facilitate maintenance when frequent disconnection is required. Since the cable is soldered to the connector inserts, the joints should be individually installed and the cable bundle firmly supported to avoid damage by vibration. Connectors have been particularly vulnerable to corrosion in the past, due to condensation within the shell. Special connectors with waterproof features have been developed which may replace non waterproof plugs in areas where moisture causes a problem. A connector of the same basic type and design should be used when replacing a connector. Connectors that are susceptible to corrosion difficulties may be treated with a chemically inert waterproof jelly. When replacing connector assemblies, the socket-type insert should be used on the half which is "live" or "hot" after the connector is disconnected to prevent unintentional grounding.

Types of Connectors

Connectors are identified by AN numbers and are divided into classes with the manufacturer's variations in each class. The manufacturer's variations are differences in appearance and in the method of meeting a specification. Some commonly used connectors are shown in (Fig. 16.2). There are five basic classes of AN connectors used in most aircraft. Each class of connector has slightly different construction characteristics. Classes A, B, C, and D are made of aluminum, and class K is made of steel.

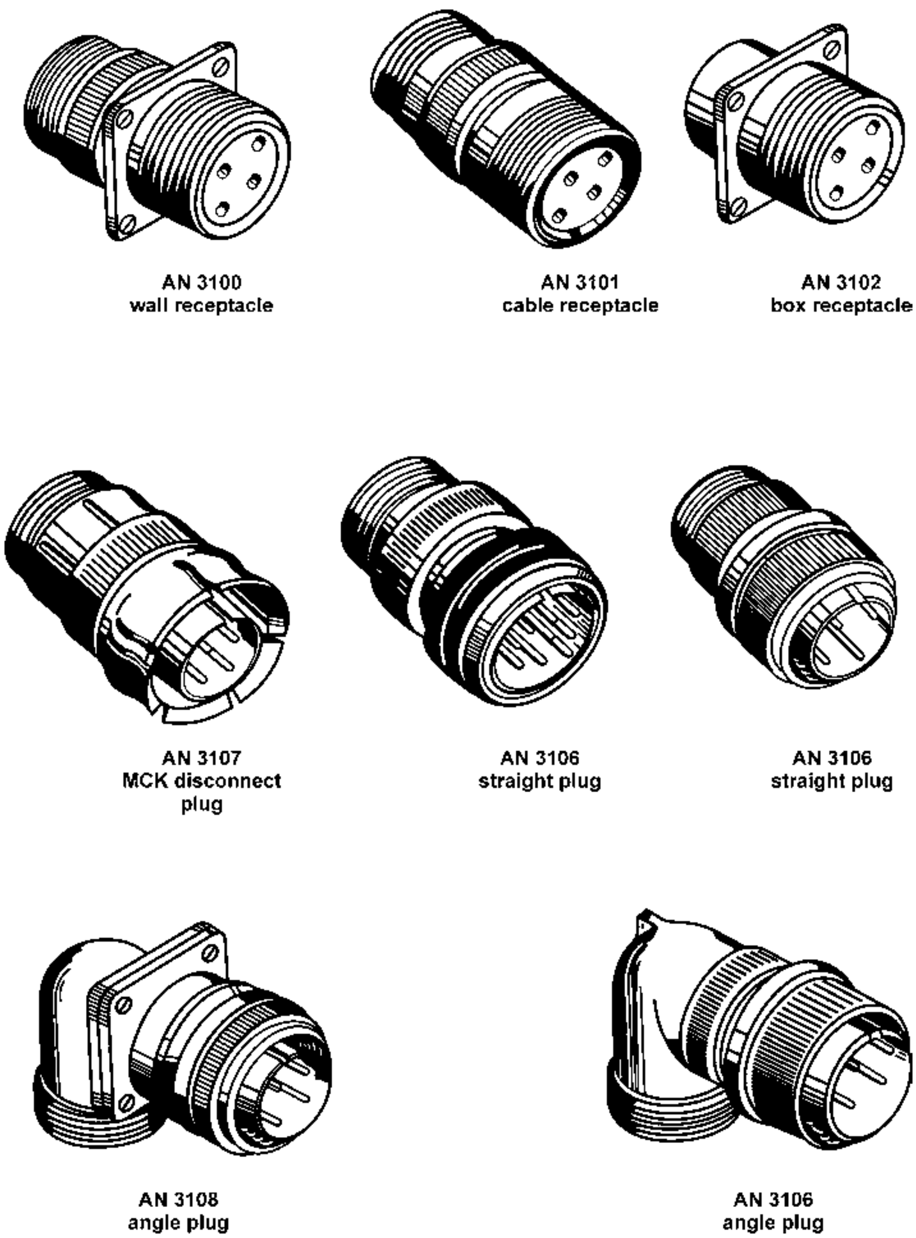

Fig. 16.2. AN connectors.

1. Class A-- Solid, one-piece back shell general-purpose connector.
2. Class B-- Connector back shell separates into two parts lengthwise. Used primarily where it is important that

the soldered connectors are readily accessible. The back shell is held together by a threaded ring or by screws.

3. Class C--A pressurized connector with inserts that are not removable. Similar to a class A connector in appearance, but the inside sealing arrangement is sometimes different. It is used on walls or bulkheads of pressurized equipment.
4. Class D-- Moisture and vibration-resistant connector which has a sealing grommet in the back shell. Wires are threaded through tight-fitting holes in the grommet, thus sealing against moisture.
5. Class K--A fireproof connector used in areas where it is vital that the electric current is not interrupted, even though the connector may be exposed to continuous open flame. Wires are crimped to the pin or socket contacts and the shells are made of steel. This class of connector is normally longer than other connectors.

Connector Identification

Code letters and numbers are marked on the coupling ring shell to identify a connector. This code (Fig. 16.3) provides all the information necessary to obtain the correct replacement for a defective or damaged part.

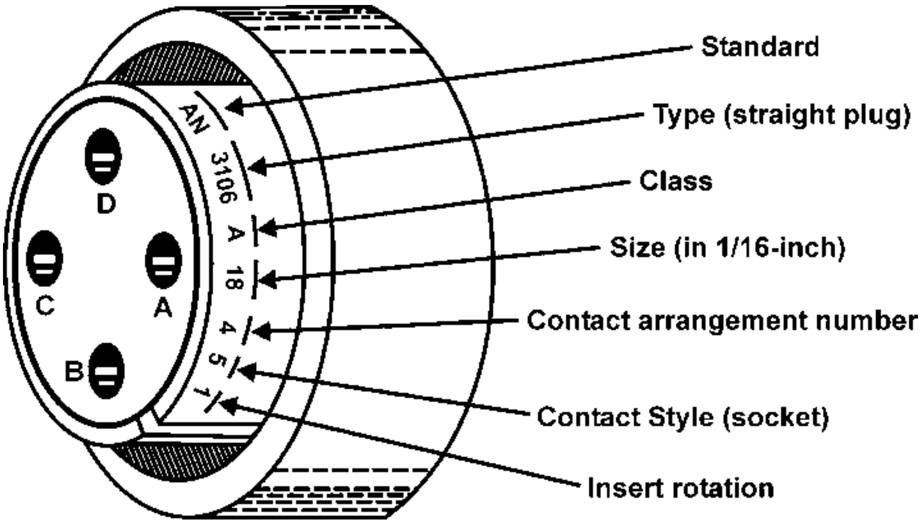

Fig. 16.3. AN connector marking.

Many special-purpose connectors have been designed for use in aircraft applications. These include subminiature and rectangular shell connectors, and connectors with short body shells, or of split-shell construction.

Installation of Connectors

The following procedures outline one recommended method of assembling connectors to receptacles :

1. Locate the proper position of the plug in relation to the receptacle by aligning the key of one part with the groove or keyway of the other part.
2. Start the plug into the receptacle with a slight forward pressure and engage the thread of coupling ring and receptacle.
3. Alternately push in the plug and tighten the coupling ring until the plug is completely seated.
4. Use connector pliers to tighten coupling rings one-sixteenth to one-eighth of a turn beyond finger tight if space around the connector is too small to obtain a good finger grip.
5. Never use force to mate connectors to receptacles. Do not hammer a plug into its receptacle, and never use a torque wrench or pliers to lock coupling rings.

A connector is generally disassembled from a receptacle in the following manner :

1. Use connector pliers to loosen coupling rings which are too tight to be loosened by hand.
2. Alternately pull on the plug body and unscrew the coupling ring until the connector is separated.
3. Protect disconnected plugs and receptacles with caps or plastic bags to keep debris from entering and causing faults.
4. Do not use excessive force, and do not pull on attached wires.

"POTTING"

This is a technique usually applied to plugs and sockets which are to be employed in situations where there is the possibility of water or other liquids passing through the cable entry. It eliminates elaborate cable ferrules, gland nuts,

etc., by providing a simple plastic shroud with sufficient height to cover the terminations, and filling the cavity with a special compound which though semi-fluid in its initial condition, rapidly hardens into a rubbery state to form a fairly efficient seal. In addition to sealing it provides reinforcement for the cable connections.
The potting compound consists of a basic material and an alkaline or acid base material (known as an "accelerator") which are thoroughly mixed in the correct proportion to give the desired consistency and hardness of the compound. Once mixed, the compound is injected into a special mould and allowed to set. When the mould is removed, the resilient hemispherically-shaped insulation extends well into the plug or socket, bonding itself to the back of the insulant around the contact and conductor joints and partly out along the conductor insulation.

CONTINUITY TESTING

A concealed break in a cable core or at a connection may be found by using a continuity tester which normally consists of a low voltage battery (2.5 volts is satisfactory) and a test lamp or low reading voltmeter.

NOTE: In some testers incorporating a test lamp, semiconductors are included in the test lamp circuit and, to prevent damage, the currents should be limited to 120 milliamps.

Before testing, the main electrical supply should be switched off or disconnected. A check should be made that all fuses are intact and that the circuit to be tested is not disconnected at any intermediate point. All switches and circuit breakers, as appropriate, should be closed to completed the circuit.

When carrying out a low voltage continuity check, it is essential to work progressively through the circuit, commencing from the relevant fuse or circuit breaker and terminated at the equipment. Large circuits will probably have several parallel paths and these should be progressed systematically, breaking down as little as possible at plug and socket or terminal block connections. In testing of this nature, it is valueless to check several low resistance paths in parallel.

INSULATION RESISTANCE TESTING

In the following paragraphs general test procedures are outlined; however, as a result of the wide variation in electrical installation and equipment which exists with different aircraft, the routing charts and Approved Test Schedule for the aircraft concerned must be consulted. All ancillary equipment should be tested separately in accordance with the appropriate manufacturers' publications.

After installation and where specified in the Approved Maintenance Schedule or Test Schedule, aircraft circuits should be tested by means of a 250-volt insulation tester which should have its output controlled so that the testing voltage cannot exceed 300 volts. In all systems having normal voltages over 30 volts, cables forming circuits essential to the safety of the aircraft should be tested individually. Other circuits may be connected in groups for test. However, the number of circuits which may be grouped for test is governed by the test results; where the insulation resistance so measured is found to be less than the appropriate minimum value stated in second paragraph of Test Results, the number of circuits grouped together should be reduced.

NOTE: Information on the testing of magneto earthing circuits is given in Leaflet EL / 3-9 of CAIP.

Immediately after an insulation test, functioning checks should be made on all the services subjected to the test. If the insulation test or subsequent functioning tests should reveal a fault, the fault should be rectified and the insulation and functioning tests should be repeated in that sequence on the affected circuits.

BONDING

Bonding is the electrical interconnection of metallic aircraft parts (normally at earth potential) for the safe distribution of electrical charges and currents.

FUNCTION OF BONDING

Bonding provides a means of protection against charges as a result of the build-up of precipitation, static, and electrostatic induction as a result of lightening strikes so that the safety of the aircraft or its occupants is not endangered. The means provided are such as to (a) minimise damage to the aircraft structure or components, (b) prevent the passage of such electrical currents as would cause dangerous malfunctioning of the aircraft or its equipment, and (c) prevent the occurrence of high potential differences within the aircraft. Bonding also reduces the possibility of electric shock from the electrical supply system reduces interference with the functioning of essential services (e.g. radio communications and navigational aids) and provides a low resistance electrical return path for electric current in each return systems.

BONDING TECHNIQUE AND TEST

The skin of an all-metal aircraft is considered adequate to ensure protection against lighting discharge provided that the method of construction is such that it produces satisfactory electrical construction is such that it produces satisfactory electrical contact at the joints.

NOTE: An electrical contact with a resistance less than 0.05 ohm is considered satisfactory.
With regard to aircraft of non-metallic or composite construction, a cage, consisting of metallic conductors having a surge carrying capacity at least carrying capacity at least equal to that required for primary conductors and to which metal parts are bonded, forms part of the configuration of the structure and must conform to the requirements of chapter D4-6 of BCAR.

The earth system which in the case of aircraft of metallic construction is normally the aircraft structure and for aircraft of nonmetallic construction is the complete bonding system, must be automatically connected to the ground on landing. This is normally achieved through the nose or tail wheel tyre, which is impregnated with an electrically conducting compound, to provide a low resistance path.

NOTE: On some aircraft, a static discharge wick or similar device trailed from a landing gear assembly is used to provide ground contact on landing.

The reduction or removal of electrostatic charges which build up on such surfaces as glass figure reinforced plastic, can be achieved by the application of a paint, e.g. PR 934, which produces a conductive surface.

BONDING CONNECTIONS
When a bonding connection is to be made or renewed, it is essential that the conductor has the specified current-carrying capacity, since the bonding may have been designed to carry relatively high electrical loads, e.g. under circuit fall conditions.

The manufacturers of solid bonding strip and braided bonding cord usually quote the cross-sectional area on the relevant data sheet. However, in the case of renewal or repair, if the original conductor cannot be matched exactly, replacement manufactured of the same type of material, but of greater cross-sectional area, should be selected.

Braided copper or aluminium cords fitted at each end with connecting tags or lugs (usually referred to as 'bonding jumpers), should be used for bonding connections to aluminium cords, anti-oxidant (crimping) compound consisting of 50% by weight of zinc oxide in white petroleum jelly, and complying with DTD5503, should be applied to the connection.

Where applicable, the soldering of tags or lugs fitted to braided copper cord should be in accordance, with Leaflet BL/6-1, using a resin flux. Special care is necessary because over beating and cooling of conductors will cause brittleness, while a loss of flexibility up to 25.4 mm (1 inch) from the lug may occur as a result of the capillary action of the molten solder.

NOTE: Primary flexible conductor are often made of 600 strands of copper wire, 0-0048 inch in diameter, and formed in a flat braids approximately 0.625 inch wide.

All bonding connection should be properly locked to prevent intermittent contact which may be caused by vibration.

NOTE: Intermittent contact is worse than no contact at all.

Bonding connections should not interfere mechanically or electrically with any associated or adjacent equipment, and bonding jumpers should not be excessively tight or slack.

The run of all primary conductors should be as straight as possible; sharp bends must be avoided.

The number of location of bonding connections to the various components is important and this should be checked and verified by reference to the relevant drawing e.g. where an engine is not in direct electrical contact with its mounting it should be bonded with at least two primary conductors, one on each side of the engine.

In most instances the following joints are considered self-bonding, provided that all insulating materials (e.g. anoetic finish, paint storage compounds etc.) are removed from the contact faces before assembly, but if any doubt exists regarding the correctness of the bonds, a bonding test should be carried out:-

a. Metal-to-metal joints held together by threaded devices, reverted joints, structural wires under appreciable tension and bolted or clamped fittings.
b. Most cowling fasteners, locking and latching mechanisms.

c. Metal-to-metal hinges for doors and panels and metal-to-metal bearings (including ball bearings).

(i) In the case of bearings for control surface hinges it should be ascertained which bearings are classified as self bonding, e.g. metal-to-metal, nylon with conducting grease.

(ii) Where applicable, bonding jumpers for control surfaces should be as flexible and as short as possible, of as low impedance as is practicable and should not be tinned. The possibility of a jumper jamming the controls must be avoided.

FLEXIBLE BONDING CONNECTIONS

Flexible hose connections used for joining rigid pipes should be bonded by fitting clips around the pipes approximately 13 mm (1/2 inch) away from the hose, and bridging with a corrupted bonding strip or jumper; the practice of tucking the ends of bonding strips between the hose and the pipe is not recommended. To obtain good electrical contact the area under each clip should be cleaned and, after the clip has been fitted, protection should be restored.

Not only must the flexible hose connection be bridged, but each pipe run should be bonded to earth at each end, particularly within a radius of 2.42 meters (8 feet) of any unscrewed radio equipment or aerial lead, where earthing bonds should not be more than 1.5 meters (5 feet apart), or less distance apart, if called for by the manufacturer.

If bridging strips or bonding cords are fractured a new conductor should be fitted. The soldering of broken ends is prohibited.

High -pressure flexible pipe assemblies are usually self-bonding, but a bonding test should be made between the assembly end-couplings to prove the integrity of the bonding.

NOTE: The provisions of paragraph (3.6.2) above also apply to any long electrically-conducting parts (including metallic conduits and metal braiding) which are not insulated from earth.

When any bonding or earth connection is made to the structure or equipment, the specified standard of protection again corrosion should be provided.

After a non-conducting protective coating has been removed from the connecting area, the preferred sealing and anti-oxidant treatment as specified on the relevant drawing and specification should be carried out.

NOTE: Non-conducting protective treatments include all generally used priming and finishing paints, varnishes and temporary protectives, chromic, anoetic and phosphate coatings. Metallic coatings, such as cadmium and tin, are satisfactory conductors and should not be removed. If a polysulphide compound is used for sealing the earth or bonding point, it must be ensured that the anti-oxidant to be subsequently applied will not have a detrimental effect on the sealing. e.g. DTD 5503 should not be used.

When the connection has been made any excess compound should be wiped off, using a rag damped in methyl ethyl ketone (MEK) and the connection and adjacent area re-protected by the specified method, this depending on the materials concerned and the position of the connection.

When a 'corrosion washer' forms part of the connecting assembly, it should be correctly fitted and be of the correct material for the type of connection concerned.

NOTE: A corrosion washer is plated, or manufactured of a material having a potential such that when placed between materials of widely differing potential it reduces the risk of corrosion caused by electrolytic action.

EARTH TERMINALS

When earth-return terminal assemblies are fitted or replaced, the correct method of fitting to the structure, the corrosion protection required and the exact location on the structure should be carefully checked. The procedure for fitting and the number of terminations to be attached will vary with the design of the terminal assembly and the type of structure, therefore reference should be made to the relevant drawings and instructions to ensure both electrical and structural integrity.

(i) All earth terminal assemblies should be checked for resistance between the lug attachment point(s) and the surrounding structure and this must not exceed the figure specified for the aircraft concern (e.g. 0.025 ohm). When earth terminal assemblies are also used to carry electrical supplies, a millivolt drop test, as outlined in paragraph 4.3 must be carried out.

(ii) If the resistance in either case is unsatisfactory, the terminal assembly should be removed, the contacting faces cleared with a fine abrasive (e.g. aluminium wool) and reassembled using, where applicable, new corrosion washers. The connecting area should be sealed and treated with anti-oxidant compound as specified in the relevant drawing and specification.

NOTE: Leads connected to earth terminal assemblies should be of insulated cable with terminal tags fitted by the crimping method. It is important that the cable is of the specified gauge for the service concerned and is kept as short as possible.

BONDING TESTING

Special test equipment, comprising a meter and two cables each of specific length, is required for checking the resistance of an ohmmeter operating on the current ratio principle, and a single 1.2 volt nickel alkaline cell housed in a wooden carrying case. The associated cables are 60 feet and 6 feet in length, and are fitted with a single-spike probe and a double-spike probe respectively. Plug and socket connectors provide for quick-action connection of the cables to the instrument.

Prior to carrying out a bonding test, a check should be made on the state of the nickel-alkaline cell of the tester by observing.

a. that a full-scale deflection of pointer of the meter is obtained when the two spikes of the 6-foot cable probe are shorted by a suitable conductor; and
b. that the meter reads zero when the two spikes of the 6-foot cable probe are shorted with the single spike cable probe.

The 60-feet lead of the test equipment should be connected to the main earth (also known as the bond datum point) at the terminal points which are usually shown diagrammatically in the relevant Aircraft Maintenance Manual. Since the length of a standard bonding tester lead is 60 feet, the measurement between extremities of the larger types of aircraft may have to be done by selecting one or more main earth points successively, in which event the resistance value between the maim earth points chosen should be checked before proceeding to check the remote point.

NOTE: When connecting the 60-feet lead to an earthing point, any protective treatment (e.g. strippable lacquer) should be removed at the point of contact.

The 6-foot test lead should be used to check the resistance between selected points ; these are usually specified in the bonding test schedule or the Maintenance Manual for the aircraft concerned. When the two spikes of the test lead probe are brought into contact with the aircraft part, the test-meter will indicate, in ohms, the resistance of the bond.

As an alternative to the above, the four terminal method of resistance measurement maybe adopted with the appropriate milliammeter (see Fig.16.4). With this type of instrument, a test current (approximately 2 amps) is supplied by the internal batteries and passed through the resistance via cables C1 and C2. The voltage drop across the resistance is measured (P1 and P2) and compared with the current flowing. The resultant value is then displayed (normally digitally) on the meter. The test leads maybe in the form of duplex spikes (see Fig.16.5) or when used in association with crocodile type test leads, single spikes. In order to check that the instrument is functioning correctly, the two hand spikes should be placed on a low resistance conductor with the potential spikes (P1 and P2) closely together (see Fig.16.6). The result of this test should be a zero reading on the meter.

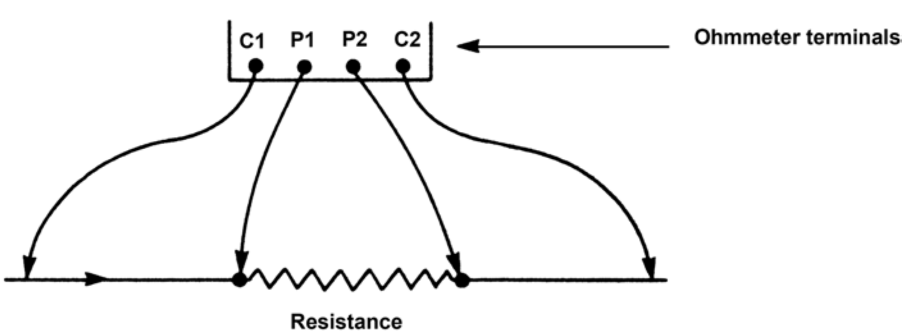

Fig. 16.4. Four terminal resistance measurement.

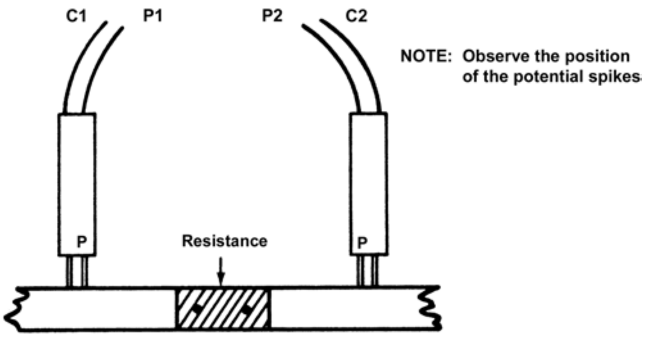

Fig. 16.5. Duplex hand spikes.

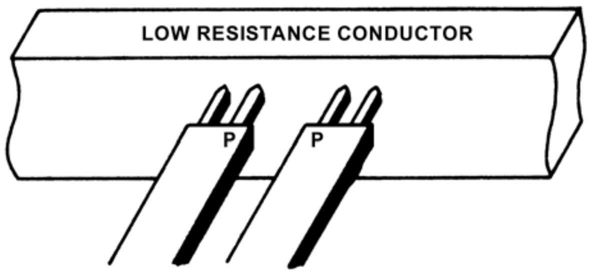

Fig. 16.6. Test position of hand spikes.

To ensure good electrical contact at the probe spikes, it may be necessary to penetrate or remove a small area of a non-conducting protective coating. Therefore, after test, any damage to the protective coating must be restored.

If the resistance at a bond connection is excessive, rectification action will depend on the type of connection. The following action should be taken for the more common types of connections:-

a. In the case of bonding jumpers, the connecting tag or lug should be removed and the contacting faces thoroughly cleaned, using a slight abrasive if necessary. The bare metal thus exposed should be only just large enough to accept the palm of the tag or lug. The connecting area should be sealed and treated with antioxidant as specified in the relevant drawing and specification.

NOTE: When an abrasive has been used it is important to ensure that all traces of it are removed.

b. Where equipment is bonded through a holding bolt, the bolt should be removed and the area under the bolt-head, or nut, thoroughly cleaned and protected as recommended in paragraph 3.10.7 (a). The correct washer (both with regard to size and material) should be fitted before the bolt is replaced and tightened.

c. Where the required bond value cannot be obtained at a structural joint the advice of the manufacturer should be sought.

NOTE: Corrosion tends to form at a bonding or earth connection and is often the cause of excessive resistance.

The resistance between the man in earth system and a metal plate on which the earthing device (e.g. tyre) is resting should be measured and should not exceed 10 megohms when measured with a 250 volt or 500 volt resistance tester, as specified in the test schedule.

NOTE: After carrying out tests, all areas where the protective coating has been removed should be re-protected using the appropriate scheme.

BONDING TESTER SERVICING

A tester requires little in the way of servicing, apart from periodic attention to the alkaline cell, which should be removed at prescribed intervals for routine servicing. When replacing the cell, it is most important that the polarity of connection is correct. The ohmmeter is normally sealed in its case and no attempt should be made to open it; if a fault should develop, then the complete instrument should be withdrawn from use and overhauled.

The leads are an integral part of the tester, and being carefully matched to the meter unit must not be modified or altered in any way. All contact surfaces of plug pins and probes must be kept scrupulously clean, and the points of the probe spikes should be reasonably sharp to give effective penetration of protective finishes, etc., on metal surfaces.

The accuracy of the tester should be checked periodically by using it to measure the resistance of standard test resistors. Normally, three such resistors are supplied for testing purposes and the readings obtained should be within 10% of the standard ohmic values.

Crimping Tools

Hand, portable power, and stationary power tools are available for crimping terminal lugs. These tools crimp the barrel of the terminal lug to the conductor and simultaneously crimp the insulation grip to the wire insulation.

Hand crimping tools all have a self-locking ratchet that prevents opening the tool until the crimp is complete. Some hand crimping tools are equipped with a nest of various size inserts to fit different size terminal lugs. Others are used on one terminal lug size only. All types of hand crimping tools are checked by gages for proper adjustment of crimping jaws.

Fig. 16.7 shows a terminal lug inserted into a hand tool. The following general guidelines outline the crimping procedure:

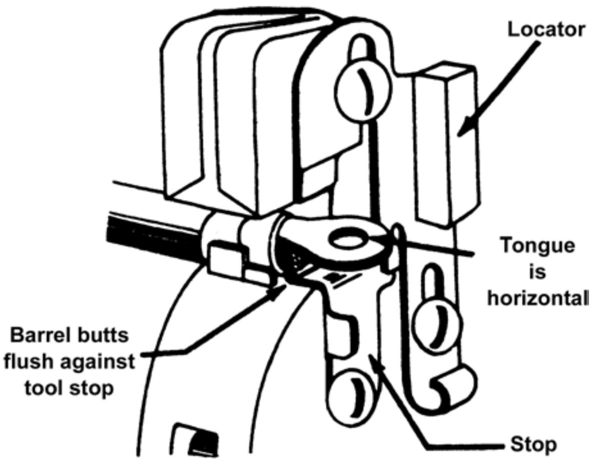

Fig. 16.7. Inserting terminal lug into hand tool.

1. Strip the wire insulation to proper length.
2. Insert the terminal lug, tongue first, into the hand tool barrel crimping jaws until the terminal lug barrel butts flush against the tool stop.
3. Insert the stripped wire into the terminal lug barrel until the wire insulation butts flush against the end of the barrel.
4. Squeeze the tool handles until the ratchet releases.
5. Remove the completed assembly and examine it for proper crimp.

CRIMP JOINTTESTING/ INSPECTION

Crimp joint testing measures the tension force required to pull apart or separate the components of a wire crimp, in most cases connected to a terminal or to another wire. The reliability of a multitude of products depends critically upon the this particular type of fastener.

Benefits of Crimp Joint Testing

- These include:
- Ensuring crimp joints are fit-for purpose
- Ensuring the safety and quality of products
- Reducing material costs and achieving lean manufacturing goals

- Compliance with industry standards

Standards

- A number of national, international and military standards have been developed for testing crimp joints including:
- ASTM B913
- BS5G 178 (Part 1)
- DEF STAN 59-71
- ISO 1966:1973
- MIL-C-39029, MIL-DTL-22520G, MIL-T-7928
- NASA-STD-8739-4
- SAE/AS7928
- UL486A

Such standards have generic similarities, each one defining a specific tensile load per cable gauge, which the crimp joint must be able to sustain without failure.

Connector pin removal and insertion

A connector insertion and removal tool for an electrical system including a circuit board and at least one electrical connector therefor includes a first portion configured for coupling to a first surface of the circuit board, and a second portion configured for coupling to the first portion. At least one of the first portion and the second portion comprises an actuator adapted for movement toward and away from the circuit board to contact at least a portion of the connector.

1. A connector insertion and removal tool for inserting and removing an electrical connector onto and from a circuit board having opposite first and second surfaces, said tool comprising: an installation mechanism configured to be positioned proximate the first surface of the circuit board, the installation mechanism being configured to inserted into a pin aperture field formed through the circuit board; and an extraction mechanism configured to be positioned proximate the second surface of the circuit board, the extraction mechanism being configured to remove the connector from the first surface of the circuit board, said installation and extraction mechanisms being coupled to one another; wherein at least one of said installation and extraction mechanisms comprises an actuator adapted for movement toward and away from the circuit board to insert and remove the connector onto and from the circuit board, said actuator comprising a plurality of extraction pins that are configured to align with and extend into the pin aperture field from the second surface toward the first surface of the circuit board, the extraction pins engaging the pins of the connector in the pin aperture field to force the connector from the first surface of the circuit board; wherein said extraction mechanism includes front and rear support plates, said the font the rear support plates, the actuator block being held stationary with respect to the front and rear support plates, the actuator element moving the extractor block toward and away from the second surface of the circuit board when the actuator element is rotated, the extractor block including the extraction pins.

2. The tool in accordance with claim 1 wherein said installation mechanism and said actuator include a groove and rib combination extending toward the first surface to guide said actuator toward and away from said the circuit board during insertion of the connector.

3. The tool in accordance with claim 1 wherein at least one of the installation and extraction mechanisms comprises at least one guide pin positioned to extend between the opposite first and second surfaces of the circuit board, said guide pin securing said installation mechanism to the first surface of the circuit board, said guide pin securing said installation mechanism to the first surface of the circuit board and securing said extraction mechanism to the second surface of the circuit board.

4. The tool in accordance with claim 1 further comprising nonconductive sections situated adjacent said actuator, thereby avoiding a conductive path through said tool.

5. The tool in accordance with claim 1 wherein said extraction mechanism comprises an alignment member configured to position the electrical connector with respect to a pin aperture field in the circuit board.

6. The tool in accordance with claim 1 wherein each of said installation mechanism and said extraction mechanism comprises a plurality of modular blocks mounted on the held stationary with respect to the circuit board, and at least one movable block configured to move toward and away from the circuit board.

7. The tool in accordance with claim 1 wherein at least one said installation mechanism and said extraction

mechanism comprises a positioning plate configured for sliding engagement with a guide track.

8. The tool in accordance with claim 1, further comprising a board guide pin that secures the installation and extraction mechanisms to one another with the circuit board supported therebetween, such that the installation and extraction mechanisms to one another with the circuit board supported therebetween, such that the installation and extraction mechanisms prevent flexure of the circuit board while inserting and removing the connector onto and from the circuit board.

9. The tool in accordance with claim 1, wherein the installation and extraction mechanisms engage and support the opposite first and second surface of the circuit board.

10. The tool in accordance with claim 1, further comprising guide pins that extend through guide openings in the circuit board, and securing elements threaded on the guide pins to secure the both-installation and extraction mechanisms to the circuit board.

11. A connector insertion and removal tool for inserting and removing an electrical connector onto and from a circuit board having opposite first and second surfaces, said tool comprising: an installation mechanism configured to be positioned proximate the first surface of the circuit board, the installation mechanism being configured to insert the connector onto the first surface of the circuit board; and an extraction mechanism configured to be positioned proximate the second surface of the circuit board, the extraction mechanism being configured to remove the connector from the first surface of the circuit board, said installation and extraction mechanisms comprises an actuator adapted for movement toward and away from the circuit board to insert and remove the connector onto and from the circuit board, said actuator comprising a plurality of extraction pins that are configured to align with a pin aperture field that is included on the second surface of the circuit board, the extraction pins extending into the pin aperture field to force the connector from the first surface of the circuit board, wherein said extraction mechanism includes front and rear support plates and a board guide pin securing said extraction and installation mechanisms to one another, the actuator including an actuator element and an extractor bock, the actuator element moving the actuator block toward and away from the second surface of the circuit board when the actuator element is rotated, the actuator block including the extraction pins.

Co-axial Cables

Co-axial cables contain two or more separate conductors. The innermost conductor may be of the solid, or stranded copper wire type, and may be plain, tinned, silver-plated or even gold-plated in some applications, depending on the degree of conductivity required. The remaining conductors are in the form of tubes, usually of fine wire braid. The insulation is usually of polyethylene or Teflon. Outer coverings or jackets serve to weatherproof the cables and protect them from fluid, mechanical and electrical damage. The materials used for the covering are manufactured to suit operations under varying environmental conditions.

Co-axial cables have several main advantages. First, they are shielded against electrostatic and magnetic fields; an electrostatic field does not extend beyond the outer conductor and the fields due to current flow in inner and outer conductors cancel each other.

Secondly, since co-axial cables do not radiate, then likewise they will not pick up any energy, or be influenced by other strong fields. The installations in which coaxial cables are most commonly employed are radio, for the connection of antennae, and capacitance type fuel quantity in indicating systems for the interconnection of tank units and amplifiers. The construction of a typical coaxial cable and also the sequence adopted for attaching the end fitting are shown in (Fig. 16.8). The outer covering is cut back to expose the braided outer conductor (step "A") which is then fanned out and folded back over the adapter (step "B" and "C"). At the same time, the insulation is cut back to expose the inner conductor. The next step (D) is to screw the sub-assembly to the adapter thereby clamping the outer conductor firmly between the two components. Although not applicable to all cables the

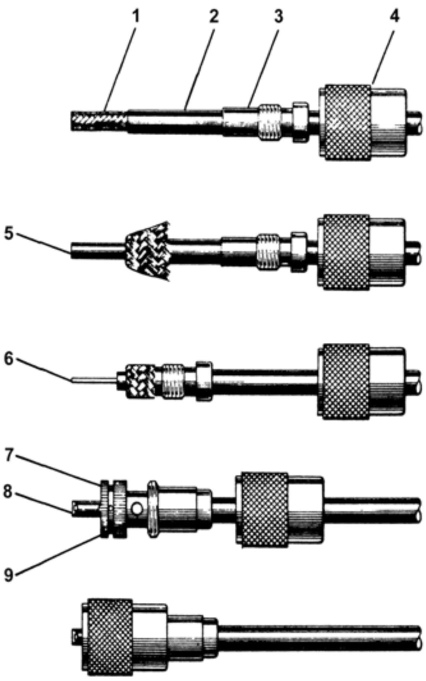

Fig. 16.8. Typical coaxial cable and end fitting

1. *Outer braid conductor*
2. *Outer covering*
3. *Adapter*
4. *Coupling ring*
5. *Insulation*
6. *Inner conductor*
7. *Plug sub-assembly*
8. *Contact*
9. *Solder holes*

outer conductor may also be soldered to the sub-assembly through solder holes. The assembly is completed by soldering a contact on to the inner conductor may also be soldered to the sub-assembly through solder holes. The assembly is completed by soldering a contact on to the inner conductor and screwing the coupling ring on to the sub-assembly.

Testing

Before carrying out tests, or when inspection is specified in the Approval Maintenance Schedule, all aircraft circuits, together with plug, sockets, terminal blocks and equipment terminals, should be examined, as appreciated, for signs of damage, deterioration, chafing, poor workmanship and security of attachments and connections. It is not intended, for the purpose of this examination, that electrical apparatus should be removed from its mounting or that cables should be unduly disturbed, but if modifications or repairs, for example, have been carried out in the vicinity, looms should be closely inspected for ingress of metallic swarf between cables. Whenever a structure is opened over wiring which is not normally visible through available inspection panels, circuits so exposed should be thoroughly inspected.

The primary purpose of the inspection is to determine the physical state of the system, especially at bends, points of support, duct entries, etc., or where high temperature or contamination could cause deterioration. Where cables are grouped together, the state of the outer cables is generally indicative of the condition of the remainder.

Cables completely enclosed in ducts obviously cannot be examined along their length, but should be checked continuity and insulation, especially if oil or water ingress is suspected. Where there is evidence of damage to the ducts, the cables should be exposed to ascertain their condition.

Terminations must be secure and good electrical contact obtained without strain on the threads of terminal pillars or studs. Torque loadings, where appropriate, should be within the limits specified.

Routing Precautions

When wiring must be routed parallel to combustible fluid or oxygen lines for short distances, as much separation as possible should be maintained. The wires should be on a level with, or above, the plumbing lines. Clamps should be spaced so that if a wire is broken at a clamp, it will not contact the line. Where a 6 in. separation is not possible , both the wire bundle and the plumbing line can be clamped to the same structure to prevent any relative motion. If the separation is less than 2 in. but more than 1/2 in., two cable clamps back-to-back (Fig. 16.9) can be used to maintain a rigid separation only, and not for support of the bundle. No wire should be routed so that it is located nearer than 1/2 in. to a plumbing line. Neither should a wire or wire bundle be supported from a plumbing line that carries flammable fluids or oxygen.

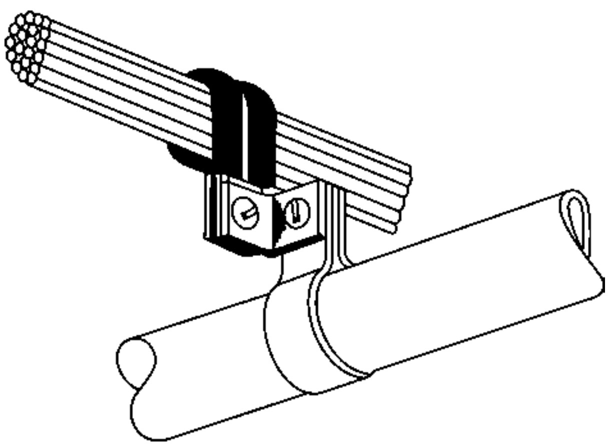

Fig. 16.9. Separation of wires from plumbing lines.

Wiring should be routed to maintain a minimum clearance of at least 3 in. from control cables. If this cannot be accomplished, mechanical guards should be installed to prevent contact between wiring and control cables.

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CHAPTER-17
WIRING PROTECTION TECHNIQUE

Electrical Wiring Installation

The following recommended procedures for installing aircraft electrical wiring are typical of those used on most types of aircraft. For purposes of this discussion, the following definitions are applicable :

1. Open wiring-- any wire, wire group, or wire bundle not enclosed in conduit.
2. Wire group-- two or more wires going to the same location, tied together to retain identity of the group.
3. Wire bundle-- two or more wire groups tied together because they are going in the same direction at the point where the tie is located.
4. Electrically protected wiring-- wires which include (in the circuit) protections against overloading, such as fuses, circuit breakers, or other limiting devices.
5. Electrically unprotected wiring-- wires (generally from generators to main bus distribution points) which do not have protection, such as fuses, circuit breakers, or other current-limiting devices.

Cable Looming

As noted earlier in this chapter, the quantity of wires and cables required for a distribution system depends on the size and complexity of the systems. However, regardless of quantity, it is important that wires and cables be routed through an aircraft in a manner which, is safe, avoids interference with the reception and transmission of signals by such equipment as radio and compass systems, and which also permits a systematic approach to their identification, installation and removal, and to circuit testing. Various methods, dependent also on size and complexity, are adopted but in general, they may be grouped under three principal headings : (i) open loom, (ii) ducted loom, and (iii) conduit.

OpenLoom

In this method, wires or cables to be routed to and from consumer equipment in the specific zones of the aircraft, are grouped parallel to each other in a bundle and bound together with waxed cording or p.v.c. strapping. A loom is supported at intervals throughout its run usually by means of clips secured at relevant parts of the aircraft structure. An application of the method to an aircraft junction box is shown in (Fig. 17.1).

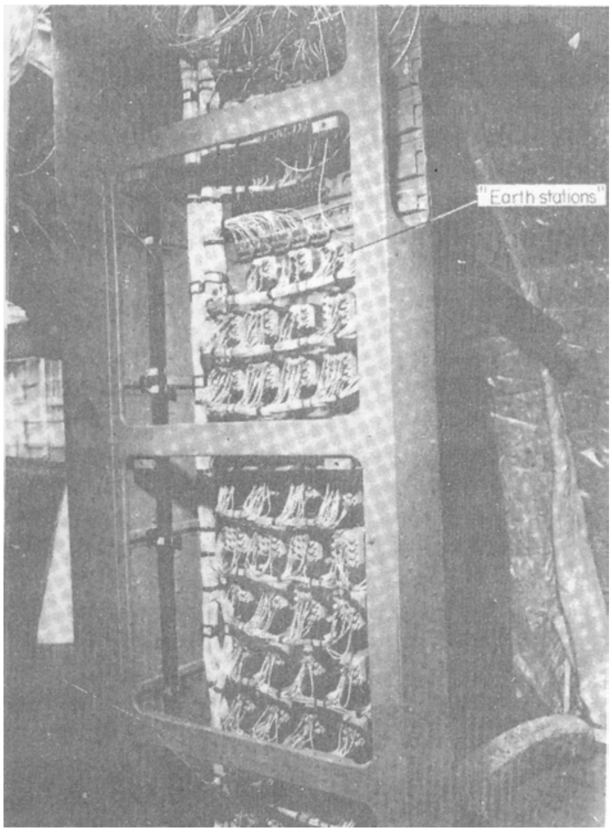

Fig. 17.1. Open looms.

The composition of a cable loom is dictated by such factors as (i) overall diameter, (ii) temperature conditions, i.e. temperature rise in cables when operating at their maximum current-carrying capacity in varying ambient temperature conditions, (iii) type of current, i.e. whether alternating, direct, heavy-duty or light-duty, (iv) interference resulting from inductive or magnetic effects, (v) type of circuit with which cables are associated; this applies particularly to circuits in the essential category, the cables of which must be safe-guarded against damage in the event of short circuits developing in adjoining cables.

Magnetic fields exist around cables carrying direct current and where these cables must interconnect equipment in the vicinity of a compass magnetic detector element, it is necessary for the fields to be cancelled out. This is achieved by routing the positive and earth-return cables together and connecting the earth-return cable at an earthing point located at a specific safe distance from the magnetic detector element of a compass system.

DuctedLoom

This method is basically the same as that of the open loom except that the bundles are supported in ducts which are routed through the aircraft and secured to the aircraft structure (see Fig. 17.2). Ducts may be of aluminium alloy, resinimprenated asbestos or moulded fibre-glass-reinforced plastic. In some applications of this method, a main duct containing several channels may be used, each channel supporting a cable loom corresponding to a specific consumer system. For identification purposes, each loom is bound with appropriately coloured waxed cording.

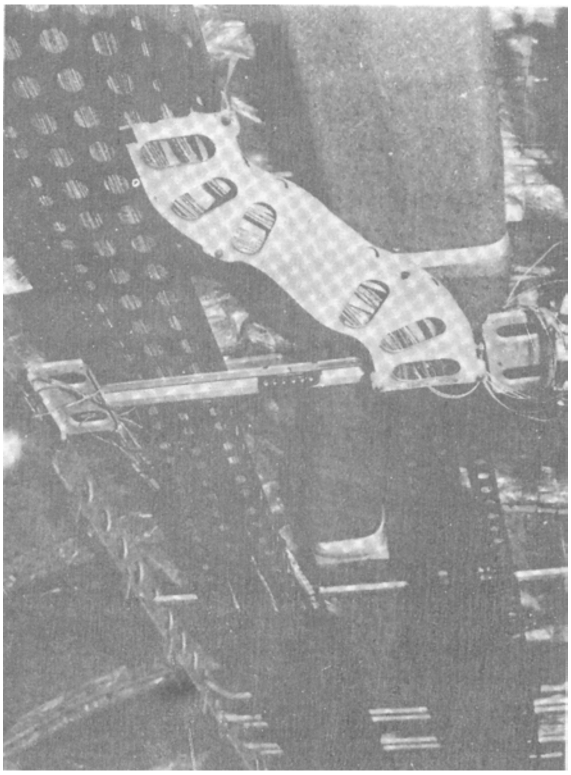

Fig. 17.2. Ducted looms.

Conduits are generally used for conveying cables in areas where there is the possibility of exposure to oil, hydraulic or other fluids. Depending on the particular application, conduits may take the form of either plastic, flexible metal or rigid metal sheaths. In cases where shielding against signal interference is necessary the appropriate cables are conveyed by metal conduits in contact with metal structural members to ensure good bonding.

Cable Seals

In pressurized cabin aircraft it is essential for many cables to pass through pressure bulkheads without a "break" in them and without causing leakage of cabin air. This is accomplished by sealing the necessary apertures with either pressure bungs or pressure-proof plugs and sockets. An example of a pressure bung assembly is shown in (Fig. 17.3). It consists of a housing, perforated synthetic rubber bung, antifriction washer and knurled clamping nuts; the housing is flanged and threaded, having a tapered bore to accept the bung. The holes in the bung vary in size to accommodate cables of various diameters, each hole being sealed by a thin covering of synthetic rubber at the smaller diameter end of the bung. The covering is pierced by a special tool when loading the bung with cables.

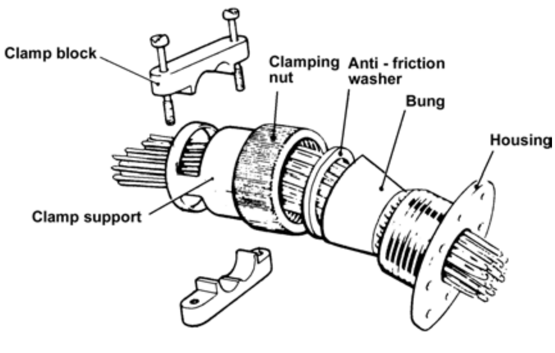

Fig. 17.3. Pressure bung assembly.

The cables are a tight fit in the holes of the bung which, when fully loaded and forced into the housing by the clamping nut, is compressed tightly into the housing and around the cables. The anti-friction washer prevents damage to the face of the bung when the clamping nut is turned. On assembly, holes not occupied by cables are plunged with plastic plugs.

In instances where cable "breaks" are required at a pressure bulkhead, the cables at each side of the bulkhead are terminated by specially-sealed plug or socket assemblies of a type similar to those shown in (Fig. 17.4).

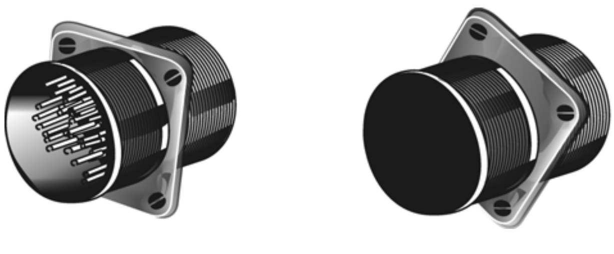

Fig. 17.4. Fixed through-type (bulkhead).

Loom Support

The wiring must be adequately supported throughout its length. A sufficient number of supports must be provided to prevent undue vibration of the unsupported lengths. All wires and wire groups should be routed and installed to protect them from:

1. Chafing or abrasion.
2. High temperature.
3. Being used as handholds, or as support for personal belongings and equipment.
4. Damage by personnel moving within the aircraft.
5. Damage from cargo stowage or shifting.
6. Damage from battery acid fumes, spray or spillage.
7. Damage from solvents and fluids.

Cable Clamps

Cable clamps should be installed with regard to the proper mounting angle (Fig. 17.5). The mounting screw should be above the sire bundle. It is also desirable that the back of the cable clamp rest against a structural member where practicable.

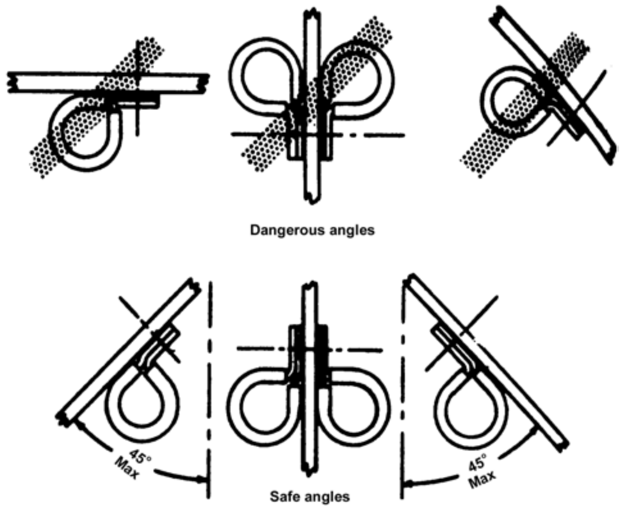

Fig. 17.5. Proper mounting angle for cable clamps.

Protection Sleeving technique

Wires and wire groups should be installed so that they are protected against chafing or abrasion in those locations where contact with sharp surfaces or other wires would damage the insulation. Damage to the insulation can cause short circuits, malfunctions, or inadvertent operation of equipment. Cable clamps should be used to support wire bundles (Fig. 17.6) at each hole through a bulkhead. If wires come closer than 1/4 in. to the edge of the hole, a suitable grommet is used in the hole, as shown in (Fig. 17.7). Some types of uninsulated terminal lugs are insulated after assembly to a wire by means of pieces of transparent flexible tubing called "sleeves." The sleeve provides electrical and mechanical protection at the connection. When the size of the sleeving used is such that it will fit tightly over the terminal lug, the sleeving need not be tied; otherwise, it should be tied with lacing cord as illustrated in figure. 17.8.

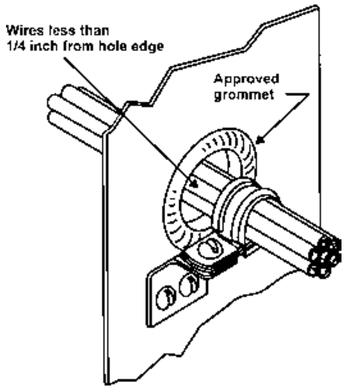

Fig. 17.6. Cable clamp at bulk head hole.

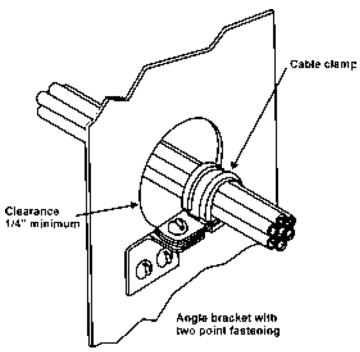

Fig. 17.7. Cable clamp and grommet at bulkhead hole.

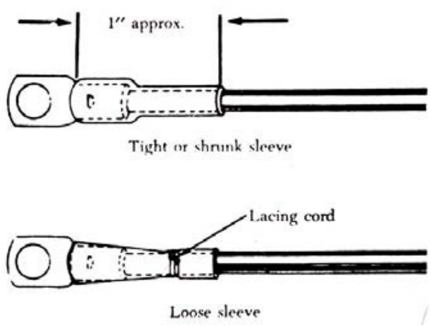

Fig.17.8. Insulating sleeve.

Sometimes it is necessary to cut nylon or rubber grommets to facilitate installation. In these instances, after insertion, the grommet can be secured in place with general-purpose cement. The slot should be at the top of the hole, and the cut should be made at an angle of 45^0 to the axis of the wire bundle hole.

Heat Shrink wrapping

To prevent insulation deterioration, wires should be kept separate from high-temperature equipment, such as resistors, exhaust stacks, heating ducts, etc. The amount of separation is normally specified by engineering drawings. Some wires must invariably be run through hot areas. Some wires must invariably be run through hot areas. These wires must be insulated with high-temperature material such as asbestos, fibre glass, or Teflon. Additional protection is also often required in the form of conduits. A low-temperature insulated wire should never be used to replace a high-temperature insulated wire.

Many coaxial cables have soft plastic insulation, such as polyethylene, which is especially subject to deformation and deterioration at elevated temperatures. All high-temperature areas should be avoided when installing these cables.

Additional abrasion protection should be given to asbestos wires enclosed in conduit. Either conduit with a high-temperature rubber linear should be used, or asbestos wires can be enclosed individually in high-temperature plastic tubes before being installed in the conduit.

Shielding

Wires carrying alternating current radiate enough energy to interfere with some of the sensitive electronic circuits, and some of the sensitive control circuits can be disturbed by stray electrical fields that are always present in the aircraft. To protect against the unwanted effect of these fields. Wire may be shielded. The insulated wire is covered with a braid of tinned copper or aluminium, and this braid is often covered with an abrasion-resisting nylon outer cover.

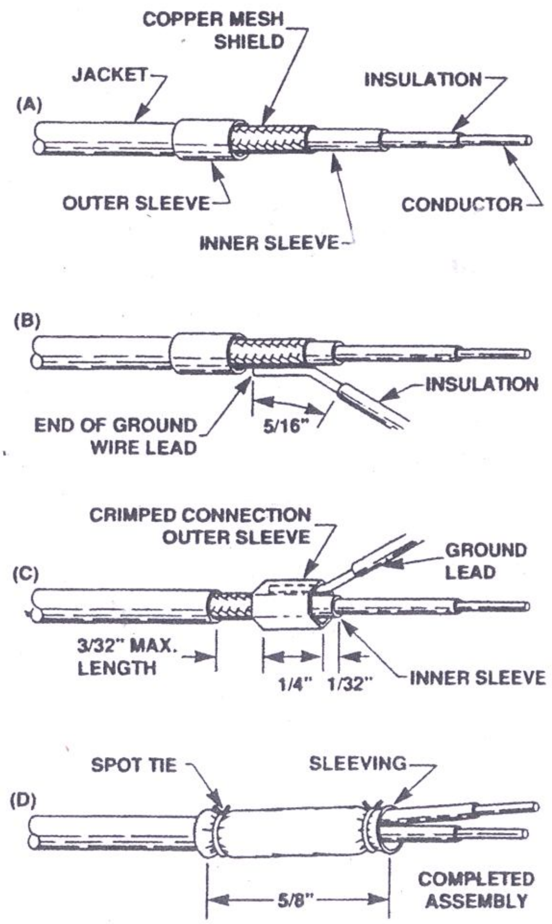

Fig.17.9 Attachment of a ground lead to a shielded wire using a crimped-on sleeve.

The shielding is grounded at only one end to prevent a flow of current within the shield itself. This ground connection should be made by attaching a ground lead to the shield with a crimped-on connector, as seen in figure 17.9). Never solder the ground lead to the shielding, as there is the danger of overheating the insulation and causing it to break down.

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CHAPTER-18
SOLDERING

SOFT SOLDERING
INTRODUCTION

This chapter gives guidance on the manufacturing processes involving the use of soft solders. Soft soldering is a method of joining metals without intentional fusion of the basis metal, the solders having a lower melting point than the metals being joined. The term "soft soldering" is used to distinguish the process from brazing, which is performed at higher temperatures.

STRENGTH OF SOLDERED JOINTS

The strength of a soldered joint is dependent on the continuity and adhesion of the solder film and the mechanical properties of the solder, and can only be verified by the destruction of the joint. In order to ensure satisfactory joints it is essential that adequate inspection is carried out at various stages throughout the process. In addition, where a large number of similar articles are being soldered, periodic tests can be made by sectioning, or by pulling surfaces apart. In the majority of applications, the solders used are considerably weaker than the materials they join; where the film of solder is too thin the joint will be brittle; conversely, if the film is too thick, the shear strength of the joint will be low.

SCOPE OF PROCESS

Most metals, with the exception of some aluminium alloys, magnesium alloys and zinc-base die-castings, can be soldered, but before applying the process it should be verified that the relevant specifications permit its use. For example, because of the danger of inter crystalline penetration by the molten solder, the soldering of high tensile steel tubes, complying with specifications such as British Standards T57, T58, T59 and T60, is prohibited, both for jointing and for the attachment of identification labels. The soldering of aluminium with aluminium solder and a suitable flux is possible and is sometimes used for radio and instrument assemblies, but is not normally permitted for other aircraft purposes.

MATERIALS

The solders and fluxes used for aircraft purpose must comply with British standards or DTD specifications. Relevant specifications are given in Table 18.1.

TABLE 18.1
SOLDERING SPECIFICATIONS

Specification	Description
BS219	Soft Solders
BS441	Rosin-cored Solder Wire.
DTD599	Non-corrosive Flux for Soft-Soldering (except high-pressure oxygen equipment).
DEF34\1	Tinning and Soldering Solution.

Solders

Solder is available in two form, i.e. stick solder with which a separate flux is used, and solder in wire from having a rosin flux core. BS219 covers a range of antimonial and non-antimonial stick solders, whilst BS 441 is concerned with wire solders having non-corrosive, activated and non-activated flux cores. (See paragraphs below)

General Purpose Solders

The solders which may be used for general soldering work are designated in BS 219 and listed in order of tin content in Table 18.2. Solder manufactured to other specifications may be recommended for particular applications, and an approved proprietary brand of tin \ lead solder containing a small percentage of copper is also available for electrical circuit bit-soldering. It is claimed that the copper content reduces bit erosion without impairing the efficiency of the solder.

TABLE 18.2
GENERAL PURPOSE SOLDERS

	Alloy (%)				
Grade	**Tin**	**Antimony**	**Lead**	**Melting Range (°C)**	**Typical Uses**
A	64 to 65	max. 0.6	remainder	183 to 184	Components liable to
K	59 to 60	max. 0.5	remainder	183 to 188	damage by heat, e.g. electrical and instrument assemblies. Nickel and high nickel alloys.
B*	49 to 50	2.5 to 3.0	remainder	185 to 204	General coppersmiths and
F	49 to 50	max.0.5	remainder	183 to 212	tinsmiths bit-soldering
M*	44 to 45	2.2 to 2.7	remainder	185 to 215	and machine work.
R	44 to 45	max. 0.4	remainder	183 to 224	
C*	39 to 40	2.0 to 2.4	remainder	185 to 227	Blowpipe soldering and
G	39 to 40	max.0.4	remainder	183 to 234	general fine work.
H	34 to 35	max. 0.3	remainder	183 to 244	Dipping baths.
L*	31 to 32	1.6 to 1.9	remainder	185 to 243	General plumbers' work.
D*	29 to 30	1.5 to 1.8	remainder	185 to 248	
J	29 to 30	max. 0.3	remainder	183 to 255	
V	19 to 20	max. 0.2	remainder	183 to 276	Electric lamps, dipping
N*	18 to 18.5	0.9 to 1.1	remainder	185 to 275	solder.

NOTES

(1) Grades marked with an asterisk are known as antimonial solders, the antimony being added to increase strength. They should not be used on zinc or galvanized work.

(2) The two figures quoted in the melting range column represent the completely solid and completely liquid states.

High Temperature Solders

Three types of solders which may be used in high temperature applications are also specified in BS 219. They are used in the manufacture of oil coolers, radiators, etc., where operating temperatures would adversely affect solders with lower melting temperature. High temperature solders may be applied by soldering iron or torch flame

TABLE 18.3
HIGH TEMPERATURE SOLDERS

	Alloy (%)				
Grade	**Tin**	**Antimony**	**Lead**	**Silver**	**Melting Range (°C)**
95A	94.5 to 95.5	4.75 to 5.25	max. 0.7	__	236 to 243
5 S	4.75 to 5.25	max. o.1	remainder	1.4 to 1.6	296 to 301
1S	1.0 to 1.5	max. 0.1	remainder	1.4 to 1.6	309 to 310

Wire Solder

Solders of this type, complying with the requirements of BS 441, are of circular cross-section, having one or more continuous cores of activated or non-activated flux. Because wire solders release flux and solder simultaneously when the appropriate temperature is applied, they are generally considered to be more efficient than stick solders. These solders are available in five grades. Information on their properties and uses is given in Table 18.4.

TABLE 18.4 (WIRE SOLDERS)

Alloy (%) Tin	Lead	Melting Range (°C)	Typical Uses
65 max.	remainder	183 to 185	Electrical, radio and instrument
60 max.	remainder	183 to 212	assemblies liable to damage by heat or requiring free running solder.
50 max.	remainder	183 to 212	Electrical, radio and instrument work where slightly higher temperature and some slight loss of penetrating power are permissible. General hand soldering and medium coppersmiths' work.
40 max.	remainder	183 to 234	Tagging components less liable to damage by heat. Tinsmiths' and coppersmiths' light gauge handwork.
20 max.	remainder	183 to 276	Blobbing electric lamp contacts.

General

Care must be taken to ensure that the solder used is of the type specified on the drawing and is the correct type for the work in hand. Apart from the effect on the strength of the joint, the use of incorrect solder may result in other damage, e.g. if solder with too high a melting point is used, damage may result to the surrounding structure from the heat required to melt the solder.

HARD SOLDERING

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.

Fluxes

Since solder will only adhere to clean metal, all surfaces to be soldered must be thoroughly cleaned. However, even after cleaning, the oxidation occasioned by heating will prevent the satisfactory adhesion of solder. The use of flux reduces the effect of oxidation, removes oxides and other impurities, helps the molten solder to run freely and results in the production of a stronger joint.

Fluxes complying with Specification DTD 599 are available in rosin, liquid and paste forms, are non-corrosive, and either activated or non-activated. Rosin to this specification is used for the flux in wire solders.

Activated Fluxes

Activated fluxes consist of wood or gum rosin, and contain a small proportion of an agent intended to facilitate the soldering process; such fluxes are usually selected when a more active cleaning agent is required.

Non-Activated Fluxes

These fluxes consist of wood or gum rosin only and are usually selected for the soldering of surfaces where active cleaning is unnecessary.

Test to Distinguish Activated from Non-Activated flux in Wire Solder

The method of conducting this test is described in BS 441. The principle of the test is that a specimen of the solder is melted on a prepared nickle plate. It is essential that the solder should be melted within a period of from two to six seconds, and if the solder on melting wets the nickel and spreads upon its surface, the flux is judged to be activated.

Fluxes for Stainless Steel Soldering

Suitable fluxes, which are all corrosive, are as follows:

(i) A liquid flux made by dissolving zinc chloride in a solution of equal volumes of hydrochloric acid and water. The solution may be applied with a brush or, if more convenient, the parts may be dipped into the solution.

(ii) Ortho-phosphoric acid, in its commercial form, which should be applied undiluted.

(iii) Phosphate-base flux pastes.

Oxygen Equipment

Rosinous fluxes, such as those complying with Specification DTD 599, must not be used for soldering oxygen equipment. A flux complying with DEF 34\1 is suitable.-

Miscellaneous Applications

(i) For Monel and nickel the rosin types of fluxes are suitable, but for Inconel and the Nimonic alloys, a more vigorous flux, such as killed spirits of salts or lactic acid, is necessary.

(ii) Parts which cannot be washed after soldering, e.g. radio, electrical and instrument equipment, should be soldered in conjunction with a flux complying with DTD 599.

(iii) Zinc-plated steel parts, including galvanized wire ropes, should be soldered in conjunction with a flux complying with DTD 599 or with a triethanolamine oleate flux.

(iv) Where such action is permissible the soldering of identification labels to steel tubes should be in conjunction with a flux complying with DTD 599.

General

Care must be taken to ensure that the flux used is of the type specified on the drawing and is of the correct type for the work in hand . The use of the wrong type of flux may not prevent oxidation of the surfaces to be joined, nor act as an efficient cleaning agent. In addition, it is imperative that a corrosive flux such as that complying with DEF 34\1 is only used on work from which its residues can be readily removed.

Flux Baths

Where a flux bath is used, the bath should be kept in a clean condition, and the contents checked at regular intervals. The acidity of fluxes of the DEF 34\1 type must be carefully controlled.

Testing of Soldered joints

Inspection of completed soldered connections should include the following:-

(i) Joints should be clean, smooth, bright and free from sharp projections, and the wire easily discernible through the solder.

(ii) As far as can be detected visually, the joint should be filled with adhering solder.

(iii) Insulation should be undamaged (i.e. not burned or affected by solvent).

(iv) There should be no pitting, corrosion, scale or other evidence of poor work- manship.

(v) Where electrical tests are specified, the results obtained should be within the prescribed limits.

SOLDERING OF ALUMINIUM

Proprietary brands of cored wire solder are available, which may be used for soldering aluminium and many aluminium alloys, and a method of ultrasonic soldering may also be used.

The normal soldering techniques is similar to that used with other materials but, because of the material's high specific heat and thermal conductivity, a greater heat input is required . An advantage of these properties is that uneven expansion and contraction are avoided, and heating of complex structures is simpler than with other materials. A soldering temperature of 280 ^{o}C to 370 ^{o}C is required, and may be obtained using a hand iron, gas torch, furnace or induction coil. Solder should be pre-positioned or handed to the edge of the joint, and heat applied adjacent to the joint to bring it quickly to the soldering temperature, so that the solder melts by indirect heating.

As aluminium expands more than most materials, light jigging, which will allow the parts to expand and contract, should be used when necessary. A joint clearance of 0.05 mm to 0.1 mm (0.002 inch to 0.004 inch) will allow the solder to fill the gap by capillary action, and give maximum strength.

Pungent fumes are given off by the flux, and soldering should be carried out in a well-ventilated working area.

Ultrasonic soldering equipment is available in the form of an iron, for normal joints, or a bath, for the quick dip-turning of aluminium wire and small parts.

The working principle of the equipment is that ultrasonic vibrations are imparted to the bit of the iron or, where baths are used , to the vessel containing the solder. When the vibrations are applied to the molten solder on the surface of the material, the effect of the ultrasonic energy is to produce imploding cavitation bubbles in the solder, which remove the oxide film and permit a wetting action by the solder to take place. No flux is required for the process and the solder used should contain 90 percent tin and 10 per cent zinc.

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CHAPTER-19
WELDING METHOD

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.

GAS WELDING

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 19.1. 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.

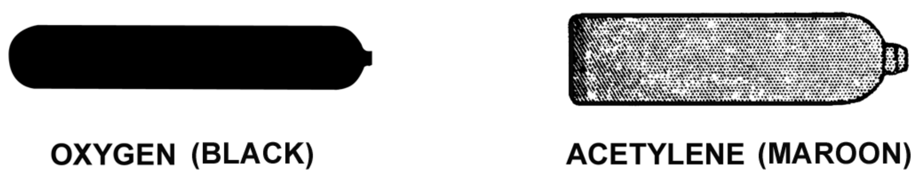


Fig. 19.1, Cylinder Identification

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.

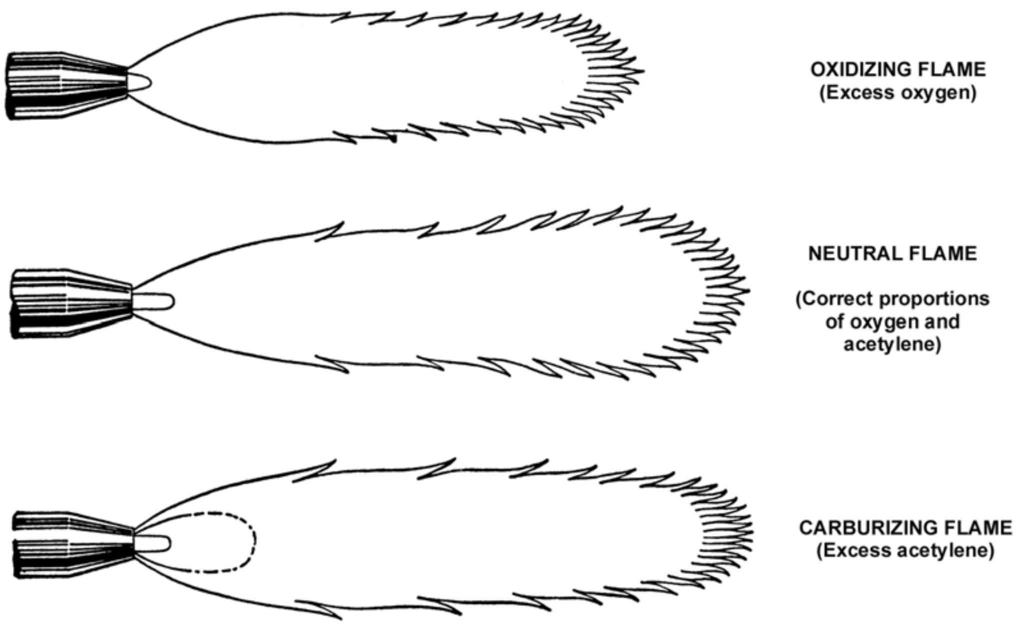


Fig. 19.2, Flame Adjustment

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 19.2.

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.

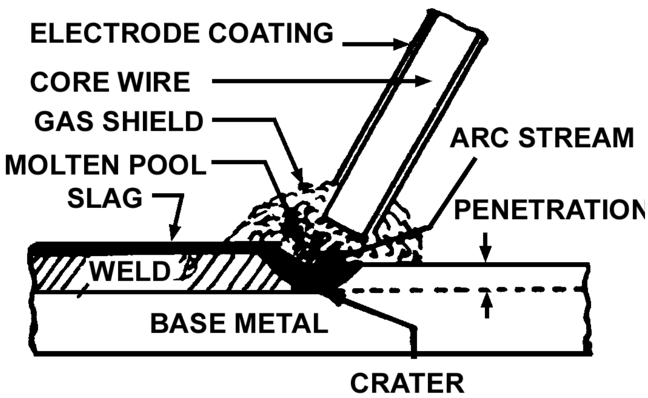


Fig. 19.3, Schematic diagram of shielded metal-arc welding.

The process is illustrated by means of a schematic diagram in 19.3. 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. 19.4. 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.

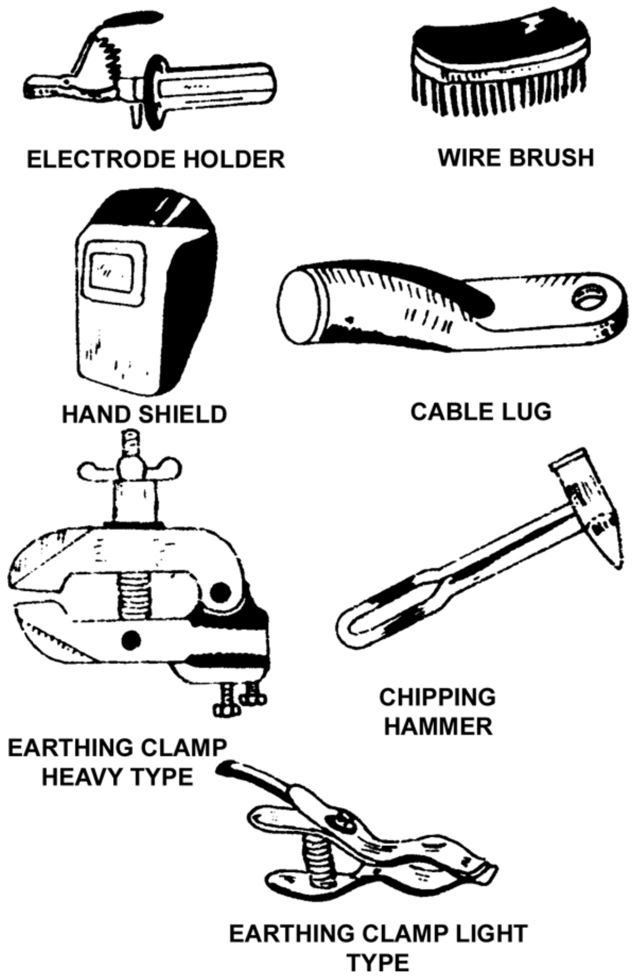


Fig. 19.4, Arc welding and safety equipment

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 19.1 below :

Table 19.1, 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, fluorspar, stealite, titanium dioxide, iron oxide, magnesium carbonate, calcium carbonate and different aluminous. 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, feldspar 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 underbid 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.

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.

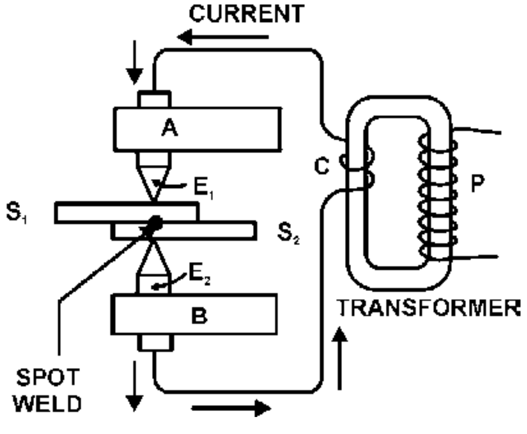


Fig. 19.5, Principle of Spot welding

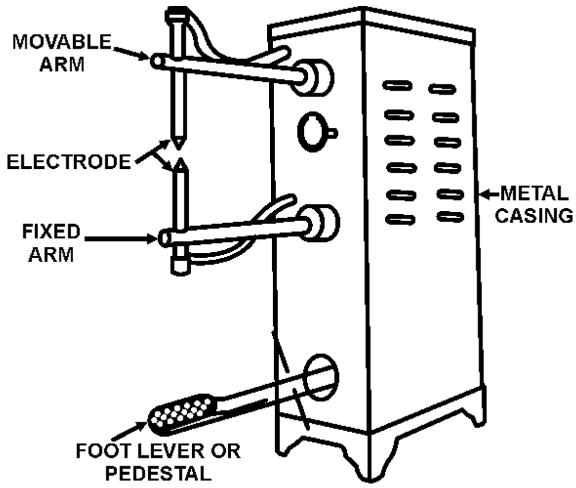


Fig. 19.6, Spot welding machine

The principle of spot welding is illustrated in Fig. 19.5, 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. 19.6. 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 19.2.

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 19.2.

Table 19.2, 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. 19.7.

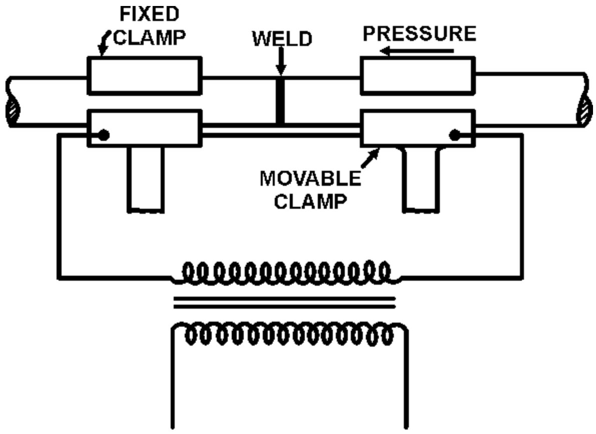


Fig. 19.7, Principle of Butt Welding

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.

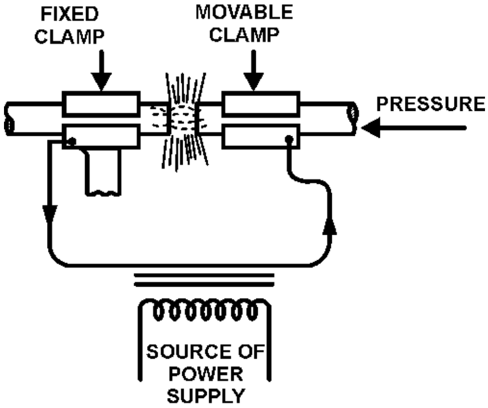


Fig. 19.8, Principle of Flash Welding

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. 19.8) 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.

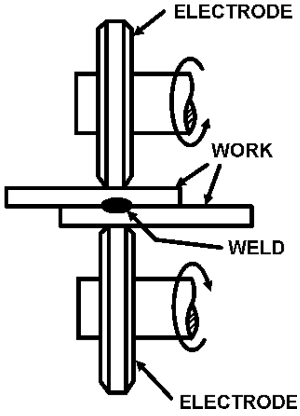


Fig. 19.9, Principle of Seam Welding.

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.19.9). 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. 19.10. 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.

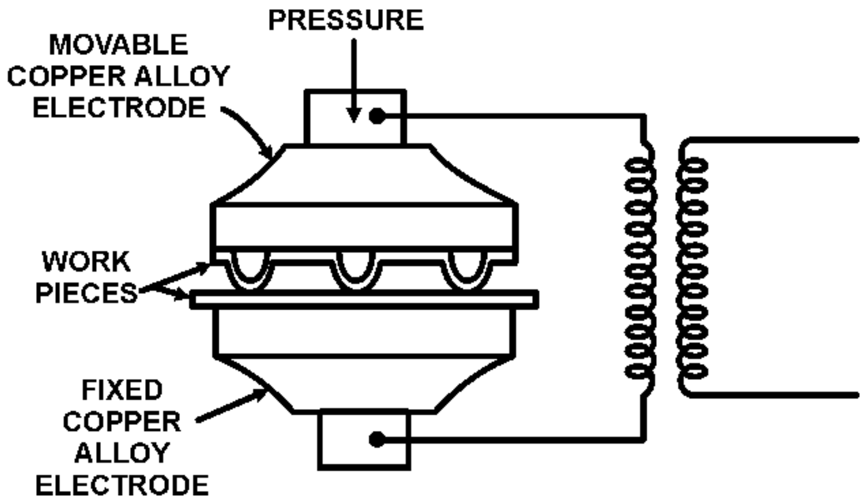


Fig. 19.10, Projection Welding

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.

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 hopper for further use. After the weld cools down the slag is removed. The rate of feeding of electrode wire and flux granules 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 hopper) 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. 19.11 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.

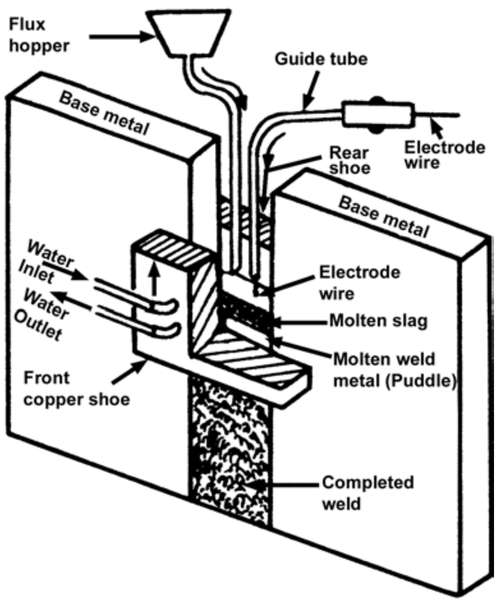


Fig. 19.11, Schematic diagram of electroslag welding. The copper shoe at the front side is shown in section to show the welding details.

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.

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, magnese 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.

Disadvantages

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 granular 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.

■■■

CHAPTER-20
BRAZING METHOD

BRAZING

INTRODUCTION

This chapter gives guidance on the brazing processes applicable to ferrous and non-ferrous metals. For the purpose of this Chapter 'brazing' means the joining of materials by a process in which a molten alloy is drawn by capillary attraction into the space between the adjacent surfaces of the parts to be joined. The parts to be joined are known as the basis, or parent, metals.

Low temperature brazing, also known as silver soldering or hard soldering, is a brazing process which uses filler alloys based mainly on the metals silver and copper, with a melting temperature within the range 600 °C to 850 °C. The strength of a joint brazed with silver brazing alloy, if properly designed, is often equal to the strength of the materials joined.

When brazing is carried out with filler alloys of high melting temperature, grain growth and softening of the parent metal often occur, thus necessitating further heat treatment to restore the required properties.

Where special techniques of brazing are applicable to certain materials, these are described under the heading of the material concerned.

STRENGTH OF JOINTS

The strength and efficiency of brazed joints depend on a number of factors, including the design of the joint, cleanliness of the surfaces to be joined, the method of applying the process, the composition of the materials to be brazed, use of the brazing method and materials specified on the drawing or manual, and the competency of the operator. Primarily the strength of the joint depends on the area of the film which unites the surfaces of the parts forming the joint and, to a lesser extent, on the thickness of the film, a thin film usually producing the strongest joint.

Specific values for the strength of joints can be misleading, since so many factors are involved. For example, most joints made in normal workshop or mass-production conditions contain voids resulting from gas or flux entrapment, or from the formation of shrinkage cavities in the filler alloy during its transition from the liquid to the solid state. Although it is seldom possible to eliminate such faults completely, they can be minimised by careful attention to cleanliness, joint gaps, heating methods and the method of feeding the filler alloy into the joint.

Overheating during brazing can have a serious adverse effect on the strength of a joint. Care is necessary, when using a hand torch, to ensure that the flame is suitable for the work in hand, otherwise grain growth, burning, distortion or melting of the parent metal may result. Particular care is necessary when using oxyacetylene gas, which has a flame temperature in excess of 3000 °C. Overheating of the parent metal may also result from the use of incorrect brazing alloys.

Strength at elevated temperatures depends largely on the type of filler alloy used, and in general terms the silver brazing alloys having the lowest melting temperature are suitable for continuous service at temperatures up to about 250 °C.

When dissimilar metals having different rates of thermal expansion are brazed, the possibility of stresses resulting from differential contraction during cooling is reduced by the use of low temperature filler alloys.

Flux should be removed from parts by washing in hot water but, with assemblies consisting of parts of dissimilar metals or with sudden changes in section, washing should not be carried out while the parts are still hot from brazing. This practice could result in stress cracking or the production of high residual stresses in the component.

SCOPE OF PROCESS

All brazing operations should be performed strictly in accordance with the requirements of the relevant drawings. Material suitable for brazing are listed in BS 1723, and various combinations of these materials may also be joined provided that a suitable technique has been established.

COMPETENCY OF OPERATORS

As stated, the strength and efficiency of brazed joints depend, amongst other factors, on the competency of the operators. It is recommended that the competency of operators responsible for the hand torch brazing of important parts, should be checked regularly by a testing programme such as that described below.

A sample should be selected for testing from the operator's production work wherever possible, but where this is not practicable, a butt, fillet, tube-to-tube, or sheet-to-sheet test piece, as appropriate to the type of work in hand, should be prepared.

The test piece should be submitted for microscopical examination to a laboratory approved for the examination of welded joints, and should show satisfactory penetration into the joint, adhesion and freedom from porosity, freedom from overheating of the parent metal, absence of coarse grain, etc. Further test pieces, to ensure continued competency, should be submitted at intervals not exceeding six months. When an operator fails a competency test he should undergo further practice and \ or training before re submitting a test piece.

An additional competency test should be submitted whenever there is a marked change in the material or types of joints being brazed.

MATERIALS FOR BRAZING

The filler alloys and fluxes used for brazing aircraft parts must conform to the appropriate British Standards or to DTD 900.

Filler Alloys

Details of the composition and melting range of filler alloys or metals which may be used for brazing are contained in BS 1845 in a series of Tables. The basic alloying elements listed in each of Tables 1 to 8 in BS 1845, provide the prefix for the filler type (i.e. AL, aluminium; AG, silver; CP, copper-phosphorous; CU, copper; CZ, brass; NI, nickel; PD, silver-copper-palladium; AU, gold) and a numerical suffix signifies the particular alloy within a group; Table 9 lists the maximum permissible content of impurities in the alloy specified for vacuum brazing.

Filler alloys are generally available in rod, wire and strip, and in some instances in granular form, the choice depending on the brazing method used. Whilst the majority of hand torch operations require the filler alloy to be fed by hand from a rod, wire or strip, better results can sometimes be obtained by placing the brazing alloy in a predetermined position in the joint, and heating the assembly by means of a fixed torch, furnace, or electrical induction or resistance methods. Filler alloy inserts for this purpose usually take the form of wire rings, but, in some cases, foil, washers, or pressing of special shape are used.

A silver brazing alloy in the form of a paste or paint is also available, and consists of finely divided filler alloy, flux and a volatile liquid medium. The proportions of the constituents are so arranged that the paste can be used with any of the various heating methods.

Fluxes

The function of a flux is to dissolve oxides; it also has the effect of reducing the surface tension of the molten filler alloy, thus assisting the alloy to flow readily between the surfaces of a joint.

It is recommended that the flux used in any brazing operations should be agreed with the supplier of the filler alloy, since in certain instances a flux suitable for one filler alloy may not be suitable for another of similar composition, for example, because of the melting range of the alloy. An example of this is borax, which has a higher melting temperature than some of the filler alloys, and , in this case, its use may result in flux entrapments.

Fluxes are normally supplied in powder form, and should be made up in accordance with the manufacturers' instructions. The application of the flux for the various processes is described in the appropriate paragraphs.

BRAZING JIGS

Components which are to be joined by a brazing process are normally specially designed to ensure correct location and filler penetration. In the majority of cases the parts fit naturally together or may be lightly supported in such a way as to permit natural expansion and contraction to take place, but in some instances the use of locating jigs is unavoidable.

Jigs should be so constructed that contact with the parts to be joined is as light as possible, and should be shaped to avoid contact with areas where brazing alloy is required to flow. Jigs should also be designed so that, whenever possible, the capillary flow of filler metal is assisted by gravity.

Where large jigs are necessary, because of the weight of the component, for instance, care should be taken to prevent the absorption of heat from the brazing area. This may be largely avoided by facing the jig with asbestos, fireclay or other ceramic material, and by limiting the size of the areas in contact with the component.

PREPARATION OF JOINTS FOR BRAZING
All scale, grease, dirt, paint, moisture and other foreign matter must be removed from the area to be brazed. Components should first be de greased with trichloroethylene or similar solvent, then cleaned by one of the processes described in the following paragraphs, immediately prior to brazing.

Steel
The methods of cleaning steels vary with the chemical composition of the steel. In general, however, steels may be divided into two main groups, i.e. low alloy steels having a carbon content not in excess of 0.2 per cent, and non-corrodible steels or heat-resisting austenitic stainless steels.

Low Alloy Steels
The area to be brazed may be prepared by sand, shot or alumina-blasting or by brushing with a wire brush. When a blasting. Process is used, the material should he brazed as soon as possible after blasting. If a pickling process is required, a solution of 7.5 per cent (by volume) Sulfuric Acid (S.G. 1.84), maintained at a temperature of 70 °C in a lead or rubber-lined tank, is suitable. An inhibitor should be added to the solution at the rate of 1 oz. per gallon of concentrated acid.

Non-Corrodible and Heat-Resisting Austenitic Stainless Steels
The area to be brazed may be prepared by an alumina-blasting process or by brushing with a brush having stainless steel bristles. The materials should not be prepared for brazing by blasting with crushed steel shot. If a pickling process is required, a solution of the following composition is suitable:-

Hydrofluoric Acid	3.4 to 4.0 per cent (by weight)
Ferric Sulphate	10 to 15 per cent (by weight)
Water	Remainder

The solution should be contained in a lead-lined tank and should be maintained at a temperature of 60 °C.

Nickel Base Materials
The areas to be brazed may be prepared by an alumina blasting process or by brushing with a brush having stainless steel bristles. After mechanical cleaning, the edges to be brazed should be wiped with a suitable solvent. These materials should not be prepared by blasting with crushed steel shot. If pickling is necessary, it must be ascertained that the process used is satisfactory for the material in question, since an inter crystalline attack may result from the use of an incorrect solution.

Aluminium and Aluminium Alloys
The surfaces to be brazed should be prepared either by abrasive blasting with alumina grit or by brushing with a brush having nylon bristles. The use of brushes having copper alloy bristles should be avoided, since, should pieces of bristle become embedded in the surface, there is a danger of bi-metallic corrosion.
If an etching process is required, a solution of the following composition is recommended:-

Sulfuric acid (d=1.84)	150 ml/1
Chromic acid	50 g\1
De-mineralized water	Remainder

The solution should be maintained at 60 °C. Components should be immersed in the solution for 30 minutes, then thoroughly washed in cold water and dried.

Copper and Copper-Based Alloys
The surface may be cleaned by mechanical means such as alumina abrasive blasting or the application of abrasive cloths. Care should be taken to remove only the surface film and not to reduce the thickness of the material when cleaning is effected with abrasive cloth, final cleaning with a solvent being recommended in either case. The parts may also be etched by immersion for two minutes in an aqueous solution containing sulfuric acid (40 ml\1) and sodium dichromate (200 g\1).

BRAZING METHODS
Capillary attraction is the major factor in making a brazed joint, and although, in theory, there is no limit to the extent of penetration by capillary attraction, in practice this is dependent on the dimensions of the joint. The best results are obtained where a joint gap of 0.05 mm to 0.1 mm (0.002 inch to 0.004 inch) is used.

If the optimum joint gap is to be maintained during the heating operation, allowance must be made for the different expansion coefficients of the component metal used in the assembly. However, if the joint gap varies from the ideal, and is, for example, up to 0.2 mm (0.008 inch), an alloy which remains plastic over a greater temperature range should be used, but such an alloy will not have the penetrating power of those normally used for standard gaps.

Heat Application

The methods of applying heat most commonly used in brazing may be classified into four categories, i.e. induction, resistance, furnace and torch, and are described in following paragraphs; flux dip brazing is described in further paragraph.

INDUCTION BRAZING

In this type of heating the parts to be brazed are placed within the influence of the field of a coil which carries high frequency alternating current. The heating effect is rapid and, by careful design of the induction coil, the heat can be closely localized to minimise distortion, grain growth and oxidation. Since the heating effect is influenced by the thermal conductivity and electrical resistance of the component, copper and similar materials will take longer to heat up than materials such as iron or nickel. This method is particularly suitable for high speed brazing of ferrous materials in production line quantities but, because of the high cost of the equipment and the need to design special coils for each particular job, it is not often used for small quantity work.

Induction machines often employ a valve type generator with outputs of up to 15 kVA at frequencies ranging from 100 kHz to 3 MHz, and are usually fitted with timing mechanisms to control the actual heating time. The coils are usually made from copper tube through which water is passed for cooling purpose but solid copper coils may also be used.

In order to take advantage of the speed of induction brazing, paste flux and pre-placed filler alloy are often used, but, in some instances, e.g. when brazing titanium pipe fittings, brazing may be carried out in an argon atmosphere, and no flux is required.

RESISTANCE BRAZING

Resistance brazing is often used where precisely localised heating is required to prevent loss of mechanical properties throughout the parent metal. A high electrical current of low voltage is passed through a resistive circuit so that the heat developed in the circuit raises the temperature in the joint area to the brazing temperature. There are two main methods in use, carbon resistance heating and interface heating.

In carbon resistance heating the electrodes are made from carbon, which has very high resistivity and heats up quickly. The electrodes are in direct contact with the area to be brazed and heat is conducted into the work piece where the temperature is raised sufficiently to melt the brazing alloy and form the joint. Since the temperature of the electrodes is very high, some marking on the surface of the work piece may result, but this can often be alleviated by the use of pulsed current.

In interface resistance heating the electrodes are made from, or faced with, a material of relatively low resistivity. Most of the heat is developed through the resistance to the passage of current at the electrode \ work interface, and some is also developed in the work itself because of its resistivity. The amount of heat in the work piece itself is substantially higher than in the carbon electrode method.

With resistance brazing direct heating is often used, the work piece being gripped between the electrodes at the position where heating is required. In some cases, however, indirect heating may be used, both electrodes being located on one side of the largest component and the smallest component being heated by conduction.

FURNACE BRAZING

The main advantages of using a furnace for brazing are that high rates of output can be achieved, uniform results obtained and an inert or reducing atmosphere used to prevent oxidation. This method is particularly suitable for large batches of small articles which are self-locating or easily jigged, or for parts likely to distort through uneven heating.

Steel or nickel alloys can be successfully furnace brazed using a copper or bronze filler alloy. Brazing is usually carried out in a controlled atmosphere of cracked ammonia, town gas or hydrogen, and flux is not normally required although it may be recommended in some cases.

Furnace brazing of aluminium and aluminium alloy is widely used. Brazed joints may be made between aluminium and aluminium alloy parts either by the use of inserts of aluminium brazing alloys, or by using sheets with an integral coating of brazing alloy. The use of a suitable flux is essential. Since the difference in melting temperature between the filler and the basis metal is very small, close control of the furnace temperature is most important.

TORCH BRAZING

The brazing methods previously mentioned all require a high initial outlay or are only suitable for specialised tasks; they are, therefore, mainly used for large quantity brazing. Brazing by means of a hand torch, although requiring a skilled operator, is inexpensive and is widely used for all types of work.

A wide variety of gas mixtures is suitable for brazing. Oxygen may be combined with acetylene, hydrogen, propane or coal gas; air with propane, butane or methane; or compressed air with coal gas. Of these the most commonly used are oxygen \ acetylene and compressed air \ coal gas.

The selection of a gas for a particular job depends on the size of the component, the temperature required and the rate of heating required, but account must also be taken of the likelihood of overheating, with consequent excessive oxidation and the possible loss of physical properties in the component.

A mixture of compressed air and coal gas burns at approximately 1000°C and is especially suitable for preheating components and for brazing components of light construction, while and oxygen \ acetylene mixture burns at temperatures up to 3000°, and is used where high rates of heating are required.

Brazing Process

It is recommended that before heating is commenced, flux should be applied in the form of an aqueous paste, both to the joint area of the assembly and to the filler alloy. Where the duration of heating or the size of the joint makes it necessary to add flux during the brazing operation, such additions are best made by dipping the hot end of the filler rod or strip into dry flux. If the overlap of a joint exceeds 4 3\4 mm (3\16 inch) the surfaces should be coated with flux prior to assembly.

In all cases rapid heating of the joint is essential, and the flame must be adequate for this purpose, but care must be taken to avoid overheating. When an oxy-acetylene flame is used, a large jet should be employed than that used for the welding of similar material of similar thicknesses. The envelope of the flame should be kept constantly on the move over as large a portion of the joint as possible, since a static flame is likely to cause local overheating and loss of heat control.

Heating should be started with the torch held several inches from the work so that the outer flame envelope spreads over a large area of the joint. Where parts of unequal thickness are brazed, the flame should be concentrated on the heavier part to ensure uniform heating.

(i) As heating is continued, the flux first bubbles then settles down to a thin clear liquid. When this stage is reached, the work is approaching the correct temperature for application of the brazing alloy.

(ii) The brazing filler strip or rod should then be placed in contact with the joint, but if the filler does not melt on contact with the work, it should be removed and the heating continued until the correct temperature is reached. The filler must not be melted by the flame and so allowed to drop on the work; heat should be applied to the work, and the heat from the work used to melt the filler.

When the brazing alloy melts in contact with the assembly, the feeding in of the strip should be continued until the joint is slightly over filled to allow for shrinkage on solidification. When this stage is reached and the molten filler has had time to penetrate the joint fully, heating should be discontinued. Unless the work has sudden changes of section, or is an assembly of metals of widely different expansion characteristics, and if there is no specific instruction on the drawing, it is usual to quench in water after the filler has set.

Oxyacetylene Flame

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 20.1.

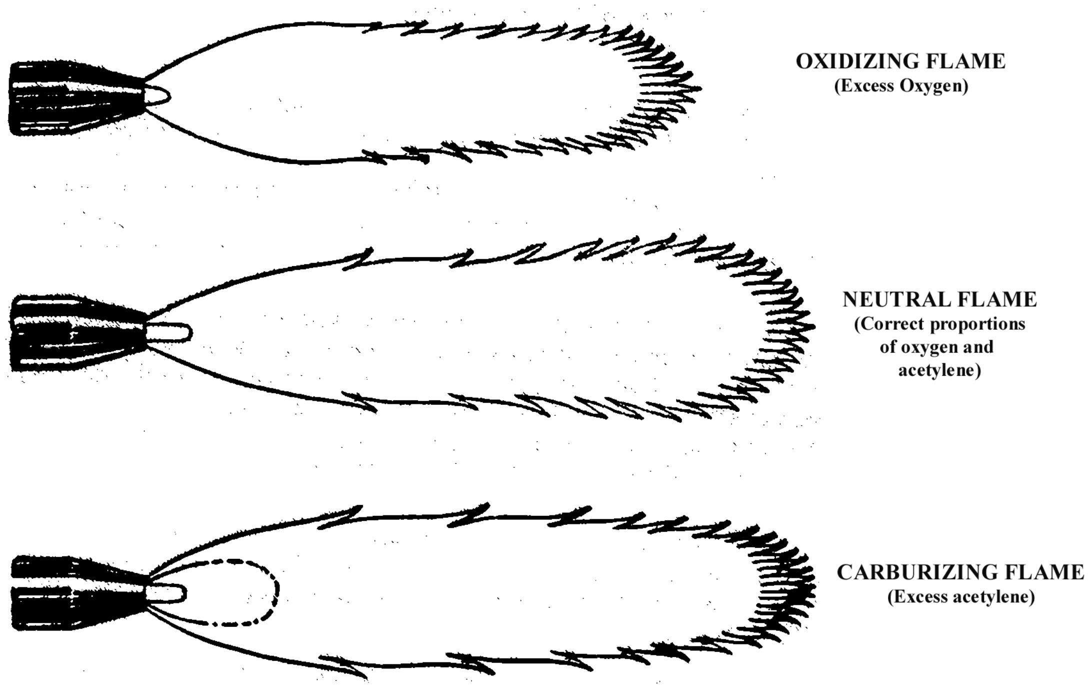


Fig. 20.1, Flame Adjustment

Torches

Brazing torches vary in design according to the gas used. When oxyacetylene is employed, a welding torch, together with the normal welding equipment, is used, the flame being adjusted to suit the brazing work in hand.

There are several types of torches available for brazing with coal gas and air. Brazing torches are designed for lightness and balance to avoid physical strain on the operator. Flame control is obtained by various means, such as two adjustable levers, knurled knobs or, in some instances, a spring loaded trigger-type of levers.

A typical brazing or braze welding hand torch embodies the following features: (a) quick action valves with conveniently place thumb control for the gas and air supplies; (b) a built-in economizer that cuts off the gas and air supply when the operator's grip is relaxed, and restores the flame when the torch is again grasped; this same control enables a soft warming-up flame to be obtained by partial operation of the lever; (c) a pilot flame adjustable to suit different gas pressures; (d) several interchangeable flame units to provide various flame characteristics to suit a wide range of work and gas combinations.

Air is supplied by an electric blower, a foot operated bellows, a compressed air bottle, or the normal factory supply suitably regulated to the required pressure.

Fixed Torches

A logical development of the hand torch is to use fixed burners stationed around a turntable, conveyor belt or similar equipment. Conventional torches are used, but special burners have been developed for this purpose. Compressed air and coal gas are fed to the burner, which comprises a series of fine jets. This produces a flame which does not ' bounce' and has a good depth of heating. These arrangements are commonly fitted with electric timers.

BRAZE WELDING

Braze welding, also known as bronze welding, is a process suitable for use with metals of high melting temperature, in which the main strength of the joint is obtained by building up a fillet alloy. No fusion of the basis metal takes place, but some penetration of the filler alloy into the joint gaps may occur through capillary action.

Filler rods for braze welding are specified in BS 1724, and are basically a copper \ zinc alloy, but may contain quantities of nickel, manganese, silicon or tin, depending on the metals being joined.

Fluxes

Proprietary types of fluxes are used, usually on the recommendation of the manufacturer of the braze welding rod. Fluxes should only be applied after the joint has been suitably prepared.

Torches

Because of the high temperatures required for braze welding, an oxyacetylene torch is normally used.

FLUX REMOVAL

Flux residue is likely to promote corrosion when exposed to atmospheric moisture. The residue cannot be neutralized and should be removed from brazed joints by either chemical or mechanical means, removal being facilitated by the use of adequate amounts of flux and by the avoidance of overheating or prolonged heating during the brazing operation.

Aluminium and Aluminium Alloys

The following procedure may be used for removing flux residue from joints in aluminium or aluminium alloy assemblies:-

(i) Wash in boiling water for 10 to 60 minutes according to the complexity of the assembly, preferably in a bath through which their is a continuous flow of water.

(ii) Rinse in clean hot water.

(iii) Wash in a solution of 10 per cent nitric acid in water at a temperature of 65 ^{o} C for 20 minutes.

(iv) Rinse in water and inspect visually for signs of flux residue.

If flux residue is still present, continue as follows:-

(v) Immerse for up to 30 minutes in a second nitric acid bath to which 1 to 5 per cent sodium dichromate may be added.

(vi) Rinse in clean hot water, drain and dry.

(vii) Inspect for flux residue and, if necessary, repeat operations (v) and (vi).

Materials Other than Aluminium

Where no harmful effects can occur, flux removal is assisted by quenching the work in water as soon as the filler has solidified, but where the component parts of an assembly are of dissimilar materials or have sudden change in section, they should be allowed to cool before washing. The parts should then be thoroughly dried to avoid the possibility of corrosion.

Fluoride Fluxes

Washing in water, followed by brushing with a wire brush, will generally remove the residue of fluoride fluxes, especially if hot or boiling water is used. In difficult cases, soaking in a cold solution of 5 per cent (by volume) of sulfuric acid (SG 1.84) in water, followed by a thorough washing in water and subsequent brushing, will facilitate flux removal, but it will be necessary first to ensure that such an operation will not prove harmful to the finished work, e.g. by entrapment of the solution.

Borax Fluxes

Residues of these fluxes are only slowly soluble in water; they may be removable by the methods specified in above paragraph but mechanical methods such as shot or grit blasting are sometimes necessary. In instances where mechanical methods are impractical the manufacturer may recommend that residues be dissolved in a hot caustic soda solution.

BRAZING ALUMINIUM AND ITS ALLOYS

There is a distinction between brazing aluminium and brazing of other metals. For aluminium and its alloys, the filler metal is of the aluminium-silicon type with a melting point only slightly lower than that of the basis metal. Consequently there is a much smaller margin (compared with the brazing of other materials) between the melting point of the filler and the temperature at which overheating and collapse of the basis metal can occur; accurate control of temperature is therefore most important.

BS 1845 gives a list of the filler materials which are suitable for brazing aluminium and its alloys. Some of the basis metals which can be brazed easily are the various grades of pure aluminium, and some of the alloys of aluminium and magnesium or aluminium, magnesium and silicon. The brazing of alloys containing more than 2 per cent magnesium is not recommended because of the difficulty of removing the oxide film.

Many types of proprietary fluxes are available for brazing aluminium and its alloys; these are generally of the alkali halide type, and the recommendations of the manufacturer of the filler material, regarding their use, should be observed. A standard aluminium brazing flux containing chlorides of sodium, potassium and lithium gives satisfactory results when used with aluminium which has been chemically cleaned.

Most fluxes for aluminium and its alloys absorb moisture very rapidly, and their efficiency is reduced accordingly. It is essential, therefore, that fluxes should be stored in airtight containers. Containers manufactured from aluminium or glass are suitable for this purpose, but steel or brass should not be used, since these materials causes contamination.

Brazing Process

The three main methods of brazing aluminium and aluminium alloys are : torch or flame brazing, furnace brazing and flux dip brazing.

Torch Brazing

In torch brazing, actylene and hydrogen are the preferred fuel gases, although other gases, e.g. coal gas, are used; all these gases are often used with oxygen.

(i) A brazing torch, which is often a standard welding torch, is suitable for most aluminium brazing work. The flame must be maintained in a neutral condition, but should this prove difficult, a slightly reducing flame is preferable to an oxidizing flame (see Figure 20.1).

(ii) When using oxy-acetylene the possibility of overheating must be kept in mind. The melting point of the filler alloy must occur before the temperature of the joint causes sagging or plasticity of the basis metal.

Furnace Brazing

Furnace brazing requires a temperature control of + 5 °C. -0°C. over a range of 540 °C ti 650 °C, according to the material being brazed. The general requirements for brazing aluminium are, a rapid rise in temperature, a short period at the brazing temperature, and a rapid cooling to below the solidifying temperature of the brazing alloy. Any heat-treatment furnace giving such conditions, and having its linings protected from attack by flux, is suitable.

(i) A high rate of heat input ensures that the work is raised to the brazing temperature rapidly and so prevents excessive alloying between the filler metal and the basis metal. An even distribution of the heat throughout the chamber is a definite advantage. No useful purpose is served by having an inert or reducing atmosphere in the furnace.

(ii) As a general guide to timing, light gauge sheets take 2 to 6 minutes from the time the brazing temperature is reached until the filler metal has filled the joint area, and 4 to 15 minutes for complete furnace treatment, havier sections may take up to half-an-hour for the complete furnace treatment.

(iii) Heat-treatable alloys must be reheated and quenched at the appropriate temperature to restore their properties, although quenching from the brazing temperature results in partial restoration. Quenching also loosens and partly removes the residual flux, thereby simplifying the final cleaning process. Thin gauge materials may become distorted if quenched by immersion, and water sprays may be used to minimize this by ensuring that all parts are cooled simultaneously.

Flux Dip Brazing

Flux dip brazing is used largely in the quantity production of assemblies having a large area of jointing in relation to their size, for example, heat exchanger or radiators, and is useful for the brazing of parts in an inaccessible position which cannot be brazed by other methods. This process is suitable for any aluminium alloy that is suitable for furnace brazing.

(i) Components should be cleaned, assembled with pre-placed filler material and heated in a furnace to a temperature just below the melting point of the filler alloy.

(ii) Assemblies should then be transferred to a bath containing molten flux at a temperature high enough to melt the filler, but not the parent metal ; they should be removed as soon as the filler has had time to flow freely through the joints. Overlong immersion may result in flux attack and allow excessive diffusion between the filler and parent metal.

(iii) Heat-treatable assemblies should then be quenched or re-heated as described in paragraph (iii) under furnace brazing.

Flux Removal

The quick removal of flux after brazing is essential ; immediately the assembly can be handled, it should be treated as described in previous paragraph.

Properties of Brazed Aluminium Joints

As the brazing temperature is higher than the recrystallization temperature of aluminium and aluminium alloys, annealing takes place during brazing.

Brazed assemblies made of non heat-treatable alloy have their design strength based on the strength of the annealed material.

Suitable assemblies made of heat-treated alloy of the aluminium-magnesium-silicon type may be strengthened after brazing by quenching, followed by natural or artificial ageing according to the requirements of the specification. Alternatively, assemblies may be re-heat-treated to restore the full strength of the basis material.

Aluminium filler alloy does not show a significant increase in strength after heat-treatment and limits the design strength of a brazed assembly.

HIGH NICKEL ALLOYS

These alloys are usually specified for their heat and corrosion resistant properties.

Most of the high nickel alloys can be readily joined by silver brazing, but may be subject to inter crystalline penetration by the filler alloy if brazed in a state of stress. When high melting point filler alloys are used all stresses are relieved during the brazing process but, if low melting point filler alloys are used on heavily worked components, stress cracking may result if the components are not stress-relieved prior to brazing. Nickel alloy should normally be brazed in the annealed condition.

Cleanliness

Cleanliness is essential, and it is particularly important that all foreign matter which might contain sulphur or lead is removed before any heating takes place, as all nickel alloys are subject to some degree of attack by inter crystalline penetration by these elements, resulting in embrittlement. Possible sources of such contamination are: oil, grease, paint, marking pencils and cutting lubricants. Cleaning should be carried out just before the actual brazing operation. The tenacious oxide film requires vigorous treatment for its removal, particularly on the chromium-containing alloys, and especially after long storage. Mechanical methods, such as grinding, buffing, etc., are generally used, but chemical cleaning may also be employed.

Brazing Materials

Sliver brazing alloys complying with the AG series of filler alloys in BS 1845 are readily available and are recommended for use with nickel alloys. The flux should be of a type recommended by the manufacturer of the filler alloy; borax is not a satisfactory flux for this material. The flux is generally mixed with water and applied with a brush but, alternatively, the parts may be coated with flux and assembled whilst wet. Flux residue must be removed.

Heating

Any of the methods of heating previously described may be used with nickel alloys. The hand torch method may be applied to most work, but particular care is necessary when using an oxyacetylene torch, as the flame can easily produce temperatures well above those required for silver soldering and may overheat the basis metal.

HIGH TEMPERATURE BRAZING

Where joints are required to retain their strength and corrosion resistance at elevated temperatures, high temperature brazing may be used.

Brazing alloys containing palladium or nickel are widely used for joining the Nimonic and Inconel types of alloys; these brazing alloys make joints which combine good mechanical properties at high temperatures with a high resistance to oxidation.

Brazing Methods

Brazing is usually carried out in a vacuum furnace or in a furnace containing an atmosphere of cracked ammonia or hydrogen, but salt bath or induction heating may also be used. Except when vacuum brazing, a flux should normally be used, but if, because of the difficulty of removing the residue, the use of a flux is undesirable, components are sometimes electroplated with nickel before being brazed.

BRAZING STAINLESS STEEL

Stainless steel parts are often joined by brazing. The method is adaptable to repetitive techniques and provides a simple means of making joints which are often as strong as the parent metal.

The success of the brazing operation depends on the use of a suitable stainless steel alloy and on the selection of a suitable filler and flux.

When stainless steels are heated, the formation of chromium carbide within the metal reduces the amount of chromium available and may decrease its resistance to corrosion. This effect is known as weld decay and has been largely overcome by the use of ‘stabilised’ steels containing titanium or niobium. If it becomes necessary to braze un stabilised stainless steels the effects of carbide precipitation may be minimised by keeping the brazing temperature and heating time to a minimum.

Joints in nickel-free stainless steel often suffer from a defect known as crevice corrosion when subjected to conditions of high humidity. Sliver brazing alloys are generally employed where this type of corrosion is likely.

Nickel brazing alloys and alloys containing palladium and gold have been found particularly suitable for furnace brazing in a protective atmosphere, the resulting joints being resistant to chemical attack and crevice corrosion. Bronze filler alloys may also be used but are less resistant to chemical attack.

Fluoride fluxes are normally used when brazing with silver brazing alloys, but special fluxes with improved wetting properties are often recommended for use with stainless steel because of the formation, during, of a thin film of residue which is insoluble in normal flux.

Flux residues should be removed after brazing.

SAFETY PRECAUTIONS

All brazing operations involve the use of flame or heat and the handling of metals at high temperatures ; it is necessary, therefore, that certain simple safety precautions are observed. Additional precautions are necessary because of the use of alloys or fluxes, which may have toxic properties under certain conditions.

General Precautions

Components may retain their heat for a considerable period after brazing and should always be handled with care. Unless asbestos gloves are worn, unquenched parts should always be handled with pliers or tongs.

Torches should always be pointed away from the operator when being lit and should be lit either from the side or from below. If possible, hand torches should be fitted with a switch hook, in which a pilot jet and hook are connected to a valve in the gas supply. When the torch is hung from the hook, its weight cuts off the main gas supply but when it is picked up the flame relights.

Controlled atmosphere furnaces often have a curtain of burning gases at the entry and exit doors. These flames are often nearly invisible under certain light conditions and particular care may be necessary when inserting or removing components.

Hand torch brazing should always be carried out in a location shielded from flammable materials by refractory bricks or asbestos.

Induction Brazing

Metal articles heat up very quickly when placed within an induction coil. For this reason the hands should not be placed in a coil if a ring, watch or bracelet is worn, as severe burns could result.

Salt Baths

Molten salts splashed from a salt bath may cause very severe burns; protective clothing, including overall, gloves and goggles, should always be worn when working with a salt bath. Components must be completely dry before being immersed in the bath and must be lowered very slowly into the salts to prevent splashing. Salt residue should always be scrubbed from the hands before handling food.

Brazing Alloys

Most silver brazing alloys contain zinc or cadmium which, if overheated, give off fumes which may be irritating and injurious to health. Adequate ventilation must be provided when brazing with these alloys and overheating must be avoided.

Fluxes

Most brazing fluxes cause skin irritation, and physical contact should be avoided whenever possible. The hands should be washed frequently and a barrier cream used. In the event of flux being swallowed, medical attention should be sought immediately.

INSPECTION OF BRAZED JOINTS

In order to obtain the most successful brazed joints, close control of all operations is essential. The design, manufacture and cleaning of the component parts of the joint, the brazing alloy and flux used, the heating process selected, the method of removing flux residues and the application of any necessary heat treatment, should all be in accordance with proven methods and substantiated by the manufacture and testing of sample joints.

Adequate control of the heating method is essential, particularly for induction heating, resistance heating and furnace heating, and staff should be competent to ensure that consistent results are obtained. Hand torch operators should have their work checked at frequent intervals.

At specified intervals a completed assembly should be selected and subjected to strength tests and sectioning to ensure that the complete brazing operation remains satisfactory.

The following points should be checked when visually inspecting a finished joint:-

(i) The joint and surrounding surfaces should be free from pitting, corrosion, scale, flux residue and other evidence of bad workmanship.

(ii) The filler alloy must have penetrated throughout the joint. In the case of pipe joints an examination should be made for excessive penetration which may partially obstruct the pipe bore.

(iii) Fillets of filler alloy should be smooth and continuous.

(iv) The dimensions of the assembly should be in accordance with the appropriate drawing.

A visual examination may sometimes be insufficient to establish that the filler alloy has penetrated through the joint. In these cases, X-ray, ultrasonic or eddy current inspections may be required.

In some instances, brazed joints which have been found unsatisfactory, may be re-brazed under suitably controlled conditions. Care is necessary to prevent the build up of an excessive amount of filler alloys, particularly in the case of pipe joints .

INSPECTION OF WELDED JOINTS

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.

Bonding method & inspection carried out relating various bonded joints

Bonding is the practice of connecting various aircraft components to the metal airframe with an appropriate conductor for the purpose of eliminating the build-up of unwanted static charges. Eliminating the build-up of unwanted static charges will reduce radio interference and the possibility of fire. Grounding also connects various aircraft components using appropriate wires; however, grounding is done to provide a return path for electrical components which are not mounted directly to the airframe metal structure. Grounding is also performed on most ground (earth-based) equipment which comes into contact with the aircraft. This is particularly important during fuelling. If a static charge causes an electrical spark at the fuel opening, there is an extreme fire hazard.

General Procedures/ Method/ Technique

Bonding is essentially the connection of the equipment to ground, normally using a braid or some type of flexible uninsulated wire. In some instances, the bonding connection will also act the ground connection for an electrical component.

When installing bonding jumpers, be sure that they are as short as practical and have a resistance of no more than about milli ohms (0.003 ohms). If the bonding strap must also carry very much ground return current, you must be sure there is no appreciable voltage drop across the bonding connection. If the component that is bonded is shock-mounted (figure), be sure there is sufficient slack in the bonding braid that it will not be under a strain when the unit flexes to the maximum extent allowed by the shock mounts.

Since the bonding braid carries current, take special care to prevent is flowing through dissimilar metals, which would cause corrosion. Aluminum alloy jumpers are used to connect between an aluminum alloy structure and an aluminum alloy component, and cadmium-plated copper is used to bond stainless steel, cadmium plated steel or brass. If it is impossible to avoid dissimilar metal junctions, be sure to use a bonding jumper that is more susceptible to corrosion than the structure it is bonding. Before connecting a jumper to an anodized aluminium alloy part, remove the oxide coating that protects the metal, as this coating is an insulator. After the connection is made, apply an appropriate protective coating.

Testing

In general, most bonding jumpers or ground straps must have each connection made to have 0.003 ohms or less in resistance. This measurement must be taken between the surface being bonded and the bonding jumper as illustrated in figure .

This test may be performed using an extremely sensitive ohmmeter or a bonding tester, and should be done anytime a connection has been modified, added to or temporally disconnected.

■■■

CHAPTER-21
AIRCRAFT WEIGHT AND BALANCE

Purpose

The primary purpose of aircraft weight and balance control is safety. A secondary purpose is to achieve the utmost in efficiency during flight.

Improper loading reduces the efficiency of an aircraft from the standpoint of ceiling, maneuverability, rate of climb, speed, and fuel consumption. It can be the cause of failure to complete a flight, or even to start it. Possible loss of life and destruction of valuable equipment may result from overstressed structures or from a sudden shift in cargo and consequent change in flight characteristics.

The empty weight and the corresponding e.g. center of gravity) of all civil aircraft must be determined at the time of certification. The manufacturer can weigh the aircraft, or he can compute the weight and balance report. A manufacturer is permitted to weigh one aircraft out of each 10 produced. The remaining nine aircraft are issued a computed weight and balance report based on the averaged figures of aircraft that are actually weighed. The condition of the aircraft at the time of determining empty weight must be one that is well defined and can be easily repeated.

Need for Reweighing

Aircraft have a tendency to gain weight because of the accumulation of dirt, greases, etc., in areas not readily accessible for washing and cleaning. The weight gained in any given period of time will depend on the function of the aircraft, its hours in flight, atmospheric conditions, and the type landing field from which it is operating. For this reason, periodic aircraft weighings are desirable and, in the case of air carrier and air taxi aircraft, are required by Federal Aviation Regulations.

Privately owned and operated aircraft are not required by regulation to be weighed periodically. They are usually weighted when originally certificated, or after making major alterations that can affect the weight and balance. Even though the aircraft need not be weighed, it must be loaded so that the maximum weight and e.g. limits are not exceeded during operation.

Airline aircraft (scheduled and nonscheduled) carrying passengers or cargo are subject to certain rules that require owners to show that the aircraft is properly loaded and will not exceed the authorized weight and balance limitations during operation.

Theory of Weight and Balance

The theory of weight and balance is extremely simple. It is that of the familiar lever that is in equilibrium or balance when it rests on the fulcrum in a level position. The influence of weight is directly dependent upon its distance from the fulcrum. To balance the level the weight must be distributed so that the turning effect is the same on one side of the fulcrum as on the other. In general, a lighter weight far out on the lever has the same effect as a heavy weight near the fulcrum. The distance of any object from the fulcrum is called the lever arm. The lever arm multiplied by the weight of the object is its turning effect about the fulcrum. This turning effect is known as the moment.

Similarly, an aircraft is balanced if it remains level when suspended from an imaginary point. This point is the location of its ideal e.g. An aircraft in balance does not have to be perfectly level, but it must be reasonably close to it. Obtaining this balance is simply a matter of placing loads so that the average arm of the loaded aircraft falls within the e.g. range. The exact location of the range is specified for each type of airplane.

Weight and Balance Data

Weight and balance data can be obtained from the following sources:

a. The aircraft specifications.
b. The aircraft operating limitations.
c. The aircraft flight manual.
d. The aircraft weight and balance report.

When weight and balance records have been lost and cannot be duplicated from any source, the aircraft must be re-weighed. A new set of weight and balance records must be computed and compiled.

Datum location and Centre of Gravity

The datum is an imaginary vertical plane from which all horizontal measurements are taken for balance purpose, with the aircraft in level flight attitude. It is a plane at right angles to the longitudinal axis of the aircraft. For each aircraft make and model, all locations of equipment, tanks, baggage compartments, seats, engines, propellers, etc., are listed in the Aircraft Specification or Type Certificate Data Sheets as being so many inches from the datum. There is no fixed rule for the location of the datum. In most cases it is located on the nose of the aircraft or some point on the aircraft structure itself. In a few cases, it is located a certain distance forward of the nose section of the aircraft. The manufacturer has the choice of locating the datum where it is most convenient for measurement, locating equipment, and weight-and-balance computation.

The datum location is indicated on most aircraft specifications. On some of the older aircraft, where the datum is not indicated, any convenient datum may be selected. However, once the datum is selected, it must be properly identified so that anyone who reads the figures will have no doubt about the exact datum location. Figure 21.1 shows some datum location used by manufacturers.

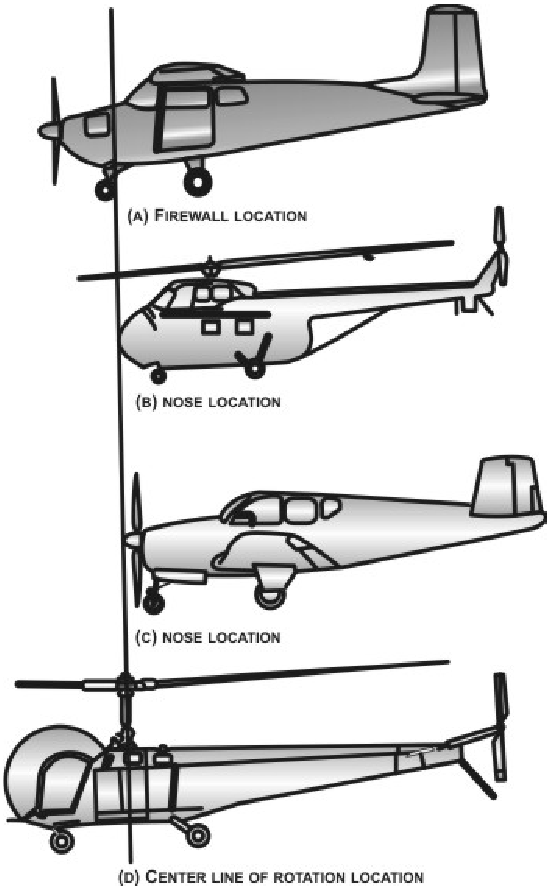


Fig. 21.1. Various datum locations.

The Arm

The arm is the horizontal distance that an item of equipment is located from the datum. The arm's distance is always given or measured in inches, and, except for a location which might be exactly on the datum (0), it is preceded by the algebraic sign for plus (+) or minus (-). The plus (+) sign indicates a distance aft of the datum and the minus (-) sign indicates a distance forward of the datum. If the manufacturer chooses a datum that is at the most forward location on an aircraft (or some distance forward of the aircraft), all the arms will be plus(+) arms. Location of the datum at any other point on the aircraft will result in some arms being plus (+), or aft of the datum, and some minus (-), or forward of the datum.

The arm of each item is usually included in parentheses immediately after the item's name or weight in the specifications for the aircraft, e.g., seat (+23). When such information is not given, it must be obtained by actual measurement. Datum, arm, c.g., and the forward and aft e.g. limits are illustrated in figure 21.2.

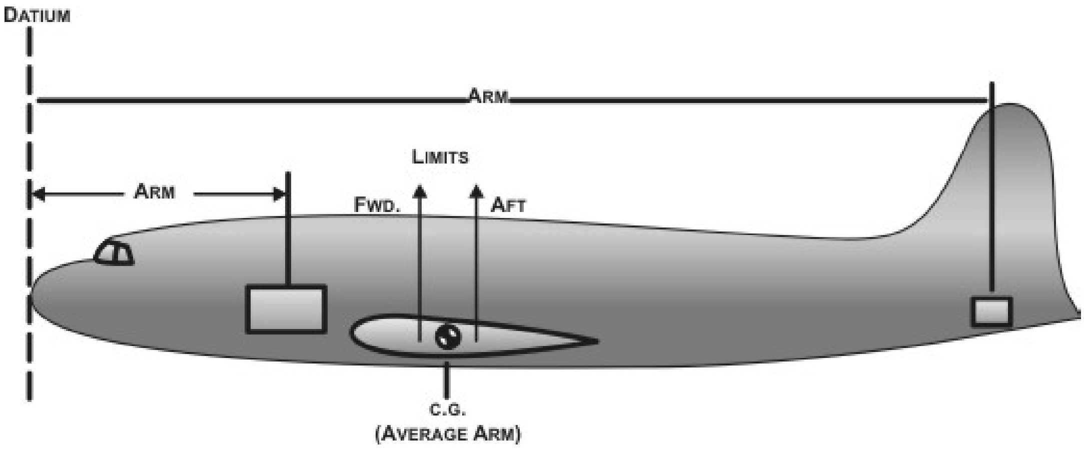


Fig. 21.2. Datum, arm, c.g., and c.g. limits

The Moment

A moment is the product of a weight multiplied by its arm. The moment of an item about the datum is obtained by multiplying the weight of the item by its horizontal distance from the datum. Likewise, the moment of an item about the c.g. can be computed by multiplying its weight by the horizontal distance from the c.g.

A 20-pound weight located 30 inches from the datum would have a moment of 20×30 or 600 lb.-in. Whether the value of 600 lb.-in. is preceded by a plus (+) or minus (-) sign depends on whether the moment is the result of a weight being removed or added and its location in relation to the datum. Any item of weight added to the aircraft either side of the datum is plus weight. Any weight item removed is a minus weight. When multiplying a weight by an arm, the resulting moment is plus if the signs are alike and minus if the signs are unlike.

Centre of Gravity

The c.g. of an aircraft is a point about which the nose-heavy and tail-heavy moments are exactly equal in magnitude. An aircraft suspended from this point would have no tendency to rotate in either a noseup or nosedown attitude. It is the point about which the weight of an airplane or any object is concentrated.

Maximum Weight

The maximum weight is the maximum authorized weight of the aircraft and its contents, and is indicated in the specifications. For many aircraft there are variations to the maximum allowable weight, depending on the purpose and conditions under which the aircraft is to be flown. For example, a certain aircraft may be allowed a maximum gross weight of 2,750 pounds when flown in the normal category, but when flown in the utility category, the same aircraft's maximum allowable gross weight would be 2,175 pounds.

Empty Weight

The empty weight of an aircraft includes all operating equipment that has a fixed location and is actually installed in the aircraft. It includes the weight of the airframe, powerplant, required equipment, optional or special equipment, fixed ballast, hydraulic fluid, and residual fuel and oil.

Residual fuel and oil are the fluids that will not normally drain out because they are trapped in the fuel lines, oil lines, and tanks. They must be included in the aircraft's empty weight. Information regarding residual fluids in aircraft systems which must be included in the empty weight will be indicated in the aircraft Specification.

Useful Load

The useful load of an aircraft is determined by subtracting the empty weight from the maximum allowable gross weight. For aircraft certificated in both the normal and utility categories, there may be two useful loads listed in the aircraft weight and balance records. An aircraft with an empty weight of 900 pounds will have a useful load of 850 pounds, if the normal category maximum weight is listed as 1,750 pounds. When the aircraft is operated in the utility category, the maximum gross weight may be reduced to 1,500 pounds, with a corresponding decrease in the useful load to 600 pounds. Some aircraft have the same useful load regardless of the category in which they are certificated.

The useful load consists of maximum oil, fuel, passengers, baggage, pilot, copilot, and crew-members. A reduction in the weight of an item, where possible, may be necessary to remain within the maximum weight allowed for the category in which an aircraft is operating. Determining the distribution of these weights is called a weight check.

Empty weight Center of Gravity

The empty weight c.g., abbreviated EWCG, is the c.g. of an aircraft in its empty weight condition. It is an essential part of the weight and balance record of the aircraft. It has no usefulness in itself, but serves as a basis for other computations and not as an indication of what the loaded c.g. will be. The EWCG is computed at the time of weighing, using formulas established for tailwheel- and nosewheel-type aircraft.

Empty Weight Center of Gravity Range

The EWCG range is an allowable variation of travel within the c.g. limits. When the EWCG of the aircraft falls within this range, it is impossible to exceed the EWCG limits using standard specification loading arrangements. Not all aircraft have this range indicated on the Aircraft Specifications or Type Certificate Data Sheets. Where it is indicated, the range is valid only as long as the aircraft is loaded according to the standard specification. The installation of items not listed in the specification will not permit use of this range.

Operating Center of Gravity Range

The operating c.g. range is the distance between the distance between the forward and rearward c.g. limits indicated in the pertinent Aircraft Specification or Type Certificate Data Sheets. These limits, determined at the time of design and manufacture, are the extreme loaded e.g. positions allowable within the applicable regulations controlling the design of the aircraft. These limits are shown in either percent of MAC (mean aerodynamic chord) or inches from the datum of the aircraft.

The loaded aircraft c.g. location must remain within these limits at all times. Accordingly, detailed instructions for determining load distribution are provided on placards, loading charts, and load adjusters.

Mean Aerodynamic Chord

The MAC is the mean average chord of the wing. An airfoil section is cross section of a wing from leading edge to trailing edge. A chord is usually defined as an imaginary straight line drawn parallel to the airfoil through the leading and trailing edges of the section. The MAC of a constant chord wing would be the same as the actual chord of the wing. Any departure from a rectangular wing plan form will affect the length of the MAC and the resulting distance from the MAC leading edge to the aircraft wing leading edge. Figure 21.3 shows the MAC for a sweptwing aircraft.

The aircraft c.g. is usually placed at the maximum forward position of the center of pressure on the MAC to obtain the desired stability. Because of the relationship between the c.g. location and the moments produced by aerodynamic forces, the greatest of which is lift, the e.g. location is generally expressed with respect to the wing. This is done by specifying c.g. in percent of the wing's MAC.

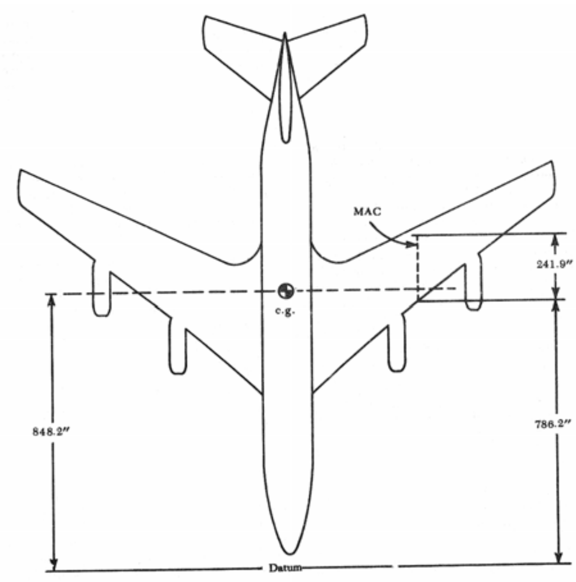


Fig. 21.3.The c.g. shown in relation to MAC.

The location of the MAC, in relation to the datum, is given in the Aircraft Specifications or Type Certificate Data Sheets, the weight and balance report, or the aircraft flight manual. Computer the c.g. location in percent of MAC as follows:

1. Find the difference between the distance to the empty weight c.g. location form the datum and the distance to the

leading edge of MAC from the datum.
2. Divide the difference by the length of the MAC.
3. Multiply the answer by 100.
4. The final answer is then expressed in percent.

An example problem that utilizes the equation for computing percent of MAC is shown in figure 21.4.

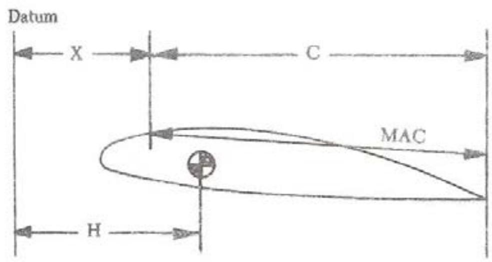


Fig. 21.4. Finding percent of MAC.

Aircraft Leveling Means

Reference points are provided for leveling the aircraft on the ground. They are designated by the manufacturer and are indicated in the pertinent Aircraft Specifications. The most common leveling procedure is to place a spirit level at designated points on the aircraft structure. Some aircraft have special leveling scales built into the airframe structure. The scale is used with a plumb bob to level the aircraft longitudinally and laterally.

Weighing Points

In weighing an aircraft, the point on the scale at which the weight is concentrated is called the weighing point. When weighing light- to mediumweight land planes, the wheels are usually placed on the scales. This means that the weighing point is, in effect, the same location obtained by extending a vertical line through the center line of the axle and onto the scale.

Other structural locations capable of supporting the aircraft, such as jack pads on the main spar, may also be used if the aircraft weight is resting on the jack pads. The weighing points should be clearly indicated in the weight and balance report.

Zero Fuel Weight

The zero fuel weight is the maximum allowable weight of a loaded aircraft without fuel. Included in the zero fuel weight is the weight of cargo, passengers, and crew. All weights in excess of the zero fuel weight must consist of usable fuel.

Minimum Fuel

The term "minimum fuel" should not be interpreted to mean the minimum amount of fuel required to fly an aircraft. Minimum fuel, as It applies to weight and balance, is the amount of fuel that must be shown on the weight and balance report when the airplane is loaded for an extreme condition check.

The minimum fuel load for a small aircraft with a reciprocating engine for balance purposes is based on engine horsepower. It is calculated in the METO (maximum except 'take-off) horsepower and is the figure used when the fuel load must be reduced to obtain the most critical loading on the c.g. limit being investigated. Either of 2 formulas may be used.

Formula 1:

Minimum furl = 1/12 gallons per horsepower.

$hp \times 1/12 \times 6lb.$

$1200 \times 1/12 \times 6 = 1200 \times 1/12 \times 6 = 600$ lb. fuel.

Formula 2:

Minimum fuel = 1/2 lb. per engine horsepower.

$hp \times 1/2 = \text{min imum fuel}$

$1200 \times 1/2 = 600$ lb. fuel

This will be the minimum pounds of fuel required for the forward or rearward weight check.

For turbine-engine powered aircraft, the minimum fuel load is specified by the aircraft manufactures.

The fuel tank location in relation to the e.g. limit affected by the computation determines the use of minimum fuel. For example, when a forward weight check is performed, if the fuel tanks are located forward of the forward e.g. limit, they are assumed to be full. If they are located aft of the forward e.g. limit, they are assumed to be empty. If the minimum fuel required for a particular air· craft exceeds the capacity of the tanks located forward of the forward e.g. limit, the excess fuel must be loaded in the tanks that are aft of the forward e.g. limit. When a rearward weight check is conducted, the fuel loading conditions ire opposite to those used for the forward check.

Full Oil

Full oil is the quantity of oil shown as oil capacity in the Aircraft Specification. When weighing an aircraft, the oil tank may either contain the number of gallons of oil specified or be drained. When an aircraft with full oil tanks is weighed, the weight of the oil must be subtracted from the weight of the oil must be subtracted from the recorded readings to arrive at the actual empty weight. The weight and balance report must show whether weights include full oil or if the oil tanks were drained.

Tare Weight

Tare includes the weight of all extra items, such as jacks, blocks, and chocks on the weighing scale platform, except that of the item being weighed. The weight of these items, when included in the scale reading, is deducted to obtain the actual weight of the aircraft.

Weighing Procedure

Before beginning a study of aircraft weighing procedure or attempting the actual weighing of an aircraft, it is necessary to become familiar with the weight and balance information in the applicable Aircraft Specification or Type Certificate Date Sheet..

The specification for Taylocraft, model BC and BCS airplanes, illustrated in figure 21.5 has been reproduced in its entirety. A few of the items need explaining; the rest are self-explanatory.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

A-696
Revision 16
TAYLORCRAFT

BC	BCS12-D
BCS	BC12-D1
BC-65	BCS12-D1
BCS-65	BC12D-85
BC12-65 (ArmyL-2H)	BCS12D-85
BCS12-65	BC12D-4-85
BC12-D	BCS12D-4-85

AIRCRAFT SPECIFICATION NO. A - 696 **9 September 4969**

Type Certificate Holder	Taylocraft Aviation Corporation 104 Prospect Street Alliance Ohio 44601	
I-ModelBC,2 PCLM, Approved August 24, 1938; ModelBCS, 2 PCSM, Approved April5, 1939		
Engine	Continental A-50-1, (see item 114 (a) for optional engines)	
Fuel	73 min, grade aviation gasoline	
Engine Limits	For all operations, 1900 r.p.m. (50 hp.)	
Propeller Limits	Diameter: Maximum 83 in.	
Airspeed Limits.	Landplane:	Level flight or climb 10.5 m.p.h (91 knots)
(True Ind.)		Glide or dive 131 m.p.h. (114 knots)
	Seaplane :	Level flight or climb 95 m.p.h. (83 knots)
		Glide or dive 129 m.p.h. (112 knots)
Center of Gravity (C.G.) Range	Landplane	(+14.5) to (+19.7)
	Seaplane	(+15.1) to (+19.4)
Empty Weight C.G. Range	Landplane	(+15.3) to (+18.5)
	Seaplane	(15.9) to (+18.3)
	When empty weight C.G. falls within pertinent range, computation of critical for and aft C.G. positions is unnecessary. Ranges are not valid for non-standard arrangements.	
Maximum Weight	Landplane	1100 lb (S/N 1407 and up are eligible at 1150 lb.)
	Seaplane	1128 lb
Number of Seats	2 (+23)	
Maximum Baggage	30 lb (+40)	
Fuel Capacity	12 gal. (–9), See item 115 for auxiliary tank.	
Oil Capacity	4 quart (–21)	
Control Surface Movements	Elevators: Up 25° Down 27°	
	Rudders Right 26° Left 26°	
	Aileron (Not available)	
Serial No. Eligible	1001 and up	
Required Equipment	Landplane : 1 or 4, 104, 202, 203, 210(a), 401	
	Seaplane : 1 or 4, 104, 205, 401	
Specifications Pertinent to All Models,		
Datum	Leading edge of wing	
Leveling Means,	Upper surface of horizontal stabilizer	
Certification Basis,	Part 04 of the Civil Air Regulations effective as amended to May 1, 1938. Type Certificate No.696 issued.	
Production Basis,	None Prior to original certification, an FAA representative must perform a detailed inspection for workmanship, materials and conformity with the approved technical data, and a check of the flight characteristics.	

The designation 2 PCLM is read "2-place, closed land monoplane" and indicates that the airplane seats two persons, has an enclosed cockpit, can be operated from the solid part of the earth's surface, and has only one wing. Two closed sea monoplane." It should be noted that the c.g. range, EWCG range, and the maximum weight are different for the landplane and the seaplane. The location of the seats indicates a side-by-side arrangement. The datum and the leveling means are shown in the portion of the specification that is pertinent to all models. Since the datum and the leveling means are directly connected to weight and balance, they would be among the first items referred to in planning the weighing operation.

Although the location or arrangement of the landing gear is not shown in figure 21.5, this information is given in the Aircraft Specification or Type Certificate Data Sheets and the maintenance manual. The location of the wheels has important significance, since this can be used as a doublecheck against actual measurements taken at the time of weighing.

Preparation of aircraft for weighing
Drain the fuel system until the quantity indication reads zero, or empty, with the aircraft in a level attitude. If any fuel is left in the tanks, the aircraft will weigh more, and all later calculations for useful load and balance will be affected. Only trapped or unusable fuel (residual fuel) is considered part of the aircraft empty weight. Fuel tank caps should be on the tanks or placed as close as possible to their correct locations, so that the weight distribution will be correct.

In special cases, the aircraft may be weighed with the fuel tanks full, provided a means of determining the exact weight of the fuel is available. Consult the aircraft manufacturer's instructions to determine whether a particular model aircraft should be weighed with full fuel or with the fuel drained.

If possible, drain all engine oil from the oil tanks. The system should be drained with all drain valves open. Under these conditions, the amount of oil remaining in the oil tank, lines, and engine is termed residual oil and is included in the empty weight. If impractical to drain, the oil tanks should be completely filled.

The position of such items as spoilers, slats, flaps, and helicopter rotor systems is an important factor when weighing an aircraft. Always refer to the manufacturer's instructions for the proper position of these items.

Unless otherwise noted in the Aircraft Specifications or manufacturer's instructions, hydraulic reservoirs and systems should be filled; drinking and washing water reservoirs and lavatory tanks should be drained; and constant-speed-drive oil tanks should be filled.

Inspect the aircraft to see that all items included in the certificated empty weight are installed in the proper location. Remove items that are not regularly carried in flight. Also look in the baggage compartments to make sure they are empty.

Replace all inspection plates, oil and fuel tank caps, junction box covers, cowling, doors, emergency exits, and other parts that have been removed. All doors, windows, and sliding canopies should be in their normal flight position. Remove excessive dirt, oil, grease, and moisture from the aircraft.

Properly calibrate, zero, and use the weighing scales in accordance with the manufacturer's instructions.

Jacking & levelling for weighing
Some aircraft are not weighed with the wheels on the scales, but are weighed with the scales placed either at the jacking points or at special weighing points. Regardless of what provisions are made for placing the aircraft on the scales or jacks, be careful to prevent it form falling or rolling off, thereby damaging the aircraft and equipment. When weighing an aircraft with the wheels placed on the scales, release the brakes to reduce the possibility of incorrect readings caused by side loads on the scales.

All aircraft have leveling points or lugs, and care must be taken to level the aircraft, especially along the longitudinal axis. With light, fixed-wing airplanes, the lateral level is not as critical as it is with heavier airplanes. However, a reasonable effort should be made to level the light airplanes around the lateral axis. Accuracy in leveling all aircraft longitudinally cannot be overemphasized.

Weighing
Weighing an aircraft is a very important and exacting phase of aircraft maintenance and must be carried out with accuracy and good workmanship. Thoughtful preparation saves time and prevents mistakes.
To begin, assemble all the necessary equipment, such as:

1. Scale, hoisting equipment, jacks, and leveling equipment
2. Block, chocks, or sandbags for holding the airplane on the scales.

3. Straightedge, spirit level, plumb bobs, chalk line, and a measuring tape.
4. Applicable Aircraft Specifications and weight and balance computation forms.

If possible, aircraft should be weighed in a closed building where there are no air currents to cause incorrect scale readings. An outside weighing is permissible if wind and moisture are negligible.

Measurement

The distance from the datum to the main weighing point centerline, and the distance from the main weighing point centerline to the tail (or nose) weighing point centerline must be known to determine the c.g. relative to the main weighing point and the datum.

An example of main weighing point to datum and main weighing point to tail weighing point is shown in figure 21.6. See figure 21.7 for an example of main weighing point to datum and main weighing point to nosewheel measurements.

These distance may be calculated using information from the Aircraft Specifications or Type Certificate Data Sheets. However, it will often be necessary to determine them by actual measurement.

After the aircraft has been placed on the scales (figure 21.8) and leveled, hang plumb bobs from the datum, the main weighing point, and the tail or nose weighing point so that the points of the plumb bobs touch the floor. Make a chalk mark on the floor at the points of contact. If desired, a chalk line may be drawn connecting the chalk marks. This will make a clear pattern of the weighing point distances and their relation to the datum.

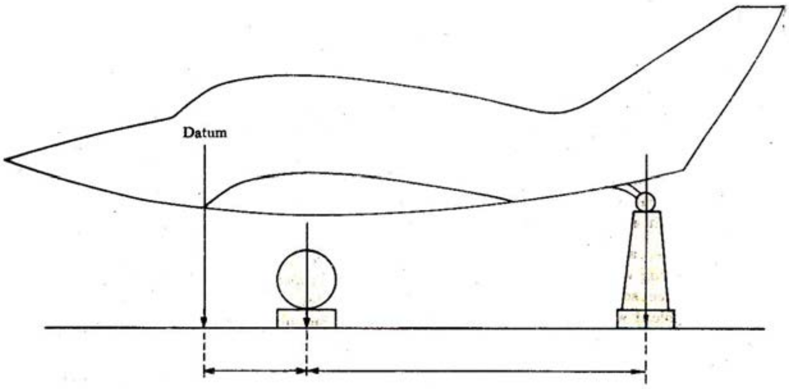


Figure 21.6 Main weighing point to datum and main weighing point to tail weighing point.

Empty Weigh

The empty weight of the aircraft is determined by adding the net weight on each weighing point. The net weight is the actual scale reading, less the tare weight.

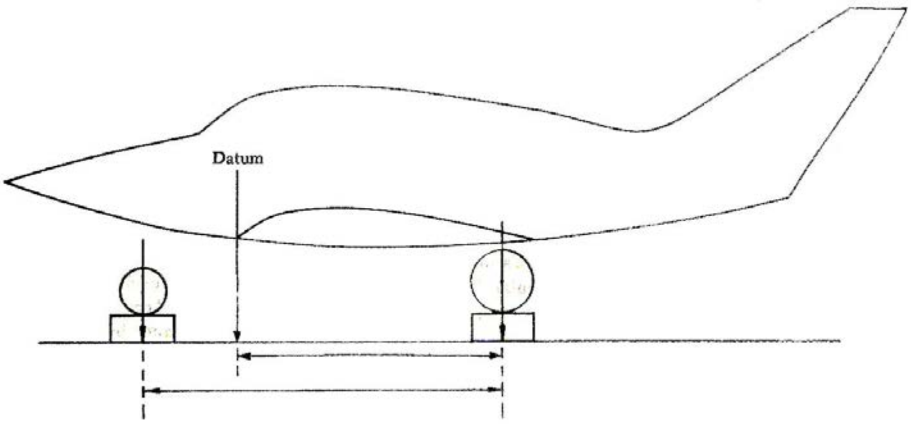


Figure 21.7 Main weighing point to datum and main weighing point to nose weighing point.

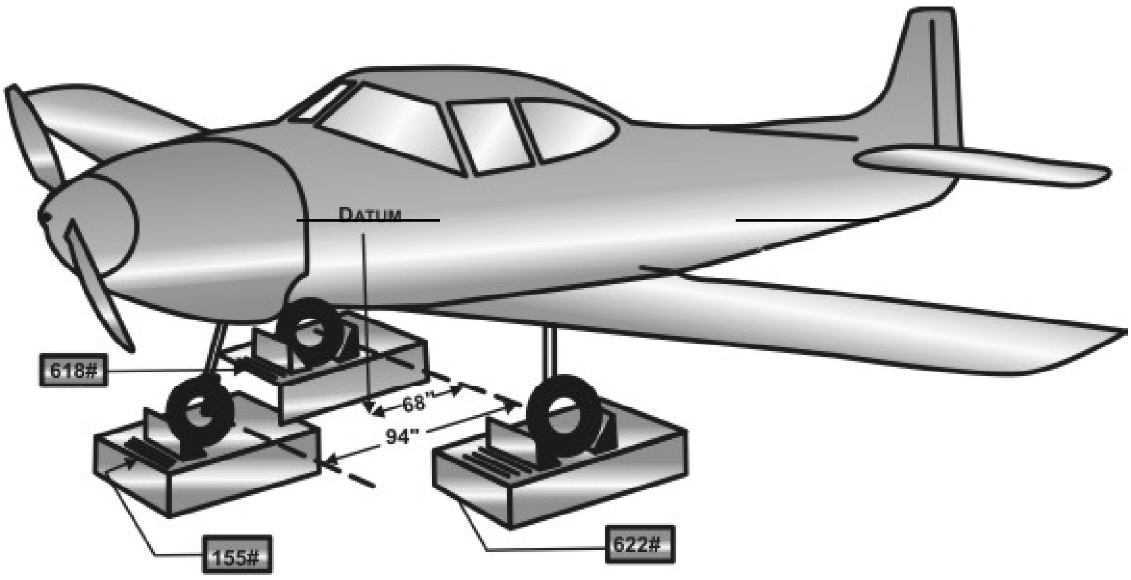


Fig.21.8 Weighing an aircraft using platform scales.

Documentation

Record the weights indicated on each of the scales and make the necessary measurements while the aircraft is still level. After all weights and measurements are obtained and recorded, the aircraft may be removed from the scales. Weigh the tare and deduct its weight from the scale reading at each respective weighing point where tare is involved.

Balance Computation

To obtain gross weight and the c.g. location of the loaded airplane, first determine the empty weight and the EWCG location. When these are known, it is easy to compute the effect of fuel, crew, passengers, cargo, and expendable weight as they are added. This is done by adding all the weights and moments of these additional items and re-calculating the c.g. for the loaded airplane.

The scale reading and measurements recorded on the sample form in figure 21.9 form the basis for the examples of computing the empty weight and the empty weight c.g.

Empty Weight

The empty weight of the aircraft is determined by adding the net weight on each weighing point. The net weight is the actual scale reading, less the tare weight.

Weight scale point	*Scale reading (lbs.)*	*Tare (lbs.)*	*Net weight (lbs.)*
Left main wheel	622.00	-5.00	617.00
Right main wheel	618.00	-4.00	614.00
Nosewheel	155.00	-3.00	152.00
	Total		1,383.00

This gives the aircraft weight as weighed.

Empty Weight C.G.

The c.g. location is found through the progressive use of two formulas. First calculate the total moments using the following formulas:

$$\text{Moment} = \text{Arm} \times \text{Weight}$$

Weight point	*weight* (lbs.)		*Arm* (in.)		*Moment* (lb.in.)
Left main wheel	617.0	×	68”	=	41,956.0
Right main wheel	614.0	×	68”	=	41,752.0
Nose wheel	152.0	×	-26”	=	-3,952.0
	1,383.0				79,756.0

WEIGHINGFORM

MAKE ___Rotary___ MODEL ___A___SERIAL ___0242___ N ___411___.

DATUM LOCATION Leading edge of wing at root

Aircraft weighed with full oil.

1. Main weighing point is located (–_______________” forward) (+68” aft) of datum.
2. Tail or nose weighing point is located (–26” forward) (+__________” aft) of datum.

	Weight Point	Scale Reading	–Tare	=Net Weight	× Arm	= Moment
3.	Left Main Wheel	022.00	–5.00	317.00	68”	41,956.00
4.	Right Main Wheel	618.00	–4.00	614.00	68”	41,752.00
5.	Sub-Total	1,240.00	–9.00	1,231.00	68”	83,708.00
6.	Tail or Nose Wheel	155.00	–3.00	152.00	–26”	–3,952.00
7.	Total as Weighed	1,395.00	–12.00	1,383.00	57.67	79,756.00

Space for listing of Items when Aircraft is not Weighed Empty.

	Item	Net Weight	Arm	Moment
8.	Oil – 8 gallons @ 7.5 p/p/g	–60.00	–30.00	1,800.00
9.	Aircraft Empty Weight & c.g	1,323.00	61.64”	81,556.00

Maximum Allowable Gross Weight 1,773 pounds

Useful Load 450 pounds

Computed by : Frank A. Adams

A & P Number 1366968

Fig. 21.9 . Sample Weighing form.

then divided the sum of the moments by the total weights involved.

$$\text{c.g.} = \frac{\text{Total moment}}{\text{Total weight}} = \frac{79{,}756.0}{1{,}383} = 57.67\,\text{in}.$$

Consequently the c.g. , as weighed, is 57.67 in. from the datum.
Since the aircraft was weighed with the oil tank full, it is necessary to remove the oil to obtain the empty weight and empty weight c.g.

Item	Weight (lbs.)	Arm (in.)	Moments (lb. -in.)
Acft. total as weighed	1,3830.0	57.67	79,756.0
Less oil, 8 gallons, @7.5 lbs. per gallon	-60	-30.00	1,800.0
Acft. empty weight and moment	1,323.0		81,556.0

Again using the formula:

$$\text{c.g.} = \frac{\text{Total moment}}{\text{Total weight}} = \frac{81{,}556.0}{1{,}323}$$

=61.64 in.

The EWCG is located 61.64 in. aft of the datum.

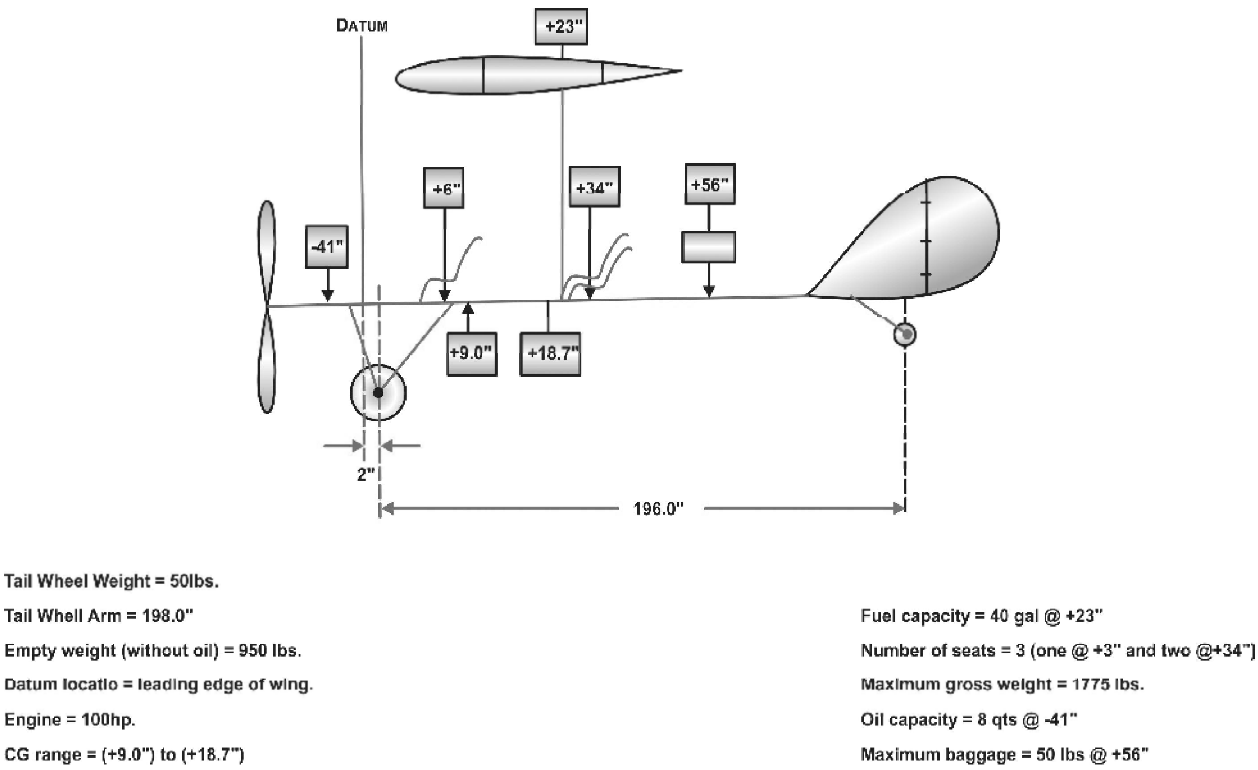


Fig. 21.10 Schematic diagram for forward weight and balance check.

The maximum allowable gross weight as shown in the Aircraft Specifications is 1,733 pounds. By subtracting the aircraft empty weight from this figure, the useful load is determined to be 450 pounds.

Weight and Balance Extreme Conditions

The weight and balance extreme conditions represent the maximum forward and rearward c.g. position for the aircraft.

An aircraft has certain fixed points, fore and aft, beyond which the c.g. should not be permitted at any time during flight. A check should be made to ensure that the c.g. will not shift out of limits when crew, passengers, cargo, and expendable weights are added or removed. If the limits are exceeded and the aircraft is flown in this condition, it may lead to insufficient stability, with resulting difficulty in controlling the aircraft.

Adverse loading checks are a deliberate attempt to load an aircraft in a manner that will create the most critical balance condition and still remain within the design c.g. limits of the aircraft.

It should be noted that when the EWCG falls within the EWCG range, it is unnecessary to perform a forward or rearward weight and balance check. In other words, it is impossible to load the aircraft to exceed the c.g. limits, provided standard loading and seating arrangements are used.

Forward Weight and Balance Check

To make this check, the following information is needed:

1. The weight, arm, and moment of the empty aircraft.
2. The maximum weight, arms, and moments of the items of useful load are located ahead of the forward c.g. limit.
3. The minimum weights, arms, and moments of the items of useful load that are located aft of the forward c.g. limit.

The example shown in figure 21.10 presents one method of conducting an extreme-condition check. This method makes it easy to visualize exactly where the weights of various loading arrangements are distributed and how they affect c.g. location.

Using the data given in figure 21.10 determine if the airplane can be loaded to cause the c.g. to go beyond its limits.

First Step : Load the airplane as follows:
Oil - 8 qts. @ -41in. = (15.0 lbs.) (-41 in.).
Pilot - 170 lbs. @ + 6 in. = (170.0 lbs.) (+6 in.).
Fuel, minimum - 50 lbs. @ + 23 in. = (50.0 lbs.) (+23 in.).
No passengers.
No baggage.

Fill any fuel tanks which are ahead of the forward limit. If the fuel tanks are to the rear of the forward limit, use the minimum required amount of fuel.

SECOND STEP: Total all weights and moments.

Item	**Net Weight (lbs.)**	**Arm (in.)**	**Moments (lb. -in.)**
Acft. EW	950.0	+12.3	+11,685.0
Oil	15.0	+41.0	-615.0
Pilot	170.0	+6.0	+1,020.0
Fuel (min.)	50.0	+23.0	+1,150.0
Total	1,185.0		13,240.0

The above figures require careful consideration. Notice that each weight is multiplied by its arm to obtain its moment. All the weights are added to obtain 1,185 lbs., the total weight. However, when adding the moments, all the plus moments are added :

$$\begin{array}{r} 11{,}685.0 \\ 1{,}020.0 \\ 1{,}150.0 \\ \hline 13{,}855.0 \end{array}$$

The minus moment of 615.0 is subtracted from the sum of the plus moments:

$$\begin{array}{r} 13{,}855.0 \\ -615.0 \\ \hline 13{,}240.0 \end{array}$$

THIRD STEP : Find the most forward c.g. position by dividing the total moments by the total weight

$$\frac{13{,}240.0}{1{,}185} = 11.17 \text{ in.}$$

Since the total moment is plus, the answer must be plus. Therefore, the forward extreme position of the c.g. is located at 11.17 aft of the datum.

The forward limit for this example airplane is +9.0 in. aft of the datum; therefore, it is easy to see that it can be safely flown with this loading arrangement.

Rearward Weight and Balance Check

To establish that neither the maximum weight nor the rearward c.g. limit is exceeded, the following information is needed:

1. The weight, arm, and moment of the empty aircraft.
2. The maximum weights, arms, and moments of the items of useful load that are located aft of the rearward c.g. limit.
3. The minimum weights, arms, and moments of the items of useful load that are located ahead of the rearward c.g. check, except in this case the airplane is loaded so that it will be tail-heavy.

FIRST STEP: Load the airplane in a manner that will make it most tail-heavy.
Oil - 8 qts. @ -41in. = (15.0 lbs.) (-41 in.).
Pilot - 170 lbs. @ + 6 in. = (170.0 lbs.) (+6 in.).
Fuel, (max.) - 40 gals. @ + 23 in. = (240.0 lbs.) (+23 in.).
Passengers-two @ 170 lbs. each = 340 lbs. @ +34 in. = (340 lbs.) (+34 in.).
Baggage. (max.)-50 lbs. @ +56 in. = (50 lbs.) (+56 in.)

Fill any fuel tanks which are aft of the rear limit. If the fuel tanks are forward of the rear limit, use the minimum required amount of fuel.

SECOND STEP : Total all weights and moments as shown here:

Item	Net Weight (lbs.)	Arm (in.)	Moments (lb. -in.)
Acft. EW	950.0	+12.3	+11,685.0
Oil	15.0	+41.0	- 615.0
Pilot	170.0	+6.0	+1,020.0
Fuel (max..)	240.0	+23.0	5,520.0
Passengers (two)	340.0	+34.0	11,560.0
Baggage (max.)	50.0	+56.0	+2,800.0
Total	1,765.0		31,970.0

THIRD STEP : Find the most rearward c.g. position by dividing the total moments by the total weight.
Most rearward c.g. when loaded as shown in figure 21.10:

$$\frac{31{,}970.0}{1{,}765} = 18.11 \text{ in.}$$

The rearward c.g. limit for this example airplane is +18.7 in. aft of the datum; therefore, it can be flown safely with this loading arrangement.

INSTALLATION OF BALLAST

Ballast is used in an aircraft to attain the desired c.g. balance. It is usually located as far aft or as far forward as possible to bring the c.g. within limits using a minimum amount of weight. Ballast that is installed to compensate for the removal or installation of equipment items and that is to remain in the aircraft for long periods is called permanent ballast. It is generally lead bars or plates bolted to the aircraft structure. It may be painted red and placarded: PERMANENT BALLAST - DO NOT REMOVE. In most cases, the installation of permanent ballast results in an increase in the aircraft empty weight.

Temporary ballast, or removable ballast, is used to meet certain loading conditions that may vary from time to time. It generally takes the form of lead shot bags, sand bags, or other weight items that are not permanently installed. Temporary REMOVAL REQUIRES WEIGHT AND BALANCE CHECK. The baggage compartment is usually the most convenient location for temporary ballast.

The places for carrying ballast should be properly designed, installed, and plainly marked. The aircraft operation manual must include instructions regarding the proper placement of the removable ballast under all loading conditions for which such ballast is necessary.

Controlling c.g. Position with Ballast

Figure 21.11 shows an example aircraft whose c.g. exceeds the forward c.g. limit under certain loading conditions. The forward c.g. is exceeded.

Most forward c.g. check

Item	*Weight (lbs.)*	*Arm (in.)*	*Moments (lb.in.)*
Acft. EW	1,600.0	+15.6	+24,960.0
Oil	22.5	-22.0	-495.0
Fuel (min.)	115.0	+18.0	+2,070.0
Pilot	170.0	+10.0	+1,700.0
Total	1,907.5		+28,235.0

$$\text{Most forward c.g.} = \frac{\text{Total moment}}{\text{Total weight}}$$

$$= \frac{28{,}235}{1{,}907.5} = 14.8$$

Without ballast placed somewhere aft to bring the c.g. within the designated limits of +16.5 in. to +20.0 in., the aircraft is unsafe to fly when loaded with the pilot and minimum fuel. The problem of determining how many pounds of ballast are needed to move the c.g. within the approved limits can be solved by using the following formula:

Ballast weight needed:

$$\frac{\text{(Weight of acft as loaded) (Distance out of limits)}}{\text{Arm from variable weight location to limit affected}}$$

Inserting in the formula the applicable values:
Weight of the aircraft as loaded = 1907.5
Distance out of limit =+1.7 in.
Arm from variable weight location to the limit affected = 53.5 in.
We obtain the following:

$$\frac{(1907.5)(1.7)}{53.5} = 60.6 \text{ lbs., ballast weight needed in the baggage compartment..}$$

When the mathematical computation ends in a fractional pound, use the next higher whole pound as the actual ballast weight. Consequently, 61.0 pounds must be placed in the baggage compartment to bring the c.g. safety within the c.g. range.

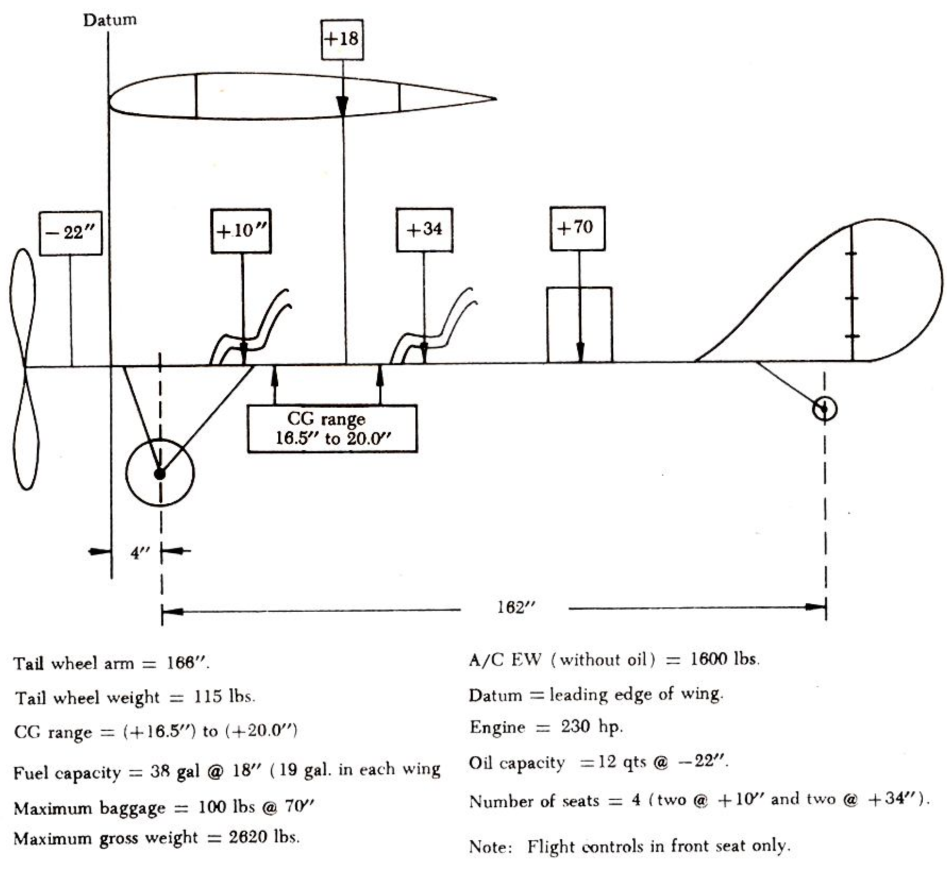


Fig. 21.11 Example aircraft whose c.g. exceed the forward c.g. limit.

A final forward weight and balance check should be made to prove that by adding 61.0 pounds of ballast in the baggage compartment, this aircraft could be safely flown with minimum fuel aboard. Place a placard in the cockpit in a conspicuous place for the pilot, or anyone concerned, to see. The placard should read: FOR SOLO FLIGHT CARRY A MINIMUM OF 61.0 POUNDS IN BAGGAGE COMPARTMENT.

Maximum Load Conditions

A rearward weight and balance check will determine whether the airplane shown in figure 21.11 can be flown safely when fully loaded without exceeding the aft c.g. limit or its maximum gross weight.

Most Rearward c.g. check.

Item	*Weight (lbs.)*	*Arm(in.)*	*Moments (lb.-in.)*
Acft. EW	1,600.0	+15.6	24,960.0
Oil	22.5	-22.0	-495.0
Fuel (max.)	228.0	+18.0	4,104.0
Pilot	170.0	+10.0	1,700.0
Passenger	170.0	+10.0	1,700.0
Passengers (two)	340.0	+34.0	11,560.0
Baggage (max.)	100.0	+10.0	7,000.0
Total	2,630.5		50,529.0

$$\text{Most rearward c.g.} = \frac{\text{Total moment}}{\text{Total weight}}$$

$$= \frac{50{,}529.0}{2{,}630.5} = 19.21 \text{ in.}$$

The c.g. is well within the c.g. range when fully loaded; however, the maximum allowable gross weight is exceeded by 10.5 pounds. In this case a number of alternatives are available to remedy this overloaded condition without appreciably reducing the aircraft payload or flight range, as follows:

Alternative No.1 - reduce baggage by 10.5 lbs.

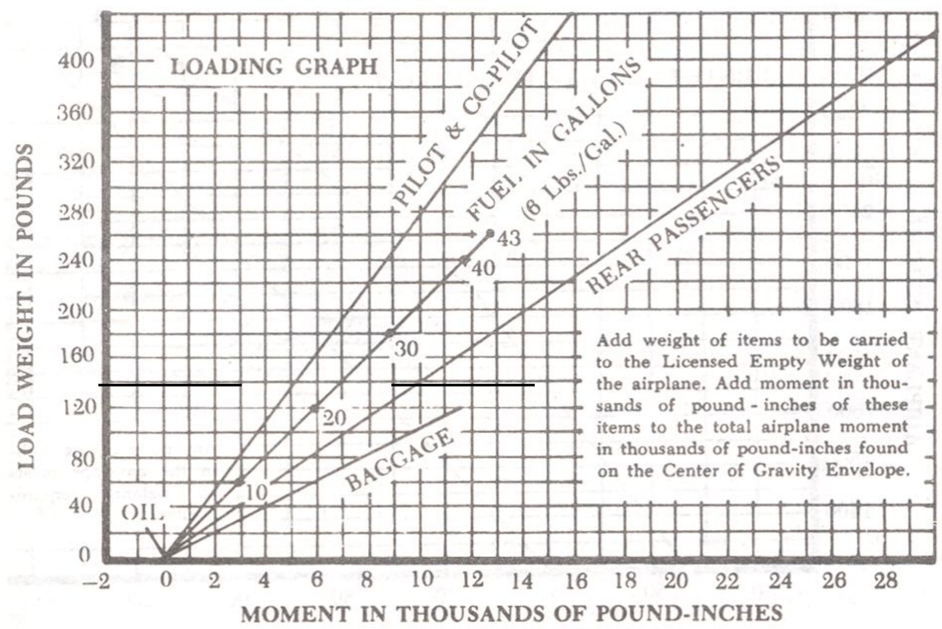
Alternative No.2 - reduce fuel by 10.5 lbs., or 1.75 gals.

Alternative No.3 - reduce passenger load by one passenger.

Each alternative listed will require a placard stating the loading arrangement by which the gross weight and c.g. will be retained within their designated limits. Compute a new c.g. position for each alternate loading arrangement.

Loading Graph and C.G. Envelopes

The weight and balance computation system, commonly called the loading graph and c.g. envelop system, is an excellent and rapid method for determining the c.g. location for various loading arrangements. This method can be applied to any make and model of aircraft.



Fig,. 21.12 Typical loading graph.

Aircraft manufacturers using this method of weight and balance computation prepare graphs similar to those shown in figure 21.12 and 21.13 for each make and model aircraft at the time of original certification. The graph become a permanent part of the aircraft records. Along with the graphs are the data for the empty weight arm and moment (index number) for that particular make and model aircraft..

The loading graph illustrated in figure 21.12 is used to determine the index number of any item or weight that may be involved in loading the aircraft. To use this graph, find the point on the vertical scale that represents the known weight. Project a horizontal line to the point where it intersects the proper diagonal weight line (i.e., pilot, copilot, baggage, etc.). From the point of intersection, read straight downward to the horizontal scale to find the moment or index number.

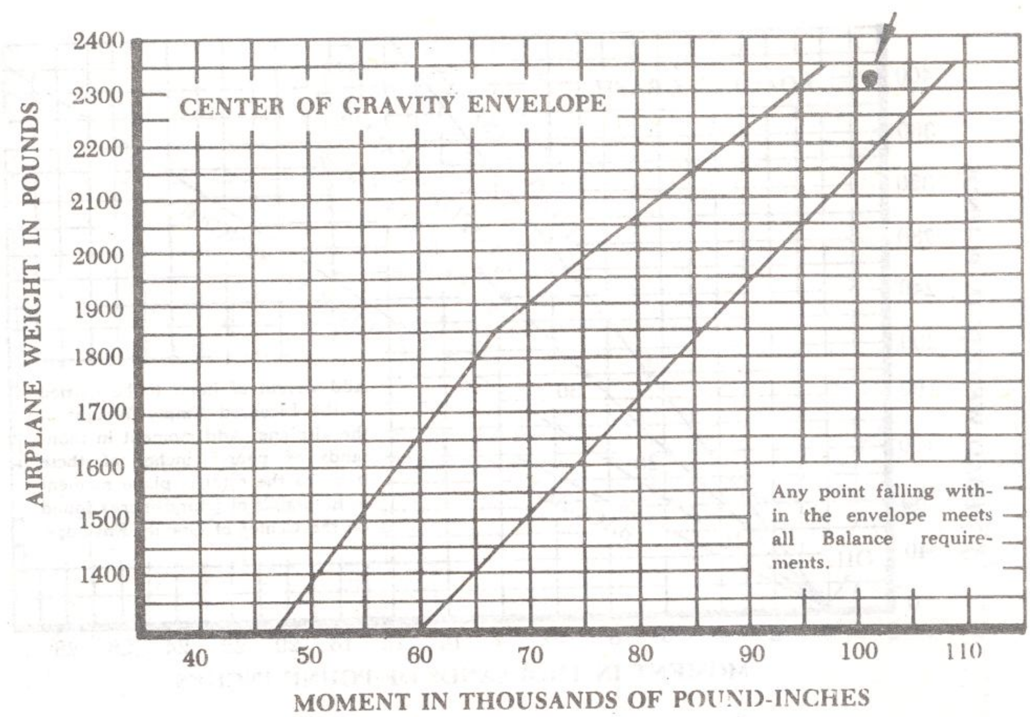


Fig. 21.13. Center of gravity envelope.

After the moment for each item of weight has been determined, all weights are added and all moments are added. With knowledge of the total weight and moment, project a line from the respective point on the c.g. envelope shown in figure 21.13, and place a point at the intersection of the two lines. If the point is within the diagonal lines, the loading arrangement meets all balance requirements.

The following is an actual weight and balance computation using the graphs in figure 21.12 and 21.13. For this example, assume that the aircraft has an empty weight of 1,386.0 pounds and a moment of 52,772.0 pound-inches. The index number for the empty weight of the aircraft is developed by dividing the empty-weight moment by 1,000. This gives an index number of 52.8 for the airplane's empty-weight moment. Load the aircraft to determine whether the c.g. will fall within the diagonal lines of figure 21.13. Arrange item weights and index numbers in an orderly form to facilitate adding.

Item	Weight (lbs.)	Moment (thousands of lb. -in.)
Acft. EW	1,386.0	52.8
Oil	19.0	-0.4
Pilot & copilot	340.0	12.2
Rear passengers (two)	340.0	24.1
Baggage	20.0	1.9
Fuel	245.0	11.8
Total	2,350.0	102.4

The Total airplane weight in pounds is 2,350.0, and the moment is 102.4 Locate this point (2,350 @ 102.4) on the c.g. envelope illustrated in figure 21.13. Since the point falls within the diagonal lines, the loading arrangement meets all weight-and-balance requirements.

ELECTRONICWEIGHINGEQUIPMENT

Electronic weighing equipment greatly simplified the mechanics of weighing large, heavy aircraft. Figure 21.14 shows one type of electronic scales. The complete weighing kit is contained in a portable carrier. Included in the kit are a steel tape, plumb bobs, spirit level, straightedge, hydrometer (for determining the fuel specific gravity) and the load cells. The load cells are actually strain gages that reflect the load imposed upon them by the aircraft in terms of voltage change. This change is indicated on a scale that is calibrated to read in pounds.

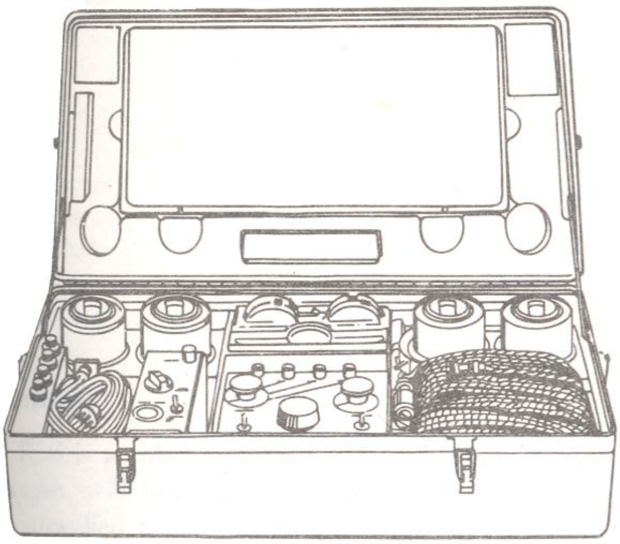


Fig. 21.14. Aircraft electronic weighing kit.

One load cell is placed between the jack-pad and the jack at each weighing point. Each load cell must be balanced or "zeroed" before applying and load to the cell. After completing the weighing operation, remove all load from the cells and check to see if the cell reading is still zero. Any deviation from zero is referred to as the "zero scale shift" and constitutes the tare when using electronic weighing scales. The direction of shift is the factor that determines whether the tare is added to or subtracted from the scale reading. Always follow the instructions of the manufacture whose scales you are using.

HelicopterWeightandBalance

The weight and balance principles and procedures that have been described apply generally to helicopters. Each model helicopter is certificated for a specific maximum gross weight. However, it cannot be operated at this maximum weight under all conditions. Combinations of high altitude, high temperature, and high humidity determine the density altitude at a particular location. This, in turn, critically affects the hovering, takeoff, climb, autorotation, and landing performance of a helicopter. A heavily loaded helicopter has less ability to withstand shocks and additional loads caused by turbulent air. The heavier the load, the less the margin of safety for the supporting structures, such as the main rotor, fuselage, landing gear, etc.

Most helicopter have a much more restricted c.g. range than do airplanes. In some cases this range is less than 3 inches. The exact location and length of the c.g. range is specified for each helicopter and usually extends a short distance fore and aft of the main rotor mast or the centroid of a dual rotor system. Ideally, the helicopter should have such perfect balance that the fuselage remains horizontal while in a hover, and the only cyclic adjustment required should be that made necessary by the wind. The fuselage acts as a pendulum suspended from the rotor. Any fuselage acts as a pendulum suspended from the rotor. Any change in the center of gravity changes the angle at which it hangs from this point of support. More recently designed helicopters have loading compartments and fuel tanks located at or near the balance point. If the helicopter is not loaded properly and the c.g. is not very near the balance point, the fuselage does not hang horizontally in a hover. If the c.g. is too far aft, the nose tilts up, and excessive forward cyclic control is required to maintain a stationary hover. Conversely, if the c.g. is too far forward, the nose tilts down and excessive aft cyclic control is required. In extreme out-of-balance conditions, full fore or aft cyclic control may be insufficient to maintain control. Similar lateral balance problems may be encountered if external loads are carried.

Upon delivery by the manufacturer, the empty weight, empty weight c.g., and the useful load are noted on the weight and balance data sheet in the helicopter flight manual. If, after delivery, additional fixed equipment is added or removed, or if a major repair or alteration is made, which may affect the empty weight, empty weight c.g., or useful load, the weight and balance data must be revised. All weight and balance changes should be entered in the appropriate aircraft record.

■■■

CHAPTER-22
AIRCRAFT HANDLING AND STORAGE

Movement of Aircraft

General

Movement of large aircraft on an airport and about the flight line and hanger is usually accomplished by towing with a tow tractor (sometimes called a “mule or tug”). In the case of small aircraft, most moving is accomplished by hand, by pushing on certain areas of the aircraft surface. Aircraft may also be taxied about the flight line, but usually only by certain qualified persons.

Towing of Aircraft and Towing Equipments

Towing aircraft can be a hazardous operation, causing damage to the aircraft and injury to personnel, if done recklessly or carelessly. The following paragraphs outline the general procedure for towing aircraft; however, specific instructions for each model of aircraft are detailed in the manufacturer’s maintenance instructions and should be followed in all instances.

Before the aircraft to be towed is moved, a qualified man must be in the cockpit to operate the brakes in case the tow bar should fail or become unhooked. The aircraft can then be stopped, preventing possible damage.

Some types of tow bars available for general use (figure 22.1) can be used for many types of towing operations. These bars are designed with sufficient tensile strength to pull most aircraft, but are not intended to be subjected to torsional or twisting loads. Although many have small wheels that permit them to be drawn behind the towing vehicle going to or from an aircraft, they will suffer less damage and wear if they are loaded aboard the vehicle and hauled to the aircraft.

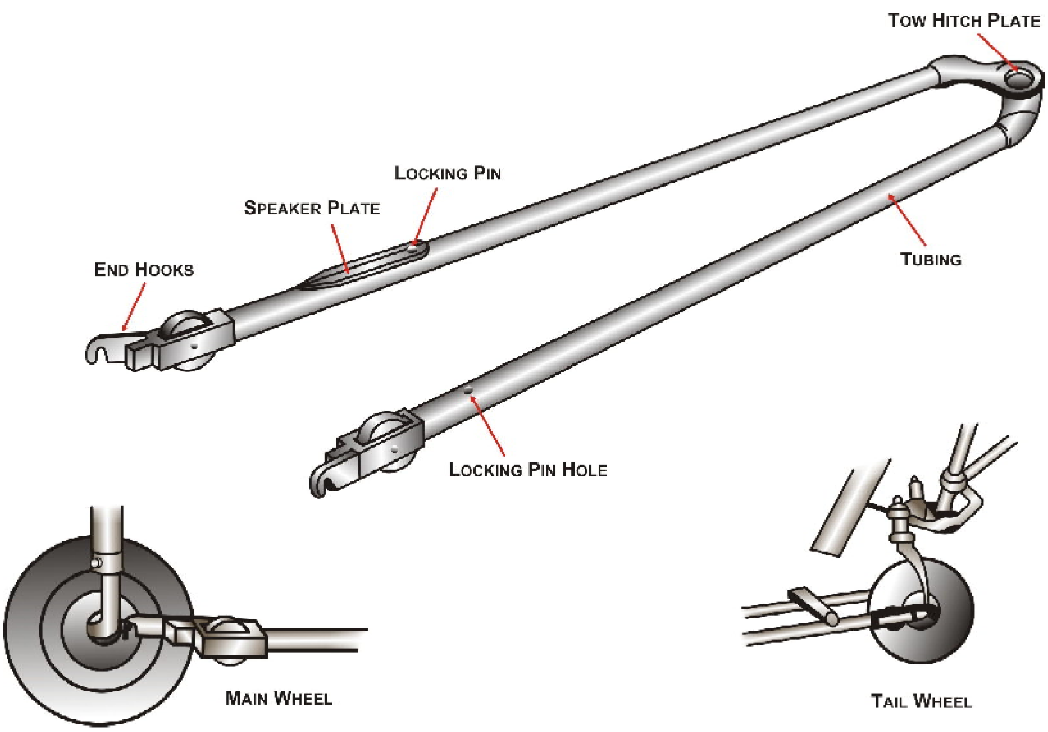


Fig.22.1. A front or rear tow bar.

Some tow bars are designed for towing various types of aircraft; however, other special types can be used on a particular aircraft only. Such bars are usually designed and built by the aircraft manufacturer.

Towing Procedure

1. The towing vehicle driver is responsible for operating his vehicle in a safe manner and obeying emergency stop

instructions given by any team member.

2. The person in charge should assign team personnel as wing walkers. A wing walker should be stationed at each wing tip in such a position that he can ensure adequate clearance of any obstruction in the path of the aircraft. A tail walker should be assigned when sharp turns are to be made, or when the aircraft is to be backed into position.
3. A qualified person should occupy the pilot's seat of the towed aircraft to observe and operate the brakes as required. When necessary, another qualified person is stationed to watch and maintain aircraft hydraulic system pressure.
4. The person in charge of the towing operation should verify that, on aircraft with a steerable nosewheel, the locking scissors are set to full swivel for towing. The locking device must be reset after the tow bar has been removed from the aircraft. Persons stationed in the aircraft should not attempt to steer or turn the nosewheel when the tow bar is attached to the aircraft.
5. Under no circumstances should anyone be permitted to walk or ride between the nosewheel of an aircraft and the towing vehicle, nor ride on the outside of a moving aircraft or on the towing vehicle. In the interest of safety, no attempt to board or leave a moving aircraft or towing vehicle should be permitted.
6. The towing speed of the aircraft should not exceed that of the walking team members. The aircraft's engines usually are not operated when the aircraft is being towed into position.
7. The aircraft brake system should be charged before each towing operation. Aircraft with faulty brakes should be towed into position only for repair of brake systems, and then only with personnel standing by ready with chocks for emergency throughout any towing operation.
8. To avoid possible personal injury and aircraft damage during towing operations, entrance doors should be closed, ladders retracted, and gear downlocks installed.
9. Prior to towing any aircraft, check all tires and landing gear struts for proper inflation. (Inflation of landing gear struts of aircraft in overhaul and storage is excluded.)
10. When moving aircraft, do not start and stop suddenly. For added safety, aircraft brakes must never be applied during towing except in emergencies, and then only upon command by one of the tow team members.
11. Aircraft should be parked in specified areas only. Generally, the distance by great enough to allow immediate access of emergency vehicles in case of fire, as well as free movement of equipment and materials.
12. Wheel chocks should be placed fore and aft of the main landing gear of the parked aircraft.
13. Internal or external control locks (gust locks or blocks) should be used while the aircraft is parked.
14. Prior to any movement of aircraft across runways or taxiways, contact the airport control tower on the appropriate frequency for clearance to proceed.
15. An aircraft should not be parked in a hangar without immediately being statically grounded.

Precautions observed while towing

When towing the aircraft, the towing vehicle speed must be reasonable, and all persons involved in the operation must be alert.

When the aircraft is stopped, the brakes of the towing vehicle alone should not be relied upon to stop the aircraft. The man in the cockpit should coordinate the use of the aircraft brakes with those of the towing vehicle. A typical tow tractor (or tug) is shown in figure 22.2.

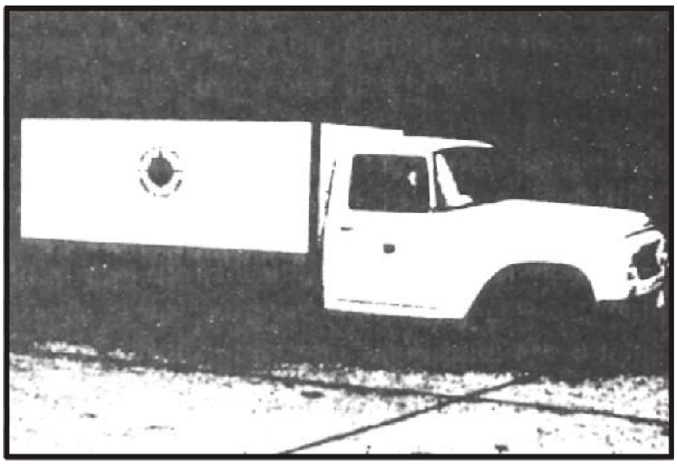


Fig.22.2 Tow Tractor.

The attachment of the tow bar will vary on different types of aircraft. Aircraft equipped with tailwheels are generally towed forward by attaching the tow bar to the tow rings on the main landing gear. In most cases it is permissible to tow the aircraft in reverse by attaching the tow bar to the tailwheel axle. Anytime an aircraft equipped with a tailwheel is towed, the tailwheel must be unlocked or the tailwheel locking mechanism will be damaged or broken.

Aircraft equipped with tricycle landing gear are generally towed forward by attaching a tow bar to the axle of the nosewheel. They may also be towed forward or backward by attaching a towing bridle or specially designed towing bar to the towing lugs on the main landing gear. When an aircraft is towed in this manner, a steering bar is attached to the nosewheel to steer the aircraft.

The following towing and parking procedures are typical of one type of operation. They are examples, and not necessarily suited to every type of operation. Aircraft ground-handling personnel should be thoroughly familiar with all procedures pertaining to the types of aircraft being towed and local operating standards governing ground handling of aircraft. Only competent persons properly checked out should direct an aircraft towing team.

Procedure of taxying
Many ground accidents have occurred as a result of improper technique in taxiing aircraft. Although the pilot is ultimately responsible for the aircraft until the engine is stopped, a taxi signalman can assist him around the flight line. In some aircraft configurations, the pilot's vision is obstructed while he is on the wheels nor under the wings, and has little idea of what is behind him. Consequently, he depends upon the taxi signalman for directions. Figure 22.3 shows a taxi signalman indicating his readiness to assume guidance of the aircraft by extending both arms at full length above his head, palms facing each other.

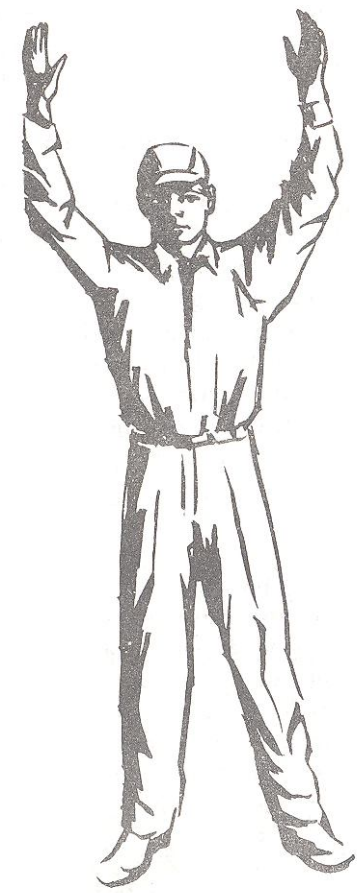


Fig. 22.3. The taxi signalman.

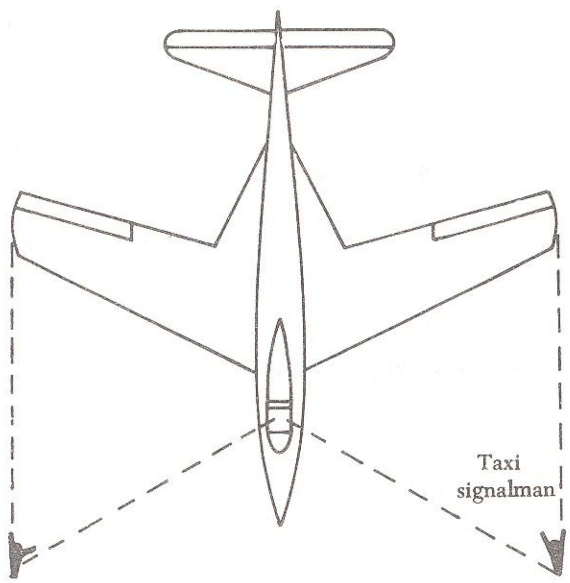


Fig. 22.4. Position of the taxi signalman.

The standard position for a signalman is slightly ahead of and in line with the aircraft's left wingtip. As the signalman faces the aircraft, the nose of the aircraft is on his left (figure 22.4). He must stay far enough ahead of the wingtip for the pilot to see him easily. He should follow a foolproof test to be sure the pilot can see his signals. If he can see the pilot's eyes, the pilot can see his signals.
Figure 22.5 shows the standard aircraft taxiing signals published in the Airmen's Information Manual by the Federal

Aviation Administration. It should be emphasized that there are other standard signals, such as those published by the Armed Forces. In addition, operating conditions in many areas may call for a modified set of taxi signals. The signals shown in figure 22.5 represent a minimum number of the most commonly used signals. Whether this set of signals or a modified set is used is not the most important consideration, as long as each flight operational center uses a suitable, agreed-upon set of signals.

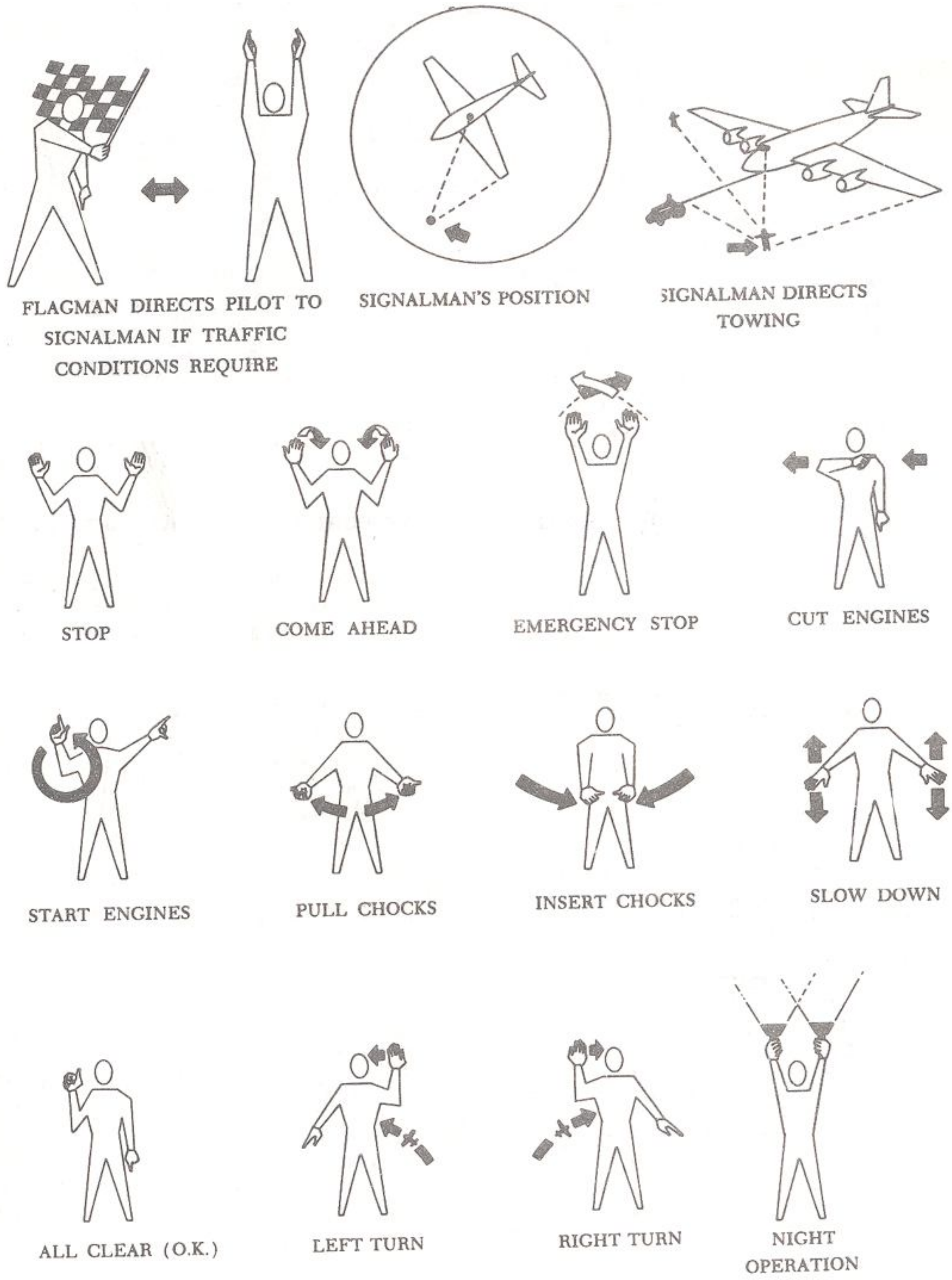


Fig.22.5 Standard FAA hand taxi signals.

Who is authorised for towing/taxying

As a general rule, only rated pilots and qualified airframe and powerplant technicians are authorized to start, run up, and taxi aircraft. All taxiing operations should be performed in accordance with applicable local regulations. Figure 22.6 contains the standard taxi light signals used by control towers to control and expedite the taxiing of aircraft. Refer to the following section, "Taxi Signals," for detailed instructions on taxi signals and related taxi instructions.

Light	***Meaning***
Flashing green	**Cleared to taxi**
Steady red	**Stop**.
Flashing red	**Taxi clear of runway in use.**
Flashing white	**Return to starting point.**
Alternating red and green	**Exercise extreme caution.**

Fig. 22.6 Standard taxi light signals.

Figure 22.7 illustrates some of the most commonly used helicopter operating signals. The taxi signals to be used should be studied until the taxi signalman can execute them clearly and precisely. The signals must be given in such a way that the pilot cannot confuse their meaning. It should be remembered that the pilot receiving the signals is always some distance away, and must often look out and down from a difficult angle. Thus, the signalman's hands should be kept well separated, and signals should be overexaggerated rather than risk making indistinct signals. If there is any doubt about a signal, or if the pilot does not appear to be following the signals, the "stop" signal should be used and the series of signals begun again.

The signalman should always try to give the pilot an indication of the approximate area in which the aircraft is to be parked. The signalman should glance behind himself often when walking backward to prevent backing into a propeller or tripping over a chock, fire bottle, tiedown line, or other obstruction.

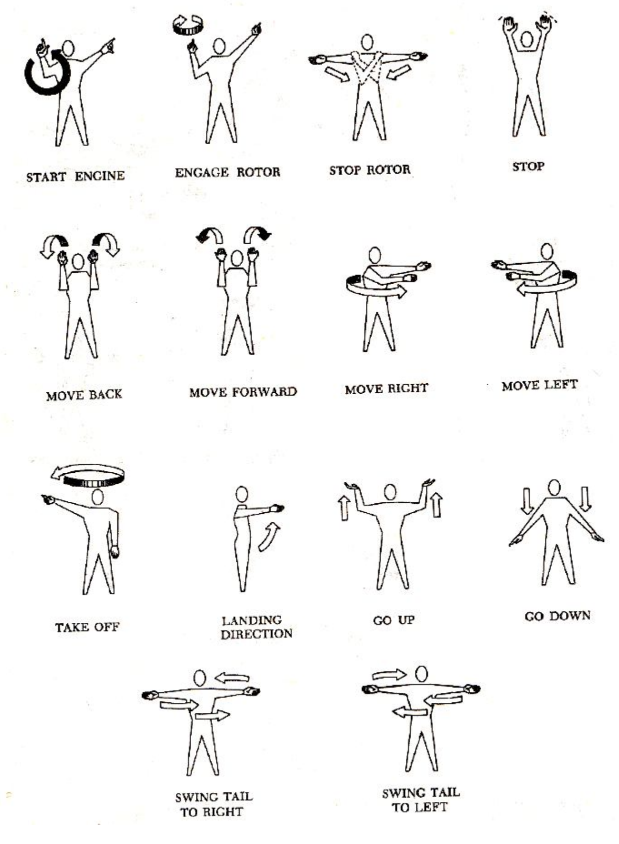


Fig. 22.7 Helicopter operating signals

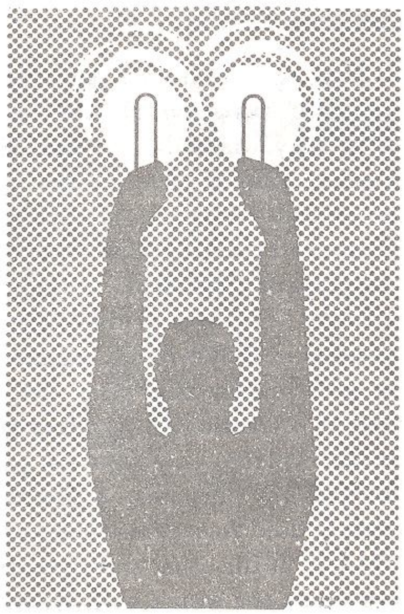


Fig. 22.8 Night operations with wands.

Taxi signals are usually given at night with the aid of illuminated wands attached to flashlights (fig,.22.8). Night signals are made in the same manner as day signals with the exception of the stop signal. The stop signal used at night is the "emergency stop" signal. This signal is made by crossing the wands to form a lighted "X" above and in front of the head.

Precautions observed while taxying

Position the aircraft at starting point nose to the wind

1. Start the engine after taking clearance from ground crew, observing all the taxing precautions
2. Check all the engine parameters are with in limit.
3. Ask the ground crew to remove the chocks.
4. Take permission from A.T.C. (Air trafic control) for taxing
5. Release the brakes
6. Ask for clearance to move the Aircraft
7. Taxi the Aircraft observing all the precautions
8. Bring back the a/c to starting point after taxing is over.
9. Position the a/c at correct parking place
10. Switch off the engines
11. Position chocks fore & aft at both main landing gear wheels
12. Release the brakes
13. Restore all the controls & switches to their correct position
14. Secure the Aircraft

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CHAPTER-23
AIRCRAFT JACKING, CHOCKING, SECURING AND ASSOCIATED SAFETY PRECAUTION

KNOWLEDGE OF DIFFERENT TYPES OF JACKS

There are two main types of jacks used on aircraft, namely tripod jacks and bottle jacks; both types are hydraulically operated. The base of both jacks forms a reservoir for hydraulic fluid, supplying a hand pump which is used to extend the jack ram. A release valve (which is sometimes operated by rotating the pump handle) allows fluid to return to the reservoir and the jack to retract.

A tripod jack has three equally-spaced support legs and a central vertical column which houses a hydraulic cylinder, the ram of which is threaded and fitted with a locking collar as a safety feature. These jacks are used at main aircraft jacking points and are fitted with an adaptor at the top of the ram which engages the jacking pad on the aircraft; the adaptor is sometimes used in conjunction with a transducer for aircraft weighing purposes.

Tripod jacks may be extended to nearly twice original height during use, and care is necessary to ensure that the ram is vertical; if it is not, side forces on the jack could result in its toppling over, with serious consequences to the aircraft and to personnel. When the ram is extended or retracted, the locking collar should be kept in close proximity to the top of the tripod, to prevent the collapse of the ram through hydraulic failure; the locking collar should be locked onto the tripod when the ram is fully raised.

Bottle jacks, which are similar in principle to tripod jacks, are made in various sizes and may have a single or double ram depending on the extension required. Bottle jacks are used mainly for raising individual undercarriage legs for the purpose of changing wheels, brake units, etc., and may be used on their own or in conjunction with a special fitting which attaches to the undercarriage leg or bogie beam.

As with tripod jacks, it is essential that the ram is vertical during use and the locking collar is kept close to the jack body.

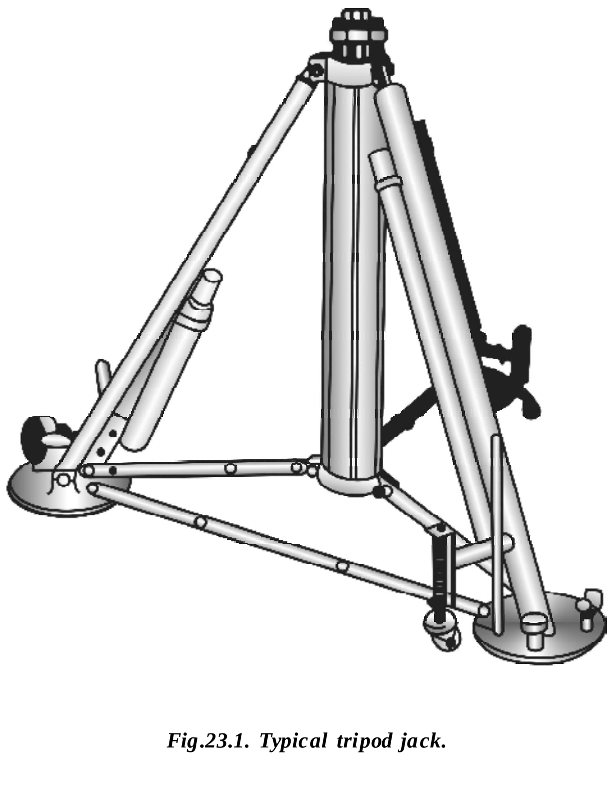

Fig.23.1. Typical tripod jack.

The aviation technician must be familiar with the jacking of aircraft in order to perform maintenance and inspection. Since jacking procedures and safety precautions vary for different types of aircraft, only general jacking procedures and precautions are discussed. Consult the applicable aircraft manufacturer's maintenance instructions for specific jacking procedures.

Extensive aircraft damage and serious personal injury have resulted from careless or improper jacking procedures. As an added safety measure, jacks should be inspected before use to determine the specific lifting capacity, proper functioning of safety locks, condition of pins, and general serviceability. Before raising an aircraft on jacks, all work stands and other equipment should be removed from under and near the aircraft. No one should remain in the aircraft while it is being raised or lowered, unless maintenance manual procedures require such practice for observing leveling instruments in the aircraft.

The aircraft to be jacked must be located in a level position, well protected from the wind. A hangar should be used if possible. The manufacturer's maintenance instructions for the aircraft being jacked should be consulted for the location of the jacking points. These jacking points are usually located in relation to the aircraft center of gravity so the aircraft will be well balanced on the jacks. However, there are some exceptions to this. On some aircraft it may be necessary to add weight to the nose or tail of the aircraft to achieve a safe balance. Sandbags are usually used for this purpose.

Tripod jacks similar to the one shown in figure 23.1 are used when the complete aircraft is to be jacked.

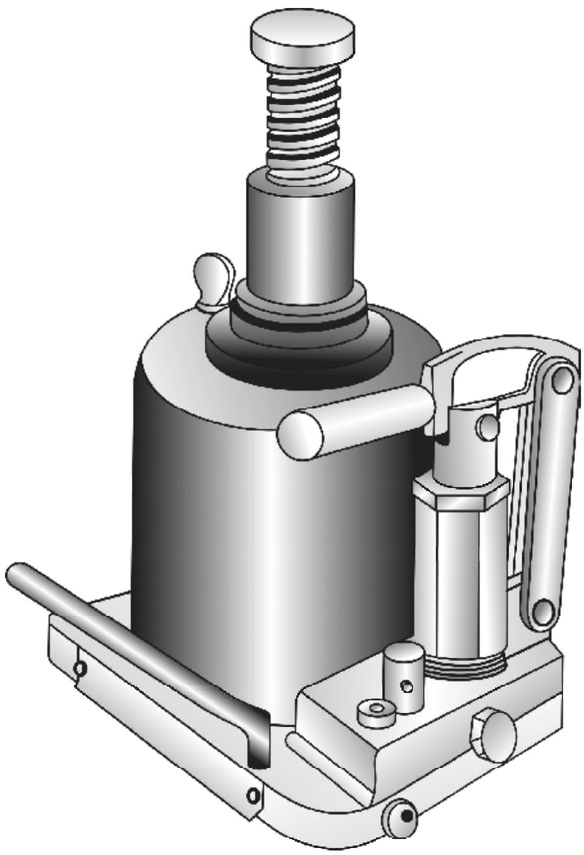

Fig. 23.2. Typical single-base jack.

A small single-base jack similar to the one shown in figure 23.2 is used when only one wheel is to be raised. The jacks used for jacking aircraft must be maintained in good condition; a leaking or damaged jack must never be used. Also, each jack has a maximum lifting capacity, which must never be exceeded.

Jacking Complete Aircraft

Prior to jacking the aircraft, an overall survey of the complete situation should be made to determine if any hazards to the aircraft or personnel exist. Tripod jacks of the appropriate size for the aircraft being jacked should be placed under the aircraft jacking points and perfectly centered to prevent them from cocking when the aircraft is raised. The legs of the jacks should be checked to see that they will not interfere with the operations to be performed after the aircraft is jacked, such as retracting the landing gear.

At least three places or points are provided on aircraft for jacking purpose; a fourth place on some aircraft is used to stabilize the aircraft while it is being jacked at the other three points. The two main places are on the wings, with a smaller one on the fuselage near either the tail or the nose, depending on the landing gear design.

Most aircraft have jack pads located at the jack points. Others have removable jack pads that are inserted into receptacles bolted in place prior to jacking. The correct jack pad should be used in all cases. The function of the jack pad is to ensure that the aircraft load is properly distributed at the jack point and to provide a convex bearing surface to mate with the concave jack stem. Figure 23.3 illustrates two types of jack pads.

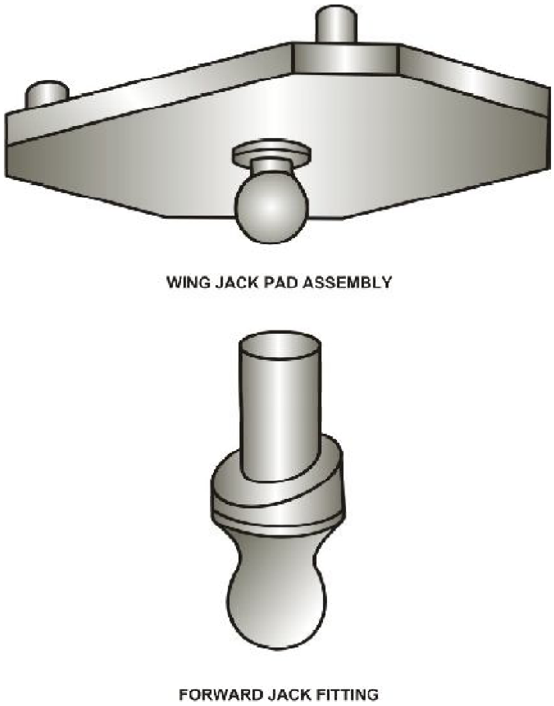

Fig.23.3. Typical jack pads.

Prior to jacking, determine if the aircraft configuration will permit jacking. There may be equipment or fuel which has to be removed if serious structural damage is to be avoided during jacking. If any other work is in progress on the aircraft, ascertain if any critical panels have been removed. On some aircraft the stress panels or plates must be in place when the aircraft is jacked to avoid structural damage.

Extend the jacks until they contact the jack pads. A final check for alignment of the jacks should be made before the aircraft is raised, since most accidents during jacking, are the result of misalined jacks.

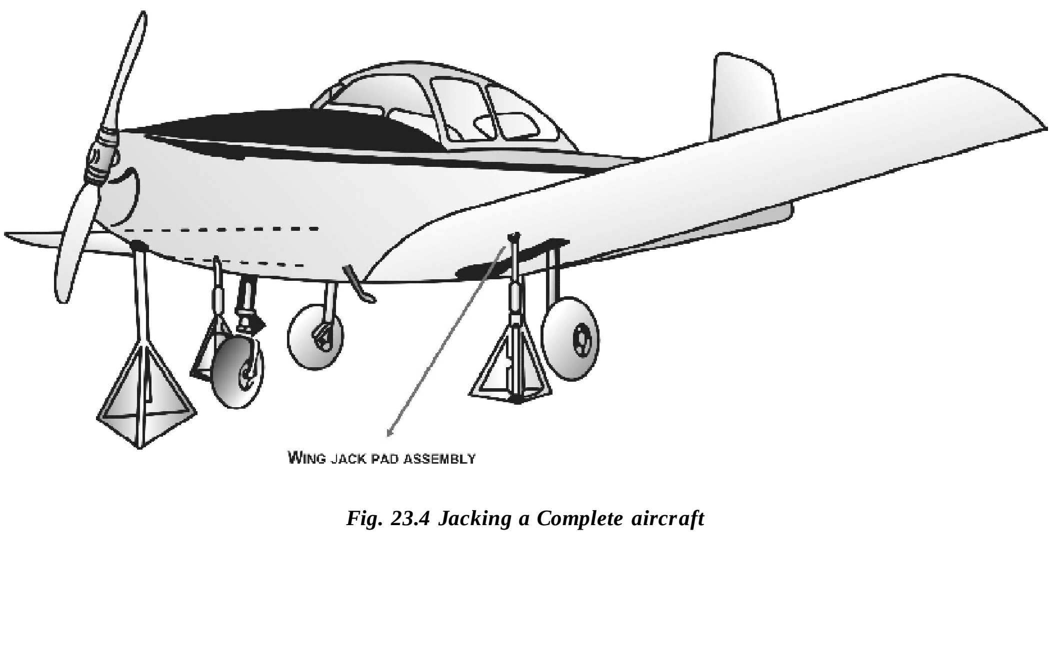

Fig. 23.4 Jacking a Complete aircraft

When the aircraft is ready to be raised, a man should be stationed at each jack. The jacks should be operated simultaneously to keep the aircraft as level as possible and to avoid overloading any of the jacks. This can be accomplished by having the crew leader stand in front of the aircraft and give instructions to the men operating the jacks. Figure 23.4 shows an aircraft being jacked.

Caution should be observed, since on many jacks the piston can be raised beyond the safety point; therefore, never raise an aircraft any higher than is necessary to accomplish the job.

The area around the aircraft should be secured while the aircraft is on jacks. Climbing on the aircraft should be held to an absolute minimum, and no violent movements should be made by persons who are required to go aboard. Any cradles or necessary supports should be placed under the fuselage or wings of the aircraft at the earliest possible time, particularly if the aircraft is to remain jacked for any length of time.

On collect-equipped jacks, the collect should be kept within two threads of the lift tube cylinder during raising, and screwed down firmly to the cylinder after jacking is completed to prevent settling.

Before releasing jack pressure and lowering the aircraft, make certain that all cribbing, work-stands, equipment, and persons are clear of the aircraft, that the landing gear is down and locked, and that all ground locking devices are properly installed.

Jacking One Wheel of an Aircraft

When only wheel has to be raised to change a tire or to grease wheel bearings, a low single-base jack is used. Before the wheel is raised, the remaining wheels must be chocked fore and aft to prevent movement of the aircraft. If the aircraft is equipped with a tailwheel, it must be locked. The wheel should be raised only high enough to clear the concrete surface. Figure 23.5 shows a wheel being raised using a single-base jack.

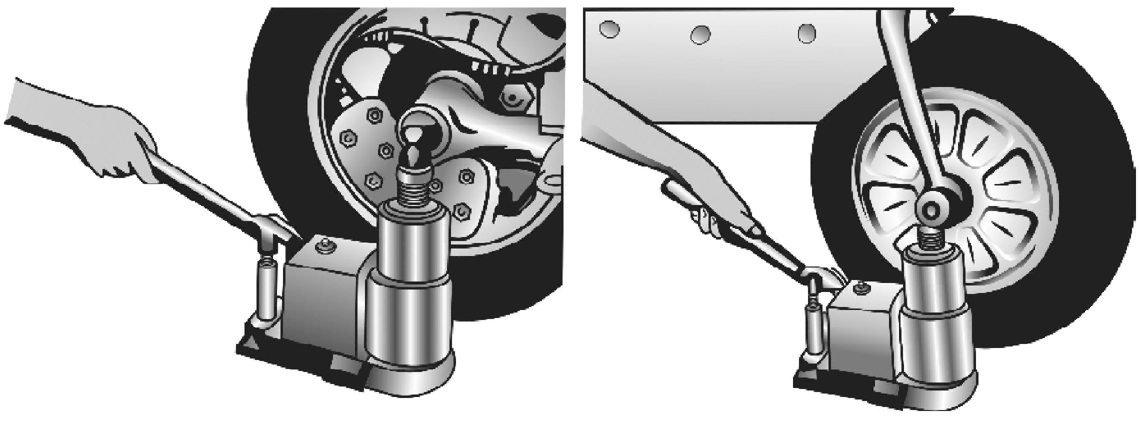

Fig. 23.5 Jacking one wheel

JACKING

Jacking an aircraft may have to be jacked up for a variety of reasons, including servicing, weighing, changing wheels, and retraction tests, and care is necessary to avoid damaging the aircraft. Jacking points are provided in the wings and fuselage to enable individual wheels to be changed. Some aircraft require a jacking pad to be fitted to each jacking point in the wings and fuselage, and adapters to be fitted to the jacks, while in other cases special stirrups or beams may be required to lift individual axles.

Because of the position of the jacking points, the centre of gravity of some aircraft may, although satisfactory for fight, fall behind the main jacking points and thus be unsatisfactory for jacking purpose. In these cases it may be necessary to add ballast forward of the main jacking points to bring the centre of gravity within limits specified in the relevant Maintenance Manual. In addition, each jacking or steadying point may have a load limit which, if exceeded, could result in structural damage. To avoid exceeding the limiting load at the jacking points it is sometimes necessary to fit hydraulic or electrical load cells to the jacks, while ballast may have to be used to avoid exceeding the loading limit at a steadying point.

Micro-switches fitted to the undercarriage legs and operated by the extension or contraction of the shock absorbers, are used to arm or disarm various electrical circuits on an aircraft. If the aircraft is jacked up these circuits will operate as required during flight, and this may not be desirable. These circuits should, therefore, be isolated by tripping the appropriate circuit-breakers or by removing the associated fuses, as necessary.

Lowering

Before lowering an aircraft to the ground, all ground equipment, work stands, supports, etc., should be moved clear of the aircraft structure to prevent inadvertent damage, and the wheels should be rotated by hand to check that the brakes are free. The jacks should be lowered slowly in unison, by opening their pressure release valves, and, to guard against failure of a jack, the locking nuts on the jack rams should be unscrewed while the jacks are lowered and kept within 50 mm (2 in) of the jack heads. The jacks should be fully lowered after the aircraft is resting on its wheels and the pressure release valves should be closed. Chocks should then be placed in position, the jacks, jacking pads and adapters should be removed from the aircraft, and any electrical circuits which were disarmed as a safety measure should be reinstated.

Precautions observed while jacking and lowering

As a safety precaution, light aircraft should normally be jacked inside a hanger, but large aircraft may be jacked in the open provided that they are headed into wind and that the surface is level and strong enough to support the weight of the aircraft at the jacking points. A maximum safe windspeed for jacking is generally specified in the relevant Maintenance Manual.

The following procedure will generally ensure the satisfactory jacking of most aircraft, but account should also be taken of any additional precautions or actions specified in the Maintenance Manual for a particular aircraft. One person should be located at each jacking position and a co-ordinator should supervise the operation. On large aircraft the levelling station should also be manned, and all ground crew concerned should be in communication with the co-ordinator, headphones being used when necessary.

(a) Check that the aircraft weight, fuel state and centre of gravity are within the limits specified in the aircraft Maintenance Manual.
(b) Head the aircraft into wind if it is to be jacked in the open, chock the main wheels front and rear, and release the brakes.
(c) If jacking an aircraft in a restricted space, ensure that there is adequate clearance above every part of the aircraft to allow for its being raised, and adequate access and lifting space for cranes or other equipment which may be required.
(d) Connect earthing cables to the earthing points on the aircraft.
(e) Install the undercarriage ground locks.
(f) Fit jacking pads to the aircraft jacking points and adapters to the jacks as required. Load cells should also be fitted to the jacks at positions where a maximum jacking load is specified.
Note: The capacity and extension of the jacks should be adequate for the aircraft size and weight The minimum requirements will normally be stated in the relevant Maintenance Manual.
(g) Position the jacks at each jacking point and raise them until the adapters are located centrally in the jacking pads. Care must be taken to ensure that the jacks are vertical, and that the weight is evenly distributed over the legs of each jack.
(h) Remove the wheel chocks and slowly raise the aircraft, maintaining it in a horizontal attitude as nearly as possible, until the undercarriage legs are fully extended and the wheels are a few inches off the ground. As a safety measure the locking nuts on the jack rams should be kept in close proximity to the jack shoulders as the jacks are raised.
(i) Tighten the jack ram locking nuts, and place supports under the outer wings and rear fuselage as indicated in the Maintenance Manual. The positioning of these supports is most important, as they are usually shaped to fit the undersurface of the wing or fuselage and must be located at a strong point such as a rib or frame; they are not intended to support the weight of an aircraft.

STORAGE OF AN AIRCRAFT

Aircraft engines and components will deteriorate rapidly when stored unless adequate precautions are taken to protect them from climatic conditions, damp, condensation and accumulation of dust. The most suitable environment for storing complete aircraft is cool, dry hanger with relative humidity of less than 60% where the structure is protected from strong sun light, rapid changes of temperatures atmospheric impurities of marine or industrial origin and the corrosive effect of blown dust before prolong storage contemplated. It is advisable where possible, to remove all sound insulating and textile materials of a hygroscopic nature, After storage special attention should be given to parts of structures which have remained in contact with material of hygroscopic nature. It should be also noted that damp wood will evolve acids that can be harmful to adjacent metal even though the wood may not be in direct contact with it.

A/C should be stored in dry clean condition, All drain and vents should be clear and unobstructed and blank should be fitted to intakes, and apertures in which condensation might occur, colour indicated type silicagel may be used in enclosed space to absorb atmospheric moisture.

Aircraft storage is divided into 2 Parts
1. Short Term Storage
2. Long Term Storage

Short Term Storage
Those aircraft which are likely to remain out of service or use for not more than six months due to repair, modification or other assignment
Following procedure is followed for short term storage
1. Fit landing gear locks
2. Remove attractive items, label them with A/C No. and store separately under lock & key.
3. Fit cockpit covers, intake covers, static vent plugs, exhaust covers and blank other ducts & openings
4. Liberally apply grease to those exposed portions of control cables.
5. OLEO legs, sliding portions of hydraulic jacks and exposed portions of electrical jacks are to be coated with grease
6. Fit external controle locks.
7. Accumulator stowages are to be treated with solution of Bi-Corbonate of Soda, washed with clean water dried them with sulfuric paints.

Long Term Storage of Aircraft
A/C is out of use for indefinite period (longer than six months) due to major repair, modifications, withdrawal from service etc.
1. Fit landing gear locks
2. Thoroughly clean and dry out interior of aircraft remove all oil & grease from fabrics, leather & wooden components.
3. External surfaces & Components of the aircraft are to be thoroughly cleaned taking special care to remove oil and exhaust deposits from fabric components.
4. External surfaces of metal components of Airframe if prone to corrosion are to be cleaned and brushed with lenoline resin protective for temporary rust prevention.
5. Coat all exposed controle cables Jack end etc with lenoline resin all chain sprockets, bearings, oleo struts, sliding portions of Hyd. Jacks etc are to be coated with low temperature grease.
6. Touch up scratches, or damages on surfaces with original paints or dope
7. After all items have been removed Air Frame may be sealed, all inspection panels, Hoods, window joints, controle surface hinges and all apertures are to be sealed with fabrics
8. External & internal controle locks are to be fitted where metal controle surfaces are left in Ci-tu.
9. Metal blade propellers are to be coated with corrosion inhibitors
10. Dingees if fitted are to be removed.
11. Fit covers on cockpit, intake, wheel, propeller (wooden), all miscellaneous ducts are to be suitably blanked off.
12. Picket Aircraft properly if Aircraft is stored out of doors.
13. Colour indicator type of silica gel may be used in enclosed spaces to absorb atmospheric moisture

Documentation
Make entry in the relevant documents, clearly stating the type of storage, date, place and time and next due date, sign the documents properly. Hang a card to the aircraft stating clearly no. of Aircraft date of storage type of storage and next due date. With a warning Aircraft under storage not to disturb.

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CHAPTER-24
REFUELLING/DEFUELING PROCEDURES

Identification & Knowledge of fuel/grade/octane
Octane and performance numbers designate the antiknock value of the fuel mixture in an engine cylinder. Aircraft engines of high power output have been made possible principally as a result of blending to produce fuels of high octane ratings. The use of such fuels has permitted increases in compression ratio and manifold pressure, resulting in improved engine power and efficiency. However, even the high-octane fuels will detonate under severe operating conditions and when certain engine controls are improperly operated.

Antiknock qualities of aviation fuel are designated by grades. The higher the grade, the more compression the fuel can stand without detonating. For fuels that have two numbers, the first number indicates the lean-mixture rating and the second the rich-mixture rating. Thus, grade 100/130 fuel has a lean-mixture rating of 100 and a rich-mixture rating of 130. Two different scales are used to designate fuel grade. For fuels below grade 100, octane numbers are used to designate grade. The octane number system is based on a comparison of any fuel with mixtures of iso-octane and normal heptane. The octane number of a fuel is the percentage of iso-octane in the mixture that duplicates the knock characteristics of the particular fuel being rated. Thus, grade 91 fuel has the same knock characteristics as a blend of 91 percent iso-octane and 9 percent normal heptane.

With the advent of fuels having antiknock characteristics superior to iso-octane, another scale was adopted to designate the grade of fuels above the 100-octane number. This scale represents the performance rating of the fuel-its knock-free power available as compared with that available with pure iso-octane. It is arbitrarily assumed that 100 percent power is obtained from iso-octane alone. An engine that has a knock-limited horsepower of 1,000 with 100-octane fuel will have a knock-limited horsepower of 1.3 times as much (1,300 horsepower) with 130 performance number fuel.

The grade of an aviation gasoline is no indication of its fire hazard. Grade 91/96 gasoline is as easy to ignite as grade 115/145 and explodes with as much force. The grade indicates only the gasoline's performance in the aircraft's engine.

A convenient means of improving the antiknock characteristics of a fuel is to add a knock inhibitor. Such a fluid must have a minimum of corrosive or other undesirable qualities, and probably the best available inhibitor in general use at present is TEL (tetraethyl lead). The few difficulties of ethylized gasoline are insignificant when compared with the results obtained from the high antiknock value of the fuel. For most aviation fuels the addition of more than 6 ml. per gallon is not permitted. Amounts in excess of this have little effect on the antiknock value, but increase corrosion and spark plug trouble.

There are two distinct types of corrosion caused by the use of ethyl gasoline. The first is caused by the reaction of the lead bromide with hot metallic surfaces, and occurs when the engine is in operation; the second is caused by the condensed products of combustion, chiefly hydrobromic acid, when the engine is not running.

Fuel Identification
Gasolines containing TEL must be colored to conform with the law. In addition, gasoline may be colored for purposes of identification. For example, grade 100 low lead aviation gasoline is blue, grade 100 is green and grade 80 is red. See figure 24.1.

100/130 gasoline is manufactured (1975) in two grades- high-lead, up to 4.6 milliliters of lead per gallon and low-lead, not over 2.0 milliliters per gallon. The purpose being to eliminate two grades of lower octane fuel (80/87) and 91/96). The high-lead will continue to be colored green whereas the low-lead will be blue.

The low-lead will replace the 80/87 and 91/96 octane fuels as they are phased out. Engine manufacturers have prepared instructions to be followed in making adjustments necessary for change over to the 100 octane fuel.

A change in color of an aviation gasoline usually indicate contamination with another product or a loss of fuel quality. A color change can also be caused by a chemical reaction that has weekend the lighter dye component. This color change in itself may not affect the quality of the fuel.

A color change can also be caused by the preservative in a new hose. Grade 115/145 gasoline that has been trapped for a short period of time in new hose may appear green. Flushing a small amount of gasoline through the hose usually removes all traces of color change.

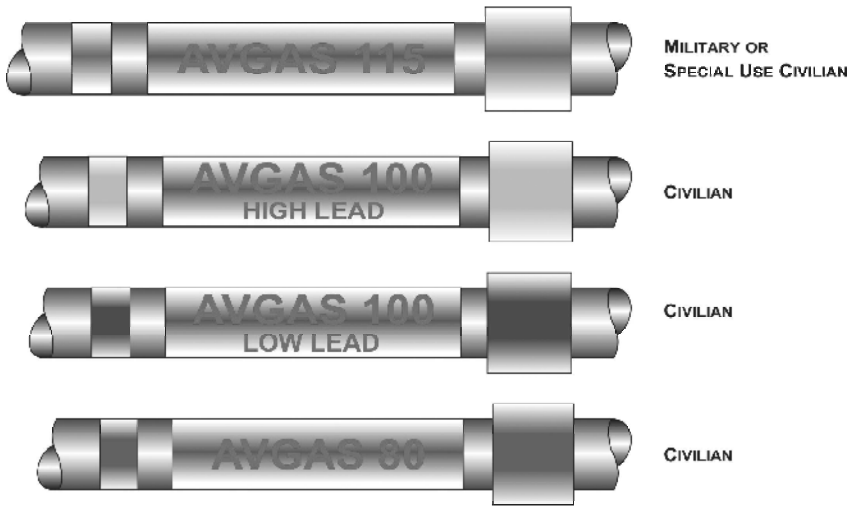

Fig. 24.1 Identification of avgas

Fuel Identification Markings

The most positive method of identifying the type and grade of fuel includes the following:

1. *Marking of Hose.* A color band not less than one foot wide painted adjacent to the fitting on each end of hose used to dispense fuel. The bands completely encircle the hose, and the name and grade of the product is stenciled longitudinally in one-inch letters of a contrasting color over the color band.
2. *Marking of Fuel Carriers.* Pits and Fill Stands. Tags identifying the name and grade of the product permanently affixed to each discharge meter and fill pipe. Porcelain tags (4"X 6") carrying the same information permanently bolted to the 9 year compartment of fuel servicing equipment. The delivery pipes of truck fill stands are banded with colors corresponding to that used on the dispensing hose.

Turbine Engine Fuels

The aircraft gas turbine is designed to operate on a distillate fuel, commonly called jet fuel. Jet fuels are also composed of hydrocarbons with a little more carbon and usually a higher sulphur content than gasoline. Inhibitors may be added to reduce corrosion and oxidation. Anti-icing additives are also being blended to prevent fuel icing.

Two types of jet in common use today are: (1) Kerosene grade turbine fuel, now named Jet A; and (2) a blend of gasoline and kerosene fractions, designated Jet B. There is a third type, called Jet A-1, which is made for operation at extremely low temperatures. See figure 24.2.

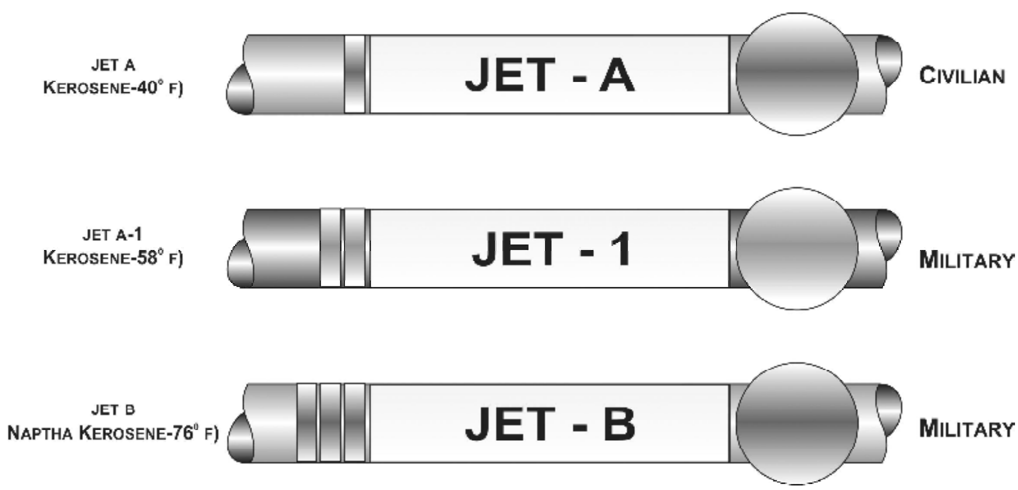

Fig. 24.2 Identification of jet fuels

There is very little physical difference between Jet A (JP-5) fuel and commercial kerosene. Jet A was developed as a heavy kerosene having a higher flash point and lower freezing point than most kerosenes. It has a very low vapor pressure, so there is little loss of fuel from evaporation or boil-off at higher altitudes. It contains more heat energy per gallon than does Jet B (JP-4).

Jet B is similar to Jet A. It is a blend of gasoline and kerosene fractions. Most commercial turbine engines will operate on either Jet A or Jet b fuel. However, the difference in the specific gravity of the fuels may require fuel control adjustments. Therefore, the fuels cannot always be considered interchangeable.

Both Jet A and Jet B fuels are blends of heavy distillates and tend to absorb water. The specific gravity of jet fuels, especially kerosene, is closer to water than is aviation gasoline; thus, any water introduced into the fuel, either through refueling or condensation, will take an appreciable time to settle out. At high altitude, where low temperatures are encountered, water droplets combine with the fuel to form a frozen substance referred to as "gel." The mass of "gel" or "icing" that may be generated from moisture held in suspension in jet fuel can be much greater than in gasoline.

Volatility

One of the most important characteristics of a jet fuel is its volatility. It must, of necessity, be a compromise between several opposing factors. A highly volatile fuel is desirable to aid in starting in cold weather and to make aerial restarts easier and surer. Low volatility is desirable to reduce the possibility of vapor lock and to reduce fuel losses by evaporation.

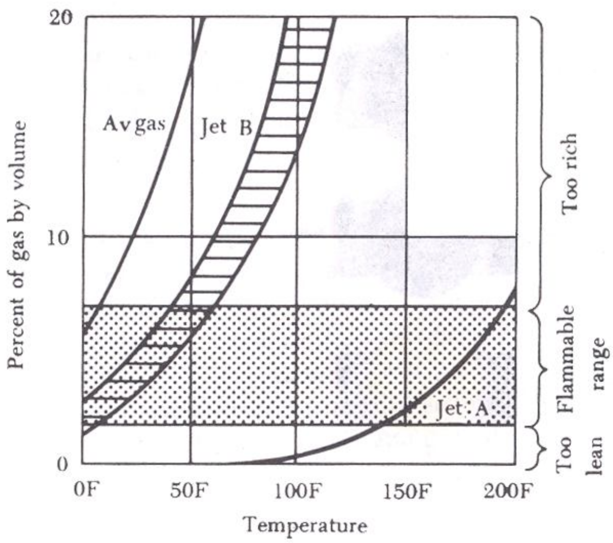

Fig. 24.3 Vaporization of aviation fuels at atmospheric pressure

At normal temperatures, gasoline in a closed container or tank can give off so much vapor that the fuel/air mixture may be too rich to burn. Under the same conditions, the vapor given off by Jet B fuel can be in the flammable or explosive range. Jet A fuel has such a low volatility that at normal temperatures it gives off very little vapor and does not form flammable or explosive fuel/air mixture. Figure 24.3 shows the vaporization of aviation fuels at atmospheric pressure.

Identification

Because jet fuels are not dyed, there is no on sight identification for them. They range in color from a colorless liquid to a straw-colored (amber) liquid, depending on age or the crude petroleum source.

Jet fuel numbers are type numbers and have no relation to the fuel's performance in the aircraft engine.

Discussion about refueller and sampling of fuel

There are several forms of contamination in aviation fuel. The higher the viscosity of the fuel, the greater is its ability to hold contaminants in suspension. For this reason, jet fuels having a high viscosity are more susceptible to contamination than aviation gasoline. The principal contaminants that reduce the quality of both gasoline and turbine fuels are other petroleum products, water, rust or scale, and dirt.

Water

Water can be present in the fuel in two forms: (1) Dissolved in the fuel or (2) entrained or suspended in the fuel. Entrained water can be detected with the naked eye. The finely divided droplets reflect light and in high concentrations give the fuel a dull, hazy, or cloudy appearance. Particles of entrained water may unite to form droplets of free water.

Fuel can be cloudy for a number of reasons. If the fuel is cloudy and the cloud disappears at the bottom, air is present. If the cloud disappears at the top, water is present. A cloud usually indicates a water-in-fuel suspension. Free water can cause icing of the aircraft fuel system, usually in the aircraft boost-pump screens and low-pressure because the water short-circuits the aircrafts electrical fuel cell quantity probe. Large amounts of water can cause engine stoppage. If the free water is saline, it can corrosion of the fuel system components.

Foreign Particles

Most foreign particles are found as sediment in the fuel. They are composed of almost any material with which the fuel comes into contact. The most common types are rust, sand, aluminum and magnesium compounds, brass shavings, and rubber.

Rust is found in two forms: (1) Red foreign particles are found as sediment in the fuel. They are composed of almost any material with which the fuel comes into contact. The most common types are rust, sand, aluminium and magnesium compounds, brass shavings, and rubber.

Rust is found in two forms; (1) Red rust, which is nonmagnetic and (2) black rust, which is magnetic. They appear in the fuel as red or black powder (which may resemble a dye), rouge, or grains. Sand or dust appears in the fuel in a crystalline, granular, or glass like form.

Aluminum as a form of white or gray appear in the fuel as a form of white or gray power or paste. This powder or paste becomes very sticky or gelatinous when water is present. Brass is found in the fuel as bright gold-colored chips or dust. Rubber appears in the fuel as fairly large irregular bits. All of these forms of contamination can cause sticking or malfunctions of fuel metering devices, flow dividers, pumps, and nozzles.

Contamination with Other Types or Grades of Fuel

The unintentional mixing of petroleum products can result in fuels that give unacceptable performance in the aircraft. An aircraft engine is designed to operate most efficiently on fuel of definite specifications. The use of fuels that differ from these specifications reduces operating efficiency and can lead to complete engine failure.

Operators of turbine-powered aircraft are sometimes forced by circumstances to mix fuels. Such mixing, however, has very definite disadvantages. When aviation gasoline is mixed with jet fuel, the TEL in the gasoline forms deposits on the turbine blades and vanes. Continuous use of mixed fuels may cause a loss in engine efficiency. However, on a limited usage basis, they will have no determental effects on the engine.

Aviation gasoline containing by volume more than 0.5 percent of jet fuel may be reduced below the allowable limits in knock rating. Gasoline contaminated with turbine fuel is unsafe for use in reciprocating engines.

Pressure /underwing refuelling

Pressure fueling is used on many late-model aircraft. This fueling process, sometimes referred to as single-point or underwing fueling, greatly reduces the time required to service large aircraft. There are also other advantages in the pressure fueling process. It eliminates aircraft skin damage and hazards to personnel and reduces the chances for fuel contamination. Pressure fueling also reduces the chance of static electricity igniting fuel vapors.

Because of the limited fuel tank area, there are fewer advantages of a pressure fueling system in light aircraft. Thus, they are usually incorporated only in medium size executive jets and large military or commercial transport aircraft.

Most pressure fueling systems consist of a pressure fueling hose and a panel of controls and gages that permit one man to fuel or defuel any or all fuel tanks of an aircraft. A single-point fueling system is usually designed so that an in-the-wing fueling manifold is accessible near a wingtip or under the wing near the wing root. The valves connecting the various tanks to the main fueling manifold are usually actuated in response to fuel pressure signals.

Fueling and defueling procedures are normally placarded on the fueling control panel access door. The fueling operator should possess a thorough knowledge of the aircraft fuel system to recognize malfunction symptoms. Since the design of pressure fueling systems varies somewhat with each type of aircraft, the fueling operator should consult the manufacturer's instructions for detailed procedures.

Due to varying procedure in defueling aircraft, it is important to consult the applicable manufacturer's maintenance instructions.

Procedure

1. Position the fuel tanker with correct grade and specification of fuel.
2. Ground aircraft & fueling tanker.
3. Connect electrical power to aircraft or start A.P.U.

Note - It is permissible for the APU to be operating or started during fueling operation

4. Open fueling station access door.
5. Position gage test switch to test to check the gages and varify that fueling quantity indicators are operating.
6. Press fueling valve position lights to test the bulbs service ability.
7. Connect fueling pressure coupling ground cable to receptical on wing.
8. Remove fueling receptical cap.
9. Connect fueling coupling to fueling receptical.

Note :- If tanks are being loaded to full capacity proceed as following

10. Place all fueling value switches in open position.
11. Start fueling truck pump, adjust to correct fueling pressure
12. Proceed to fuel tanks until they are full or truck flow meter ceases to register fuel flow.

Note: - The fuel tank foal switches will close each individual tanks fueling shut off valve as fuel load reaches full level.

13. Place all fueling valve switches in close position and stop fueling truck pump
14. Disconnect fueling hose coupling.
15. Disconnect grounding cable connection.
16. Install fueling receptical cap.
17. Close fueling station access door.
18. Disconnect fueling truck grounding cable connection.
19. Disconnect Aircraft grounding cable connection and secure the Aircraft.
20. Make relevant document entries in proper document.

Manual/owerwing refuelling

In the overwing fueling of large aircraft, the man with the CO_2 bottle stands close to the aircraft to be refueled. The fuel hose handler on the truck unreels the hose and passes it up to the man on the aircraft who is to do the fueling. Care should be taken in bringing the hose nozzle up to the filler neck of the fuel tank to avoid excessive marring of the aircraft finish. Attached to the nozzle is a ground wire which is plugged into the receptacle adjacent to the fuel tank to be filled. Another type of ground wire commonly used terminates in an alligator clip connected to a grounding post. This connection is made before the fuel tank cap is removed from the filler neck. This serves as a continuous ground connected to a suitable ground on the apron (A of figure 24.4). The aircraft should also be grounded to the apron.

This grounding arrangement may take other forms. In many cases, the fuel truck is grounded by a metal chain that is grounded by a carbon strip embedded in the tires; and the aircraft and fuel truck are held at a common electrical potential by a conducting wire encircling the fuel hose from nozzle to tank fitting. All this is to prevent a spark from static electricity that may be created as the fuel flows through the fuel hose into the aircraft's fuel tank.

The fueling of light aircraft involves fewer problems. While the fueler's responsibilities are still the same, it is usually a one or two-man operation. The danger of marring the aircraft finish is minimized since the height and location of the fuel tanks usually permit easy accessibility to the filler neck. In addition, small aircraft can be easily pushed by hand to a fueling position near a fuel truck or a fueling island. Figure 24.5 shows a small aircraft being fueled.

When the fuel tank is nearly full, the rate of fuel flow should be reduced for topping off the tank; that is, the tank should be slowly filled to the top without spilling fuel on the wing or ground. The filler cap is replaced on that tank, the ground wire plug removed from its receptacle, and then the man handling the fuel nozzle takes the hose and moves on to the next tank to the filled. This procedure is followed at each tank until the aircraft is completely refueled. Then the ground wires are disconnected from the aircraft, and the hose is rewound onto the hose reel in the truck. During this operation the hose or nozzle should not be allowed to drop to the ground.

Procedure

1. Position the fuel tanker with correct grade of fuel.
2. Position one man with fire extinguisher near the a/c

3. One man on the wing to carryout the refueling.
4. One man for assisting him to provide the refueling hose.
5. One man near the fuel tanker to check the operation.
6. Position the fuel tanker on a firm and parallel ground.
7. Ground airplane & fuel tanker to prevent possibility of fire or explosion due to discharge of static electricity.
8. Wait for 15 minutes and carry out fuel sampling, once satisfied proceed for fueling.
9. Unroll the hose and take it over the wing near the refueling point, ground the nozzle to receptical adjacent to fueling port.

Note :- Do not remove filler cap before grounding the nozzle.

10. Remove filler cap from over wing fuller port of the fuel tank.
11. Insert fueling nozzle in to filler port and start fueling operation - maintaining proper pressure while refueling. When tank is loaded with fuel, remove fueling nozzle and install filler port cap.
12. Disconnect fueling nozzle grounding connection.
13. Remove fueling truck grounding cable connection.
14. Remove Aircraft grounding cable connection.
15. Remove fuller and secure the Aircraft.
16. Make relevant document entries.
17. Never reverse the refueller.

DEFUELLING

Light aircraft fuel tanks are usually filled through over-wing filler caps, and drained by means of suitable cocks or plugs in the tanks or pipelines. These features are often retained on large transport aircraft for emergency refuelling and for draining individual tanks, but as these methods are very slow, refuelling and defuelling are normally carried out through pressure refuelling connections situate in the lower wing or fuselage surfaces.

Pressure defuelling of the main tanks or center-wing tank is accomplished through a defuelling valve located in the inboard dry bay of each wing. The fuel boost pumps in the main tanks or the override pumps in the center-wing tank deliver fuel to the defuelling valves through their respective fuel-manifold valves. The defuelling rate is approximately 50 gal/min [189.5 L/min] for each tank. Alternatively, fuel can be drawn from the tanks through the defuelling valve by means of the truck defuelling pump. The reserve tanks are defueled through the reserve-tank-transfer valve to the adjacent main tanks. Residual fuel in each can be drained through fuel-sump drain cocks located in the bottom of each tank.

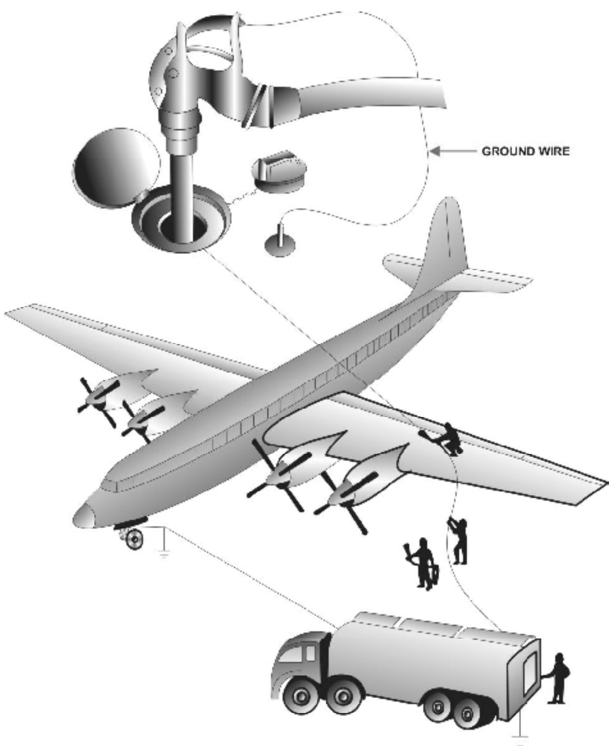

Fig.24.4. Refueling an aircraft

Fig.24.5. Fueling a small aircraft

PRECAUTIONS OBSERVED WHILE REFUELING/DEFUELING

Strict fire precautions must be adhered to during the fueling process. Smoking is not permitted in or around an aircraft during fueling. Also, open flames such as oil lanterns, candles, or matches are prohibited. Exposed electric switches, slip rings or commutators, dynamos or motors, spark-producing electrical equipment, or any burning material must not be permitted within 100 feet of an aircraft being fueled or defueled. No lights other than approved explosion-proof lights are permitted within 100 feet of these operations, and no light of any sort may be placed where it can come in contact with spilled fuel. Warning signs should be posted as a precautionary measure.

All aircraft fuels or other combustible liquids accidentally spilled should be immediately removed by washing with water or covered with a other means. The proper fire authorities must be notified if necessary.

If indications of underground leakage of combustible liquids are discovered, areas must be guarded by appropriate means, and the proper fire authorities must be notified immediately.

It is recommended that aircraft fuel tanks be filled before storing aircraft in hangars, since this leaves no space for explosive vapors to form. This practice is also recommended after each flight to prevent water condensation in fuel tanks.

The fuel tanks should not be filled completely to the top when aircraft are stored in hangars, especially if the outside temperature is cooler than the inside temperature. If it is warned inside the hangar than outside, fuel in the tanks expands and causes overflow through the fuel tank's venting system, creating a fire hazard.

Nonspark tools must be used when working on any part of a system or unit designed for storing or handling combustible liquids.

Use of leaky tanks or fuel lines is not permitted. Repairs must be made on discovery, with due regard to the hazard involved.

All fuel is filtered and passes through water-separating equipment at the tank farm when it is delivered to the mobile refueller; or in the case of island-type refueling stations, as it leaves the supply connections. The mobile refueller also passes the fuel through a system of filters and water separating equipment before its delivery to the aircraft. These filters and separators are usually checked in the morning for evidence of dirt and water, and each time thereafter that the mobile refueller is reloaded. When the mobile refueller is loaded, it must sit at least 15 minutes and then have the sumps checked for water before any aircraft are refueled from it.

When using fuel which has been stored in cans or barrels, it must be run through a strainer funnel before being put into aircraft. This practice is necessary as condensation and rust develop inside cans and barrels.

If a chamois is used to filter the fuel, an increase in the static electricity hazard results from the passage of gasoline through the material. The chamois must be grounded and remain grounded until all gasoline has drained through the filter. This can be done by contact with a supporting metal screen which is positively grounded. Never use a plastic funnel, bucket, or similar nonconductive container when servicing from storage cans or barrels.

Aircraft should be fueled in a safe place. Do not fuel or defuel an aircraft in a hanger or other enclosed space except in case of an emergency. Aircraft should be free from fire hazards, and have engine switches off and chocks placed under the wheels prior to fueling or defueling.

A person who functions as a fireguard with a CO_2 extinguisher or other fire fighting equipment should possess a thorough knowledge of all fuel-servicing hazards. He should guard against breathing hydrocarbon vapors, which may cause sickness or dizziness, or may even be fatal. Adequate ventilating measures to prevent the accumulation of fumes should be provided.

Because of its high lead content, fuel should not be allowed to come in contact with clothes, skin, or eyes. Fuel-saturated clothing should be removed as soon as possible and the parts of the body exposed to the fuel washed thoroughly with soap and water. Wearing clothing saturated with fuel creates a dangerous fire hazard, and painful blisters (similar to those caused by fire burns) may result from direct contact with fuel. If fuel enters the eyes, medical attention should be sought immediately.

Documentation

Make the fueling/defueling entry in applicable document and fueling register of the fuel tanker with date time and proper signature of the person who is refueling/defueling the aircraft.

■■■

CHAPTER-25
DEICING/ ANTI-ICING PROCEDURES

ICING
Ice formation on an aircraft effect its performance and efficiency in many ways. Ice buildup increases drag and reduces lift. It causes destructive vibration, and hampers true instrument readings. Control surfaces become unbalanced or frozen. Fixed slots are filled with ice and movable slots jammed. Radio reception is hampered and engine performance is affected.

The methods used to prevent icing (anti-icing) or to eliminate ice that has formed (deicing) vary with the aircraft make and model. In this Chapter ice prevention and ice elimination using pneumatic pressure, application of heat, and the application of fluid will be discussed.

TYPES OF ICING
The two types of ice encountered during flight are rime and glaze. Rime ice forms a rough surface oh the aircraft leading edges. It is rough because the temperature of the air is very low and freezes the water before it has time to spread. Glaze ice forms a smooth, thick coating over the leading edges of the aircraft. When the temperature is just slightly below freezing, the water has more time to flow before it freezes.

Ice Prevention
Several means to prevent or control ice formation are used in aircraft today: (1) Heating surfaces using hot air, (2) heating by electrical elements, (3) breaking up ice formations, usually by inflatable boots, and (4) alcohol spray. A surface may be anti--iced either by keeping it dry by heating to a temperature that evaporates water upon impingement; or by heating the surface just enough to prevent freezing, maintaining it running wet; or the surface may be deiced by allowing ice to form and then removing it.

Ice prevention or elimination systems ensure safety of flight when icing conditions exist. Ice may be controlled on aircraft structure by the following methods.

	Location of Ice	***Method of Control***
1.	Leading edge of the wing	Pneumatic, Thermal
2.	Leading edge of vertical and and horizontal stabilizers	Pneumatic, Thermal
3.	Windshields, windows, and radomes	Electrical, Alcohol
4.	Heater and Engine air inlets	Electrical
5.	Stall warning transmitters	Electrical
6.	Pitot tubes	Electrical
7.	Flight controls	Pneumatic, Thermal
8.	Propeller blade leading edges	Electrical, Alcohol
9.	Carburetors	Thermal, Alcohol
10.	Lavatory drains	Electrical

DIFFERENT METHODS OF ANTI-ICING
1. PNEUMATIC/THERMAL ANTI-ICING/DE-ICING
GENERAL
In systems of this type, the leading edge sections of wings and tail units are usually provided with a second inner skin positioned to form a small gap between and the inside of the leading edge section. Heated air is ducted to the wings and tail units and passes into the gap, providing sufficient heat in the outer skin of the leading edge to melt ice already formed and prevent further ice formation. The air is exhausted to atmosphere through outlets in the skin surfaces and also, in some cases, in the tips of wings and tail units. The temperature of the air within the ducting and leading edge sections is controlled by a shutter or butterfly type valve system the operation of which depends on the type of heating system employed.

AIR SUPPLIES
There are several methods by which the heated air can be supplied and these include bleeding of air from a turbine engine

compressor, heating of ram air by passing it through a heat exchanger located in an engine exhaust gas system and combustion heating of ram air.

In a compressor bleed system the hot air is tapped directly from a compressor stage and after mixing with a supply of cool air in a mixing chamber it passes into the main ducting. In some systems, equipment, e.g. safety shut-off valves, is provided to ensure that an air mass flow sufficient for all de-icing requirements is supplied within pressure limits acceptable to duct and structural limitations.

The heat exchanger method of supplying warm air is employed in some types of aircraft powered by turbo-propeller engines. The heat exchanger unit is positioned so that exhaust gases can be diverted to pass between tubes through which outside air enters the main supply ducts. The supply of exhaust gases is usually regulated by a device such as a thermostatically controlled flap fitted in the ducting between the exhaust unit and the heat exchanger.

In a combustion heating system ram air is passed through a cylindrical jacket enclosing a sealed chamber in which a fuel/air mixture is burned, and is heated by contact with the chamber walls. Air for combustion is derived from a separate air intake and is supplied to the chamber by means of a blower.

DUCTING

The type of ducting, materials used, methods of inter connection and disposition in an aircraft vary between de-icing systems, and reference should therefore always be made to the relevant Aircraft Maintenance Manual for details.

Light alloy and stainless steel are materials normally used in construction, stainless steel being adopted principally in compressor bleed systems. Flanged and bolted end fittings, or band-type vee-clamps with interposed sealing rings are common methods of connecting duct sections together, and in some cases an additional means of sliding duct sections one end into the other and securing by adjustable clamps may be adopted.

In some installations in which ducting passes through the fuselage, joints between duct sections are sealed to prevent loss of cabin air pressure. Fuselage ducting may, in some types of aircraft, comprise an inner stainless steel duct surrounded by an outer fiberglass duct. The two ducts are approximately 13 mm (1/2 in) apart and the interspace is filled with glass wool to provide thermal insulation. The purpose of this ducting arrangement is to serve as a leak warning system by venting interspace air through venturis which operate pressure switches and a warning light.

Expansion and contraction of ducting is catered for by bellows or gimbal type expansion joints and in aircraft having variable incidence tailplanes and other moveable aerofoil surfaces such as leading edge slats and Kruger flaps, swivel joints and telescopic joints are fitted in the ducts supplying air to these surfaces.

In some installations, ducting in certain areas is lagged with a fire-resisting, heat-insulating material, normally fiberglass held in place by glass-cloth bound with glass cord.

TEMPERATURE CONTROL

he control of the air temperature within ducting and leading edge sections is an important aspect of thermal de-icing system operation and the methods adopted depend on the type of system.

In a typical compressor bleed system, control is effected by temperature sensing units which are located at various points in the leading edge ducting and by valves in the main air supply ducting. The sensing units and valves are electrically interconnected so that the valves are automatically positioned to regulate the flow of heated air to the system thus maintaining the temperature within a predetermined range. Indications of air temperature conditions are provided by resistance type temperature sensing elements and indicators, temperature sensitive switches and overheat warning lights. On some aircraft the electrical supplies to the valves are interrupted by landing gear controlled relays when the aircraft is on the ground. Under these conditions, valve operation is accomplished by holding the system control switch to a 'TEST' position.

When heat exchangers are employed, temperature control is usually obtained by the use of adjustable flaps and valves to decrease or increase the supply of heating and cooling air passed across the exchangers. The method of controlling the flaps and valves varies with different aircraft but a typical system incorporates an electric actuator, which is operated automatically by an inching device controlled by a temperature sensing element fitted in the duct on the warm air outlet side of the heat exchanger. In some systems, actuators are directly controlled by thermal switches, so that the flaps or valves are automatically closed when a predetermined temperature is reached. Indications of air temperature conditions are provided by resistance type temperature sensing elements and indicators, temperature sensitive switches and overheat warning lights.

In systems incorporating combustion heaters, the temperature is usually controlled by thermal cyclic switches located in the heater outlet ducts, so that when the temperature reaches a predetermined maximum the fuel supply to the heaters is automatically switched off.

2. ELECTRICAL ANTI-ICING SYSTEM/DE-ICING

This system employs a windscreen of special laminated construction heated electrically to prevent, not only the formation of ice and mist, but also to improve the impact resistance of the windscreen at low temperatures.

The film-type resistance element is heated by alternating current supplied from the aircraft's electrical system. The power required for heating varies according to the size of the panel and the heat required to suit the operating conditions. Details of these requirements are given in the relevant aircraft Maintenance Manual.

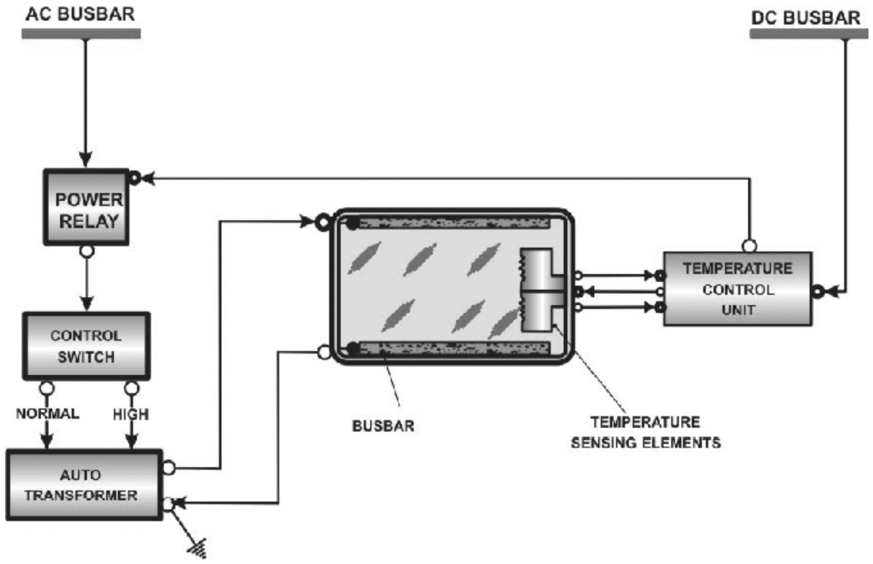

Fig.25.1. Typical Electric Anti Icing System.

The circuit embodies a controlling device, the function of which is to maintain a constant temperature at the windscreen and also to prevent overheating of the vinyl inter layer which would cause such permanent damage is vinyl 'bubbling' and discoloration. In a typical anti-icing system shown schematically in Figure 25.1, the controlling device is connected to two temperature sensing elements laminated into the windscreen. The elements are usually in the form of a fine wire grid, the electrical resistance of which varies directly with the windscreen temperature. One sensing element is used for controlling the temperature at a normal setting and the other is used for overheat protection. A system of warning lights and, in some cases, magnetic indicators, also forms part of the control circuit and provides visual indications of circuit operating conditions, e.g. 'normal', 'off' or 'overheat'.

When the power is applied via the system control switch and power relay, the resistance element heats the glass. When it attains a temperature pre-determined for normal operation the change in resistance of the control element causes the control device or circuit to isolate, or in some cases to reduce, the power supply to the heater element. When the glass has cooled through a certain range of temperature, power is again applied and the cycle is repeated. In the event of a failure of the controller, the glass temperature will rise until the setting of the overheat sensing element is attained. At this setting an overheat control circuit cuts off the heating power supply and illuminates a warning light. The power is restored and the warning light extinguished when the glass has cooled through a specific temperature range. In some systems a lock out circuit may be incorporated, in which case the warning light will remain illuminated and power will only be re-applied by cycling the system control switch to 'OFF' and back to 'ON'.

(a) In addition to the normal temperature control circuit it is usual to incorporate a circuit which supplies more heating power under severe icing conditions when heat losses are high. When the high power setting is selected, the supply is switched to higher voltage output tappings of an auto transformer which also forms part of an anti-icing system circuit thus maintaining the normal operating temperature. The temperature is controlled in a manner similar to that of the normal control temperature circuit.

(b) For ground testing purposes, the heating power supply circuit may also be controlled by landing gear shock-strut microswitches in such a way that the voltage applied to the resistance elements is lower than that normally available in flight.

3. ALCOHAL SPRAY/ FLUID DE-ICING SYSTEM

The method employed in this system is to spray the windscreen panel with a methyl-alcohol based fluid. The principal components of the system are a fluid storage tank, a pump which may be a hand-operated or electrically-operated type, supply pipe lines and spray tube unit. Figure 25.2 illustrates the interconnection of components based on a typical aircraft system in which fluid is supplied to the spray tubes by two electrically-operated pumps. The system may be operated using either of the pumps or both, according to the severity of icing.

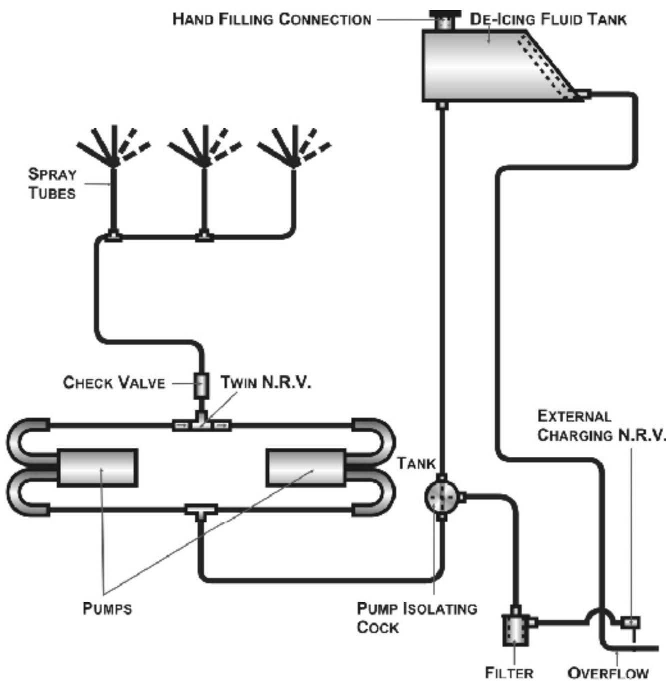

Fig.25.2. Typical Fluid De-Icing System.

GENERAL

In systems of this type, a de-icing fluid is drawn from a storage tank by an electrically driven pump and fed through micro filters to a number of porous metal distributor panels. The panels are formed to the profiles of the wing and tail unit leading edges into which they are fitted. At each panel the fluid passes into a cavity, and then through a porous plastic sheet to a porous stainless steel outer skin. As the fluid escapes it breaks the bond between ice and the outer skin and the fluid and ice together are directed rearward, by the airflow, over the airfoil.

The interconnection of components of a typical fluid de-icing system is shown in Figure25.3. The head compensating

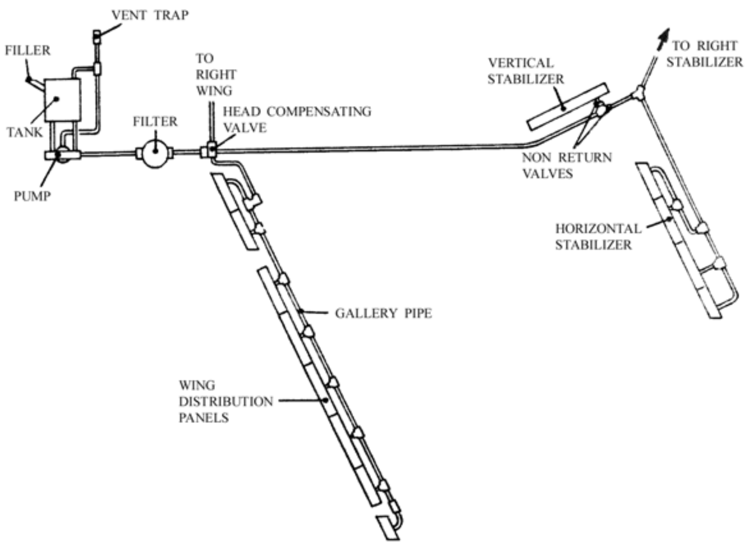

Fig. 25.3.Typical Fluid De-Icing System.

valve is fitted in some types of aircraft to correct for variations in system pressure (head effect) due to differences in level between the wings, horizontal and vertical stabilisers. The non-return valves prevent back flow when the system is inoperative. Nylon pipelines are usually used throughout the system; those for the main fluid supply being of 8mm (5/16 in) inch outside diameter and those for connections to individual distributor panels of 4.7 mm (3/16 in) outside diameter.

A sectional view of a typical distributor panel is shown in Figure25.4. The connector contains a metering tube which is accurately calibrated to provide the required rate of fluid flow through the distributor. In some aircraft the metering of fluid to the distributor panels is done via proportioning units containing the corresponding number of metering tubes. To prevent electrolytic corrosion, plastic sealing strips are interposed between the stainless steel panel and the metal used in the airfoil structure. In some installations an epoxy resin sealing compound is used, and to facilitate the removal of a panel it is sprayed along its edges with a thin coating of poly tetra flouroethylene (p.t.f.e.) to act as a release agent. In addition, a strip of p.t.f.e. tape may be laid along the mating surfaces of the aerofoil structure.

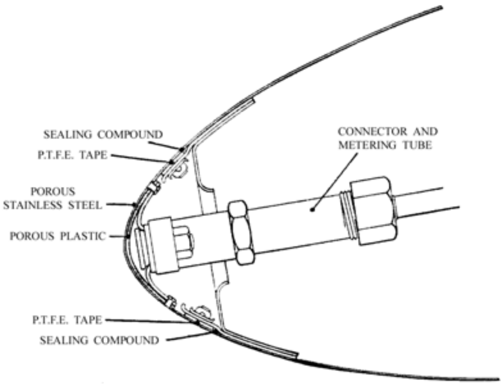

Fig.25.4. Section Of A Typical Distributor Panel.

4. PNEUMATIC DE-ICING SYSTEM BOOTS /SHOES
GENERAL

A schedule of the Air Navigation Order requires that public transport aircraft shall be provided with certain protective equipment for flights in which the weather reports available at the time of departure indicate the probability that conditions predisposing to ice formation will be encountered.

Airfoil surfaces are included in those features of the aircraft which are required to be so protected. Certain basic standards have to be met by all aircraft whether or not they are required to be protected by the requirements of the Air Navigation Order and these are intended to provide a reasonable protection if the aircraft is flown unintentionally for short periods in icing conditions. The requirements specified in BCAR and JAR cover such considerations as the stability and control balance characteristics, jamming of controls and the ability of the engine to continue to function in icing conditions.

COMPONENTS AND APPLICATION OF SYSTEMS

Pneumatic dicing systems are employed in certain types of piston-engined aircraft and twin turbo-propeller aircraft. The number of components comprising a system vary together with the method of applying the operating principle. The arrangement of a typical system is illustrated schematically in Figure 25.5.

System.

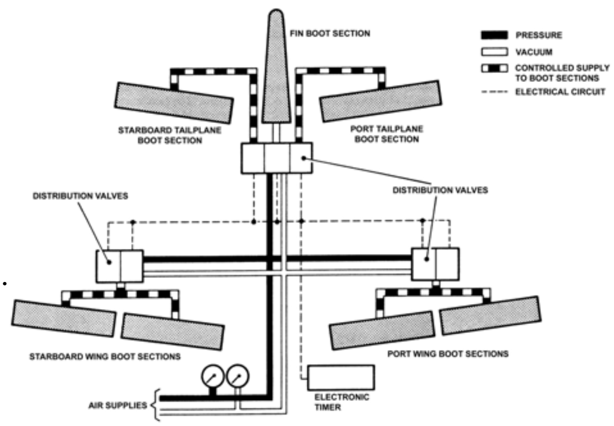

Fig.25.5. Schematic Diagram Of A Pneumatic De-Icing System.

De-icer Boots

The de-icer boots, or overshoes, consist of layers of natural rubber and rubberised fabric between which are disposed flat inflatable tubes closed at the ends. The tubes are made of rubberised fabric and are vulcanised inside the rubber layers. In some boots the tubes are so arranged that when the boots are in position on a wing or tail plane leading edge the tubes run parallel to the span; in others they run parallel to the chord. The tubes are connected to the air supply pipelines from the distribution valves system by short lengths of flexible hose secured to connectors on the boots and to the pipelines by hose clips. The external surfaces of boots are coated with a film of conductive material to bleed off accumulations of static electricity. Depending on the type specified, a boot may be attached to a leading edge either by screw fasteners (rivnuts) or by cementing them directly to the leading edge.

Metal fairing strips are fitted to cover the edges of screw-fastened type boots, both on the upper and lower surfaces of an airfoil, and also at the ends of the boots. These latter strips serve to secure the ends of the boots and prevent inward 'creep'. The strips are secured by the same screws used for securing the edges of the boots to the rivnuts.

Air Supplies and Distribution

The tubes in the boot sections are inflated by air from the pressure side of an engine-driven vacuum pump, from a high-pressure reservoir or in the case of some types of turbo-propeller aircraft, from a tapping at an engine compressor stage. At the end of an inflation stage of the operating sequence, and whenever the system is switched off, the boots are deflated by vacuum derived from the vacuum pump or, in systems utilizing an engine compressor tapping, from the venturi section or an ejector nozzle.

The method of distributing air supplies to the boots depends on the de-icing systems required for a particular type of aircraft but, in general, three methods are in use. One method employs shuttle valves which are controlled by a separate solenoid valve; in the second method air is distributed to each boot by individual solenoid-controlled valves; in the second method air is distributed to each boot by individual solenoid-controlled valves; in the third method distribution is effected by a motor-driven valve.

Controls and Indicators

The controls and indicators required for the operation of a de-icing system depend on the type of aircraft and on the particular arrangement of its de-icing system. In the basic arrangement, a main on-off switch, pressure and vacuum gauges or indicating lights form part of the controlling section. Pressure and vacuum is applied to the boots in an alternating timed sequence and the methods adopted usually vary with the methods or air distribution. In most installations, however, timing control is effected by means of an electronic device. Reference should always be made to the relevant aircraft Maintenance Manual for details of the appropriate controlling system and time cycles.

OPERATION

When the system is switched on, pressure is admitted to the boot sections to inflate the tubes. The inflation weakens the bond between ice and the boot surfaces, causing the ice to break away. At the end of the inflation stage of the operating sequence, the air in the tubes is dumped to atmosphere through automatic opening valves and the tubes are fully deflated by the vacuum supply. This inflation and deflation cycle is repeated during the period the system is in operation. When the system is switched off vacuum is supplied continually to all tubes of the boot sections to hold the sections flat against the wing and tail unit leading edges thus minimising aerodynamic drag.

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CHAPTER-26
ELECTRICAL, HYDRAULIC & PNEUMATIC GROUND SUPPLIES ON GROUND

SOURCE OF THE ELECTRICAL SUPPLY

Ground Power Unit (G.P.U.)

The provision of external electrical power to aircraft for engine starting purposes or for the operation of aircraft systems and equipment, is normally by means of an engine-driven generator set mounted on a trailer. The engine is normally coupled to a brushless revolving-field generator, and the power-unit is provided with full controls and instrumentation. Units suitable for static installation are also available and normally comprise a motor-generator unit consisting of a brushless synchronous motor and a revolving-field generator on a common shaft.

Power Outputs

Ground power units are typically capable of supplying a selection of power outputs such as the following:-

(a) **A.C. Outputs**

(i) 75 kVa, line voltage 200, 400 Hz, 3 phase, 0.8 continuous power factor.

(ii) 100 kVa, line voltage 200, 400 Hz, 3 phase, 0.8 power factor for 20 minutes.

(iii) 180 kVa, line voltage 200, 400 Hz, 3 phase, 0.4 power factor for 5 minutes.

(b) **D.C. Outputs**

(i) 28.5 volts:

800 amperes continuous; or 2,000 amperes intermittent.

(ii) 112 volts:

300 amperes continuous; or 1,000 amperes intermittent for 30 seconds; or 1,200 amperes peak instantaneous.

D.C. outputs are usually available simultaneously or independently at continuous ratings, or independently at intermittent ratings; d.c. outputs are not available at the same time as an a.c. output.

Trailers

The trailers, upon which the engine and generator units are mounted, are usually provided with leaf spring suspension, cable operated brakes and steerable front wheels; a suitable canopy, with transparent panels, where required, encloses the equipment.

Operating Procedures

It is essential that personnel who are required to use ground power-units are trained and fully familiar with the operating instructions defined in the appropriate technical manual for the equipment concerned. The following practices would be typical:-

(a) Before starting the engine, the unit should be placed on firm, level ground, the parking brake should be applied and the bonding connection should be connected to the aircraft.

(b) After starting the engine, the oil pressure should be checked and the engine should be allowed to warm up for several minutes before an electrical load is applied.

(c) Oil pressure, coolant temperature and battery charging current should be checked periodically while the engine is running.

(d) When selecting the required a.c. or d.c. power output the manufacturer's procedure should be followed.

(e) When connecting or disconnecting the external power supply to the aircraft, it must be ensured that electrical power is first disconnected from the external power line. On many ground power units a 'power on' indicator is provided to show when power is being supplied to the socket.

The electrical power produced by a ground power-unit is sufficient to cause damage to an aircraft and serious injury to personnel. In addition, careless use of the equipment could result in a discharge of electricity which could lead to the ignition of flammable vapours in the vicinity. It is therefore important that any safety measures contained in the manufacturer's manuals or in notices on the equipment should be observed.

Maintenance

A record should be kept of all ground power-unit running times, and maintenance should be carried out in accordance with the schedule drawn up for the particular equipment. During normal use, the checks outlined in paragraphs 1 to 3 should be carried out to ensure continuing serviceability of the equipment.

1. A daily inspection should include checks on coolant, oil and battery electrolyte levels, serviceability of lamps and indicators, and an examination for damage, leaks and security of attachments. Any bonding connections should be checked for condition and security.

2. Cables and aircraft connectors are subjected to hard usage and should be inspected weekly for abrasion, tears and general deterioration. The aircraft connector should be examined to check the condition of its insulation and contact tubes, and to ensure that the tubes are not proud of the insulation.
3. At monthly intervals an electrical quality check should be carried out. This should test the voltage and frequency protection units, phase rotation polarity at the output sockets and current overload. In addition, the resistance and continuity of the bonding lead should be checked.

SOURCE OF HYDRAULIC SUPPLY

The testing of aircraft hydraulic systems requires a controlled and filtered supply of hydraulic fluid at high pressure, and this is normally provided by a specially designed servicing trolley. A typical hydraulic test rig would consist of a 75 kW (100 HP) electric motor operating from a 380/440 volt, 3 phase supply, driving a variable-delivery hydraulic pump through a gear box, clutch and flexible coupling; the output from the rig would be up to 175 liters/min (38 gal/min) at 20 MN/m^2 (3,000 lbf/in^2), with a filtration of 3 microns. The hydraulic circuit would function by drawing fluid form the aircraft system through a heat exchanger and low pressure filter, and returning it to the aircraft system through suitable flow control valves and flow meters and a high pressure filter; self-sealing, quick-disconnect couplings, installed in the aircraft, permit the connection of flexible hoses from the test rig to the aircraft system. In some cases provision is made for fitting a different pump on the test rig, but usually a rig is designed specifically for one type of aircraft and one type of fluid.

Operating Procedure

Hydraulic test rigs vary considerably in design, and operating instructions for a particular type are usually printed on a plate attached to the trolley and/or contained in a manual or booklet; these instructions should be carefully followed when carrying out a test, since incorrect operation could cause damage to the rig or aircraft system. General guidance on operating procedures is outlined in below paragraphs.

Before starting a test rig all flow valves should be closed and, where applicable, the aircraft hydraulic system reservoir air pressure should be checked. Because of the filtration requirements of hydraulic systems, the suction and pressure hoses from the rig should be carefully inspected for cleanliness before they are connected into the aircraft system. The hose connections are fitted with caps which should only be removed immediately before the hoses are connected to the aircraft; the caps should be replaced immediately after the hoses are disconnected from the aircraft.

After starting the electric motor, the pump can be brought on tiny by operation of the clutch, and pressure will be indicated on the rig pressure gauge. The main rig flow control valve can then be opened and the rig will form part fop the aircraft system; enabling functional tests to be carried out by use of the aircraft system selector valves. By utilising additional low-flow valves and low-reading flow meters on the test rig, the measurement and monitoring of internal leakage in the aircraft system components is possible.

Maintenance

Because, during tests, a hydraulic test rig shares the hydraulic system of an aircraft, the degree of filtration, and condition of the pump and fluid, must be at least as good as those in the aircraft. Cleanliness is, therefore, of the utmost importance, and regular quality checks should be carried out on fluid samples from the rig to prevent fluid aircraft to aircraft. To ensure satisfactory operation of the rig, the following operations should be carried out on a regular basis:-

(a) The rig should be kept clean and free from leaks. This is particularly important with the hoses and hose connections, which must be capped when not in use and must be checked for cleanliness each time they are coupled to an aircraft.
(b) The filter should be cleaned or renewed regularly according to rig usage, and special procedures such as ultrasonic cleaning, which may be required for wire cloth filters, should be followed. Paper filter elements should be discarded when removed.
(c) All gauges should be subjected to calibration checks at regular intervals.
(d) The condition and functioning of all electrical equipment should be checked at intervals depending on rig usage.

SOURCE OF PNEUMATIC SUPPLY

AIR STARTER UNITS

Air starter units are designed to start aircraft engines which are equipped with air turbine starters; they can also be used in checks on auxiliary systems, for limited air conditioning or for de-icing. The units generally consist of a turbo-charged diesel engine driving a single-stage compressor, mounted on a truck chassis and enclosed by a suitable canopy. The compressor delivers a continuous flow of warm, oil-free, compressed air. The engine is completely self-contained and has its own electrical system, starter system and fuel supply. A regulating valve controls the delivery air pressure, exhausting all air while the engine is being started (to reduce load), and thereafter maintaining a constant working pressure of 275 to 300 kN/m^2 (40 to 43 lbf/in^2) irrespective of the air take-off. A safety valve fitted to the delivery manifold opens at approximately 325 kN/m^2 (47 lbf/in2). All instruments, controls and warning lamps are grouped on a control panel.

Operating Procedures

Operating procedures for air starter units will vary according to the particular design, and the manufacturer's instructions and recommendations should always be followed. The following practices would be typical:-

(a) Before starting the engine, the unit should be placed on firm, level ground, and the bonding lead should be connected to the aircraft.

(b) After starting the engine, it should be ensured that oil pressure is building up and that all warning lights are extinguished. The engine should be allowed to warm up for several minutes.

(c) When the engine has warned up, the throttle should be opened to check that air pressure builds up to normal operating pressure.

(d) During an aircraft starting operation a constant check should be kept on the air pressure gauge, and the starter unit throttle should be adjusted as necessary to maintain normal operating pressure without exceeding the maximum permissible starter unit engine speed.

Maintenance

A record should be kept of engine running hours and engine starting cycles, and maintenance should be carried out in accordance with the schedule drawn up for the particular equipment. During normal use, the checks outlined in paragraphs 1 to 3 should be carried out to ensure continuing serviceability of the equipment.

1. A daily inspection should include checks on coolant, oil and battery electrolyte levels, serviceability of lamps and indicators, and an examination for damage, leaks and security of attachments. Any bonding connections should be checked for condition and security.
2. Cables and aircraft connectors are subjected to hard usage and should be inspected weekly for abrasion, tears and general deterioration . The aircraft connector should be examined to check the condition of its insulation and contact tubes, and to ensure that the tubes are not proud of the insulation.
3. At monthly intervals an electrical quality check should be carried out. This should test the voltage and frequency protection units, phase rotation polarity at the output sockets and current overload. In addition, the resistance and continuity of the bonding lead should be checked.

A record should be kept of engine running hours and engine starting cycles, and maintenance should be carried out in accordance with a schedule drawn up for the particular equipment. A daily inspection should include the topping-up of fuel, coolant and oil systems, and a check for damage, leaks and security of components.

The air delivery hose is generally seamless and lined with silicone rubber, and normally has low temperature flexibility and high resistance to abrasion. However, the rubber will eventually deteriorate, particularly at the ends; shortening the ends by a small amount (approximately 50 mm (2 in)) may rectify this but other cracking or damage will necessitate replacement. The life of a hose can be prolonged by exercising reasonable care in its use, and by avoiding sharp bends, tautness and twisting.

Inspection of an air delivery hose should be carried out after approximately 50 hours of operation or 600 aircraft starts.

Knowledge of above system

The efficient ground handling of medium and large aircraft is dependent on the use of sophisticated ground equipment to supply. for example, external power for the operation of aircraft services and for engine starting. Facilities provided in hangars, and other equipment search as hydraulic system test rigs are essential for maintenance purposes.

In order to be available for instant use, all equipment of this nature should be kept serviceable and in good working order. It is recommended that all aircraft operators should employ planned maintenance schemes for their ground equipment, with comprehensive schedules and work sheets. Maintenance activities should be based on the manufacturer's recommendations and a record should be kept for each piece of equipment.

Where particular types of ground equipment and vehicles carrying ground equipment are fitted with internal combustion engines, engines, particular care should be taken to ensure that these engines are maintained in such a condition that the possibility of sparks of flame emitted from the exhausts is remote. For certain vehicle the use of flame-damped exhausts may be recommended.

Precautions observed while handling above equipment

Covered along with the topic.

Maintenance of above equipment

Covered along with the topic

EFFECTOF ENVIRONMENTALCONDITIONONAIRCRAFTHANDLINGANDOPERATION

Effect of icing

If the ice is allowed to be formed on aircraft surface it effects the performance and efficiency of Aircraft in any ways.

1. Ice building increases drag and reduces lift.
2. Causes destructive vibration and hampers true instrument readings.
3. Control surfaces become unbalanced orphozen.
4. fixed slots are filled with ice and moveable slots are jammed.
5. Radio reception is hampered and engine performance is effected.

IceFormationLocation

1. Wing Leading edges
2. Vertical and Horizontal stabilizers leading edges.
3. Wind shields windows and radomes.
4. Engine air inlet
5. Staff warning Transmeters
6. Flt. Controls
7. Propeller blades leading edges

EffectofTurbulence

When an aircraft encounters a gust condition the air load on the wings exceeds the normal wing loads supporting the aircraft weight. The gust tends to accelerate the aircraft while its inertia acts to resist this change. If the combination of gust velocity and our speed is too severe, the induced stress can cause structural damage. A special inspection should be performed after a flight through severe turbulence. Emphasis should be placed upon inspecting the upper and lower wing surfaces, for shearing of the rivets, fuel leak etc.

Effect of Altitude and Pressure

Altitude does effect the performance of the aircraft. As an aircraft gains altitude, the pressure of air will decrease and the temperature of air will become colder. As pressure decreases, so the thrust out put, beet as the temperature decreases the thrust increases, however the pressure of the out side air decreases faster than the temperature. So an aircraft engine produces less thrust as altitude increases.

The temperature stops falling off and remains constant at about 36,000 altitude but the ambient pressure continued to drop steadily with increasing altitude because of this the thrust out put will drop rapidly with increase in altitude.

Effect of Temperature/Density/Pressure

On a colder days the density of our increases, so the mass of air entering compressor for a given engine speed is greater, therefore thrust is greater. The denser air does, however increases the power required to drive the compressor or compressors thus the engine will require mare fuel to maintain the same engine speed.

On a hot day density of air is less reducing the mass of air entering the compressor and consequently the thrust of the engine for a given R.P.M. Because less power is required to drive the compressor, the fuel flow is reduced to maintain constant engine speed. However because of decrease in air density the thrust will be lower.

Since both temperature and pressure decreases with altitude, it might appear that density of air will remain firmly constant with increase altitude this is not true, how ever for pressure decreases more rapidly with increase altitude than does temperature, the result is that density decreases with increase altitude.

At a temperature of 40°C. (104°F) depending a type of engine a loss of thrust of 20% will be recorded. This means that some sort of thrust argumentation device such as water methanol injection may be required.

EffectofHumidity

The water content of the air has slight effect on density of air. The humid air at a given temperature and pressure is lighter than dry air at the same temperature and pressure.

The increase in humidity causes a decrease in weight per unit volume of air with in the turbine engine. However its reducing effect on out put is almost negligible, because the turbine engine operates with more air than is needed for complete combustion of all fuel. Any lack of weight in the combustion Air supply to give proper air fuel ratio will be made up by the cooling air supply. So no much loss will be reloded.

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CHAPTER-27
DISASSEMBLY, INSPECTION, REPAIR AND ASSEMBLY TECHNIQUES

DISASSEMBLY

To avoid damage and distortion to the structure and components, it is essential that the correct extractors, and special tools are used for dismantling. As items are removed they should be placed on properly designed stands, racks and bins and should be identified so that they can be re re-assembled without any difficulty.

The disassembly sequence in the manufacturers manual should be followed at all times, so that the effect of damage can be easily traced and minimized.

INSPECTION

Every precaution must be taken to ensure that all corrosion is detected in its early stages. Corrosion cannot always be found by visual examination alone, and one of the methods of non-destructive examination such as radiological examination may be of assistance. However, corrosion tends to blister paint and its presence can be suspected if the paint flakes off when pressed.

NOTE

Because of the rapid improvements that have been made in radiological techniques, the latest information on this subject should be sought from the aircraft Manufacturer.

At the time specified in the Approved Maintenance Schedule and whenever the aircraft has been subjected to especially corrosive conditions, the inside and outside of the structure should be thoroughly examined . The upholstery and floor coverings should be removed and all access panels should be opened to facilitate inspection. With a strong light, a detailed examination should be made of the spars, ribs, frames, bulkheads, stringers, etc.. Particular attention should be given to poorly vented regions and to places where dampness and condensation are apparent or suspected. Strontium chromate inhibitor pellets are sometimes used in areas where water accumulates and the condition of such inhibitors should be assessed. The satisfactory adhesion of sealant fillets and paint work should also be verified.

(a) Special attention should be given to parts of the fuselage where condensation may tend to collect. Considerable condensation will occur on the inner surfaces of pressure cabin structures. Water will run down the cabin wall structure and this will tend to start corrosion in the lower parts of the structure.

(b) Inspector should give special attention to such areas and particularly to the laying surface between stringers and skin, where moisture may remain trapped and promote corrosion. In some cases it may be necessary to dismantle parts of the structure to ensure adequate inspection.

NOTE

On some types of aircraft operating under widely different conditions, recent investigations have revealed the presence of serious corrosion which had remained undetected in parts of the structure. In some instances it has been shown that normal methods of inspection and radiological examination were inadequate, and dismantling, particularly of pressurised skin structures, was therefore necessary.

Where evidence of surface corrosion exists, the extent of pitting or exfoliation should be tested by probing with a fine needle. Whenever possible, the strength of all suspect rivets should be tested by applying a moderate shear load to the rivet head. The remedial action to be taken will depend on the depth and extent of the attack and the thickness and function of the affected parts, but any areas where rivets fail must obviously be repaired in accordance with the appropriate Repair Manual. Elsewhere , if the attack is not serious , the corrosion can be cleaned off and the part re-protected, but any intergranular or widespread surface corrosion will also necessitate repair by renewal of the damaged areas.

Assessment of the condition of parts subjected to high temperatures is not easy but, as a general rule, discoloration and light scaling are normally acceptable (light scale sometimes protects the metal from further attack) whilst heavy scale is an indication that the strength of the metal has been reduced. However the majority of exhaust systems fitted to aero engines are manufactured form stainless steel or inconel and visual examination of these components is often misleading. This is because those parts of the system which are subjected to the highest temperatures will, after extensive periods in service, suffer form intergranular corrosion. If undetected this is obviously dangerous and may constitute a fire hazard, but detection is possible by measurement of magnetic permeability. A rough check for this condition can be made with a small horse-shoe magnet, the component under examination being rejected if the magnet shows any tendency to adhere to it, but sensitive instruments which measure the relative magnetic permeability should be used whenever possible. The guidance of the Manufacturer should be followed when assessing the condition of particular exhaust systems.

It is a wise precaution to remove a sample number to key assembly bolts during major inspections, care being taken to ensure that different bolts are removed at each inspection. Bolts securing engine mounting, wing and empennage attachment bolts, and undercarriage assembly bolts should be examined for signs of fretting corrosion. The bolt holes and surrounding material should be inspected for intergranular penetration and fatigue cracks.

NOTE
This should only be done by skilled personnel with the appropriate jigs and assembly equipment.

It should be remembered that metal tubes may corrode internally as well as externally. Sealed tubes, which have been protected internally before assembly should not cause concern, but open-ended tubed can accumulate moisture.

Visual examination for corrosion is one of the most essential aspects of inspection and is necessary on all components, pipelines, control cables, electrical equipment, instruments, etc. For further information on the inspection of particular systems and components, reference should be made to the appropriate Manual

REPAIR
Repair must be carried out in accordance with the appropriate repair manual or approval repair drawings relatively in conjunction with any other related information contained in other documents recognised, approved by DGCA.

Detail as inspection necessary before repair and the method as assessing the extent as damage, supporting the structure, checking alignment and assessing allowance for dressing of damage and limits of wear are generally given in repair manual.

ASSEMBLY TECHNIQUE
All parts should be given a final examination for cleanliness before re-assembly commences. Surplous cleanliness is ajeourse essential at all the time during reassembly and care must be taken to ensure that no foreign objects finds their way. All apertures should be blanked off until appropriate connections are made to them.

Systematic inspection at each stage of reassembly is necessary to ensure that all parts are accurately aligned and fitted, that all lockings are in accordance with approved methods and that the torque loadings are those recommended by the methods and that the toque loadings are those recommended by the manufacturers. If new parts have been fitted they should receive particular attention details as their part number, fits and clearances are taken care.

TREATMENT OF STRUCTURAL PARTS
Wherever corrosion is found in aircraft it is essential that the corrosion products should be completely removed. This is necessary for two reasons, firstly to permit the extent of the damage to be assessed and secondly because the presence of corrosion products assists in the continuation of the attack. The full value of protective treatments will only be achieved if the surfaces are thoroughly cleaned and the treatments are applied immediately after cleaning.

Preliminary Cleaning of Corroded Areas
Parts which cannot be removed for cleaning should have all oil, grease, moisture and surface dirt cleaned off before the application of corrosion-removing chemicals. Oil and grease should be wiped off with rags soaked in organic solvents such as trichloroethylene fluid (BS 580) (Type 2 or other suitable grade), or a mixture of equal volumes of white spirit (BS245) and either (a) solvent naptha (BS 479) or (b) 3 ° xylene (BS 458), used at room temperature as recommended in DEF STAN 03-2. (De greasing procedures are detailed in specification DEF 1234.) Surface dirt should be removed with detergent solutions, using hand brushes with non-metallic bristles such as nylon.

Removal of Old Protective Coatings
To facilitate the inspection and re protection of corroded surfaces, the protective coatings in the vicinity of the damage should be removed. Whenever possible this should be done chemically, as mechanical methods such as wire brushing, grinding or rubbing with emery, may overheat the surface or remove an undesirable amount of material. There is also the danger that abrasive methods may drag surface metal over the corroded area or cause particles to become embedded which will cause further corrosion later.

Air-blast abrasive equipment has been proved satisfactory, particularly for relatively large areas of surface corrosion removal. The abrasive must in all cases be aluminium oxide or glass beads. Never silicon carbide; for coarse and rapid removal the particle size should not exceed 180 mesh (0.08 mm) and for fine control the size should be 400-600 mesh (0.038-0.0225 mm). Due to the possibility of cladding removal from aluminium skins and cadmium plating form steel fasteners, etc., abrasive should only be considered if a completed organic finish is to be applied.

Removing Organic Coatings
Non-flammable paint strippers should be used to remove paint, varnishes, synthetic enamels, cellulose, etc., A number of proprietary solutions are available which are satisfactory for the majority of organic coatings; they are neutral and will not attack the underlying metal provided they are rinsed off after the paint has been removed. The strippers should be brushed over the paint, left on the surface for a few minutes and loosened paint then wiped off with a cloth, aluminium wool or non metallic material, e.g. wood, Tuflon or suitable plastics materials. Steel wool should not be used.

Where a paint coating is required or renewed in localised areas only, surrounding areas should be masked by means of suitable tapes, and these should be removed at suitable stages during the painting process to prevent subsequent contamination of later stages, and as soon as practicable after completion of the painting operation.

Where damage or removal of pressure cabin sealants or other sealing or stopping material has occurred, these should be renewed either before or at some convenient point during repainting operations. Where stopping materials have been used originally, these may be replaced with an approved air drying scheme compatible with original.

NOTE
The effects of certain strippers on adhesive-bonded joints, plastic parts and windows should be borne in mind, and care should be taken to avoid caustic strippers on aluminum, alloys. Rubber gloves and goggles should be worn to prevent any contact between the stripper and the skin.

Removal of Corrosion Products
Although the cleaning methods outlined in paragraph above will remove superficial corrosion, surfaces which have been seriously attacked may still retain powdered oxides, salt crystals, etc., in pits and surface cavities. Chemicals suitable for cleaning each of the principal materials used in aircraft construction are available, but in some cases the chemicals will themselves cause corrosion if they penetrate faying surfaces. There is also evidence that some pickling and electro-chemical polishing techniques have an adverse effect on fatigue life and this aspect should receive serious consideration when selecting cleaning processes for parts which are subjected to fluctuating stresses in service. When doubt exists regarding the corrosive nature of certain chemicals, they should be tested as recommended in the following paragraph.

Test for Cleaning Chemicals
a. Prepare two panels of approximately 900 cm^2 (1 ft^2) area from material of the same specification as that to be treated.
b. Apply the chemical to be tested to one face of each test pieces and clamp the treated faces together.
c. Expose the sandwiched test panels to alternate humid and dry atmospheric conditions in temperature conditions of 38^{o}C (100^o F). About 16 hours a day in humid conditions and 8 hours a day in dry conditions is recommended.
d. After approximately 10 days the panels should be separated, rinsed and scrubbed , and examined for corrosions.
e. The chemical will be acceptable if the metal is only lightly etched, but should not be used on the aircraft if it has caused deep pitting or intergranular corrosion of the test panels.

Chemical Cleaning of Steel
The removal of rust from steel by pickling in acid is often recommended, but it is not a practical method for in situ parts or welded steel tubular structures. A variety of proprietary rust removing solutions is available; most of them are solutions containing phosphoric acid, which, in addition to dissolving oxide film, partly inhibit the steel surface from further rusting. These solutions should always be applied as directed by their Manufacturers.

NOTE
Where parts are removable, the use of alkaline de-rusting solutions (with cleaning agents) is recommended.

Chemical Cleaning of Aluminium Alloys
Cleaning methods will vary according to the extent and location of the corrosion and the specification of the alloy concerned. General guidance on some recommended methods of cleaning are given below:
a. Light corrosion deposits on aluminium alloys can often be wiped off with solvents or detergents which will leave a clean surface ready for pre-treatment and re-protection. The use of nonflammable preparations which are free of caustic substances is recommended. Swabbing with trichloroethylene is not advised because concentration of the fumes can be harmful and, in any case, the function of this chemical is to remove grease and not corrosion products. When solid particles are held in suspension with surface grease, they will be removed if the parts can be immersed in boiling trichloroethylene liquor but this is seldom a practical method of cleaning aircraft structural

parts during maintenance. The use of an inhibited phosphate chemical brightener is also recommended.

b. Heavy deposits on clad aluminium alloys should be removed chemically because mechanical cleaning will take off the protective cladding and expose a greater area of the core to subsequent corrosion. Preparations of thickened phosphoric acid are recommended for this purpose. All other material, including non-clad aluminium alloys, should be masked to prevent them being attacked by the acid. The corroded surface should then be brushed with the acid and, after an interval of not more than 3 minutes, scrubbed with a stiff nonmetallic brush until all corrosion products are removed from pits, rivet heads, etc. The surface should then be rinsed off with generous quantities of water to remove all traces of remaining acid, and should then be thoroughly dried.

c. Heavy deposits on non-clad aluminium alloys can be removed mechanically, i.e. by scraping, wet sanding with fine sandpaper or by light abrasion with aluminium wool (steel wool should not be used), provided dimensional tolerances are not exceeded. A general purpose surface wash which will also form a base for painting can be made up as follows:

Butyl alcohol	40%	
Isopropyl alcohol	30%	By volume
Phosphoric acid (85% solution)	10%	
Water	20%	

The alcoholic-phosphate wash should not be used on high strength wrought aluminium alloy such as DTD 5024,5044,5114 and 5124. On other alloys it should not be allowed to remain on the surface for longer than 15 minutes; in fact shorter times are desirable, particularly if the temperature is high. It should be applied with a soft cloth or bristle brush, washed off with water and the surface dried. As an alternative proprietary 'brush on' solutions mentioned in paragraph below may be used.

d. The use of phosphoric acid corrosion removers is usually followed by the application of a chromate bearing conversion coating treatment such as the Alocrom series. These remove the final traces of corrosion and provide an improved surface conditions for painting. The application of a 10% chromic anhydride solution for a few minutes is also efficacious, particularly on polished skins.

Chemical Cleaning of Magnesium Alloys

A solution of 10% by weight of chromic acid in distilled water with 0.1 % sulfuric acid added is a satisfactory chemical for removing corrosion products from magnesium alloys. The solution should be brushed over the corroded area, working it well into pits and crevices, and should be left for about 5 minutes. It should then be rinsed off with clean water. Reference should be made to the requirements of specification DTD 911.

Note on Mechanical Cleaning

Although mechanical cleaning is often necessary when preparing fabricated parts for anti-corrosive treatments, its use should be restricted during maintenance work on complete aircraft.

a. Steel and non-clad aluminium parts should be rubbed down with fine 'wet' glass paper in preference to emery papers. Wet sanding methods are more efficient, as water acts as a lubricant and permits a finer grain to be used; the rubbing should be in the direction of the working stress.

b. Castings, forgings and extruded members can be hand scraped to blend out corrosion pits. Steel carbide tipped scrapers are recommended and should be used so that pits are transformed into saucer-shaped depressions which relieve stress concentration. Afterwards the depth and area of the depressions, and the total number per unit area of surface, should be assessed to ensure that the material has not been unduly weakened.

c. Light abrasion is sometimes helpful in removing heavy deposits from skin panels. Pumice powder applied with a solvent-moistened cloth is generally satisfactory. If clad aluminium alloy sheet is cleaned by this methods, a simple test with caustic soda should be made afterwards to determine whether sufficient aluminum remains to protect the alloy core. If the surface layer of pure aluminium has been rubbed off, a spot of dilute caustic soda solution will turn the surface black. After making the test the caustic soda should be thoroughly washed off.

TREATMENT OF COMPONENTS

The information in this paragraph relates to component parts which can be removed for immersion treatments.

Degreasing

The trichloroethylene vapour method is satisfactory for most aircraft materials, but in cases of heavy contamination the following alternative may be used:

Aluminium Alloys

Mild alkaline baths effectively remove grease from aluminium but the baths should be inhibited to limit attack on the metal. A satisfactory bath can be prepared from a 4-5 % w\v (36 to 48 g\ litre (6 to 8 oz\ gal)) of a mixture of crystalline trisodium phosphate and sodium metasilicate in proportion between 2:1 and 1:2 w\w (if anhydrous trisodium phosphate is used , the proportion will be between 1:1 and 1:4) with or without a suitable wetting agent.

Steels

The immersion pickling processes will remove residual grease as well as rust, scale and other surface dirt. However, cleaning with trichloroethylene or other solvents is necessary prior to pickling.

Magnesium Alloys

Sometimes pickling in a 5 to 10 % solution of concentrated nitric acid in water is recommended for castings and parts which are not machined to close tolerances. The electrolytic-fluoride process will also remove corrosion products and has the further advantage that the fluoride film created on the surface is, to a certain degree, corrosion-resistant.

Pickling Processes

The following immersion processes are of value in preparing metal parts for subsequent protection treatment. Their action is generally twofold: they remove corrosion products and the residue of original treatments, and to some degree they etch the treated surfaces to provide a better key for organic protective.

Aluminium Alloys

Treatments should be selected to suit the nature of the parts and to prepare them for the finish specified in the drawings or repair scheme. Some suitable processes for the preparation of clad sheet for painting are described in DEF STAN 03-2; they are for use as an alternative to etch primers. When proprietary processes are used the Manufacturer's instructions should be carefully followed to ensure that the fatigue resistance of the metal will not be lowered.

a. Chromic-sulfuric Acid Process

After degreasing and rinsing the parts, they should be immersed for approximately 20 minutes in one of the alternative solutions given below. The temperature of the solutions should be maintained between 43 to 65 °C (110 to 150 °F). This process should not be used for spot welded or riveted assemblies but is satisfactory for castings, forgings, extrusions, etc., provided they are thoroughly rinsed and dried afterwards.

Solution 1	Sulfuric acid (Sp.Gr. 1.84)	15 % by volume
	Chromic acid (CrO_3)	5 % by weight
	Water	Remainder
Solution 2	Sulfuric acid (Sp.Gr. 1.84)	15 % by volume
	Sodium bichromate	7 1\2 % by weight
	Water	Remainder

b. Phosphoric Acid Processes

The constituents of an alcoholic-phosphate wash are given in paragraph before; this solution can be used in a mild steel tank to pickle aluminium alloy components. A variety of proprietary solutions containing phosphoric acid are also available; some of these build up a thin phosphate film which provides a good base for painting. However, a distinction should be made between phosphoric acid processes which create phosphate films and those which only clean and etch. The proprietary cleaning processes listed in DTD 900 include Titanine metal degreasing paste, Jenolite AKSI etching compound and the ICI Deoxidine process 202. These are materials which can be brushed over aluminum assemblies surfaces thoroughly after treatment, drying carefully after washing. Deoxidine 170 is a hot dip process which is suitable for both steel and aluminium alloy ; another treatment not covered by the specification is Deoxidine 125 which can be applied to both these metals by fold dipping or by brushing. If any of these treatments are applied by brush, all crevices and seams should be blown out with compressed air before proceeding to paint the treated area. Painting should follow promptly since none of these treatments builds a resistant film.

c. Chromic-phosphoric Acid Process

After degreasing and rinsing the parts, if specified in the Maintenance Manual or other appropriate instructions, they should be immersed in a near-boiling aqueous solution as follows, for 20 minutes, if of sheet material, or up to 1 hour if cast.

Chromic acid (CrO_3)	0.75-1.0 % w/v
	[7.4 - 9.9 g/litre (1.2-1.6oz/gal)]
Phosphoric acid (Sp.Gr. 1.75)	0.5 - 0.75 % v/v
	[5 - 7.4 cm^3/litre [0.8-1.2 fl.oz/gal)]

NOTE

The use of Deoxidine 624 followed by Alocrom 1200 is recommended. Alocrom 1200 or other similar conversion coating treatment should be used after pickling processes (particularly phosphoric acid) prior to painting, except when etch or wash primers are to be used.

ASSESSMENT OF CORROSION DAMAGE

After removing paint, greases and corrosions products, the affected parts should be examined to determine whether their strength has been lessened beyond permissible limits. Pitting may cause local stress concentrations which may seriously impair both the static and the dynamic strength of thin sections whilst surface corrosion, without causing pitting, can lower the fatigue strength of load-bearing members. Cleaning operations often cause an appreciable reduction in cross-sectional area which must also be considered when evaluating the decrease of strength.

NOTE

A corrosive attack on a structural member will cause a reduction in strength out of all proportion to the reduction in thickness of the member; this should be borne in mind at all times when assessing corrosion damage and particularly when light gauge construction is involved such as a pressurised skin structure.

Skin Panels

Corrosion damage to aircraft skins should be classified as negligible according to the extent, depth, loading and location of the damage. It is not possible to give a general rule for classification based on the percentage reduction of skin gauge or the number of pits per unit area, as the load distribution through the affected panels must be considered. It is therefore essential to consult the approved repair scheme for the aircraft concerned. Some general guidance on the assessment and rectification of damage is given in the following paragraphs. It must be appreciated, however, that all pervious corrosion rectification must be taken into consideration.

If no pronounced pitting or roughening of the skin is evident after the removal of corrosion products, it is usually satisfactory to re-protect the part by applying the appropriate finishing scheme .

Skin panels which have a rough and pitted surface after the corrosion products have been removed should be smoothed down with fine grade wetted sandpaper. The minimum reduction of cross-sectional area consistent with the blending out of jagged pits should be the aim. After smoothed down with fine grade wetted sandpaper. After smoothing the minimum skin thickness in the affected region should be computed by measuring the depths of the deepest depressions.

NOTE

Where access is difficult, radiological and \or ultrasonic examination techniques are often prescribed to determine the presence or extent of a corrosive attack. In some instances, however, such as at faying surfaces of stringers to skin panels, dismantling of specified parts of the structure has been found necessary as the only means of ensuring adequate inspection.

If the damage exceeds the general limits specified by the Manufacture as negligible but is not thought to be of such a severs nature as to warrant renewal of the whole panel affected, the Manufacturer may, in some instances, issue a repair scheme whereby the original strength of the panel can be restored by the addition of local reinforcements.

If the smoothing down of corrosion damage would reduce the thickness of skin panels or similar components beyond permissible limits, they should be renewed. During removal the condition of rivets and faying surfaces should be examined. If these show signs of corrosion, repairs will be necessary over a wider area than that indicated by the extent of the surface damage.

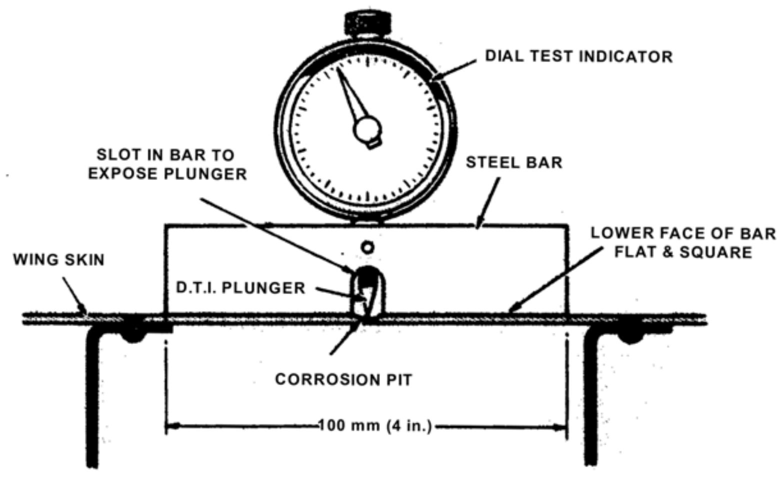

Fig. 27.1, Assessment of Skin Panel Corrosion

Load-bearing Members

The effects of corrosion on the strength of main load bearing members can be serious. It has been clearly established that the fatigue life of wing spars can be drastically shortened by corrosive attack and these member should therefore receive the most careful attention during periodic inspections.

The inspection of spars is often rendered difficult because of limited access to the interior of the wing structure and because portions of the spar are obscured by electrical cable installations, fuel pipes, control mechanisms, etc. Special optical aids to facilitate inspection should be used to detect corrosion and, after its removal, to assess the damage it has caused. Areas affected by pitting should be checked for cracks by the penetrant dye method

Serious cases of spar corrosion should be reported to the Manufacturer of the aircraft. If minor corrosion is discovered, rectifications should be possible in accordance with the approved repair manual for the aircraft.

When specified in the appropriate publication or at other times at the discretion of the inspector, a selection of the main assembly bolts should be removed and examined for sign of corrosion. The aircraft structure must be adequately supported to prevent strain and distortion before the bolts are removed Before replacing assembly bolts they should be magna-flux tested and the bolt holes should be carefully inspected for evidence of attack on the surrounding material. If cadmium has been removed from the bolts, they should be replated before replacement and at all times jointing compound should be applied immediately before insertion, in accordance with the appropriate instructions.

NOTE

The inspection of bolt holes is a matter of great importance but often of usual difficulty. Pits and cracks tend to be concealed by corrosion products, which are forced into them as the bolt is extracted. If the hole is reamed before inspection, the reaming action tends to close the edges of cracks; the hole should therefore be inspected both before and after reaming. In some cases satisfactory results may be obtained by cleaning the hole with a round bristle brush using the mixture of white spirit and naphtha . After cleaning it may be possible to adapt the penetrant dye or fluorescent method of detection to the particular job, using an endoscope or a light probe in the bore of the hole. The eddy current method of examining bolt holes is effective and is often used where inspection by optical means is impracticable.

Tubular Members

Welded steel or aluminium alloy tubes used in aircraft construction are usually thin-walled and can therefore be seriously weakened by corrosion . Although external corrosion can be seen during inspection, internal corrosion may remain undetected until the tube is so weakened that failure occurs. For this reason it is essential that tubes are protected internally during assembly and sealed to prevent accumulation of moisture. Open-ended tubes should be protected internally and externally by the same method.

There is no completely reliable method of determining whether a sealed tube is corroded internally, short of cutting it open, but ultrasonic and radiological methods of examination will give an indication of reduction of thickness.

During assembly or after repair the interior of sealed tubes should be flushed with a protective material and reference should be made to the Manufacturer for the appropriate one to be used. Some such corrosion inhibitors are hot linseed oil, lanolin or zinc chromate pigmented lanolin to specification DTD 279 being particularly suitable. The flushing liquid is normally introduced through small holes, for which the appropriate design approval should first be obtained, drilled in the tubing. Surplus liquid should be drained off through suitable drain holes. It may be possible as an alternative, to remove an existing bolt or rivet ensuring that the hole is not enlarged. When sufficient liquid has been introduced to give a good coating, the holes should be plugged to exclude air or moisture.

NOTE

(1) If, for any reason, the above procedure cannot be carried out, the danger of corrosion will be greatly reduced if the enclosed air is dry and the tube is effectively sealed against the ingress of moisture. The interiors of steel tubes can be further safeguarded by the introduction of a Vapour Phase Inhibitor . Marketed in powder form, vapour inhibitors consists of stable organic nitric compounds which release corrosion-inhibiting vapour at a slow rate. The vapour will prevent corrosion even when oxygen and moisture are both present.

(2) During maintenance and overhaul, radiological methods of examination are sometimes used for the detection of damage in tubes of relatively thin cross section. This method will show changes in sectional thickness when corrosion is present and, with the correct technique, some idea of the depth of the corrosive attack can be obtained. Similarly, in some instances where tubular members are made of heavy gauge, ultrasonic methods of examination will give an indication of local reductions in thickness.

General

Components which are not part of the structure can usually be removed for anti-corrosive treatment. If items such as pumps, valves and electrical equipment are found to be corroded, rectification appropriate to the particular material and its duty should be made. Reference to the relevant Manufacturer's publications for the aircraft concerned should be made at all times. Some points of special interest are listed below.

Doped fabrics in contact with painted metal surfaces sometimes cause the paint to deteriorate with the result that the metal is attacked. The metal should be protected by the application of a dope-resisting paint on top of the normal finish.

A method of protecting seaplane floats is to tie bags of potassium or sodium dichromate to the keelson so that the dicromate permeates the bilge water.

Light alloy tanks containing leaded fuels should normally be protected by corrosion inhibitor cartridges. Typically, these cartridges consist of strontium chromate or calcium chromate tablets contained in a linen bag. It is a requirement with such cartridges that the linen bag should be thoroughly wetted with water before installation, and after tank repair operations.

When locking wire is used, it should be of a material which will not cause electro-chemical reaction with the part locked.

Control cables should be protected after installation, and at intervals, by applications of rust-preventing compounds. Lanolin-resin compounds or preparations containing zinc chromates are sometimes recommended; theses should be diluted and applied so as to ensure penetration of the compound between the strands of the cable whilst avoiding an excess accumulation which would cause stickiness of controls in fairleads and pulleys.

NOTE

British Standards W9 and W11 call for a lubricant to be applied during the spinning of cables. It is therefore important, when cleaning these cables, not to wash out the lubricant by saturating the cables with a grease solvent.

During assembly and repair, dissimilar metals should be insulated form each other unless there are overriding structural and functional considerations. Corrosion-inhibiting sealing compounds should be applied wet between all faying surfaces immediately prior to assembly: solutions containing zinc or barium chromate are generally used. Most of the proprietary materials and processes are to be found in specification DTD 900. The compound should be applied in sufficient quantities to cover all contacting faces and to cause a small quantity to be squeezed out at the boundaries to form sealing fillets. Where special compounds are used for particular purposes. e.g. to seal pressure cabins or integral fuel tanks, they should be used to insulate dissimilar metals in addition to forming a seal.

NOTE

Unsatisfactory results will be obtained if inhibiting jointing compounds are kept in open containers which allow the compound to become semi-dry before application. This trouble can be avoided if the compound is supplied in squeeze-tubes, from which it can be directly applied to the joint.

Metal parts in contact with wood should be treated with the prescribed compound before assembly, in order to prevent corrosion due to moisture in the wood.

Protective Treatments

Metal surfaces (on other than stainless steels and un-alloyed titanium) should never be left unprotected after cleaning or repair. Where practicable the original protective treatment should be restored. In other cases alternative treatments suitable for application during maintenance work may be authorised.

PREVENTION OF CORROSION AND METHOD OF PROTECTION

This chapter gives guidance on the selection and application of protective treatments to safeguard aircraft from corrosion. When re-protecting aircraft, reference must be made to the appropriate Manufacturer's publications for guidance on the anti-corrosive treatments specified for the aircraft concerned. Reference should also be made to the latest issues of the relevant British Standards and Ministry of Defence DTD Specifications when these are quoted.

Protection against corrosion can be provided in a number of ways. Some of the principles involved are briefly summarised in the following paragraphs.

Choice of Metal

Certain metals and alloys have a high natural resistance to corrosion. This applies to the noble metals because they have a low affinity for oxygen and other nonmetallic elements, but the resistant materials which are used in aircraft construction, e.g. stainless steel and aluminium, owe their properties to thin films of oxides which protect the metal from further attack. However, because of strength or weight considerations, many aircraft parts cannot be made of 'self-protecting' material and hence require anti-corrosive treatment.

Passivity

In certain conditions metals and alloys commence to corrode and the initial products of corrosion form protective films which limit further attack. Natural passivity is sufficient protection for pure aluminium and the stainless steels, but passivity has to be produced under controlled conditions to be of value for aluminium alloys. The anodic treatment is a form of artificial passivation.

Surface Finish

The oxide films on non-stainless steels do not become passive but corrosion-resistance can often be greatly increased by careful attention to mechanical finish. Thus some internal engine parts are highly polished but otherwise are only protected by a coat of clear varnish.

Chemical Inhibition

One of the most widely used methods of protection is to treat the metal with chemicals which inhibit or stifle corrosion and so artificially induce a form of passivity. The phosphate process for steel and the chromate and fluoride treatment for magnesium alloys are inhibiting treatments. Paints and primers usually contain inhibiting substances to increase the effectiveness of the protection they offer. It should be appreciated, however, that the inhibiting treatments are temporary and that the full treatment will include oil or paint films.

Sacrificial Protection

When two metals of different electric potential are in close contact, the element of a voltaic call are established and the metal which is anodic to the other may be preferentially attacked. This principle is often deliberately applied to the metal which is anodic to the other may be preferentially attacked. This principle is often deliberately applied to protect constructional materials. For example, cadmium and aluminium coatings protect steel because these metals are anodic to steel; at the same time the protection they render is long-lasting because they corrode at a much slower rate than steel. Similar protection is extended to aluminium-alloy sheet when it is clad by surface coats of pure aluminium; this protection is effective even at the sheared edges and where holes are drilled.

Mechanical Protection

Corrosion can be prevented by excluding water, oxygen and corrosive chemicals from the surface of the metal. This form of protection is the basis of most organic coatings, such as varnishes, paints and enamels, which are applied on form of protection is the basis of most organic coatings, such as varnishes, paints and enamels, which are applied on top of inhibitive priming coats. To be effective the coats should be as watertight as possible, but, since even the best paint coats only delay rather than prevent the ingress of water, periodic re-protection is essential. Metallic coatings applied by spraying, dipping or electro-deposition may also give satisfactory mechanical protection.

TREATMENT OF AIRCRAFT PARTS

It is the responsibility of Approved Design Organisations to specify the forms of protection to be used during the manufacture of each particular type of aircraft. During the operational life of the aircraft the original treatment should be renewed when necessary, but where this is impracticable a suitable alternative method should be specified.

Chemical and Electro-chemical Treatments

Treatments in this category are those which strengthen the natural oxide film of the base material or which convert the metal surface chemically to a protective coating of phosphate, chromate, etc. The most satisfactory results are usually obtained by immersion treatments but where these are impracticable brush-on applications can often be used. In the following paragraphs the standard immersion treatments for the principal aircraft constructional materials are given, together with brush-on substitutes which can be used for repair or in emergencies.

Steel

The majority of chemical treatments for steel involve the formation of phosphate films. Proprietary immersion and brush-on applications, if approved under the provision of the latest issue of DTD 900, can be used to inhibit corrosion and to form a base for painting steel parts which cannot be protected by metallic coatings. Certain process can be followed by immersion in mineral oil to render them suitable for moving parts; the phosphate coating absorbs the oil and provides a wear-resisting surface. Chemical treatments do not provide adequate protection for steel if used alone; further corrosion-proofing, e.g. painting, is usually specified.

Aluminium and Aluminium Alloys

The most satisfactory chemical treatment for these materials is anodic oxidation. Unless clad with pure aluminium, the majority of aluminium alloy parts are anodised. Anodised structural components usually receive further protection from priming and paint coats.

a. There are a number of proprietary processes which increases corrosion resistance and improve the adhesion of paint to aluminium and aluminium alloys. They are mostly simple chemical processes in which the parts are immersed in hot solutions of salts for periods of up to 10 minutes. It is not essential to apply paint immediately after the application of such processes as Alocrom or Walterisation L, as these render the surface passive ; on the other hand it is undesirable to leave the treated surfaces so long that they become dirty before being painted.

NOTE

Processes which merely pickle the surface of aluminium-alloys , such as the Chromic-Sulphuric acid treatment of Specification DEF 130 and the Deoxidine treatments, do not protect against corrosion and should be followed immediately by priming and painting.

b. Films can be produced by the application of pastes to parts in situ, e.g. Alocrom 1200; they are not as satisfactory as films produced by immersion treatments but are useful for items not exposed to weathering or abrasion.

Magnesium Alloys

The immersion processes are all chromating processes but local repairs to protective films can be effected by the Alocrom 1200 chromate conversion by swab method. Another method of protecting these alloys is by the electrolytic fluoride method known as "Fluoridising". This involves anodising the components in a solution of ammonium fluoride. It is a particularly effective method for the removal of moulding contaminants and for restoring corrosion resistance which may have been reduced by processes such as shot or grit blasting. The process consists of applying a.c. current when the items are immersed in the solution, the voltage being gradually increased to a value of 100 volts. The current falls proportionately as impurities are removed from the surface of the magnesium alloy and a thin coating of magnesium fluoride is formed. This coating has a protective value about equal to that of a chromate film and forms a good paint base. To obtain satisfactory results, full details of the process should be obtained from the Manufacturer.

Zinc Coated Components

Metallic coatings of zinc are sometimes used to protect steel parts, but zinc coatings tend to corrode rapidly unless rendered passive. After plating with zinc, the chromate passivation process described in DTD 923 should be employed.

Metallic Coatings

The protection of one metal by the application of a surface coating of another of greater corrosion resistance is common practice. Thus, aluminium-alloy sheet used in aircraft construction is usually clad on both faces with thin layers of pure aluminium rolled on during manufacture. Steel is protected by a greater variety of methods, the more important of which are summarised below.

Cadmium Plating

The electro-deposition of cadmium provides the most satisfactory form of protection for AGS and other parts of non-stainless steel. It is the standard anti-corrosive treatment for streamline wires, tie-rods and similar parts which are not usually painted. Where steel bolts and other parts are in close contact with light alloys, cadmium plating greatly reduces-the danger of corrosion resulting from the proximity of dissimilar metals; it has been found that this is so even when the cadmium coat is scored or partially rubbed off. Cadmium plating can be applied to close dimensional limits and is suitable for the protection of closely fitting attachment bolts. The relevant British Standards for cadmium plated bolts with close tolerance shanks are A59 and A111, and for shear bolts A60 and A112.

NOTES

1. It should not be assumed that stainless steels in contact with aluminium alloys are unlikely to promote intergranular corrosion or corrosion fatigue. For this reason it is advisable that they too should be cadmium plated, but a special technique is essential to ensure good adhesion of the cadmium. A plating technique is essential to ensure good adhesion of the cadmium. A plating technique that is suitable for some specifications of stainless steel involves degreasing, anodic pickling in dilute sulphuric acid , the deposition of a preliminary coating of nickel and, finally cadmium plating by the usual method.
2. Further protection by painting is not usually necessary on interior cadmium plated parts but, if it is specified, the cadmium coating should first be passivated by the process given in Specification DEF 130 or an etch primer should be used.

Nickel and Chromium Plating

These two metals are electrically deposited in a similar manner to cadmium; nickel-plating is cathodic to steel but will give good corrosion resistance if the coating is uniform and free from discontinuities. It is used for some turbine parts which are subjected to fairly high temperatures, and for the protection of many springs. Chromium is sometimes applied directly to the steel parts of aircraft as an anti-corrosive treatment and sometimes is deposited on top of nickel plating to improve appearance. Chromium plating is also used to resist wear in some engine cylinders, landing-gear shock-struts, jack rods, etc.

Metallising

Aluminium, zinc, cadmium and certain other metals can be sprayed directly on to steel from special pistols. The metal is fed into the pistol as a wire or a powder and is melted by an oxyacetylene flame. Compressed air then blows it in the form of tiny molten globules on to the surface to be coated, where it solidifies. Spray coats of aluminium are applied to engine bearers, steel tube assemblies, combustion chambers, etc. Some of these items are afterwards painted but this is not always necessary.

Flame Plating

This process, similar to some metallising, is carried out on many aircraft part which are subject to wear by fretting, particularly engine components such as compressor and impeller blades, combustion chamber parts and seals. It is sometimes applied to hydraulic pumps and motors. Briefly, the process consists of a charge of powdered tungsten carbide, chromium carbide or similar hard material, suspended in an oxygen\acetylene mixture in the breech of a special gun. The mixture is detonated and the particles become plastic; they are then blasted on to the areas being coated. This is repeated until the entire surface is coated to the required depth. Stripping of worn coatings can be carried out and new coatings applied, and thus the life of expensive components is considerably extended.

Powder Processes

Metal coatings of zinc and aluminium can be produced by packing steel parts, after sand blasting, in suitable mixtures containing the appropriate metal and heating them in sealed containers to specified temperatures. The application of aluminium by this method is known as Calorising. Sheradising, covered by BS 4921, creates a coat of zinc-iron alloy on steel parts.

Replating Local Areas

Local repairs to damaged metallic plating, and the deposition of metals in places where accessibility is limited. Can be accomplished by certain plating processes without immersion in a plating bath. The part to be plated should be made cathode by connecting it to a d.c. power unit. The electrolyte is brushed over the metal surface by an absorbent pad attached to the end of a graphite anode ; the anode, which is called a “tampon “ , is air or water-cooled according to size. Plating solutions and current densities should be selected according to the Manufacturer ‘s recommendations. Cadmium, copper, zinc, tin, etc., can be deposited very rapidly by this method.

Organic Coatings

Paints, varnishes and enamels protect metals by inhibition, by mechanical exclusion of corrosion influence, or by a combination of both these methods. Before application, the metal surfaces should be cleaned and pre-treated to provide a good key for the paint; Mechanical roughening, chemical etching, chemical film formation or preliminary deposition of metal coating should be in accordance with approved practice for the materials concerned. Reference should always be made to the relevant aircraft Manufacturer for details of the organic coating scheme to be applied to a particular aircraft.

Priming Coats

Most aircraft painting schemes commence with the application of a primer containing an inhibiting chemical such as zinc chromate. The majority of primers are air drying, but when a stove enamel finish is specified the priming coat is also stoved (BS X 31). Primers can be directly applied by brush or spray to aircraft parts in situ, but dipping is sometimes preferred for detachable items. Primers to suit the wide range of finishing schemes covered by the Ministry of Defence Process Specification selected is appropriate to the particular job. When painting certain aluminium alloy structures it is sometimes advantageous to use etching primers which obviate the need for preliminary etching by Deoxidine and similar chemicals.

Cellulose Finishes

Cellulose finishes are specified for many individual components of civil aircraft as well as for the exterior finishing of metal-skinned aircraft, as they give finishes which have good adhesion and resistance to weathering. Although the best results are obtained by spraying on top of a suitable primer, one-coat applications direct to pre-treated aluminium or aluminium-clad alloys have sometimes been used.

Synthetic Finishes

A number of external finishing schemes for the metal surfaces of aircraft are based on the use of pigmented oil varnishes or pigmented synthetic resin finishes. The relevant British Standard is BS X 28 and the Ministry of Defence Specification is DEF 1044. The majority of finishing schemes are tow-coat treatments; the pre-treated metal surface is given a brush or spray coat of the primer application to the scheme and , after the primer has dried, spray coat of the primer applicable to the scheme and, after the primer has dried, the finishing coat is applied by spray. Synthetic finishes should only be thinned with approved thinner (DTD 96); thinner for cellulose paints and dopes are generally unsuitable. As a general rule priming coats require a longer drying period for synthetic finishes than for cellulose finishes.

Lanolin-resin Finishes
Lanolin-resin preparations to Specifications DTD 279 and 633 are brush, spray or dip treatments which remain soft for considerable periods and are only occasionally applied to parts of aircraft in service. They have a limited application for the protection of marine aircraft. DTD 420 covers a range of matt pigmented lanolin-resin finishes suitable for use on metal surfaces exposed to sea water. Generally, two-coat finishes applied by brush or spray are recommended.

Stoving Finishes
Stoving enamels generally have a much higher degree of resistance to abrasion than air-drying finishes and are therefore used for some power-plant components and certain airframe parts which are not adversely affected by stoving temperatures. For maximum durability, two-coat schemes are recommended. High temperature stoving finishes, such as those covered by DTD 56, generally consist of two coats of enamel, each of which is baked separately; low temperature finishes, whether proprietary or to BS X31, usually consist of a preliminary priming coat which is baked first, followed by application of the enamel and further stoving.

NOTE
There are some kinds of enamel, e.g. the synthetic glossy black enamel specified in DEF 1044, which can be either air dried or stoved. The principal advantage of stoving is that it shortens the drying time.

Epoxide Finishes
Interior and exterior protective finishing schemes of the cold curing epoxide type are now frequently used. There are three schemes: Scheme 1 consists of etch primer, filler and finish or epoxy primer, filler and finish ; Schemes 3 consists of etch primer, epoxy primer and finish. Details of the schemes are covered in Specification DTD 5555 whilst the requirements for the materials are detailed in Specification DTD 5567.

Special Fuel Tank Treatments
Special sealing and anti-corrosion treatments are often given to fuel tank structures. In certain instances where there are undrainable areas, these are filled with a light 'void' filler, to prevent the formation of stagnant water pockets in which microbiological growths can form. Basic structural components are chemically treated, e.g. Alocrom 1200, etc., and in assembly all joints are inter-layed with a sealant such as Thiokol PR 1422. After assembly, all joints are brush-treated with rubber sealant compound such as Buna-N (EC 776) and PR 1005 L, and some tanks are then given a final 'slushing ' treatment with Buna-N in the tank, to impart a uniform protective final 'slushing' treatment with Buna-N in the tank, to impart a uniform protective film on all inner surfaces. The tank (or structural assembly) is slowly rotated in a special rig, and this ensures that the protective film is free from pinholes. Reference should always be made to the relevant aircraft Manufacturer for the appropriate treatment for any particular aircraft.

TESTING PROTECTIVE TREATMENTS
The efficacy of a protective treatment depends on its nature, its adhesion to the surface of the base metal, its thickness, its uniformity and its chemical stability. In many cases the only guarantee of satisfactory protection lies in close control of pre-treatment, but sometimes it is necessary to test the treated part, or an equivalent test piece, to ensue that the specified properties have been obtained. It is, advisable to consult the relevant aircraft Manufacturer for the preferred methods.

Chemical Treatments
There is no simple and reliable test for chemically produced films, since they are usually too thin to permit measurement of the thickness of deposits by checking the gauge. Parts on which phosphate films have been produced should be inspected for colour; a finely crystalline grey surface is required, as coarse or sparkling films indicate inadequate cleaning or wrong bath composition. Chromate films on magnesium alloys are judged by their colour .

Anodic Treatment for Aluminium Alloys
Two practical methods of testing anodic films, are the methyl violet test for sealing and the electrical potential test. The average thickness of anodic films can be checked by the method given in B S 1615, in which a test piece with a surface area of not less than 32 cm^2 (5 in^2) is anodised and then stripped in a boiling solution of phosphoric acid and chromic acid in distilled water. The test piece should be immersed until constant weight is obtained, the loss of weight being taken as the weight of the anodic film.

NOTE
Eddy current instruments are available and can be utilised to gauge anodic films.

Coating Thickness Measurement

The thickness of conducting or non-conducting coating on ferrous or nonferrous bases can be measured using basic eddy current methods, although measurement becomes difficult where the conductivity of the coating and base metal are similar. When measuring thin coatings it is recommended that equipment designed specially for coating thickness measurement should be used.

Electro-Plated Coatings

The British Non-Ferrous Metal Research Association has devised a standard test for the inspection of elector-deposited metallic coatings; the BNF Jet Test is for local thickness measurements and has the advantage over other chemical methods in that it gives the thickness at any desired point . An adhesion test for the detection of local non-adherence of metallic coatings is given in BS 1224, Appendix C.

The BNF Jet Test

The apparatus for conducting this test is illustrated in Figure 27.2 The separating funnel should be filled with a reagent solution appropriate to the nature of the metal; suitable solutions for testing cadmium and zinc coatings are given below. The test should be made as follows:

a. The article to be tested should be clamped so that the surface under test is at an angle of about 45 ° to the horizontal and about 6 mm (1\4 in) below the tip of the jet.

b. Jet Test solutions for cadmium and zinc coatings are :

	Cadmium	Zinc
Ammonium nitrate	17.5 g	70 g
N\1 Hydrochloric acid	17.5 ml	70 ml
Distilled water to produce	1 litre	1 litre

c. The tap should be opened and, simultaneously, a stop-clock should be started. At the end of 5 to 10 seconds, the tap should be closed and the clock stopped simultaneously and, without moving the specimen, the test piece should be examined for penetration.

d. The process in (c) should be repeated until the first sign of penetration is seen below the jet. The total time of impingement is taken as a guide for a further test in which the reagent is allowed to run continuously until the end-point is nearly reached.

e. The temperature of the solution and the total time for penetration are the data from which the thickness is calculated. The time required for a particular penetration at the temperature of the test should be obtained from curves supplied by the Manufacturer of the test apparatus and the total time of penetration should be divided by this time.

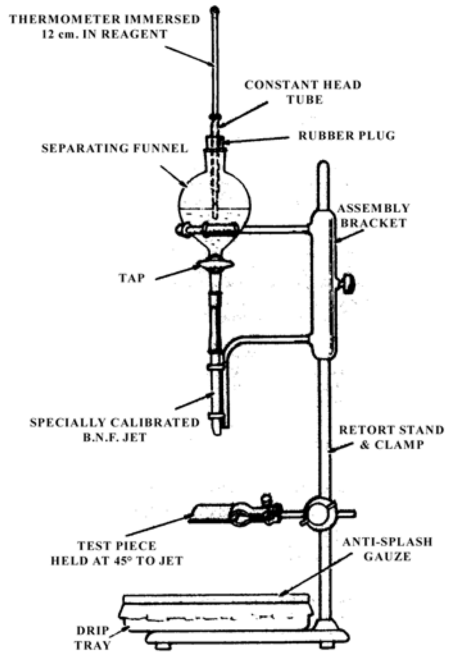

Fig. 27.2, Apparatus for BNF Jet Test

Test for Determination of Adhesion

An area of 6 cm ^{2} (1 in ^{2}) of the plated surface should be rapidly and firmly rubbed for 15 seconds with the smooth edge of a metal implement such as a copper coin, the pressure being sufficient to burnish the film at every stroke without cutting into it. If inspection then shows no detachment of the deposit, the adhesion is satisfactory. A blister which grows with the rubbing indicates poor adhesion; splitting and peeling of the deposit shows it to be of inferior quality.

Organic Finishes

The standard method of testing the corrosion-resistant properties of paint, varnish, lacquer and related products is by means of the salt spray test specified in Method No. 24 of Ministry of Defence Specification DEF 1053. The apparatus for making this test is shown in Figure 27.3 . It consists of a glass tank with a close fitting lid in which a salt mist is produced by spraying the test solution through an atomiser. Test panels, the preparation of which is given in detail in Method No. 2 of the specification, are painted with the finish under test and are then supported on nonmetallic supports with their test faces upwards. They should be at approximately 15^0 to the vertical in the tank so that they will be evenly coated with droplets of solution. But the spray must be prevented by a baffle from impinging directly on to the test faces. The salt solution drained from the panels should not be re-circulated. The composition of the solution should be as follows:

Calcium sulphate (CaSO 4)	1.3 g
Magnesium chloride (MgCl 2)	2.6g
Magnesium sulphate (M gSo 4)	1.7 g
Sodium chloride (NaCI)	21.4 g
Water (distilled)	1000 ml

Test panels are normally exposed for periods of 10 days, at the end of which period they should be removed, washed in running water and dried with absorbent paper. Any deterioration in the paint film should then be noted, after which a strip 150 mm x 50 mm (6 in by 2 in) should be cleaned off with a suitable paint remover to permit inspection of the underlying metal for corrosion.

NOTE: When required, the thickness of paint coats can be gauged by using the electrodes of a capacitance-type proximity meter. This method is applicable whether the base is ferrous or nonferrous. Eddy current (for nonferrous bases) and magnetic (for ferrous bases) thickness meters are now in use. They are not greatly affected by permeability or curvature of the base material and may be used on organic or metallic coatings.

EXTERNAL FINISHING OF AIRCRAFT

Finishing schemes for metal-skinned aircraft are selected to provide the maximum of corrosion protection with the minimum weight of paint. Adherence of finish, effect on aircraft performance and appearance are also important; therefore, verification of the scheme used should be obtained from the relevant aircraft Manufacturers.

Surface Finishes

Cellulose or synthetic finishes give satisfactory protection if applied on top of suitable primers. After pre-treatment the metal surface should be finished in accordance with a recognised scheme; for the best results it is advisable to use compatible primers, undercoats and finishing coats from the same Manufacturer. Polyurethane and acrylic finishes are now widely used in some modern aircraft, whilst others utilise epoxy paint and epoxide primers.

Retouching Local Areas

It is not always necessary to clean down to the bare metal before touching up a damaged finish but this is advisable if there is any evidence of flaking or blistering. The area should be flattened down with 'wet' sandpaper or with pumice powder applied with a damp cloth. The edges of the area should be feather-edged. If stopping is required, the stoppers should be applied with a knife. The priming coat should then be sprayed on using a round instead of a fan spray and spraying from the feather-edge inwards. The same technique should be used for the finishing coat, for which it is advisable to adjust the spray gun to give a finer spray than usual.

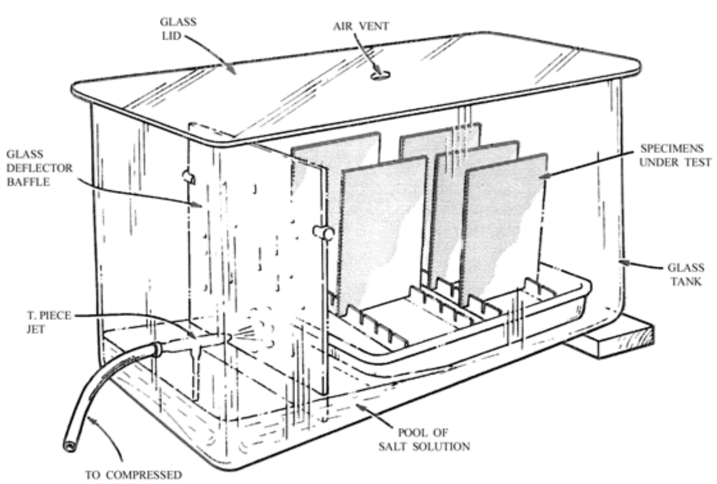

Fig.27.3, Apparatus for Salt Spray Test

Experience has shown that external paint schemes reduce maintenance labour and enhance the appearance of an aircraft. Stoving is carried out where practicable, but the paint materials used, including the latest epoxy\polyamide, will be suited to air-drying touch-up operations which might be necessary form time to time. Most paint materials are described in Ministry of Defence Specification DTD 827, 5555, 5567, 5580 and 5599.

INTERNAL FINISHING OF AIRCRAFT
The interior of wings, fuselage, etc., are usually protected by at least one coat of zinc- chromate or general purpose primer. This should be applied by spray, care being taken to ensure that all corners and enclosed spaces are adequately covered. Where greater resistance to abrasion is required, a cellulose or synthetic finish is applied on top of the primer. Special additional treatments are given to areas subject to excessive contamination.

Some aircraft Manufacturers ensure that every component receives a full protective treatment, including painting, at the detail stage. Paint is applied to clean pre-treated metal surfaces and stoved to ensure the best adhesion and durability. This finish has good resistance to knocks and abrasives, and the parts are thus protected from damage during assembly, paint and interfaying compound is present in all joints, giving enhanced protection from corrosions and fretting.

Aluminium-alloy parts are often protected by the Alocrom 1200 process which has no deleterious effect on the fatigue properties of the metal, and gives a good bond for paint adhesion. Steel components are cadmium plated and then given chromate passivation, which improves the paint adhesion and provides increased corrosion resistance. The paint treatment is often an epoxy/polyamide system using a chromate pigmented primer and a gloss finish which is suited to air-drying touch up operation. Areas subject to slight contamination may receive chemical cleaning, chemical protection and primer painting only, whilst areas contaminated by water, oil, etc,., may receive an additional process of hard gloss finishing paint. Those areas subject to attack from acid or corrosive fluids are given a further treatment of epoxy nylon lacquer.

Some Manufacturers apply a water displacing corrosion inhibitors to supplement the finishing scheme, and similar material may also be used, where permitted, incases where interior paint work has been damaged. These inhibitors are volatile liquids which are sprayed or brushed on the surfaces to be treated; the liquid carrier then evaporates leaving a waxy film on the surface. The inhibitor penetrates small cavities and between faying surfaces and thus prevents the ingress of moisture.

These inhibitors are usually slightly toxic and the appropriate precautions should be observed during their application. In addition, corrosion inhibitors may contain flammable components and may present a fire hazard when mixed with oxygen or subjected to high temperatures. All safety precautions recommended by the Manufacturer should therefore be observed.

THE CONTROL OF CORROSION
Details of corrosion control during design and production are outside the scope of this chapter: the following paragraphs relate to care and maintenance under operating conditions.

Cleaning
It cannot be too strongly emphasized that frequent cleaning is essential for the prevention of corrosion. During take-off and landing, aircraft are splashed with mud and water; during flight, engine oil and exhaust products are deposited on parts of the structure, and at all times contamination by atmospheric dirt is likely to occur.

Metal-skinned structures should be washed down thoroughly using solutions, materials and equipment which are recommended by the aircraft Manufacturer. Non-flammable de greasing cleaners for aluminium alloys are available in powder or ; they should be applied with a bristle brush, care being taken to remove all dirt from odd corners, panel edges, screw and rivet heads, etc. If deterioration of protective treatments or signs of corrosion are revealed by cleaning, the affected parts should be treated. Cleaning preparations should be washed off with cold water after they have loosened the dirt, and the parts should be dried thoroughly before restoring any protective treatments.

NOTE
There are certain proprietary cleaners which , although harmless to metals, are inclined to rot fabric and other textile materials. It follows that care should be taken to prevent them from wetting fabric or upholstery. Transparent plastics can also be damaged by cleaning chemicals and should therefore be suitably protected.

At the intervals specified in the Approved Maintenance Schedule, marine aircraft should be beached and hosed down with fresh water. The bilges should be drained and flushed through with fresh water at the same time. Care should be taken that all deposits of salt and marine growths are removed from both the inside and outside of the aircraft and that all damage to protective coatings is made good. All submerged parts of the hull and floats should then be sprayed with liquid lanolin, pigmented lanolin or seaplane varnish, the spraying being continued to approximately 0.6 m (2 ft) above the water line.

Where battery or other acids have been spilled, the surrounding area should be rinsed with generous quantities of clean water to dilute and remove the acid. The affected part should then be brushed with a dilute solution of sodium bicarbonate for lead acid batteries, and diluted acetic acid for nickel cadmium batteries, to neutralize any remaining electrolyte. After this has remained on the surface for a few minutes, the area should again be washed with water, finally wiped dry, and the protective treatments restored.

NOTE
In cases where spillage of acid or heavy concentrations of battery fumes (e.g. due to a runaway battery) have occurred which are not contained within a known area, it may be necessary to dismantle parts of all the surrounding structure to ensure the effective removal of all traces of electrolyte.

High octane fuels, which are doped with tetra-ethyl-lead and ethylene dibromide, produce lead bromide when burnt. This is ejected in the exhaust gases and can do considerable harm if deposited on aluminium alloys. Such deposits should be removed by using detergents or emulsifiable cleaners which will not soften the underlying paint coat. Where possible all apertures at wing root joints, etc., should be sealed to exclude exhaust gases from the inside of the structure, but if the gases do penetrate, internal cleaning will also be necessary. If the deposits are so hardened that they will not yield to normal cleaning, a paint stripper should be applied . Using a high pressure jet of water or rubbing with a damp rag, the stripper and paint can then be removed together. Afterwards the cleaned area must be re-protected

NOTE
Paint strippers containing methylene dichloride or ethylene dichloride can seriously reduce the strength of resin-bonded joints, and hence aircraft on which processes such as "Redux " bonding have been used should only be cleaned with strippers which are recommended for the purpose by the aircraft Manufacturer. Information on acceptable materials, if not in the appropriate Manual, is normally available in Service Bulletins published by the Manufacturer's Service Department.

Although accumulation of oil and grease may not in themselves be corrosive, they tend to retain dirt and metal particles, to damage surface finishes and prevent inspection for cracks, etc. They should be removed from such parts as the landing gear and engine nacelles by means of solvents or emulsifiable cleaners. The cleaning agents recommended by the aircraft Manufacturer should always be used.

NOTE
It is important that the cleaning fluids specified by the manufacturers are used in the strength recommended and in applications where their use has been specified. Cases have arisen where cleaning fluids in combination with kerosene have had a deleterious effect on aircraft structures, the penetrating qualities of kerosene promoting seepage into skin joints. Such cases are particularly troublesome and it becomes difficult to diagnose the cause of corrosion. Also, unspecified cleaning fluids might contaminate or destroy jointing compounding, bonding adhesives or sealing mediums.

Wrong methods of cleaning can do more harm than good. The following points should be noted:

a. Steel wool should not be used on aluminum alloy or magnesium alloy surfaces as particles may be lodged in crevices or embedded on organic coating and so provide starting points for electro-chemical attack.

b. Aluminium-clad light alloy sheet should not normally be polished with mechanical buffing wheels, except under a carefully controlled technique, as this will remove the coating of pure aluminium and the unprotected alloy core will be subjected to corrosion.

c. Dirt and swarf should not be washed or brushed inside the structure where particles may be trapped behind stringers, frames, etc. (Trapped water can do more damage than the dirt.) Interior cleaning should be done with an efficient vacuum cleaner.

d. Pressure cleaning should be used with caution, particularly where bearings are in use. Steam cleaning should only be used when specified, for it can penetrate joints and leave water residues.

TYPES OF DEFECT AND VISUAL INSPECTION

Inspection

The structure should be maintained in a clean condition and a careful check should be made for any signs of dust, dirt or any extraneous matter, especially in the more remote or 'blind' parts of the structure. Loose articles such as rivets, metal particles, etc., trapped during construction or repair, may be found after the aircraft has been in operation for some considerable time. It is important to examine these loose article to ensure that they did not result from damaged structure. It is generally easy to determine if a loose article has formed part of the structure by its condition, e.g. an unformed rivet could be considered as a loose article, but a rivet which had been formed would be indicative of a failure.

General
The structure should be examined for any signs of distortion or movement between its different parts at their attachment points, for loose or sheared fasteners (which may sometimes remain in position) and for signs of rubbing or wear in the vicinity of moving parts, flexible pipes, etc.

NOTES: A wing structure has been known to have had a rib, sheared at its spar attachments due to the accidental application of an excessive load, without any external evidence of damage, because the skin returned to its original contour after removal of the load.

The protective treatment should be examined for condition. On light alloys a check should be made for any traces of corrosion, marked discoloration or a scaly, blistered or cracked appearance. If any of these conditions is apparent the protective treatment in the area concerned should be carefully removed and the bare metal examined for any traces of corrosion or cracks. If the metal is found satisfactory, the protective treatment should be restored.

NOTE: To assist in the protection of structures against corrosion some constructors may attach calcium chromate and/ or strontium chromate sachets to the vulnerable parts of the structure. The presence of chromate in the sachets can be checked by feel during inspection. After handling these materials, the special precautions, e.g. hand washing, given in the constructor's manual, should be followed.

In most cases where corrosion is detected in its early stages, corrective treatment will permit the continued use of the part concerned. However, where the strength of the part may have been reduced beyond the design value, repair or placement may be necessary. Where doubt exists regarding the permissible extent of corrosion, the constructor should be consulted.
The edges of faying surfaces should receive special attention careful probing of the joint edge with a pointed instrument may reveal the products of corrosion which are concealed by paint. In some instances slight undulations or bumps between the rivets or spot welds, or quilting in areas of double skins due to pressure from the products of corrosion, will indicate an advanced state of deterioration. In some cases this condition can be seen by an examination of the external surface, but as previously mentioned in this leaflet, dismantling of parts of the structure to verify the condition of the joints may be required.

NOTE : To avoid damage to the structure, the probing of a joint with a pointed instrument should be carried out with discretion by an experienced person. Any damage done to the protective paint coating, however small, should be made good.

Visual Examination
Nearly all the inspection operations on aircraft structures are carried out visually and, because of the complexity of many structures, special visual aids are necessary to enable such inspections to be made. Visual aids vary from the familiar torch and mirrors to complex instruments based on optical principles and, provided the correct instrument is used, it is possible to examine almost any part of the structure.

Note: Airworthiness Requirements normally prescribe that adequate means shall be provided to permit the examination and maintenance of such parts of the aeroplane as require periodic inspection.

Light Probes
It is obvious that good lighting is essential for all visual examinations, and special light probes are often used.

(a) For small boxed-in structures or the interior of hollow parts such as the bores of tubes, special light probes, fitted with miniature lamps, as shown in Figure 1, are needed. Current is supplied to the lamp through the stem of the probe from a battery housed in the handle of the probe. These small probes are made in a large housed in the handle of the probe. These small probes are made in a large variety of dimensions, from 5 (3/10 in) diameter with stem length from 50 mm (2 in) upwards.

(b) Probes are often fitted with a magnifying lens and attachments for fitting an angled mirror. Such accessories as a recovery hook and a recovery magnet may also form part of the equipment.

(c) For the larger type of structure, but where the design does not permit the use of mains-powered inspection lamps, it is usually necessary to use a more powerful light probe. This type of light probe consists of a lamp (typically an 18 watt, 24 volt type) which is protected by a stiff wire cage and mounted at one end of a semi-flexible tube or stem. On the other end is a handle with a light switch and electrical connections for coupling to a battery supply or mains transformer. As the diameter of the light probe is quite small it can be introduced through suitable apertures to the part of the structure to be inspected.

NOTE: Where spillage or leakage of flammable fluids may have occurred or when inspecting fuel tanks, it is important to ensure that the lighting equipment used is flameproof, e.g. to BS 229.

Inspection Mirrors

Probably the most familiar aid to the inspection of aircraft structures is a small mirror mounted at one end of a rod or stem, the other end forming a handle. Such a mirror should be mounted by means of a universal joint so that it can be positioned at various angles thus enabling a full view to be obtained behind flanges, brackets, etc.

(a) A useful refinement of this type of mirror is where the angle can be adjusted by remote means, e.g. control of the mirror angle by a rack and pinion mechanism inside the stem, with the operating knob by the side of the handle, thus permitting a range of angles to be obtained after insertion of the instrument into the structure.

(b) Mirrors are also made with their own sources of light mounted in a shroud on the stem and are designed so as to avoid dazzle. These instruments are often of the magnifying type, the magnification most commonly used being 2X.

Magnifying Glasses

The magnifying glass is a most useful instrument for removing uncertainty regarding a suspected defect revealed by eye, for example, where there is doubt regarding the presence of a crack or corrosion. Instruments vary in design from the small simple pocket type to the stereoscopic type with a magnification of 20X. For viewing inside structures, a hand instrument with 8X magnification and its own light source is often used.

(a) Magnification of more than 8X should not be used unless specified. A too powerful magnification will result in concentrated viewing of a particular spot and will not reveal the surrounding area. Magnification of more than 8X may be used, however, to re-examine a suspected defect which has been revealed by a lower magnification.

(b) When using any form of magnifier, it is most important to ensure that the surface to be examined is sufficiently illuminated.

Endoscopes

An endoscope (also known as an introscope, boroscope or fiberscope, depending on the type and the manufacturer() is an optical instrument used for the inspection of the interior of structure or components. Turbine engines, in particular, are often designed with plugs at suitable locations in the casings, which can be removed to permit insertion of an endoscope and examination of the interior parts of the engine. In addition, some endoscopes are so designed that photographs can be taken of the area under inspection, by attaching a camera to the eyepiece; this is useful for comparison and record purposes.

(a) One type of endoscope comprises an optical system in the form of lenses and prisms, fitted in a rigid metal tube. At one end of the of the tube is an eyepiece, usually with a focal adjustment, and at the other end is the objective head containing a lamp and a prism. Depending on the design and purpose of the instrument a variety of objective heads can be used design and purpose of the instrument a variety of objective heads can be used to permit viewing in different directions. The electrical supply for the lamp is connected near the eyepiece and is normally supplied from a battery or mains transformer.
(i) These instruments are available in a variety of diameters from approximately 6 mm (1/4 in) and are often made in sections which can be joined to make only length required. Right-angled instruments based on the periscope principle are also available for use where the observer cannot be in direct line with the part to be examined.

(b) A second type of endoscope uses 'cold light', that is, light provided by a remote light source box and transmitted through a flexible fibre light guide cable to the eyepiece and thence through a fibre bundle surrounding the optical system to the objective head. This type provides bright illumination to the inspection area, without the danger of heat or electrical sparking, and is particularly useful in sensitive or hazardous areas.

(c) A third type of endoscope uses a flexible fibre optical system, thus enabling inspection of areas which are not in line with the access point.

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CHAPTER-28
NON-DESTRUCTIVE INSPECTION TECHNIQUES INCLUDING, PENETRANT, RADIOGRAPHIC, EDDY CURRENT, ULTRASONIC AND BOROSCOPE METHODS

OIL AND CHALK PROCESSES

INTRODUCTION

This chapter gives guidance on the surface defects, such as cracks and porosity, by processes involving the use of oil and chalk. The principle upon which the process is based is the absorption by chalk of fluids. A penetrant oil is applied to the surface of the parts to be checked and, after removing the surplus oil, a layer of chalk is applied. Oil entrapped in defects is absorbed by the chalk, the resulting stains indicating their position.

There are two basic methods of applying the process, i.e. the "Hot fluid Process" & the "Cold Fluid Process". Of these, the process employing hot oil is the more efficient and should be used wherever possible, but methods suffer serious limitations. However, some proprietary processes, e.g. the " Bristol Modified Method of Oil and Chalk Test" , which is an adaptation of the hot fluid process, are not subject to such deficiencies.

LIMITATIONS OF PROCESSES

The oil and chalk processes were devised for the detection of surface defects in nonferrous and some nonmetallic materials, but the deficiencies described in the following paragraphs should be considered before deciding upon the suitability of either of the processes for the work in hand. The processes are nor considered suitable for the detection of minute flaws or tightly shut cracks.

The processes are quite effective for such applications as the detection of large cracks in rough castings, but in general, the degree of contrast obtained by oil exudation is very poor and, unless the pre-cleaning and final drying processes are efficiently done, spurious indications of defects may be given.

Defect indications, at best, will appear only as dark grey stains on a light grey background, and are not sufficiently defined to make the detection of small cracks practicable, particularly when examining parts having dark surfaces, e.g. chromated magnesium alloy parts.

When the hot oil process is used for parts which are dimensionally large or are of intricate shape, it is often not possible to remove the surplus oil quickly enough to be able to apply the chalk before the parts become cool, thus the object of heating is defeated . On the other hand, if the drying is not done efficiently, masking of defects may occur due to the spontaneous staining of the chalk in damp areas.

HOT FLUID PROCESS

To obtain satisfactory results it is essential that the parts should be thoroughly cleaned before immersion. If the parts have previously been immersed in an acid pickle bath, paint stripper, or some other strong solutions, all traces of such solutions must be removed by adequate washing to avoid contamination of the test oil.

The parts to be examined should be immersed or (if a specified area only is to be examined) partly immersed, in a solution consisting of approximately 28 per cent (by volume) of lard oil in paraffin . The solution should be maintained at a temperature of approximately 80 o C., and the period of immersion must be sufficient to allow the parts to attain this temperature. If preferred, solutions consisting of three parts paraffin and one part lubricating oil, or 50 per cent paraffin and 50 per cent spindle oil, may be used.

After immersion the parts should be dried quickly and thoroughly with a non fluffy rag ; excellent final cleaning can be achieved by the use of unglazed tissue paper.

The parts should then be placed in the chalk cabinet and a fine layer of dry powdered French chalk should be applied, preferably by a method that will distribute the chalk in a gentle cloud. A paint spray gun with a conical funnel fitted in front of the jet, operated at a pressure of about 10 lb. sq. in. , will be found suitable for this purpose. The gun should be provided with an efficient water trap. Surplus chalk should be removed by lightly tapping the parts on a block of wood.

NOTE

The chalk cabinet should form an enclosed area in which the parts to be examined can be placed. It should have a transparent front and should be fitted with an exhaust fan to remove surplus chalk. The parts can be coated more rapidly if a turntable is used. The parts should be inspected for defects when quite cool and it will be found that if any cracks are present, the fluid will have been forced from them as the metal contracted on cooling, causing the chalk to become stained. A gentle air stream from a source pressurized at not more than 10 lb. sq. in., if directed on to the surfaces of the parts , may assist in the revelation of defects by removing the adjacent un stained chalk. It is essential that the examination should be made with the aid of a strong light.

COLD FLUID PROCESS

The efficiency of this process is not equal to that of the hot fluid process, and it should be used only where the application of the latter process would not be practicable, e.g. when examining parts of assembled structures or parts too large for immersion.

The parts should be thoroughly cleaned and then coated with a solution of lard oil and paraffin, or lubricating oil and paraffin, in the proportions recommended in. After the surfaces to be examined have been thoroughly coated, all traces of the solution should be removed with a non-fluffy rag, followed by final wiping with unglazed tissue paper. The surface should then be coated with French chalk .

Any oil entrapped in defects will be drawn out by the absorbent chalk, the resulting stains indicating the position of the defects. It is essential that the examination should be made with the aid of a strong light.

THE BRISTOL MODIFIED METHOD

In this process, finished parts or rough castings are immersed in hot oil, are removed and have the surfaces decreased, and are then sprayed or dusted with dry French chalk.

The parts to be examined should be immersed or (if a specified area only is to be examined) partly immersed, in a solution consisting of 50 per cent paraffin and 50 per cent spindle oil. The solution must be maintained at a temperature of 70°C., and the period of immersion should be sufficient to allow the parts to attain this temperature, one hour usually being sufficient.

After immersion, the parts should be allowed to stand until all surplus oil has drained off, after which they should be transferred to a degreasing tank containing a solution consisting of the following :

Teepol	5 per cent	← by volume
Cresylic Acid	5 per cent	
Water	90 per cent	

The solution should be maintained at a temperature of between 70° C. to 80° C. When the cleansing action deteriorates, additions of Teepol and cresylic acid should be made to restore the above proportions.

NOTE

The cresylic acid should comply with the requirements of British standard 524, Grades A or B.

The parts should be immersed in the degreasing solution for 3 to 5 minutes and should be agitated throughout this period. After degreasing, the parts should be transferred to a tank containing clean hot water, and should be thoroughly swilled for a period of from 3 to 5 minutes, after which they should be allowed to drain.

When dry, the parts should be coated with a layer of dry French Chalk, the equipment described under Hot Fluid Process being suitable for this purpose, except that an air pressure of 60 to 80 lb. sq. in. is recommended, after which surplus chalk should be removed by the application of a jet of air at about 25 to 30 lb. sq. in. pressure.

The parts should now be examined for defects, and cracks will be indicated by a thin white line of chalk.

PENETRANT DYE PROCESS

INTRODUCTION

This chapter gives guidance on the penetrant dye processes used for the detection of defects which break the surface of the part, such as cracks, cold shuts, folds, laps and porosity.

Penetrant dye processes are used mainly for the detection of flaws in non-ferrous and non-magnetic ferrous alloys but may also be used for ferrous parts where magnetic flaw detection techniques are not specified or are not possible. However, in some instances both penetrant dye and magnetic flaw detection techniques may be specified for a particular part. Penetrant dyes may also be used on some non-metallic materials but their use with perspex-type materials is not recommended, since crazing may result.

Although the processes are usually marketed under brand names, those used on aircraft parts for which a penetrant process of flaw detection is a mandatory requirement must comply with the requirements of Process Specification DTD 929. It must be ensured that any storage limiting period prescribed by the manufacturer of the process is not exceeded.

The processes available can be divided into two main groups. One group involves the use of penetrants containing an emulsifying agent (termed water-emulsifiable or water-washable processes) whilst in the other group a dye solvent has to be applied separately after the penetration time has elapsed if the surplus dye is to be removed by a water-wash operation. The processes may be further sub-divided in so much that with some processes the use of a dry developer is recommended whilst with others a wet developer is used. The manufacturer 's recommendations and instructions for each individual process must be followed carefully to ensure satisfactory results.

NOTE

An emulsifier is a blending of wetting agents and detergents which enables excess dye to be removed with water and, in the case of wide flaws, assists in preventing the dye seeping out too quickly.

Basically all the processes consist of applying a red penetrant dye to the surface of the part to be tested, removing after a predetermined time the dye which remains on the surface and then applying a developer, the purpose of which is to draw to the surface any dye that has entered into defects, the resultant stains indicating the positions of the defects.

The selection of the most suitable type of penetrant process (e.g. penetrant dye or fluorescent penetrant; with or without post-emulsification for any given application must largely be governed by experience, sine when used correctly a high degree of efficiency can be obtained with any of the processes. Guidance on some of the factors which should be given consideration is provided in the following paragraphs.

Within a given type of process, the post-emulsification method is generally considered to be the most sensitive and is usually selected for finished machined parts and for the detection of " tight " defects. However, its use on rougher surfaces (e.g. castings) may be less effective than would be the use of a penetrant containing an emulsifier, since it may pick up the surface texture of the material, thus rendering the detection of actual defects more difficult.

Where large heavy parts are concerned, and particularly where mechanical handling is involved, the use of penetrant dyes may be more practical than that of fluorescent penetrants, since the necessity of darkening a relatively large area before the examination can be made does not arise.

When making " in situ" checks on aircraft, the use of penetrant dyes may be more suitable where their is sufficient light but in darker areas a fluorescent process may provide better definition of defects.

NOTE

Battery-operated ultra-violet light sources are now available.

With steel castings, for example, porosity may be detected more easily by a penetrant process than by a magnetic flaw detection technique and for this reason the application of both processes is sometimes specified. If the magnetic flaw detection test precedes the penetrant test, great care will be necessary with the intervening degreasing process to ensure that all traces of the magnetic testing medium are removed, otherwise the subsequent penetrant test may be unsuccessful.

Some of the materials associated with penetrant testing have low flash point and the appropriate fire precautions should be taken.

SURFACE PREPARATION

The major reason for the failure of penetrant processes to provide indications of defects is incorrect or inadequate surface cleaning. For example, embedded extraneous matter can seal off cracks, etc., whilst contaminants remaining on the surface can trap the dye and give rise to false indications or, more detrimentally, obscure genuine defects. Thus the surface to be tested must be free from oil, grease, paint, rust, scale, welding flux, carbon deposits, etc., and the method of cleaning should be selected with the intention of removing extraneous matter from within the defects as well as from the surface to permit maximum dye penetration.

On un machined steel stamping and forging it may be necessary to remove rust or scale by sandblasting and to prepare aluminium alloy forging by light sandblasting. However, the use of such processes must be given careful consideration, since they may result in the filling or " Peening-over " of defects. Generally, unless specified otherwise, aluminium alloy forging should be prepared by a suitable pickling process (e.g. by one of the methods prescribed in Process Specification DTD 901).

Magnesium alloy castings should be tested after chromating in order to reduce the risk of corrosion, but the requirements of Process Specification DTD 911, with regard to surface protection, must be taken into account and a suitable sequence devised.

Where contamination is mainly of an organic nature, degreasing by the trichloroethylene process (unless their are instructions to the contrary) is usually suitable. However, not all types of trichloroethylene are suitable for use with titanium alloys. The cleaning of titanium alloys by methanol should be avoided.

Where parts have to be tested " in situ " , the use of volatile solvents (e.g. carbon tetrachloride) as cleaning agents should be given consideration. Where paint is present, this should be removed from the surface to be tested prior to cleaning. Subsequent to the test, the surface should be re protected in the prescribed manner.

NOTE
Suitable fire precautions must be taken when flammable materials are used.

Sufficient time should be allowed after cleaning for drying out, otherwise the efficiency of the penetrant dye may be determined by the prevailing conditions of temperature and humidity and the type of solvent used.

APPLICATION OF THE DYE
The penetrant dye can be applied to the surface by dipping, spraying or brushing, the method used depending largely on the size, shape and quantity of the parts to be examined. The surface must be dry before the dye is applied. Even the condensation which forms on a cold surface in humid conditions may interfere with dye penetration ; in such conditions the part should be warmed to a temperature of about 90° F. to 100° F. but temperatures in excess of 140°F. must be avoided, since these may result in the volatilization of some of the lighter constituents of the dye.

Dipping Method
Dipping should generally be used where large numbers of small parts are to be examined. The parts must be completely dried before immersion, since apart from affecting penetration, water or solvents will contaminate the dye.

During dipping care must be taken to ensure that the parts are so racked that air pockets are avoided and all surfaces to be examined are completely wetted by the dye.

It is not necessary for the parts to remain submerged in the tank during the penetration time but only for a period sufficient to permit thorough wetting. " Drag-out " losses can be reduced if the dye is allowed to drain back into the tank during the penetration time.

Flooding Method
The flooding method should generally be used where large areas are to be examined . The dye should be applied with low-pressure spray equipment which will not permit atomization of the fluid, any surplus dye being allowed to drain back into the tank.

Aerosol can Method
Penetrant contained in Aerosol type cans is often used for " in situ " inspections. The best results are obtained when the can is held about twelve inches from the surface under test.

Brushing Method
The brushing method is generally used for individual items and items of complicated shape. A clean soft bristle brush should be used and retained only for this purpose.

PENETRATION TIME
The penetration time is the time which has to be allowed for the dye to penetrate effectively into the defects. It is dependent upon a number of factors, such as the characteristics of the process being used, the material from which the part is made, the size and nature of the defects being sought, the processes to which the part has been subjected and the temperatures of the atmosphere, the part and the dye. Clearly the time can be decided only by experience of the particular local conditions but is usually in the range of 5 minutes to 1 hour, the smaller the defect the longer the time necessary.

Temperatures below 60° F. will retard the penetrant action of the dye, thus the penetration time should be extended proportionately. Testing in temperatures at or near freezing point should, if possible, be avoided, since in such conditions the performance of the penetrant is considerably reduced. Where the effectiveness of the pre-cleaning process cannot be guaranteed or where parts have been sandblasted, the penetration time should be extended but it should be borne in mind that this is no guarantee that defects will, in fact, be revealed in such conditions.

REMOVAL OF EXCESS DYE
Any dye remaining on the surfaces of the parts after expiry of the penetration time should be removed as thoroughly as possible but without disturbing the dye which would have found its way into any defects present. Excessive cleaning, however, may result in the dilution of the dye or its complete removal from defects. The method of removal depends on whether a water-washable or post-emulsifiable dye was used and the situation and condition of the surface under test.

WATER-WASHABLE DYE
Water-washable dye should be removed as indicated in the following paragraphs.

The dye should be removed from " in situ " parts with clean rags saturated in water, followed by wiping with clean rags until the surfaces are both dry and free from dye.

The dye should be removed from small parts with clean rags saturated in water, followed by drying as recommended

The dye should be removed from large areas or irregularly shaped parts by flushing with an aerated spray of water, followed by drying .

Post-emulsifiable Dye
Post-emulsifiable dye should be removed from small areas and " in situ " parts first by wiping with a clean rag damped with dye solvent, followed by wiping or blotting with a clean dry rag. The bulk of the dye may be removed from large areas, irregularly-shaped parts and rough-textured surfaces by a quick water wash (allowing this to drain) followed by the application of the dye solvent and a final water wash. The dye solvent should be applied by spraying, swabbing dipping or brushing, except that brushing should not be used where relatively large defects are suspected. Washing should be followed by thorough drying.

Surface Drying
Prior to applying the developer it should be ensured that the surfaces of the part under test are completely dry. The following methods of surface drying are recommended which, although slower than the use of, for example, compressed air, air less likely to disturb entrapped dye. Small areas may be wiped dry but since this may disturb the dye in the wider defects, the use of warm air is preferred. Hot-air ovens and similar equipment may be used for drying , a temperature of about 130 ° F. being suitable ; temperatures in excess of 175° F. must be avoided. The use of lamps for drying is not recommended unless uniform heat application can be guaranteed.

APPLICATION OF THE DEVELOPER
The developer usually consists of a very fine absorbent white powder which may be applied in
(a) the form of a spray, the powder being suspended in a volatile carrier liquid which rapidly evaporates, leaving a white coating on the surface.
(b) as a dip with the powder suspended in water or
(c) as a dry dipped. The action of the absorbent powder is to draw out the dye from the surface defects, thus indicating their position by the resulting stain.

Where it is suspected that microscopic defects may be present, great care is necessary to ensure that the developer is applied evenly and very thinly, since a thick layer might conceal completely a defect holding only a minute quantity of dye.

Where a wet developer is concerned, the best results are obtained when the developer is applied by means of a paint-type spray gun operating at an air pressure not in excess of 15 lb. sq. in. The pressure pot of the spray gun should be equipped with a stirrer to keep the developer agitated and the absorbent particles in suspension. Before pouring the developer into the spray gun it should be well shaken to ensure a thorough distribution of the absorbent particles. When requirements are not too exacting, small parts can be dipped into a bath of developer but the action must be performed rapidly to minimize the possibility of the dye being washed out of shallow defects. The bath should be agitated from time to time to ensure that the absorbent particles are kept in uniform suspension. The formation of pools of developer on the parts during draining must be avoided, otherwise the resultant thick coatings may mask defects.

Due to the usually uneven results obtained, the use of a brush for applying the developer is not recommended.

If the developer dries with a slightly pinkish hue, this is probably due to faulty cleaning or " carried over " penetrant in the penetrant remover but provided sufficient contrast remains to enable minute defects to be detected, the condition is acceptable.

Water must not be permitted to enter the developer containers, since its presence will retard considerably the drying rate of the developer.

INTERPRETATIONOF DEFECTS

If defects are present and all stages of the process have been applied correctly, the position of the defects will be indicated by red marks appearing on the whitened surface. The majority of defects are revealed almost immediately the developer dries by additional time (approximately equal to the penetration time) should be allowed for “tight” flaw indications to appear and for flaw patterns to reach their final shape the size. Figure 28.1

By noting and comparing the indications that appear during the first 30 seconds of development with those which exist after about 10 minutes, a more accurate assessment of the characteristics of the defects is possible. For example, the dye exuding from a shallow crack is little more after 10 minutes than after 30 seconds but in the case of a deep narrow crack, considerably more dye is present, causing a much wider indication to develop over a similar period of time. Thus the rate of staining is an indication of the width and depth of the defect, whilst the extent of staining is an indication of its volume.

Scattered dots of dye indicate fine porosity or pitting Figure 28.1 (d) whilst gross porosity may result in an entire area becoming stained. Where doubt exists as to whether the overall pinkish effect is due to inadequate washing, the process should be repeated, more care being taken particularly during the stage of cleaning off the excess dye.

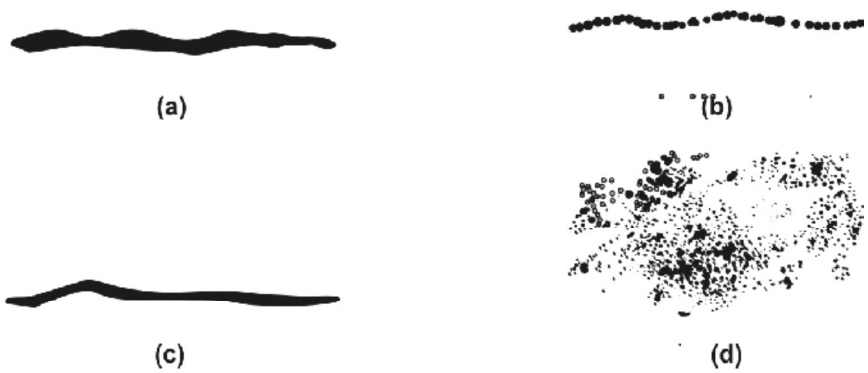

Fig. 28.1, Indications Given by Defects

Closely spaced dots in a line or curved pattern Figure 28.1 (c) usually indicate tight cracks or laps but such patterns are also characteristic of very wide defects from out of which most of the dye has been washed. Wide cracks, lack of fusion in welded parts and other similar defects are indicated by continuous lines as shown in Figures 28.1(a) and 1 (b).

Examination by means of a powerful magnifying glass is often useful when minute defects are being sought.

All defects should be suitably marked prior to removing the developer, but crayons should not be used on highly-stressed components subject to heat treatment, since this is known to induce fractures.

REMOVALOF DEVELOPER

Developer can be removed by brushing or by air or water under pressure, but since the surface is then in a condition susceptible to corrosion (where this is applicable) the prescribed protective treatment should be applied with the minimum of delay. It should be noted that the adhesion of paints and resins may be seriously impaired by certain oil-base dyes if thorough cleaning is not ensured.

LEAKTESTINGWITHPENETRANTDYES

On components or assemblies where the main purpose of the test is to locate defects which would result in a fluid leakage (e.g. cracks in pressure vessels) the methods of testing described in the previous paragraphs may not be conclusive. In such cases the inner and outer surfaces should be thoroughly cleaned and degreased, the dye being applied to one surface (usually the inside of pressure vessels) and the developer to the other. After the penetration time has elapsed, the surface should be inspected for evidence of staining.

Where no definite penetration time has been determined then, with a wall thickness of from 1/16 in. to 1\8 in., the penetration time should be at least three times that which would be allowed for a standard “ one-side-only “ test.

More than one application of the dye is often required and as a general rule an additional applications for each 1/16 in. to 1/6 in. wall thickness is recommended.

■■■

CHAPTER-29
MAGNETIC FLAW DETECTION

INTRODUCTION

This chapter gives guidance on the detection of surface and subsurface defects in ferro-magnetic materials by magnetic processes. The procedures recommended in this chapter are complementary to British standard (BS) M35, and should not be taken as overriding the techniques of examination prescribed by the manufacturer of a particular component, either in drawings or in approved manuals.

Magnetic flaw detection tests are applied to many steel parts at the manufacturing, fabrication and final inspection stages. The process is normally applied to all Class 1 aircraft parts manufactured from ferro-magnetic materials, and to any other parts where the designer or inspection authority considers it to be necessary.

NOTE

A Class 1 part is defined as a part, the failure of which, in flight or ground manoeuvres, would be likely to cause catastrophic structural collapse, loss of control, power unit failure, injury to occupants, unintentional operation of , or inability to operate, essential services or equipment.

The methods of magnetising in general use are the magnetic flow and the current flow processes, which are described in paragraph below. By choosing the most suitable process, or combination of processes, for a particular component, both surface and subcutaneous defects may be revealed.

Great care must be taken when establishing a technique of examination suitable for a particular component, in order to ensure that consistent results are obtained. Operators of magnetic flaw detection equipment should be thoroughly trained in its use, and experienced in interpreting technique requirements and the indications obtained from a test.

THE PRINCIPLE OF MAGNETIC FLAW DETECTION

If a component is subjected to a magnetic flux, any discontinuity in the material will distort the magnetic field and cause local leakage fields at the surface. Particles of magnetic material applied to the surface of the magnetised component will be attracted to the flux leakage areas and reveal the presence of the discontinuity.

The sensitivity of magnetic flaw detection depends largely on the orientation of the defect in relation to the magnetic flux, and is highest when the defect is at 90^{o} to the flux path. Sensitivity is considerably reduced when the angle between the defect and the flux path is less than 45^{o}, so that two tests are normally required with each component, the flux path in the first test being at 90^{o} to the flux path in the second test. Components of complex shape may require tests in several different directions.

A component may be magnetized either by passing a current through it, or by placing it in the magnetic circuit of a permanent magnet or electromagnet. The required strength of the applied magnetic field varies considerably, and depends largely on the size and shape of the component and on the magnetic characteristics of the material from which it is made.

The magnetic particles used to reveal defects are either in the form of a dry powder, or suspended in a suitable liquid. They may be applied by spray, pouring, or immersion, depending on the type of component. Magnetic flaw detection ‘inks’ complying with BS 4069 are used in aircraft work, and consist of finely divided black or red magnetic oxides of low corrosivity (i.e. they will not retain the magnetism induced during testing), suspended in a liquid (normally kerosene). Pigments may be added to provide a contrast with the surface of the specimen. Black inks are suitable for use on bright, machined components, but red inks may be more suitable for unmachined parts or, alternatively, a thin coat of white paint or strippable lacquer may be added to the component before carrying out the test.

If magnetic inks are left standing for long periods the solid particles settle at the bottom of the container and form a sediment which may be difficult to redisperse. If the machine does not have pump agitation, frequent manual agitation must be provided during tests to ensure satisfactory inking of the specimens. The solids concentration in inks manufactured to BS 4069 should be 0.8 to 3.2 % by volume, but with fluorescent inks the solids content is approximately one tenth of these values. Methods of determining the solids content of magnetic inks are detailed in BS 4069. Magnetic ink should be discarded if it becomes diluted by solvents or contaminated with oil or any foreign substance likely to reduce its effectiveness as a detecting medium.

Fluorescent inks are also widely used and are often specified where high sensitivity is required. Inspection of a component to which fluorescent ink has been applied, should be carried out under black light.

METHODS OF MAGNETIZATION

Current Flow Method

If an electric current is passed through a conductor, a magnetic flux is induced, both within the conductor and in the surrounding atmosphere, in a series of concentric circles at 90° to the direction of current flow. With steady current the strength of the internal magnetic flux is greatest at the surface of the conductor and decreases uniformly to zero at the centre, but with alternating current both the current and magnetic flux are confined to a thin layer at the surface, because of the effects of induction. Magnetization at the surface can be greater with alternating current than with direct current, but direct current has the advantage of greater depth of penetration. In practice, machines are often designed so that alternating or rectified current can be applied to a specimen, to make use of the advantages of each method.

Current flow machines normally provide a sustained current through the specimen, ink being applied while current flows. The specimen is usually clamped between contact pads on a static machine, but portable units are available in which the contacts take the form of hand-held prods, and these are often used for checking components which are difficult to mount in a static machine. Good electrical contact is essential, and the contacts are usually provided with copper gauze pads, sufficient pressure being used to prevent arcing between the pads and specimens. Because of the danger of burning and possible subsequent fatigue cracking, the use of prods is often prohibited on finished parts, especially those of high tensile steel.

A variation of current flow magnetisation is the "impulse" methods, which employs either direct or alternating current in the form of a short impulse (generally less than one second). Difficulty may be experienced in satisfactorily inking the specimen while current is flowing, and the specimens may be immersed in a bath of magnetic ink. Alternatively, with some materials, remaining magnetism may be sufficiently strong to provide defect indications when ink is applied after current has ceased to flow. The alternating current impulse method is not often used, due to the difficulty of interrupting the current at a point in the hysteresis loop which will leave the specimen adequately magnetised.

For testing purposes it is usual to apply a sufficiently heavy current to give a satisfactory magnetic flux in the specimen, and to use a low voltage to safeguard the operator. As a rough guide to the basic current setting to use, most steels can be satisfactorily tested using an alternating current of 500 A rms per inch diameter or, for specimens of irregular shape, 150 A rms per inch of periphery. Some steels, e.g. nickel-chrome steels, may require a higher magnetising force due to their low permeability. Current values for irregular shaped components should be decided by fixing an artificial defect to the area required, applying ink, and varying current value until a satisfactory indication is obtained.

NOTE

The effective current value with regard to magnetisation is the peak value. Ammeters do not usually record the peak value however, and testing techniques must state whether the current values specified are rms (root mean square) or peak. It is normally assumed that an ammeter reading rms is fitted to an a.c. machine, and an ammeter reading mean current is fitted to a rectified a.c. or constant potential d.c. machine. Current values producing a magnetic flux equivalent to that produced by 500 A rms, a.c., with these types of ammeter fitted , are:-

d.c.	710 A
half-wave rectified a.c.	225 A
full-wave rectified a.c.	450 A

If a peak-reading ammeter is fitted to an a.c. machine, the current value should be the same as for d.c. (i.e. 710 A). In cases where the wave form is unknown, the relationship between peak and average values must be determined empirically, and the current adjusted accordingly.

The passage of a heavy current will have a heating effect on the specimen, particularly when direct current is used. This could cause burning in specimens such as thin tubes, and possibly have an adverse effect on any heat treatment previously applied. The duration of each test should, therefore, be limited to as short a time as possible, consistent with satisfactory inking of the specimen.

Induction Methods

In all induction methods, the magnetic field external to the current-carrying element is used to induce a magnetic flux in the specimen.

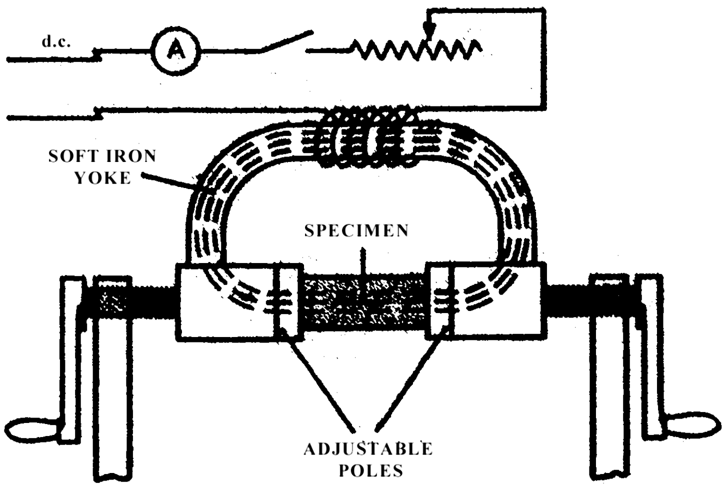

Fig. 29.1, Magnetic Flow Machine

Magnetic Flow Method

Figure 29.1 shows the arrangement of a typical magnetic flow machine, the specimen being clamped between adjustable poles in the magnetic circuit of a powerful electromagnet, Good contact between the poles and specimen is essential, otherwise a marked lowering of the field strength will result. Laminated pole pieces are often used to ensure that good contact is maintained with specimens of curved or irregular shape, and in some portable equipment which employ a permanent magnet, contact is obtained through a number of spring-loaded pins.

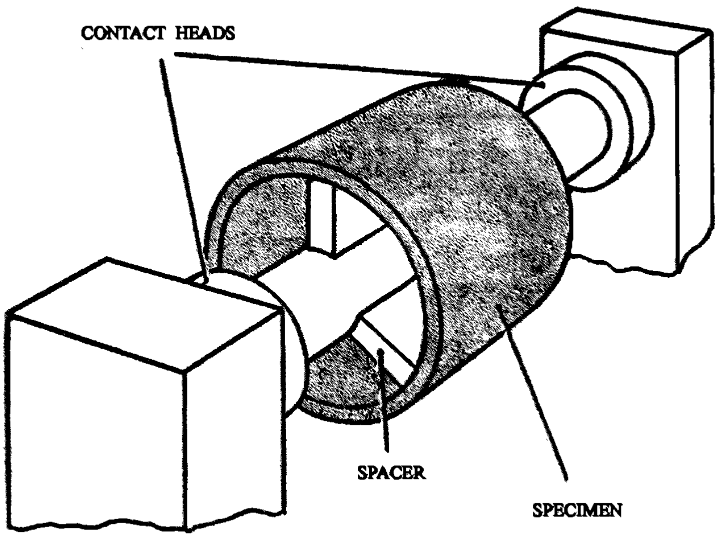

Fig. 29.2, Threading Bar Method

(i) The magnetising force required to carry out a test using a magnetic flux machine, will depend on the length, cross-section and permeability of the yoke, the number of turns of the winding, and the magnetic characteristics of the test piece. No set current value would be suitable with all machines, and tests should be conducted to ascertain the current value which will ensure magnetisation just below the saturation level. Saturation is indicated by a heavy build-up of magnetic ink at the ends of the specimen, or an overall coating on its surface . In all tests the cross-sectional area of the pole pieces should be greater than that of the specimen, but the maximum cross-sectional area which can be tested will normally be stated in the operating instructions for a particular machine.

(ii) To ensure that the strength of the magnetic flux in a specimen is sufficient to reveal defects during a test, it is common practice to employ portable flux indicators. These may take the form of thin steel discs containing natural cracks, which, when attached to the surface of a specimen during a test, will give an indication of flux strength and also , with some indicators, the flux direction.

(iii) With many machines it is easy to over-magnetise, particularly when carrying out tests on small specimens. It the machine does not have controls for adjusting the energising current, a reduction in magnetic flux can be achieved by inserting non-magnetic material between the pole pieces and the specimen.

(iv) Magnetic flow machines are generally designed to operate with direct current, the magnetising coil containing a large number of turns of wire and carrying a current of a few amps only. This type of coil would be unsuitable for use with alternating current, since the coil would have too much inductance. If it is required to use alternating current for magnetic flow tests, the coil must be replaced by one having a few turns and carrying a heavy current.

Threading Bar Method

This method is used for testing rings and tubes, and is illustrated in Figure 29.2. A current flow machine is used, and a conductor connected between the contact heads of the machine. Current flowing through the conductor induces a magnetic flux in the specimen at 90^0 to the direction of current flow; this flux may be used to reveal defects in line with the axis on the specimen. Best results are obtained when the air gap is smallest, i.e. the conductor is only slightly smaller than the internal diameter of the specimen, but a larger air gap is often necessary in order to permit examination of the interior surface.

(i) A symmetrical flux may be obtained in the specimen by inserting non-conducting spacers between the conductor and the specimen, but this is not essential except to prevent burning should the conductor overheat. If the shape of the item under going test precludes the use of a straight conductor, a heavy flexible cable may be used.

(ii) The basic current setting should be determined from the length of the flux path, i.e. the outside periphery of the specimen,. 100 to 200 amps per inch being a satisfactory basic setting for most steel specimens. The current required is unaffected by the length of the specimen, except that if the specimen is very long the resistance of the conductor may limit the available current.

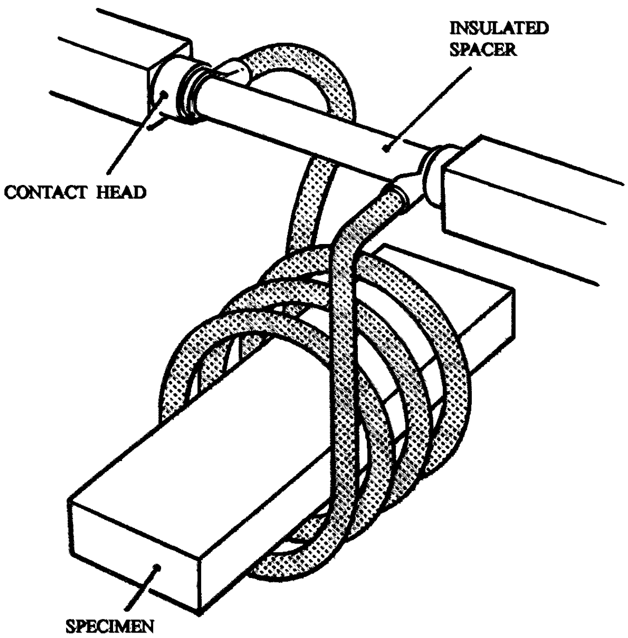

Fig. 29.3, Magnetising Coil Method

Magnetising Coil Method

A current flow machine is also used for the magnetising coil method. An insulated heavy gauge copper wire or strip is connected between the contact heads of the machine as shown in Figure 29.3, and formed into a coil ; a.c. coils have 2 1\2 to turns and d.c. coils 6 to 10 turns, the space between turns being less than the cross-sectional diameter of the wire in order to minimize flux leakage. The magnetic lines of force resulting from passing current through the coil, will induce a magnetic flux in the specimen, in the direction of the coil axis.

(i) Components of simple shape may be placed within the coil during a test, but satisfactory magnetisation will only be obtained within the length of the coil. Difficulty may be experienced with short components, due to the demagnetising effect resulting from the close proximity of the free poles (i.e. the ends of the specimen), and it is often advisable to complete the magnetic circuit using a yoke manufactured from mild steel, or extend the effective length of the component with end blocks.

(ii) When components of complicated shape are being tested, it is difficult to estimate the strength and direction of the magnetic flux in all parts of the specimen during a single test. It is often preferable to make several tests with the coil located at several positions within or around the specimen, inspecting only those parts adjacent to the coil at each position.

(iii) As with the magnetic flow method, the current required depends on a number of factors, including the relative diameters of the specimen and coil, and the length\diameter ratio of the specimen. BS M35 gives a formula for calculating the current required under specified conditions, but the most suitable values are generally obtained by experiment, and by selecting a current which gives a field strength just less than that required to saturate the material.

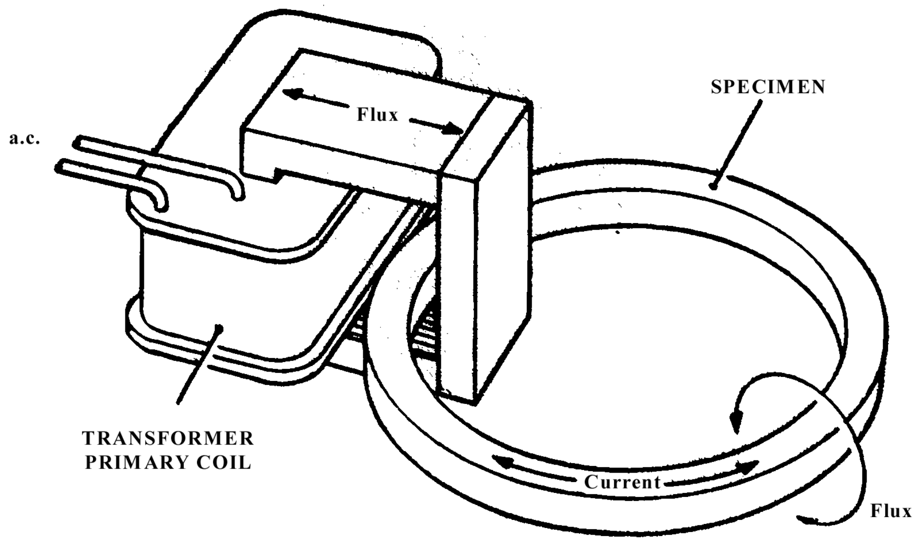

Fig. 29.4, Induced Current Flow Method

INDUCED CURRENT FLOW METHOD

Figure 20.4 shows the coil arrangements for this method, in which current is induced to flow through the specimen by the action of the primary coil of a transformer. The induced current itself provides a magnetic field within the specimen, which may be used for detecting defects lying mainly in a longitudinal direction. This method is often used on ring specimens of large diameter.

TESTING PROCEDURES

Techniques of testing by magnetic methods are established after preliminary tests have shown that defects can be consistently revealed in similar parts to those under test. When carrying out routine tests in accordance with a specified technique, each instruction must be carefully followed in order to obtain satisfactory results. The full test procedure consists of degreasing, magnetising, application of magnetic ink or powder and interpretation of indications, this process being repeated for each test specified on the technique sheet and concluding with final demagnetising and cleaning. The use of a hand lens of low magnification is normally specified for the examination of defects.

GENERAL CONSIDERATIONS

Before carrying out a test the equipment should be checked to ensure that it is functioning properly. The technique sheet will usually specify the capacity of the machine required for a test, and stipulate the type of magnetic ink or powder to use. An initial test, using a specimen containing known defects, may be carried out to verify that these defects can be revealed. Alternatively, in the absence of a cracked specimen a test may be carried out using a " portable crack " taped to the surface of the specimen. This often consists of a thin strip of material in which a crack has been artificially induced, and may be used as a guide for acceptance or rejection of the specimen under test. Equipment is usually checked with standard test pieces.

Good lighting is essential for examining the specimen. Good daylight provides the best illumination for normal inks, but fluorescent lighting, free from highlights and of correct intensity, is a suitable substitute. When using fluorescent inks, black light is essential and daylight should, as far as possible, be excluded from the viewing area ; efficiency of the black light source should be checked periodically (BS 4489).

Adequate bench space should be provided adjacent to the testing machine and, where the nature of the work permits, should be away from noisy or otherwise distracting locations.

When specimens are tested in batches and set aside in a magnetised condition for subsequent examination, they should not be permitted to come into contact with one another, or with any other magnetic material, such as steel-topped benches or steel brackets, until the examination has been completed. If specimens do come into contact with other magnetised objects a local disarrangement of the magnetic field many occur, giving an effect similar to that obtained with a real defect.

Selectionof Method

In cases where a technique of examination has not been specified, tests must be made to ensure that defects in the specimen can be satisfactorily revealed.

Factors to be considered are the size and shape of the specimen, and the capacity of the machines available. Changes of cross-section in a component will result in variations in the intensity of magnetisation through the component, requiring several tests using different current settings at each change of cross-section. The shape of a component may also modify the distribution of magnetic flux and result in misleading indications in the ink pattern. Examples of difficult specimens are toothed gears, turbine blades with fir tree roots and threaded components, where over-magnetisation may result in buildup of iron oxide at the extremities, and cause defects to be hidden. This type of component may often be examined using a remaining magnetism technique, a d. c. supply being used with fluorescent ink ; the part should be gently swilled in paraffin after application of the ink to clear the background, but retain any defect indications.

Since the majority of specimens must be tested for longitudinal and transverse defects, both current flow and magnetic flow tests are normally required ; both tests may be carried out on a single universal machine.

Table below gives guidance on the most suitable methods of testing materials of various simple shapes; components of complicated shape may require special techniques. Test using flux detectors and portable cracks will permit a satisfactory technique to be established, however, and great difficulty is not often experienced

TABLE 29.1

Specimen	Suitable Test Method
Bar	Current flow for longitudinal defects. Magnetic flow for transverse defects. Magnetising coil for transverse defects.
Tube	Threading bar for longitudinal defects. Magnetic flow for transverse defects. Current flow for longitudinal defects. Magnetising coil for transverse defects.
Ring	Threading bar for defects in line with ring axis, and radial defects. Current flow or induced current flow for circumferential defects.
Plate	Current flow or induced current flow using prods for both longitudinal and transverse defects.
Disc	Current flow or current flow using prods, with the disc rotated 90^0 between successive tests.
Sphere	Current flow or current flow using prods, sphere being rotated to reveal any defects. Magnetic flow or magnetising coil may also be used if flux path is extended using steel extension pieces.

Preparation

Specimens should be free from dirt, grease or scale, since these may hide defects and contaminate the magnetic ink. Scale may usually be removed by abrasive blasting or approved chemical methods, and trichloroethylene or other suitable solvents are normally used for degreasing when the parts are being tested away from their assembled positions. Trichloroethylene should not be used for cleaning parts in situ, due to the health hazard. It is not usually necessary to remove paint or plating except to provide good electrical contact for the current flow process.

NOTE

The fluorescent properties of certain magnetic inks may be diminished by chemical reaction with acids. When acid pickling is used as a cleaning process, care is necessary to ensure that all traces of acid are washed off.

Preparation of the specimen should also include demagnetisation. Magnetisation may have been induced by working, by machining in a magnetic chuck, or by lying adjacent to magnetised components or material. In the case of raw material, magnetisation may be removed by heating to a temperature above the Curie point for the material, but generally, for finished parts , it must be removed as detailed in paragraph.

Apertures such as oilways and deep tapered holes, which do not form part of the area to be examined, should be plugged to prevent the intrusion of ink, which may be difficult to remove.

Magnetisation

Components of simple shape will normally require magnetising in two directions, by a selection of the methods described in paragraph , so that defects of any orientation will be revealed . Components of complicated shape may require further magnetisation in selected areas to ensure completed coverage. A component should normally be demagnetized between each test, to remove the effects of residual magnetism, which could cause spurious indications.

Inking

Except where remanent magnetism is used to reveal defects, magnetic ink should be applied gently, immediately before and during the period of magnetisation. With a.c. machines the magnetic flux should be applied for at least three seconds to allow time for the ink to build up defects, but d.c. machines are often fitted with a time switch which limits the application of flux to between 1\2 and 1 second. When the immersion method is used, extreme care is necessary during removal of the specimen form the bath, in order to avoid disturbing the magnetic ink and any indications of defects which it may show.

Interpretation of Indications

Particles of magnetic ink are attracted to flux leakage fields, and these may occur at defects, brazed joints, the heat affect zone in welds, or sudden changes of section. The presence of a sudden buildup ink on a specimen is not, therefore, necessarily an indication of a crack, inclusion or similar discontinuity, and experience is essential in interpreting the indications produced by a test.

Cracks are revealed as sharply defined lines on the surface of the specimen, the magnetic particles often building up into a ridge which stands proud of the surface.

Subcutaneous defects such as may occur during manufacture of the material, will be more blurred than surface cracks. Nonmetallic inclusions are often revealed by a diffuse clustering of magnetic particles, but may sometimes give an indication which is as sharply defined as a crack.
Grinding cracks are usually readily identified, and consist of a pattern of irregular lines over the affected area, or, on small radius bends or teeth, they may appear as short parallel lines.

Tool marks may give an indication similar to cracks, but the bottom of a tool mark can usually be seen with the aid of a hand lens with approximately 5x magnification, whereas cracks are usually deep and narrow.

Localised magnetic flux resulting from ineffective demagnetisation, or careless handling after a specimen has been magnetised, may give indications known as magnetic writing. Careful demagnetising and retesting will show whether the magnetic writing is spurious, or an indication of a real defect.

Excessive magnetisation causes furring, and magnetic particles tend to follow the grain flow, giving the appearance of clusters of inclusions. The remedy is to reduce magnetization when testing areas of reduced cross-section.

Changes in permeability within a specimen, such as may occur at welds, may give misleading indications. Magnetic detection methods may not be suitable in these instances, and radiography may have to be used.

Recording of Defects

Defects are normally marked with grease pencil or paint for future reference, but it may be necessary, for record purposes, to preserve the indications obtained in a test, either on the specimen or as a separate permanent record.
If the magnetic ink has an oil based carrier, the specimen should be drained and dried or, alternatively, another test may be carried out using an ink containing a volatile carrier fluid. If dry powder is used no preparation is necessary.

In cases where the specimen is to be retained, it should be gently sprayed with quick -drying lacquer or covered with a transparent adhesive film, care being taken not to disturb the surface indications.

If a separate permanent record is to be retained the specimen may be photo-graphed, or one of the following actions taken :-

(i) The indications may be covered with a transparent adhesive tape, which may then be peeled off and applied to a paper or card of suitably contrasting color, to show the defects.
(ii) A stripe able adhesive coating may be gently sprayed on to the surface of the specimen. When carefully removed, this coating will retain the indications of defects, and these may be viewed on the surface which was in contact with the specimen.
(iii) The specimen may be heated and dipped in a thermosetting plastic powder material. When cured and stripped off, this material may be viewed as in (ii) above.

Demagnetisation

There are a number of reasons why specimens should be demagnetised before, during or after magnetic particle testing. These include the effects of magnetic writing, the difficulty which would be experienced in any subsequent machining operation due to the adherence of swarf, bearing wear due to the adherence of fine metallic particles, and interference with the aircraft magnetic compasses. A specimen should, therefore, be demagnetised before starting tests, between tests which involve a change in flux direction, and after tests have been completed.

The most commonly used demagnetiser is an aperture type of coil carrying an alternating current. The specimen should be placed inside the energised coil and withdrawn a distance of at least 1 1\2 meters (5 feet) along the coil's axis with the current switched on, or may be placed inside the coil and the current gradually reduced to zero. Ideally, the coil should be just large enough to accept the specimen.

If a demagnetising coil is not available the crack detecting machine may be used. Alternating current from the machine may be passed through two or three turns of heavy cable, which may be used in the same way as a demagnetising coil;. Alternatively, a suitably equipped direct current electromagnet machine may be used, the specimen being placed between the poles and the current being gradually reversed and reduced simultaneously to zero.

For demagnetising parts in situ an alternating current yoke is normally used. This consists of a coil wound on a laminated yoke, which is used in a stroking action on the specimen. The strokes should always be in the same direction along the specimen and the yoke should be moved away in a circle on the return stroke.

After demagnetising, the specimen should be removed from the vicinity of the demagnetising coil, the testing machine, or any other magnetised material.

Tests for Demagnetization of Parts

Any components which are manufactured from steel and liable to affect the aircraft compass, should be demagnetised and a test for remanent magnetism carried out before assembly in the aircraft. The standard test for remanent magnetism in aircraft parts is the deflection of a magnetic compass needle under controlled conditions, but an alternative method, such as the use of a flux meter, may be permitted, and suitable limits prescribed.

The test consists of placing a suitable magnetic compass in a position away from all stray magnetic influences, and slowly rotating the component at a position along the east\west axis of the compass. The distance of the component from the compass should be specified for the test, and should be the same as the distance from the aircraft compass to the installed component. Deflection of the compass needle by more than 1^0 will require the component to be demagnetised again and the test to be repeated.

Final Cleaning

When a component has been accepted following a magnetic detection test, all traces of detecting ink, contrast paint or temporary marking should be removed. Wiping or washing in solvent, or immersion in an approved degreasing agent are the methods normally used. During cleaning, any plugs or blanks fitted during the preparation for the test, should be removed. A temporary rust protective should be applied after cleaning, and the part should be identified in accordance with the appropriate drawing, to indicate that magnetic flaw detection has satisfactorily carried out.

TECHNIQUE SHEETS

A technique sheet is a document detailing all the magnetising operations to the performed when inspecting a particular component by the magnetic particle method. It may be accompanied by an illustration of the component and by instructions applicable to all magnetic particle tests, such as the methods of cleaning and demagnetising to be used.

A technique sheet should show all the relevant details for each magnetising operation, including type of equipment, strength and form of current, acceptance standard, contact areas, positions of flux detectors, type of coil, size of threading bar, and test pattern, as appropriate to the particular test. It is recommended that the symbols used in BS M 35 should be used on all technique sheets and, where appropriate, on related drawings or sketches.

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CHAPTER-30
FLOURESCENT PENETRANT

INTRODUCTION
This chapter gives guidance on the fluorescent penetrant processes used for the detection of defects in a component, such as cracks, cold shuts, folds, laps and porosity when these break the surface of the component.

Fluorescent penetrant processes are used mainly for the detection of flaws in non-ferrous and non-magnetic ferrous alloys but may also be used for ferrous parts where magnetic flaw detection techniques are not specified or are not possible. In some instances both fluorescent penetrant and magnetic flaw detection techniques may be specified for a particular part. Fluorescent penetrants may also be used on some non-metallic materials, such as plastics and ceramics, but in each case a suitable process for the particular material must be selected. The processes are not suitable for use on absorbent materials.

Although the processes are usually marketed under brand names, those used on aircraft parts for which a penetrant process of flaw detection is a mandatory requirement must comply with the requirements of Process Specification DTD 929. It must be ensured that any storage limiting period prescribed by the manufacturer of the process is not exceeded.

There are two types of fluorescent penetrants, a minor water-based group and a major oil-based group ; the manufacturers of the processes usually specify the materials for which each process is suitable. There are variations in the processes which must be taken into account. For example, some types of penetrants contain an emulsifier, whilst in other processes the penetrant and the emulsifier are applied as separate stages. Again in some processes the use of a dry developer is recommended whilst in others a wet developer is used. The manufacturer 's recommendations and instructions for each individual process must be followed carefully to ensue satisfactory results.

NOTE
An emulsifier is a blending of wetting agents and detergents which enables excess penetrant to be removed with water.

Fluorescent penetrant testing is based on the principle that when ultra-violet radiation falls on certain chemical compounds (in this case the penetrant) it is absorbed and its energy is re-emitted as visible light (i.e. the wavelength of the light is changed). Thus , if a suitable chemical is allowed to penetrate into surface cavities, the places where it is trapped and has been drawn to the surface by the developer will be revealed by brilliant greenish-yellow lines or patches (according to the nature of the defect) under the rays of an ultra-violet lamp.

The selection of the most suitable type of penetrant process e.g. penetrant dye or fluorescent penetrant ; with or without post-emulsification for any given application must largely be governed by experience, since when correctly used a high degree of efficiency can be obtained with any of the processes. Guidance on some of the factors which should be given consideration is provided in the following paragraphs.

Within a given type of process, the post-emulsification method is generally considered to be the most sensitive and is usually selected for finished machined parts and for the detection of " tight" defects. However , its use on rougher surfaces (e.g. castings) may be less effective than would be the use of a penetrant containing an emulsifier, since it may pick up the surface texture of the material, thus rendering the detection of actual defects more difficult.

Where large, heavy parts are concerned, and particularly where mechanical handling is involved, the use of penetrant dyes may be more practicable than that of fluorescent penetrants, since the necessity of darkening a relatively large area before the examination can be made does not arise.

When making " in situ " checks on aircraft, the use of penetrant dyes may be more suitable where there is sufficient light but in the darker areas a fluorescent process may provide better definition of defects.

With steel castings, for example, porosity may be detected more readily be a penetrant process than by the magnetic flaw detection techniques and for this reason the use of both processes is sometimes specified. If the magnetic flaw detection test precedes the penetrant test, great care will be necessary with the intervening degreasing process to ensure that all traces of the magnetic testing medium are removed, otherwise the subsequent penetrant test may be unsuccessful.

Some of the materials associated with penetrant testing have low flash points and the appropriate fire precautions should be taken.

SURFACE PREPARATION

The major reason for the failure of penetrant processes to provide indications of defects is incorrect or inadequate surface cleaning. For example, the surface can trap the penetrant and give rise to false indications or, more detrimentally, obscure genuine defects. Thus the surface to be tested must be free from oil, grease, paint, rust, scale, welding flux, carbon deposits, etc., and the method of cleaning selected must be capable of removing extraneous matter from within the defects as well as from the surface to permit the maximum penetration.

With un machined steel stamping and forging it may be necessary to remove rust or scale by sandblasting. Aluminium alloy forging may also need light sandblasting. However, the use of such processes must be given careful consideration, since they may result in the filling or " Peening-over " of defects. Generally, unless specified otherwise, aluminium alloy forging should be prepared by a suitable pickling process (e.g. by one of the methods prescribed in Process Specification DTD 901).

Magnesium alloy castings should be tested after chromating in order to reduce the risk of corrosion, but the requirements of Process Specification DTD 911, with regard to surface protection, must be taken into account and a suitable sequence devised.

Where contamination is mainly of an organic nature, degreasing by the trichloroethylene process (unless there are instructions to the contrary) is usually suitable. However, not all types of trichloroethylene are suitable for use with titanium alloys. The cleaning of titanium alloys by methanol should be avoided.

Where parts have to be tested " in situ ", the use of volatile solvents (e.g. carbon tetrachloride) as cleaning agents should be given consideration . Where paint is present this should be removed from the surface to be tested prior to be tested prior to cleaning. Subsequent to the test, the surface should be re protected in the prescribed manner.

NOTE

Suitable fire precautions must be taken where flammable materials are used.

Sufficient time should be allowed after cleaning for drying-out, otherwise the efficiency of the penetrant may be affected. The time interval allowed for the evaporation of solvents can only be determined by the prevailing conditions of temperature and humidity and the type of solvents used.

APPLICATION OF THE PENETRANT PROCESS (WITHOUT POST EMULSIFICATION)

Application of Penetrant The penetrant can be applied to the surface by dipping, spraying or brushing, the method used depending largely on the size, shape, and quantity of the parts to be examined. The surface must be dry before the penetrant is applied. Even the condensation which forms on a cold surface in humid conditions may interfere with penetration ; in such conditions the part should be warmed, preferably within the temperature range of 70^o F. to 90^o F.

Dipping Method

Dipping should generally be used where large numbers of small parts are to be examined. The parts must be completely dried before immersion, since apart from affecting penetration, water or solvents will contaminate the penetrant.

i) During dipping care must be taken to ensure that the parts are so racked that air pockets are avoided and all surfaces to be examined are completely wetted by the penetrant.
ii) The parts should be dipped for a few seconds and allowed to drain, care being taken to ensure that the solution is able to drain away from any pockets or cavities in the parts. If there is a tendency for the penetrant to dry on the surfaces the parts should be redipped.

Flooding Method

The flooding method should generally be used where large areas are to be examined. The penetrant should be applied with low-pressure spray equipment which will not permit atomisation of the fluid, care being taken to ensure that the penetrant completely covers the surface and remains wet. On no account should the penetrant be allowed to dry during the penetration period.

Aerosol Method

Penetrant contained in aerosol-type cans is often used for "in situ" inspections. The best results are obtained when the can is held about 12 in. from the surface under test.

Brushing Method

The brushing method is generally used for individual items and items of complicated shape. A soft clean bristle brush should be used and retained only for this purpose. On no account should the penetrant be allowed to dry during the penetration period.

Penetration Time

The penetration time is the time which has to be allowed for the penetrant to enter effectively into defects and usually a period of up to ten minutes is sufficient for the larger type defects, but longer times may be necessary where minute defects are being sought. (see Table 30.1)

Typical penetration times are given in Table 30.1 but these may vary according to the temperature and process used. The manufacturer's recommendations must always be followed where these differ from the figures given.

Where the effectiveness of the pre-cleaning process cannot be guaranteed or where parts have been sandblasted, the penetration time should be extended but it should be borne in mind that this is no guarantee that defects will, in fact, be revealed in such conditions.

TABLE 30.1

Material	**Nature of Defect**	**Penetration Time. (Minutes)**
Sheets and Extrusions	Heat treatment cracks, grinding cracks and fatigue cracks.	15
Forgings	Laps, cracks.	30
Castings	(i) Shrinkage, cracks and porosity. (ii) Cold Shuts.	3-10 20
Welds	(i) Cracks, porosity. (ii) Included flux.	20 1
Plastics	Cracks, crazing.	1-5

Removal of Excess Penetrant

Excess penetrant should be removed by spraying with running water at a mains pressure of about 30 lb. sq. in. or by the use of an air \ water gun. In the case of self-emulsifying penetrants, it may be necessary with some surfaces to use a detergent solution, supplied by the manufacturer, prior to spraying the developer. It is most important to ensure that the rinsing operation is completely effective, otherwise traces of the residual penetrant may remain on the surface and interfere with the subsequent diagnosis of defects.

After rinsing, the surfaces of the component should be quickly inspected by means of ultra-violet light to ascertain the efficiency of the rinse. If any general fluorescence it still evident the rinsing operation should be repeated.

If a wet developer is to be used, the surfaces need not be dried but drying is essential if a dry developer is to be used. On large parts the excess water can be blown off with clean, dry, oil-free air but when parts are of convenient size, drying in a recirculating hot-air drier is recommended. Excessive time in the drier should be avoided, as the penetrant will slowly evaporate.

Application of the Developer

The developer usually consists of a very fine white powder which may be applied in (a) the form of a spray, the powder being suspended in a volatile carrier, (b) as a dip with the powder suspended in water or (c) as a dry powder which may be blown on to the component or into which the component may be dipped. The action of the absorbent powder is to draw out the dye from the surface defects, thus indicating their position by the resultant yellowish-green stain when viewed under ultraviolet light.

Where it is suspected that microscopic defects may be present, great care is necessary to ensure that the developer is applied evenly and very thinly, since a thick layer might completely conceal a defect holding only a minute quantity of dye.

Where a wet developer is concerned, the best results are obtained when the developer is applied by means of a paint-type spray gun operating at an air pressure not in excess of 15 lb. sq. in. The pressure pot of the gun should be equipped with a stirrer to keep the developer agitated and the absorbent particles in suspension. Before pouring the developer into spray-gun it should be well shaken to ensure thorough distribution of the absorbent particles.

When requirements are not too exacting, small parts can be dipped into a bath of developer but the action must be performed rapidly to minimise the possibility of the penetrant being washed out of shallow defects. The bath should be agitated from time to time to ensure that the absorbent particles are kept in uniform suspension in the solvent. The formation of pools of developer on the parts during draining must be avoided, otherwise the resultant thick coatings may mask defects.

Due to the unusually uneven results obtained, the use of a brush for applying the developer is not recommended after the developer has been applied, the parts should be allowed to stand for at least 15 minutes and should then be examined in a darkened room, using ultra -violet light. Where doubt exists as to the validity of an indication, the part should be left for at least two hours and then re-examined. It viewing periods are to exceed 30 minutes, the use of special viewing goggles is recommended to reduce the risk of eyestrain and headaches.

NOTE
Portable lamps specially manufactured for fluorescent viewing are available.

APPLICATION OF THE PENETRANT PROCESS (WITH POST EMULSIFICATION)
In principle the process is similar to that described in the previous paragraph, except for the addition of the emulsification step. However, the separate application of penetrant and emulsifier does introduce additional factors which must be taken into account and these are described below.

After the parts have been dipped in the penetrant, the drain-off period should not be less than 15 minutes and not more than 2 hours. If the period is less than 15 minutes, dilution of the emulsifier by the penetrant may occur and penetration of contaminated defects may not be complete. If the period exceeds 2 hours, partial drying of the penetrant may occur, resulting in exceptionally long emulsification times. Once an optimum draining period has been determined for a particular part, it should be adhered to within ± 20 per cent, since this period directly influences the process and effects of emulsification.

The parts should be dipped into the emulsifier (the length of time the emulsifier is allowed on the parts being somewhat critical), and should be held to the minimum time necessary to give a good water wash, since this will result in the highest sensitivity. It should be determined by experience for each type of part and finish and then strictly adhered to.

An average emulsification time is about 2 minutes, but may vary between 30 seconds to 5 minutes, according to the surface condition of the part.

After removal of the emulsifier, the part should be dried, treated in the dry developer and then inspected for defects.

INTERPRETATION OF INDICATIONS
If defects are present and all stages of the process have been applied correctly, they will be indicated by brilliant greenish-yellow marks on the surface of the part ; some may appear immediately as the developer dries but others may take longer to develop. The characteristics of the markings, such as the rapidity with which they develop and their final shape and size, provide an indication as to the nature of the defect revealed see Figure 30.1.

The rate of staining is an indication of the width and depth of the defect, whilst the extent of staining is an indication of its volume. A wide shallow defect is revealed almost instantly but narrow deep defects may take some time to display the final pattern. Scattered dots indicate fine porosity or pitting Fig. 30.1 (d), whilst gross porosity may result in an entire area becoming stained.

Closely spaced dots, in a line or curved pattern Fig. 30.1 (c) , usually indicate tight cracks or laps but such patterns are also characteristic of very wide defects from out of which most of the penetrant has been washed. Wide cracks, lack of fusion in welded parts and other similar defects are indicated by continuous lines as shown in Fig 30.1 (a) and 30.1 (b). All defects should be suitably marked prior to removal of the developer, but crayons should not be used on highly-stressed components subject to heat treatment, since this is known to induce fractures.

Fig. 30.1, Indications given by Defects.

REMOVAL OF DEVELOPER
Developer should be removed by washing with water spray or by dipping the component in an aqueous solution of 2 per cent chromic acid. Since the surface is then in a condition susceptible to corrosion (where this is applicable) the prescribed protective treatment should be applied without delay.

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CHAPTER-31
ENDOSCOPE INSPECTIONS

INTRODUCTION

This chapter gives guidance on the use of endoscope inspection equipment (also known as baroscope, introscope or fibrescope equipment, depending on the type and the manufacturer) for the assessment of engine serviceability, both on a routine basis and for the investigation of developed defects. Although endoscope inspections are utilised in other areas, the information in this chapter is intended primarily for the inspection of gas turbine engines ; it is not related to any particular engine and should , therefore, be read in conjunction with the relevant Maintenance Manuals and approved Maintenance Schedules, which should also be consulted for specific damage and time limits.

Endoscope equipment permits the inspection of gas turbine engine parts which would otherwise be inaccessible with the engine installed and in service. Early gas turbine engines had poor provision of ports for this type of inspection, apart from the igniter plug and burner holes, but engine manufacturers now tend to provide improved facilities for endoscope inspection of the rotating and combustion sections of the engine. Other large engine components may also have limited facilities, as do some airframe air-conditioning turbine units, etc.

Engineers should be conversant with the techniques of endoscope inspection to enable them to use the equipment as an effective inspection and diagnostic tool and as part of normal inspection procedures. This form of use will result in a more effective assessment being made of damage caused by an in-service incident such as a bird strike or foreign object ingestion.

ENDOSCOPE EQUIPMENT

Manufacturers of endoscopes tend to market the complete range of units required and it is, therefore, usual to be able to interchange parts of one system with those of another. The following general description of the equipment is not related to any particular manufacturer and should be read in conjunction with the appropriate manufacturer 's technical instructions or service manual.

The Probe

The probe is an optical instrument which performs two functions; (a) it relays and directs a beam of light for illumination, and (b) it displays a focused and undistorted image at the eyepiece. Probes differ in that some have an integral light source, while others rely on a remote 'light box' ; another version has a small bulb at the tip of the probe to provide the illumination. In addition, facilities for adjusting the focus and magnification may be incorporated.

The probe shaft usually consists of concentric tubes, the inner one of which is the view tube, while the outer one provides a separate light path for the illumination beam. This beam is carried through an annular 'fibre optic bundle ' to the tip where the necessary change in direction is made through prisms. The image is modified throughout its travel through the view tube by a series of lenses and may also be changed in direction by the same method.

At the tip, the prisms are protected by windows which prevent dust, grit or direct contact harming the optical clarity of the image. If the probe is of the nonadjustable type, the angle of view at the tip will be marked and there are the following four variations:

a) Straight view, where the centre of the field of view is parallel to the probe shaft.

b) Lateral view, where the centre of the field of view is at right-angles to the probe shaft.

c) Oblique view, where the centre of the field of view is at an oblique angle to the probe shaft.

d) Rear view, where the centre of the field of view is at an acute angle to the probe shaft, resulting in an amount of doubled-back view.

The field of view is designed to give a fairly useful amount of visible area and magnification at the kind of distances required in the internal inspection of a gas turbine engine. The eye-piece makes the final adjustment to the image before visual perception, and provision is usually made here to indicate the relative direction of view with respect to the engineer. An array of inscribed lines, called a graticule, is sometimes provided to indicate, under specific conditions of use, a measurement of distance useful for damage assessment. Accessories can enable a still camera to be used to provided a permanent record of defects, etc., and television and video equipment can be used for applications where direct access to the probe would be uncomfortable or unsafe.

Flexible endoscopes Figure 31.1 rely on fibre optic bundles to transmit an image in the same way as the illumination beam is transmitted along the rigid probes. However, for the transmission of an image, the relationship of each fibre to all of its neighbours must be the same at the eye-piece as at the probe tip. The image bundle and the illumination bundle forming the central core. The flexible probe tips are usually changeable and are of less elaborate construction, allowing the tip to be shorter, thus not having a cumbersome non-flexible end to restrict use in a confined space.

Migration of fluids by capillary action along the bundles between the individual fibres is prevented by the application of a transparent resin to the bundle ends. Compression, twisting and kinking of the fibre optic bundle is prevented by fitting the bundles in a flexible conduit, normally of spiral or 'armadillo' construction, which will restrict the manipulation of the probe to within the capabilities of the bundles.

The Light Source

Most endoscope equipment now in use utilises a separate and remote light source to illuminate the view area. This normally takes the form of a self-contained 'light box' containing the lamps, transformers, switch gear and cooling fans to provide a high-intensity beam. This beam is focused upon an adaptor in the box to which the fibre optic light bundle from the probe is connected. Ouartz\halogen or quartz\iodine lamps provide the source of light, which may be varied in intensity to suit both the application and personal preference. Mains power supplies are normally used although some equipment can be arranged to allow typical aircraft voltage and frequencies to provide the system with power.

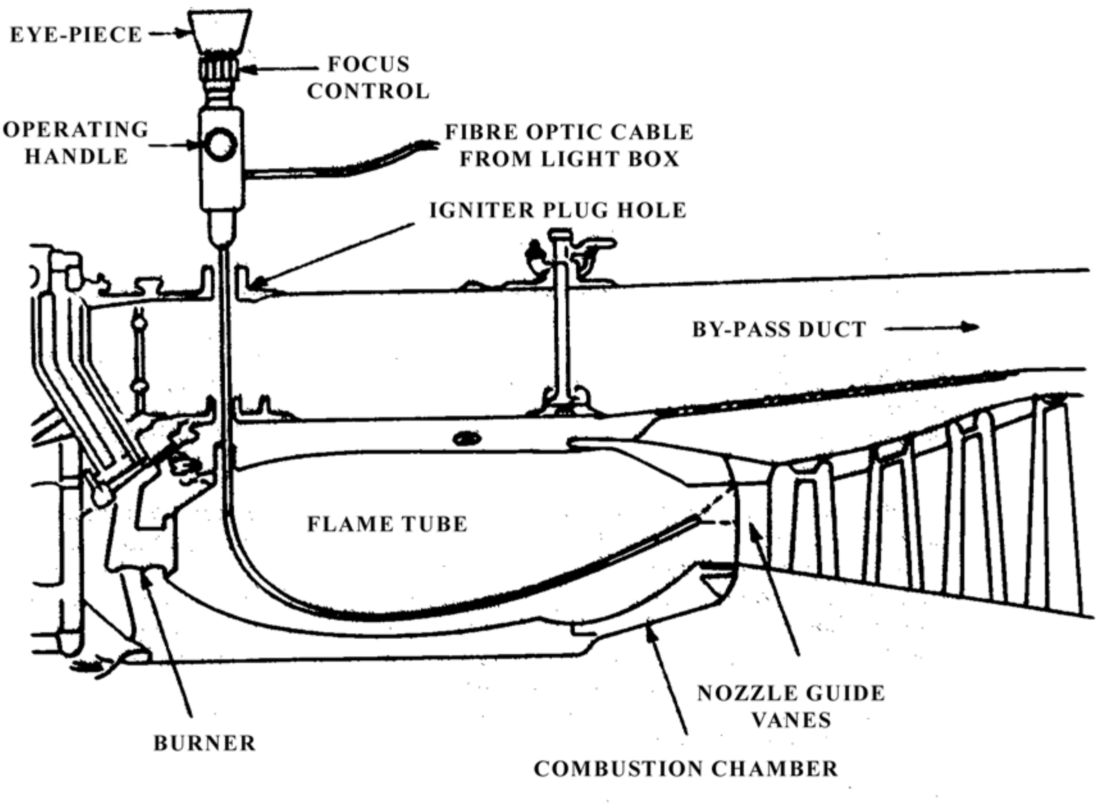

Fig. 31.1, Flexible Endoscope Inspection Equipment

PREPARATIONS

Precautions

Consideration must be given to the potential hazards involved in the inspection of gas turbine engines while under ramp or first-line maintenance conditions, and special precautions should be taken because of the engineer's preoccupation at the engine. A dangerous situation could occur in the event of the inadvertent operation of a starting system, ignition system, thrust reverser system or any mechanical or electrical controls ; these systems should therefore be inhibited.

Other factors to be considered when inspecting engines under these conditions include:

a) Dissipation of residual heat.

b) Effect of windmilling.

c) Endoscope equipment contamination.
d) Electrical potential difference between the probe\light source and the aircraft structure.
e) Fuel and oil leakage.

Access

Engines designed for endoscope inspections have access ports fitted with blanking plugs at various points in the casings, and the areas visible through these parts are detailed in the relevant Maintenance Manual. However, if specific access is not provided, a general knowledge of the layout of the engine together with access provided by the removal of igniter plugs, temperature probes, pressure sensing lines, compressor bleed valves and other air off-takes enables useful condition assessments to be made. Forward view endoscopes can also be used to view through the air intake of an axial flow compressor or, to a more limited degree, through the turbine, the latter being restricted because of the greater curvature of nozzle guide vanes

Access-port blanking plugs are subject to high temperatures and high rates of temperature change. This has the effect over a period of time of ' pinching' the blanking plugs to a higher torque than was applied at assembly. During removal, therefore, care must be taken to select a spanner which is a good fit on the plug and will provide adequate leverage. Plugs which are fitted into blind holes in engine casings invariably have thread inserts and these, under high torque removal stresses, can become extracted with the plug and will require replacement.

The 'pinching' effect can be overcome to a certain extent by applying an anti-seize compound when fitting the blanking plugs. Manufacturers usually recommend the application of a graphite-based release agent which forms a dry film on the threads. Alternatively, a paste with metal or metal oxide content is applied. Neither paste nor dry film should be applied unless it can be established which of the compounds had been used previously, as any mixing will result in the formation of a hard-setting compound.

NOTE

In consideration of this 'pinching' effect, the initial torque settings for the blanking plugs must be those recommended in the relevant Maintenance Manual..

Orientation

Familiarity with the layout of an engine and experience in the use of endoscope equipment enables an engineer to recognise the area being viewed and the extent of inspection possible through a given access port.

NOTE

Parts frequently appear larger when viewed through an endoscope and damage can seem more extensive than it really is. Familiarisation with the size (height and width) of the item being viewed is therefore essential and ideally a spare part should be available to be held in the hand and viewed with and without an endoscope probe to ensure the item is correctly assessed.

Non-rotating assemblies cause few problems because major components such as burners and stators provide points of reference. Damage reporting on non-rotating components requires that burners, flame tubes, etc., be numbered to a standard form and that areas and components are named. An inspection report can then identify areas of damage by stating :-

(a) Access port used.
(b) Direction of view.
(c) Area or component inspected (by name and \or number).
(d) Dimensions of and type of damage.

Components of rotating assemblies need to be identified for the same reasons. At overhaul, marks may be applied to the convex surface of turbine blades, together with the balance details normally applied, to number the blades consecutively around the disc. This procedure will enable positions to be fixed for the parts of the whole spool connected to that turbine. For instance, if HP turbine blades are numbered, HP compressor blades can be identified by stating:

(a) Compressor access port used.
(b) Direction of view.
(c) Details of damage.
(d) Turbine access port used.
(e) The turbine blade number visible at the centre of the field of view.

The number of blades in a particular compressor or turbine stage should be known and the blades counted while viewing to ensure that all blades in the stage are checked. When viewing large blades, such as early compressor stages, it will be necessary to make two or three passes to cover the complete blade length, i.e. view the outer third of the aerofoil, mid span section and inner third adjacent to the inner platform.

If damage is found on a rotating assembly which has no consecutive numbering of blades, point reference must be established by using an externally or internally recognisable point on the rotating assembly. Again, access ports must be stated and consecutive blades must be counted to locate the point of damage.

For ease of inspection, the HP shaft can be rotated (at a suitable speed to permit a satisfactory inspection) by an air-driven motor through the high-speed gearbox on engines with a drive facility; otherwise, hand-turning may be accomplished by using either a redundant component drive coupling or a standard socket fitting in the gearbox. Air-driven motor systems in general use have hand or foot controls to vary direction and speed; this is an advantage over using the hand-turning method which requires one person to turn the shaft while another performs the inspection.

LP shafts must be turned by hand, and to rotate an Intermediate Pressure shaft in a three-spool engine, without a gearbox, a locally - made tool may be required to turn the shaft through the IP intake..

INSPECTIONS

One of the reasons for the increased use of endosopes is the high cost involved in engine changes, either due to suspected internal damage or because of a Maintenance Schedule based on a “ Hard Time Life “ philosophy. It is, therefore, an advantage to allow the engines to remain in service until defects are revealed via performance analysis, oil analysis, endoscope inspection, or by repetitive monitoring of allowable damage.

Scheduled Inspections

Scheduled inspections are the regular ones which are carried out as part of an approved Maintenance Schedule. The frequency of such inspections is dependent upon either engine cycles or flight time and need not be concurrent with the aircraft ‘s scheduled checks. The combustion section and the turbine blades are the primary concern during these inspections, due to the high stresses and temperatures encountered during service. All defects should be recorded, normally on a chart specific to the engine type, which after completion recorded, normally on a chart specific to the engine type, which after completion constitutes a record of any deterioration taking place within that particular engine. An assessment can then be made as to whether the engine may be allowed to continue in service until the next scheduled inspection, or that it may only continue in service subject to more frequent checks.

Special Inspections

Occasionally , experience gained by frequent endoscope inspections, in-service failures or inspection during overhaul highlights the development of particular defects which can be monitored using endoscopes while the engine continues in service. Normally only one or two access ports need be disturbed because it is only the area detailed by the special inspection which needs assessing. This again enables the engine either to continue in service or to be monitored even more frequently.

NOTE

Engines are often removed after scheduled or special inspections to prevent a primarily minor defect causing secondary damage, possibly leading to engine failure.

Non-scheduled Inspections

Endoscopes can be used to great effect when it is necessary to assess the damage caused by foreign object ingestion or engine surge, diagnose the cause of developed defects, and provide a means of establishing engine serviceability following excursions beyond the normal turbine temperatures or maximum power limits. Together with other basic visual techniques of inspection, the use of endoscopes may, under certain circumstances, provide the necessary evidence to permit an aircraft to fly back to base for repair when it would otherwise require an immediate engine change.

FINAL INSPECTION

On completion of an endoscope inspection, it is essential that all access plugs are refitted correctly and securely. Failure to do so could cause a gas leak and result in a fire warning , shut-down and turn-back or in some cases cause a failure due to blade flutter or loss of cooling air. Access panels must also be correctly refitted.

APPLICATION

Components normally inspected with an endoscope, such as compressors, combustion sections and turbines, are subject to different types of damage and defects ; therefore, actual limits and the specific forms of defects can only be found in the relevant Maintenance Manual.

Compressors

Endoscope inspections after such occurrences as foreign object damage (FOD), bird strikes or surge, must be systematic, not confined to single stages, and always preceded by a comprehensive external visual examination. In addition to the endoscope ports provided, it may be possible to use bleed valve apertures and air-sensing probe points to inspect the compressor.

The most common form of damage to compressors is FOD. Centrifugal compressors have proved to be fairly damage-resistant but axial compressors are not so resistant to FOD and are also subject to surge damage. Inspection of axial compressors and their blades should, therefore, always include a search for evidence of FOD in all its manifestations- nicks, dents, scratches, and the cracks which these defects may produce.

Surge damage may be in the form of trailing edge cracks at the blade root, rubbing marks on the blade platform or blade shroud, with perhaps damage to the spacer plates between the blades. Interference between tips or shrouds and the casing can occur during surge and may bend blade tips, cause cracks, etc. Interference between rotors and stator (clanging) is a more serious defect because of the likelihood of substantial deformation. Engine manufacturers normally know the type of damage which may be caused to their engines during surge, and the Maintenance Manual may, therefore, indicate which particular stage or stages need to be inspected and which defects are particularly indicative of surge damage.

Grime and oil deposits may form on the compressor blades over a period of time. Excessive oil deposits are usually an indication of front bearing oil leakage or general wear in the engine. Where engines are operated in sandy conditions, dust tends to stick on the rear of the compressor if there are oil deposits present, and such engines could benefit from compressor washing procedures.

Compressor blades which have mid-span shrouds (or clappered blades) are sometimes subject to wear at the point where the end of each shroud abuts it neighbour. On 1 stage LP or fan blades this wear is recognized and can be measured by taking up the total free play of the whole stage, by moving half the blades clockwise about their mounting pins and the other half anticlockwise; this leaves a gap between one pair of blades which represents total shroud wear. Of course, this procedure will not be suitable for other than fans or 1 st, and maybe 2 nd, stage LP blades. Inspection of mid-span shroud wear through an endoscope is confined to a close and clear view of abutting shrouds. Shrouds which are wearing may be recognized by :

a. Metallic streaking from the join.
b. A wavy, uneven join line.
c. Hammering (which is where the abutting faces deform, like chisel shafts under the effects of frequent hammer blows).

What ever damage is found on compressor blades, its position on the blade will determine its seriousness. It is usual for the inner one-third of the blade to be classified as a ‘no damage allowable’ area, as are the areas on each side of midspan shrouds.

Combustion Section

High temperature is the reason for most combustion section defects. Burning, cracking, distortion, and erosion of nozzle guide vanes (NGVs) are typical. The combustion section may be inspected with an endoscope either through the designated access ports or through the igniter plug holes or burner apertures. The components visible depend, of course, upon engine design and the position of the access ports, but the flame tubes or liners, burner flares and swirlers, tube interconnectors and the NGV leading edges are normally inspectable.

NOTE

In the combustion section, all defects must be assessed on the basis of the likelihood of the defect causing a breakaway of material. This could lead to greater damage occurring in the turbine.

Burners

The burners protrude into the forward face of the flame tube\liner through an aperture which is usually flared ; this is sometimes called the burner flare. The burner must be concentric with this flare otherwise a loose flare or burner should be suspected. In an annular combustion chamber, the burners and flares are separated by blank segments, and these must be secure.

The burners may develop carbon deposits, which can be in the form of an irregularly-shaped protuberance from the burner face. In some engines this has a detrimental effect on starting, but when it breaks off it rarely causes any damage because it is usually soft. Hard carbon, however, can block the burner spray nozzle but does not grow large enough to cause break-off damage.

Swirlers (or swirl vanes) should be inspected for security and missing elements. All components should be inspected for cracks.

Flame Tubes \ Liners

Flame tubes (or, in annular combustion chambers, the liners) contain the flame by directing air through holes or slots to the centre of the tube. The whole surface of the tube is peppered with cooling holes of varying sizes arranged in a regular pattern, and these are usually the starting points for cracks and sometimes determine the limits of cracks. For instance, the Maintenance Manual may state that axial cracks which extend rearward beyond the third row of cooling holes are unacceptable. The allowable limits for cracks can depend on both their position and length. To assess their length through an endoscope must at times be a matter of estimation. The engineer should, however, be aware of the general dimensions of the component being inspected (these are sometimes stated in the Maintenance Manual, otherwise familiarity with the components is required); from this a near estimate can be made of crack length. The flame tubes should be inspected for cracks and other damage as follows:

Cracks

These start at holes or edges and may stop when they reach another hole or edge. Circumferential cracks can be more serious than axial cracks as they can result in pieces breaking off under the effect of airflow and flame impingement. Cracks around dilution chutes (scoops or nozzles into the airstream) are usually considered to be serious, since any distortion of the chute may create hot-spots which will accelerate deterioration and may cause torching of the flame onto the air casing.

Distortion

Usually, defined limits give the allowable amount of distortion into the airstream and the length of cracks associated with it. The construction of a flame tube normally includes sections which overlap each other; these overlaps allow cooling air to flow near the surface of the tube. The sections are joined by a 'wigglestrip' (corrugated spacer) which allows air to flow through the overlap. The wigglestrips should be inspected for security because the welds can fail, causing distortion of the strips into the airstream of the tube. Limits for this damage are measured in numbers of adjacent or total wigglestrip pitches affected.

Burning and Hot Streaking

The high temperature materials used for the flame tubes \ Liners sometimes change colour quite dramatically with heat, so coloured areas alone may not indicate serious burning. Burning is caused by the flame approaching the tube/liner and is recognized by the texture of the surface; this becomes rough and pitted, and a reduction of wall thickness is noticeable. Streaks of metallic particles sparkle under the high intensity light of the endoscope and are recognized this way. Edges of lips and overlaps are susceptible to burning and erosion. Burn limits depend upon position and area.

Holes

These can be caused in three ways; (i) pieces breaking off , (ii) cracks allowing a section of metal to be lifted off and (iii) burning through. Holes in a flame tube/liner need not be a reason to reject an engine. However, the turbine should be inspected if the hole was caused other than by burning through. Carbon deposits produced at the burner can sometimes be mistaken for hole as the carbon is an intense black; the angle of view of the suspected hole should be changed if any doubt exists. If the suspected hole is a carbon deposit no detail of the edge of the 'hole' will be visible, neither will any detail through the 'hole'

Nicks and Dents

Inspection should be extended to the NGVs if this damage is found because these are evidence of broken-off particles of FOD.

Nozzle Guide Vanes

The NGVs are subject to very high thermal and mechanical stresses, and only newest of engines do not show physical signs of this when inspected through an endoscope. If viewed from the igniter plug holes, the leading edges and some concave surfaces only will be visible. Access ports are required elsewhere to view the whole surface of NGVs as they are highly cambered. Rows of cooling-air holes are visible on most NGVs and these may be used to identify areas of the vane. Damage can be as follows:

a) **Discoloration**

   Slight discoloration is nearly always present and is not necessarily a defect. Heavy discoloration, however, is associated with burning.

b) **Cracks**

   These are allowable to a limited extent but if associated with lifting of the surface from the original contour they are not acceptable. Cracks are either axial (from leading edge to trailing edge) or radial (vertical) and their allowable length will depend on their direction ; those which converge or are in convex surfaces may well necessitate engine rejection.

c) **Burning and / or Erosion**
Erosion, although caused separately from burning, is usually found in the same areas as burning and is subject to the same limits. Erosion is the product of abrasion and looks like burning without the discoloration ; that is, roughness and pitting with a noticeable reduction in skin thickness. Burning and erosion are most common on NGV leading edges and concave surfaces. They may penetrate the outer skin and are sometimes allowable, but again subject to position and size of area affected.

d) **Dents and Nicks**
These are caused by FOD and further inspection should be carried out if they are found.

e) **Tearing**
Tearing can occur in trailing edges and is allowable only within defined limits.

Turbine Section

Access for the endoscope inspection of turbine blades is either through the ports provided or sometimes through the igniter plug holes using a flexible endoscope (flexiscope). For this, a holding tool can be made which is fed through the igniter plug hole and fixed. The flexiscope is then inserted and the holding tool guides the tip through the NGVs to view the blades. Methods of identifying blades are explained in above paragraph.

NOTE

When viewing the aerofoil surface of a turbine blade, the end of the probe is located between the blades and must be withdrawn prior to engine rotation to avoid damaging the probe and blades.

Turbine blades are subject to the same types of damage and defects as NGVs. The limits for such damage are, however, more stringent. Blades can have some leading edge damage and cracking but still remain in service; trailing edge cracks, however, can propagate quite quickly due to tearing forces imposed by centrifugal force and the twist of the blade, and these cracks are not normally allowable. Dents on aerofoil surface of hollow turbine blade can initiate cracks on the cooling-air passage wall inside the aerofoil section which can propagate to form quite large internal cracks before breaking through and becoming visible.

Deposits can form on most internal parts of gas turbine engines. When airborne sand is ingested it usually accumulates on the NGV and turbine blade leading edges. It has a sandy colour and becomes baked on by the combustion process, and is not easily removed even at engine overhaul. It can cover some cooling holes but does not usually cover significant NGV or turbine blade defects. Its effect on inspections is therefore minimal., but its overall effect is to shorten engine life.

Record of Damage

When damage is found it must be recorded in the engine records. This is the case whether the inspection was routine or a special one. Increases in crack length, for instance, can then be assessed over a period of time, thus giving time to arrange for repairs or removal. Some operators have introduced inspection sheets for use when carrying out routine and special endoscope inspections. The sheets detail the preparation work necessary before inspections and also include drawings which depict blades or flame tubes ; engineers then mark in observed defects and identify the drawings accordingly. These representations of the internal state of each engine then form part of the engine 's records and can be used in future assessments of damage and the growth of existing damage. Photographic records may also be kept, using a still camera or video tape recording.

The Maintenance Manual will sometimes define a defect as acceptable for a finite number of flying hours or cycles. Engineers should , therefore, ensure that additional entries are made in log books and/or technical log to limit engine operation to the periods allowed. If however, inspection reveals that different defects exist which are related, each with a finite allowable number of flying hours, the engineer should consider certifying such defects as allowable only for a shorter time than the most restrictive of the allowances given.

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CHAPTER-32
ULTRASONIC FLAW DETECTION AND THICKNESS MEASUREMENT

INTRODUCTION
The methods of crack detection dealt with in last chapters are of considerable value for finding surface defects but are unable to reveal the presence of internal flaws which are distant from the surface. This chapter gives general guidance on the application and scope of ultrasonic sound waves for detecting surface and internal flaws in materials and parts and for the measurement of thickness.

Ultrasonic testing is not a complete substitute for other methods of flaw detection and should generally be regarded as complementary to them. It should be considered an extension to efficient inspection but should not be regarded as a foolproof method without considered trials and its indiscriminate use could be uneconomical and misleading. There are instances, however, particularly in aircraft applications, where ultrasonic testing is the only satisfactory method, e.g. when a distant defect lies parallel with the only available surface of a component. The degree of skill and experience required to use ultrasonic apparatus, and to interpret the indications obtained, varies with the complexity of the parts to be examined, the type of equipment available and the acceptance standards specified. Operators should be properly trained and qualified on the equipment in use.

Cavities, inclusions and cracks in cast metal prior to fabrication by extrusion, rolling, forging, etc., can be found by ultrasonic techniques and automatic scanning devices are often use during the manufacturing process. Large steel or aluminium forgings, components welded by gas, arc or flash butt methods, and a variety of parts such as turbine discs, propeller blades and wing spar booms may all be examined at various stages during manufacture. Ultrasonic methods can also be used for finding fatigue cracks, and other defects arising from operating conditions, during the periodic inspection of airframe and engine and engine parts.

Thickness measurement by ultrasonic methods has some aircraft applications. It provides a satisfactory means of measuring the skin thickness of hollow propeller or turbine blades and for checking tubular members or sheet metal assemblies. Delamination of bonded assemblies can also be checked by similar methods

SOUND WAVES
Ultrasound describes sound at a pitch too high to be detected by the human ear and the frequencies used in ultrasonic testing are normally within the range 500 kHz to 10 MHz.

Sound Energy
Sound is energy produced by a vibrating body, the energy being transferred through a medium by the wave-like motion of the particles making up that medium,. The frequency of the waves is the same as that of the vibrating body and the wavelength is dependent upon the speed of sound in the particular material. This is wavelength is Figure 32.1, the ‘y’ axis representing the distance of a vibrating particle from its mean position and the ‘x’ axis its distance from the sound source. The time taken for the sound to travel one wavelength (λ) is the same as the time taken for the vibrating body to execute one complete cycle.

Wave Types
Three main types of waves may be generated. The vibrations in longitudinal (compression) waves are in the same direction as the sound motion and the vibrations in transverse (shear) waves are perpendicular to the sound motion. Waves generated along the surface of a material, known as surface waves, have an elliptical motion. Any of these types of waves may be generated in solids but only longitudinal waves can normally be generated in liquids or gasses. Other types of waves exist and are sometimes used in ultrasonic testing (e.g.. Lamb Waves, which are vibrational waves capable of propagation in thin sheet material).

The speed of sound through any particular material depends on the density and elastic constants of that material. Transverse waves travel at approximately half the speed of longitudinal waves, and surface waves at approximately 90 per cent of the speed of transverse waves.

Beam Characteristics
When sound waves are generated by a flat disc vibrating at ultrasonic frequencies the beam of sound is initially parallel

and then, at a distance from the disc related to its diameter and the sound frequency , spreads out and loses intensity, the spread increasing as frequency and disc diameter are reduced. Within the near (parallel) zone variations in sound intensity occur, and absorption results in a loss of energy with increased distance from the source. A material with a large grain structure or holes associated with porosity absorbs more energy than one with a fine grain structure but, since absorption is also a function of frequency, by decreasing the frequency absorption is also reduced.

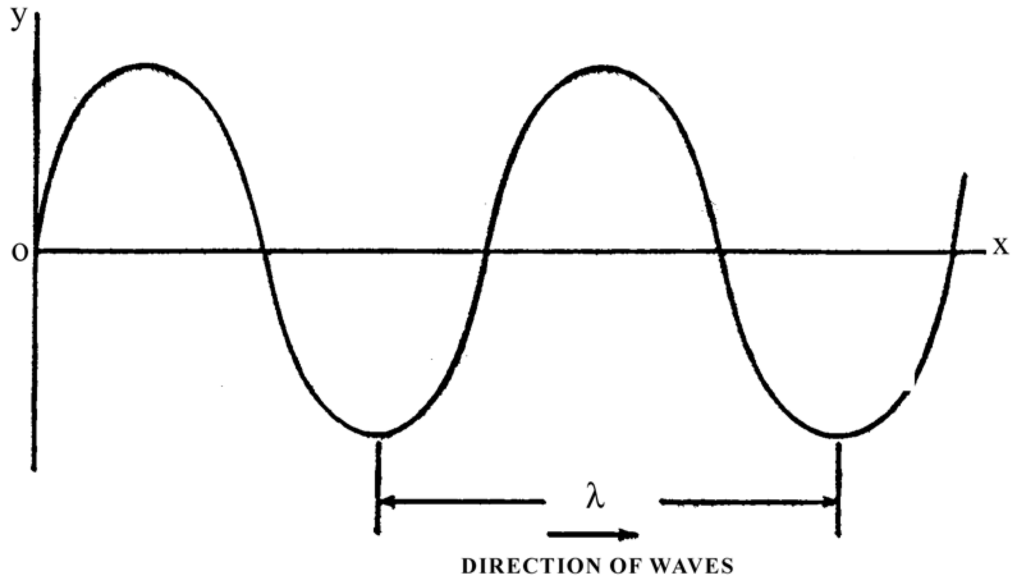


Fig. 32.1, Form of Sound Waves

Mode Conversion

When a beam of sound is directed at the boundary between two solid materials at an angle than normal to the interface, both reflection and refraction occur as shown in Figure 32.2. If material 'A' is a liquid, as in ultrasonic testing, only longitudinal waves will be reflected. Adjustment of angle 'a' will enable any of the main types of waves to be injected into material 'B'. Unfortunately mode conversion also produces unwanted reflections from the surface of a component which, due to the different speeds of the various types of waves, may give confusing results.

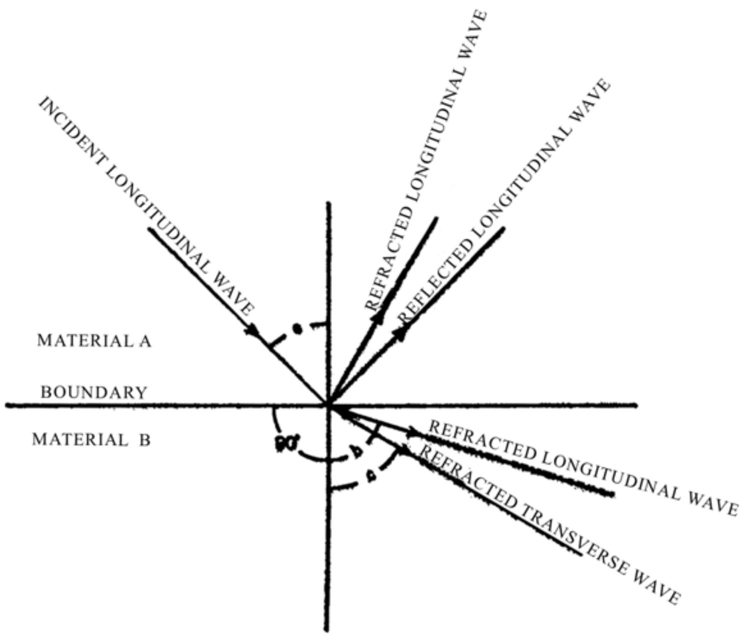


Fig. 32.2, Mode Conversion

GENERATION AND DETECTION OF SOUND WAVES

The sound waves used in ultrasonic testing are produced and detected by means of an electro-mechanical transducer, i.e. . a device which converts electrical energy into mechanical energy and vice versa. The properties of material used in the manufacture of transducers are discussed in the following paragraphs.

Piezoelectric Effect

If a mechanical stress is applied in a specified direction to certain natural crystals such as quartz, an electrical field is produced in which the voltage is proportional to the magnitude of the stress is produced in the crystal. By applying an electrical potential to the faces of an X-cut quartz crystal (i.e. a crystal cut in the form of a disc whose faces are normal to one of the axis) a vibration is produced, the frequency of which depends on the thickness of the crystal. Conversely, when such a crystal is caused to vibrate under the influence of a sound beam an alternating current is produced between the crystal faces.

A similar effect is produced in all electrically insulating materials, and certain ceramic materials such as barium titanate are particularly sensitive in this respect. Transducers made from these materials consist of a large number of tiny crystals fused together, and are permanently polarized during manufacture so as to vibrate in one plane only.

Piezoelectric crystals lose their activity when heated above a particular temperature and this may be a severe limitation for certain uses.

Crystal Frequencies

To achieve maximum efficiency crystals must be operated at their natural frequency (determined by their dimensions and elastic properties). Transducers used in ultrasonic testing are generally used in this way when searching for cracks but for resonance testing different methods are used .

Acoustic Coupling

The amount of energy transferred across a boundary between two materials depends on the Characteristic Impedance of each material, which maybe taken as the product of the density and the speed of sound in each material. Good coupling will be provided when the Characteristic Impedance of the two media are closely matched, and the capability of ultrasonic flaw detection depends on these factors. The coupling between metal and air is extremely poor and it follows that if any air is present between a probe and the material being tested very little energy will be transferred across the interface. For this reason a liquid couplant such as water, oil or grease is normally used in ultrasonic testing.

Reflection

If an ultrasonic beam is injected into a material it will continue through that material until it strikes a surface and will then either pass through the interface or be reflected, depending of the factors outlined above. If the beam strikes a discontinuity, crack or void in the material the reflection maybe picked up by a suitably placed transducer, the amount of reflected energy depending on the nature of the defect and its orientation. Most of the energy striking an external surface or void will be reflected but in cases such as bolt holes or bushes which have been well lubricated very little reflection may occur.

Probes

A probe consists of a transducer mounted in a damping material and connected electrically to the test set. For any particular application it may be necessary to use a probe of a particular design so that a sound beam is injected into the material at an angle normal to the expected defect. The required angle of the incident beam is achieved by mounting the transducer on a suitably shaped plastic block. Similar blocks are also used for injecting sound waves into a material with a uniformly shaped surface such a tube. In certain applications a wheel probe, consisting of a transducer mounted inside an oil-filled plastic tyre, has been found suitable for high speed automatic scanning.

Display

The most usual method of displaying the information obtained in ultrasonic testing is by means of a cathode ray oscilloscope. A pulsed transmission technique is normally used and is described below ; other methods are described in subsequent paragraphs.

In the cathode ray oscilloscope (Figure 32.3), a triggering device causes both the pulse generator and base control to operate simultaneously. The time base control (connected to the 'X' plates of the oscilloscope) deflects the trace produced by a beam of electrons, so that the trace moves across the screen from left to right in synchronization with the ultrasonic pulse transmissions. Vibration of the transducer result in an electrical signal at the 'Y' plates of the oscilloscope, which deflects the electron beam in the form of a peak (A) in the time base. Any returning echo acts on the receiving transducer to produce a second peak (B), the distance of the flaw from the surface being represented by half the distance between A and B. This distance can be calculated from knowledge of the speed of sound in the particular material and the time base scale. The time base scale is usually variable, and provision is often made for the attachment of a graticule scale to the oscilloscope screen so that direct measurements may be taken.

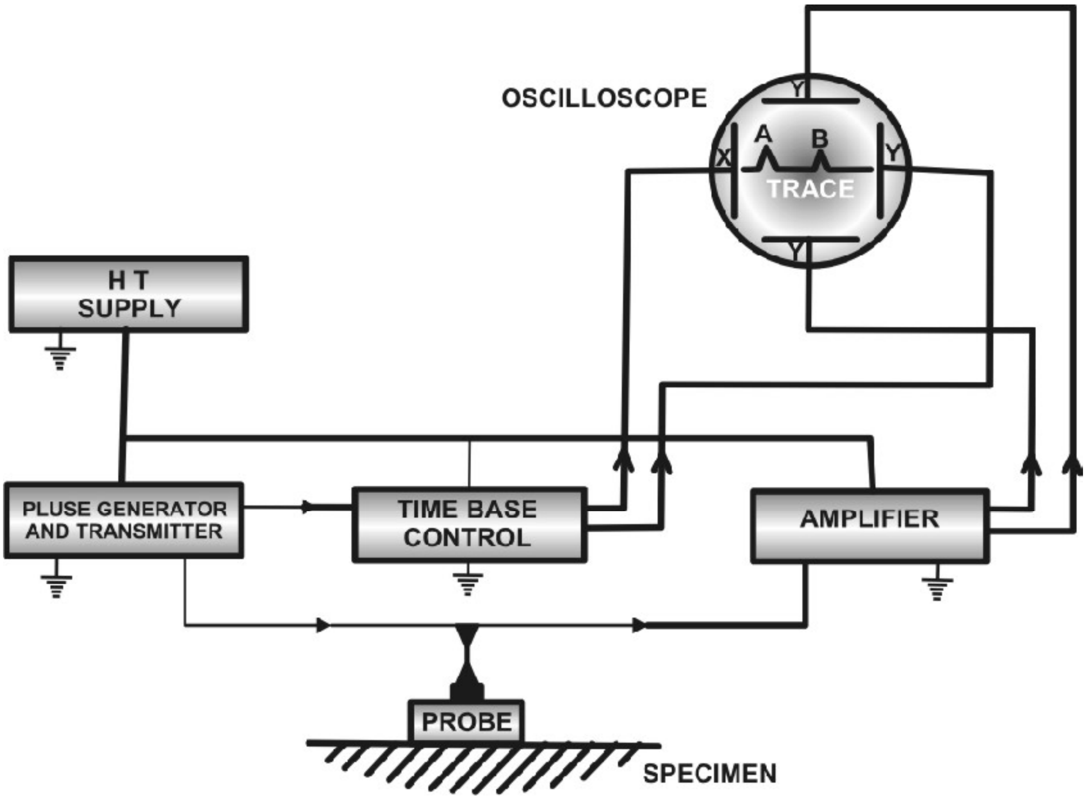


Fig. 32.3, Simple Block Diagram of Ultrasonic Set

Transducer crystals are usually damped to reduce the length of the pulse, but a layer (known as the ' dead zone') is left immediately below the surface of the test material in which defects parallel to the surface can only be examined from an opposite face. Increasing the ultrasonic frequency would reduce the depth of this layer but would also result in high absorption and might not be suitable for certain materials.

The pulse repetition frequency is extremely rapid to ensure a good trace on the oscilloscope, but must not be so quick that sound energy is still reflecting within the specimen when the next pulse is initiated.

The presentation described above is known as 'A scan' but the information may also be displayed in the form of a side elevation (B scan) or a plan view (C scan), the latter usually being used in automatically produced paper read-out form from a normal A scan oscilloscope.

METHODS OF OPERATION

Transmission Method

If a transmitting and a receiving probe are placed on opposite sides of a specimen (Figure 32.4), sound waves will be transmitted directly through the material and picked up by the receiving probe. If a flaw in the material interrupts the sound beam, a loss of signal will result and the second peak on the time base will disappear. Longitudinal wave probes are normally used for transmission scanning but angled probes may also be used when only one surface is accessible (Figure32.5).

Pulse-echo Method

This method relies on reflections from a defect being detected by the receiving probe and either a single transceiver probe or separate transmitting and receiving probes may be used (Figure 32.6).

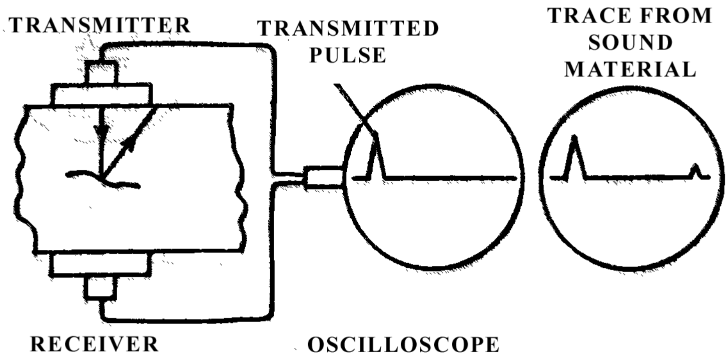


Fig. 32.4, Normal Transmission Technique

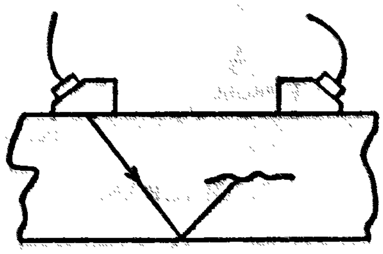


Fig. 32.5, Alternative Transmission Technique

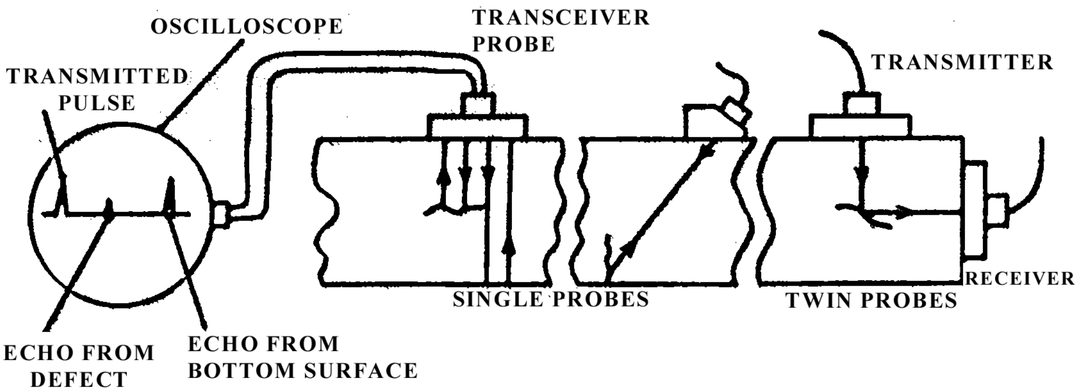


Fig.32.6, Pulse-Echo Techniques

Pulse-echo methods are also used for finding cracks at right angles to a surface. An angled probe is used to inject surface waves into a material, the waves following the surface contour and reflecting back to the probe from any discontinuity (Fig.32.7)

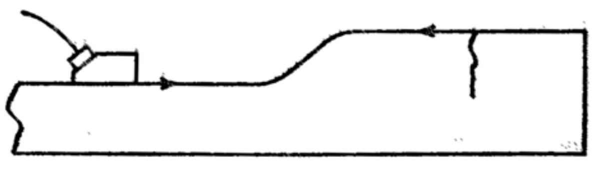


Fig. 32.7, Surface Wave Testing

Immersion Testing

The technique of holding a probe in contact with the specimen is known as 'contact scanning' , but there is also an important method of inspection known as 'immersion scanning', in which the specimen is immersed in a tank of water and a waterproof probe placed in the water, above the specimen (figure 32.8). Pulse-echo techniques are normally used but transmission techniques would also be possible.

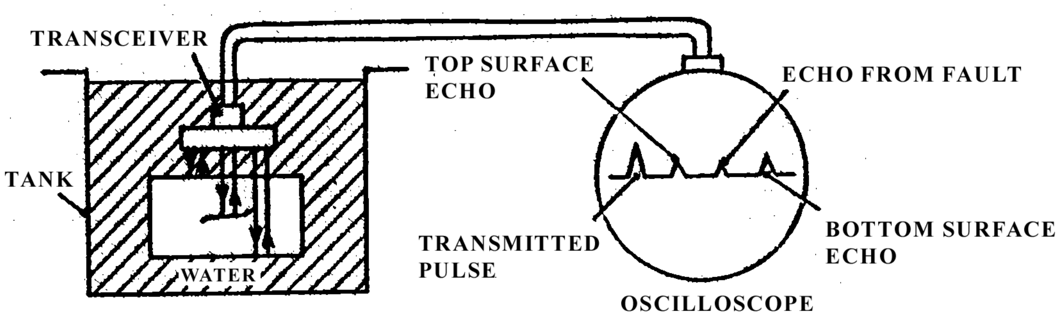


Fig. 32.8, Immersion Testing.

Pulses of ultrasound are emitted by the probe and pass through the water into the specimen. The top and bottom surfaces of the specimen are shown on the oscilloscope, together with indication from the transmitted pulse and any flaws within the material.

The distance between the probe and specimen must be selected so that confusing repeat echoes are avoided, and can also be set to avoid use of the near zone in examining the specimen.

The trace produced by a fault-free specimen will normally produce three peaks, the space between the second and third, i.e., the depth of the specimen, being the only part of interest during inspection. The time base is usually delayed, and its scale expanded, so that indications of defects are more easily seen.

Immersion scanning lends itself to automation and is frequently used for the inspection of parts of simple shape. Parts of complicated geometric shape present difficulties in that expensive electronic circuits would be required to differentiate between surface reflections and internal flaws.

Resonance Technique

If a sheet or plate specimen is caused to vibrate in the direction of its thickness, resonance will occur if the thickness is equal to exactly half the wave length of the inducing vibrations. By using a quartz transducer to vary the frequency of the vibrations, resonance is produced in the specimen and this frequency is displayed to indicate the thickness. A laminar type of defect, or loss of bonding , can also be detected by resonance methods providing that the separation is dry.

General Considerations

A number of factors must be considered before making an ultrasonic inspection and special techniques may have to be developed for a particular situation.

Surface Conditions

There are various surface conditions, such as rust, scale, loose paint etc., which will prevent inspection by ultrasonic methods and these must be removed. The rough surfaces such as are found on cast billets may present difficulties, but the use of grease as a couplant may be effective, or, alternatively, the immersion technique may be used. The shape of the specimen should also be considered so that slipper blocks may be made to provide the best acoustic contact.

Sensitivity

With too great a sensitivity, porosity and large grain size will hide flaws in a material by producing numerous peaks on an oscilloscope. It is important, therefore, that the sensitivity of the test equipment be adjusted so that unimportant features can be disregarded. The amplitude of reflections depends mainly on the size of the flaw and if the maximum acceptable size of defect were specified, then any reflection producing peaks higher than this would be known to be unacceptable.

(i) For longitudinal wave scans the acceptable size of defect is related to a flat bottomed hole of a particular diameter. Test blocks are used in which holes of various sizes are drilled, and oscilloscope sensitivity is adjusted to give a peak of , say, one inch in height on the reflection from the hole of specified size. Blocks with holes drilled to different distances from the surface may be required to check the effect of attenuation on peak height. During test, defects producing peaks lower than one inch can then be ignored.

(ii) For transverse wave scanning the acceptable size of defect is related to a hole or saw cut made in a block of the same material and thickness as that to be inspected..

(iii) Notwithstanding the sensitivity setting of the oscilloscope, some defects, such as cracks, may extend over a considerable distance and therefore be unacceptable. These would be recognized by a constant peak as the probe was moved in the direction of the cracks.

(iv) A special test piece has been designed by the International Institute of Welding and may be used for checking ultrasonic equipment in respect of both longitudinal and transverse waves ; oscilloscope scale and resolution can also be verified.

NOTE

Most ultrasonic test sets are now fitted with an attenuators. This is a device which applies calibrated attenuation to the received signal, enabling received signal strength to be measured, in decibels, relative to the signal from a reference standard.

Choice of Frequency

Both absorption and diffraction of sound waves are a function of the frequency used. For any particular test it is necessary to take into account the size and position of possible defects, the nature of the material and the distances to be scanned. With a coarse grained material a low frequency must be used, especially in large specimens, but with a fine grained material a higher frequency may be used, with a consequent increase in sensitivity.

Type of Defect

When preparing a technique for the inspection of a particular item, knowledge of the type of defect which can be expected is of great assistance. For example, if a casting has a known tendency to crack at a particular position during service, sketches can be provided showing the oscilloscope patterns obtained from both sound and faulty castings; inspectors will then not be misled by spurious reflections due to the shape of the castings.

PRACTICAL APPLICATIONS

Testing Ingots, Billets and Heavy Forgings

Large blocks of metal of simple shape are particularly suited to testing by ultrasonic methods, provided that a suitable technique and frequency are used.

Rectangular blocks can be checked by systematically scanning three faces with a longitudinal wave probe. Because it is difficult to detect flaws which are close to the surface it may be advisable to scan all faces, but this not be necessary if surface material is to be subsequently machined off.

Certain cast ingots may have such a coarse grain structure that the ultrasonic beam is scattered to a degree which renders flaw detection difficult or even impossible. If echo techniques prove to be unsuitable, the transmission method should be tried, but if this also is impracticable, it may be necessary to delay the inspection until rolling or forging have been carried out.

Inability to obtain satisfactory results can often be traced to poor acoustic coupling, a difficulty which can be overcome by use of the immersion technique.

It is common practice in industry to use automated ultrasonic techniques on billets, pipes and other similar products. A water jet, passing through a jacket within which the transducer is mounted, acts as the coupling agent, and electronic alarms trigger marking systems which record the position of a defect. An automated immersion technique is also sometimes used on finished size thin wall tubes, using Lamb waves for flaw detection.

Testing Welded Joints

Most types of welds in thick materials can be inspected by ultrasonic methods, but thin sheet metal welds are more satisfactorily checked by the use of X-rays . It is good practice to obtain a separate specimen in the same material, and to drill holes (as shown in Figure 32.9). which will indicate if it is possible to detect flaws at these positions. Experience has shown that this is not possible with all types of material and welding techniques.

But welds made by gas or arc welding methods can be checked by using an angled probe which injects transverse waves towards the weld line. If flaws are present in the weld, the beam will be reflected back to the probe. Experience in the application of scanning methods has made it possible to identify most types of welding defects, although it is not always easy to determine the acceptability of the weld from this information. When doubt exists, the information derived from the ultrasonic test should be correlated with other methods of testing, such as radiography.

Special techniques are required for testing flash butt welds, since they contain no filler metal, and flaws are normally in the plane of the weld. One method of testing is to position two probes as shown in Figure. Scanning is carried out by moving both probes simultaneously in opposite directions so that any flaws are detected by the receiver probe. The probes may, in some instances, be positioned on the same side, and certain specimens are best scanned by fixing the probes in a jig to ensure correct alignment. To determine the best method for inspecting a particular weld, all these methods should be tried until the most consistent results are obtained.

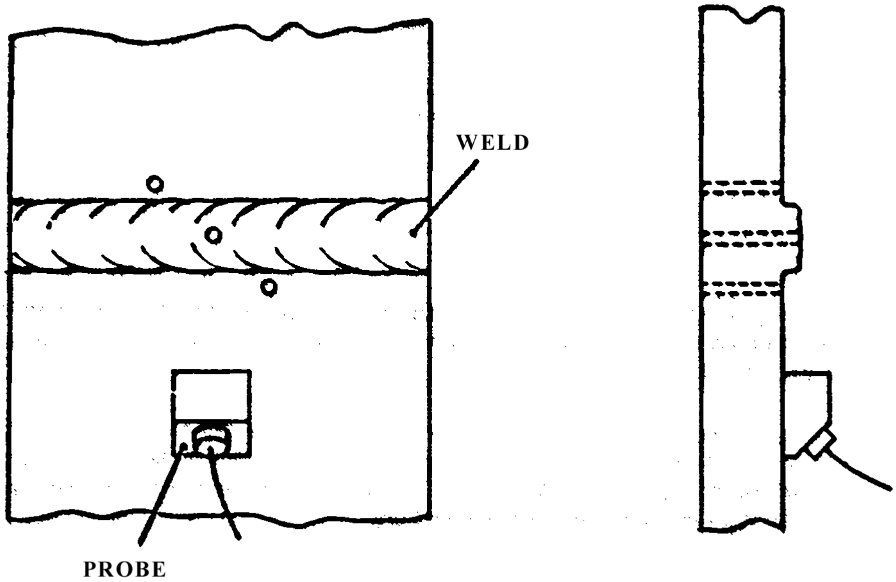


Fig.32.9, Test Holes in Weld Sample

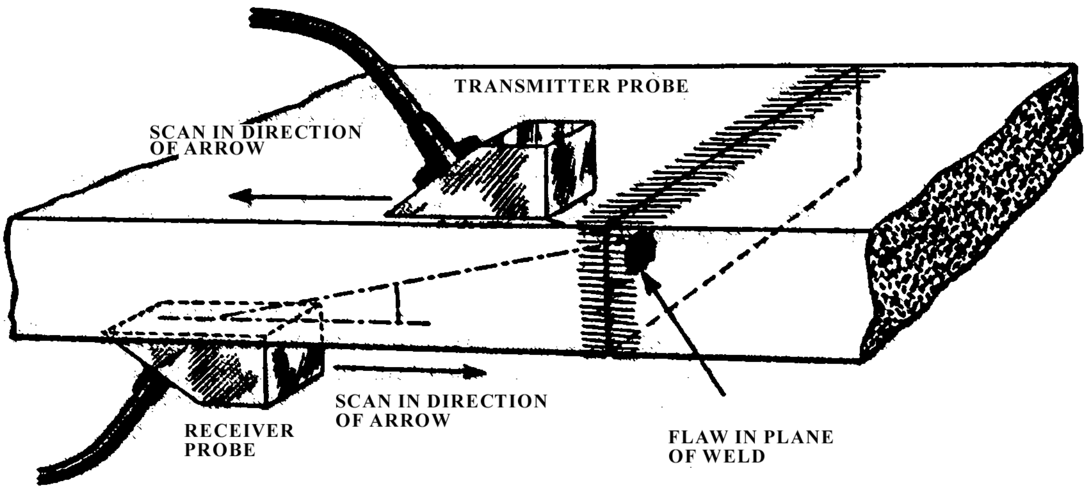


Fig. 32.10, Scanning method for finding flaws in flash butt welds.

THICKNESS MEASUREMENT

Pulse-echo Method

By the choice of suitable probes and the selection of appropriate test frequencies, several types of flaw detectors can be used for measuring thickness, but the accuracy of most is limited when dealing with material of the thin gauges used in aircraft construction. Their main application is, therefore, to the measurement of thick material during machining and manufacturing operations, particularly when the parts concerned would have to be removed from jigs or machines in order to measure them by physical methods. Vertical probes are normally used, and may be either the transceiver type or a probe combining separate transmitting and receiving crystals.

Resonance Method

This method is suitable for the measurement of new aircraft skin, structure and tubing and is normally only used during aircraft manufacture. A quartz crystal is excited by means of a valve oscillator, at a frequency well below the fundamental resonant frequency of the crystal, and held in contact with the specimen. This causes the specimen to vibrate in its thickness direction, and the frequency of the sound wave is increased until the specimen resonates. An increase in the amplitude of the vibrations results, with a corresponding increase in crystal voltage. If the crystal frequency is further increased resonance recurs (i.e. at the next harmonic), and the fundamental frequency of the material, and hence its thickness, can be determined. Resonances may be shown on a suitably calibrated oscilloscopes screen but more simple methods such as a voltmeter reading or an audible note in earphones are often used.

NOTE: The thickness is equal to an exact number of half-wave lengths, which can be calculated from the speed of sound in the material and the fundamental resonance frequency.

Detection of Lamination

There are several ways of checking materials for internal laminations, and similar methods may also be used to determine the integrity of bounded structures. The pulse-echo technique may be used on plate over 1\2 inch thick but it is unsuitable for thinner sections.

Transmission Method

If a transmitting and a receiving probe are held in alignment on opposite sides of a specimen, any lamination inside the specimen will interfere with the transmission of the ultrasonic waves, and will be shown by a reduction in received signal strength. However, because of the need to have access to both sides of the specimen, this method has limited application in aircraft work.

Resonance Method

It has been explained that resonance occurs at one of the natural frequencies of the material, the thickness being related to an exact number of half-wavelengths of the ultrasonic beam. If a material is laminated, or the bond between two layers is defective, resonance will occur at a different frequency and will result in a change in the shape of the oscilloscope trace. Special test sets have been developed for the inspection of bonded structures, and techniques have been established from which it can be determined whether a bond is satisfactory or not when the bond is dry.

Multiple Echo Method

The time base and sensitivity of an ultrasonic set can be adjusted to give a number of boundary reflections. With a set adjusted in this way, any laminations present in a specimen being scanned will show up as a sudden increase in the number of reflections, e.g., if the specimen is laminated at its centre, the number of peaks on the oscilloscopes screen will be doubled.

'Lamb' Wave Method

Laminations near to the surface of a metal plate are very difficult to detect. However, Lamb waves may be generated in plate which approximates, in thickness, to one wavelength of the sound beam, and any lamination will result in a change in the screen display. The angle of the probe is very important and varies with the thickness of the lamination; it is necessary, therefore, to scan with a variable angle probe.

TECHNIQUES FOR AIRCRAFT PARTS

Ultrasonic testing is widely used on parts removed from aircraft, but is also applicable to the examination of parts in situ where other types of inspection would require extensive disassembly. Techniques are established to ensure consistent results and these are written into the appropriate manuals.

Aircraft structural parts which can be checked by ultrasonic methods include large forgings, wheels, engine bearers, axles etc. Before these parts are installed in aircraft, or at times when they are removed during overhaul, the immersion method of testing will often give good results. Large tanks and automatic testing equipment are not necessary for examining parts of manageable proportions; such parts can be submerged in water in a convenient container, the probe being mounted in a fixture to ensure that the required beam angle is maintained. However, certain parts, such as wheels, lend themselves to automated methods and some aircraft operators have found these to be worthwhile ; their use also permits an electronic record of each inspection to be kept. The essential requirement for any test is a standard of reference and this may be provided by using an identical part of known condition as a specimen. As a check on sensitivity, defects can be introduced in the reference specimen, by drilling small holes or by spark erosion, at positions where defects are likely to occur. Reflections introduced by these artificial defects can be compared with the traces obtained from a part under test.

The chief value of ultrasonic examination in situ, is that defects, and in some individual cases corrosion, can be found in areas not accessible for visual examination. Provided that one smooth surface is accessible to the ultrasonic probe, most forgings, casting and extrusions can be satisfactorily inspected. On some aircraft, spar booms and some similar structural members require periodic examination for fatigue cracks, but the area of suspected weakness may not be accessible for examination by visual or dye-penetrant methods. Ultrasonic testing gives quick results on those defects or dye-penetrant methods. Ultrasonic testing gives quick results on those defects which lend themselves to this form of testing, i.e., the defect is normal to the directed beam. In this instance radiographic techniques would be quite unsuitable.

When carrying out ultrasonic tests in situ, the surface to be scanned by the probe should be thoroughly cleaned and covered with oil or grease to provide good acoustic contact. If parts are removed for testing, then water may be used as a couplant, but the parts should be thoroughly dried before being put into storage or service.

■■■

CHAPTER-33
RADIOLOGICAL EXAMINATION OF AIRCRAFT STRUCTURE

INTRODUCTION

This chapter gives guidance on the operation of radiological testing apparatus and establishment of satisfactory inspection techniques.

The use of radiography in accordance with an approved technique will often facilitate the inspection of structures during manufacture, overhaul and maintenance, and can be used for the examination of structures which would otherwise be inaccessible. A number of airframe and engine manufacturers, and aircraft operators, have devised techniques for particular inspections, and these are written into the appropriate Maintenance Manuals and Maintenance Schedules or included in a separate Non-destructive Testing (N.D.T.) Manual. General information on radiographic techniques is included in British Standard (BS) M34.

Radiographic methods may also be used to advantage where normal physical methods of measurement are difficult or impractical . It has been shown, for example, that it is extremely difficult to detect eccentricity in items with long bored or counter bored holes and that wall thickness in these cases can be accurately determined by means of a radiograph. Where this type of measurement is considered necessary, the appropriate technique should be quoted on drawings or inspection instructions.

Radiography should be considered as an extension to efficient inspection and is sometimes of value in providing a second opinion where inconclusive results have been obtained by other methods. It should not be regarded as a foolproof method of inspection without considered trails and its indiscriminate use would be both uneconomical and misleading.

The misuse of radiographic equipment could result in the release of physically harmful radiations and it is therefore extremely important that operators should be properly trained and aware of the regulations concerned with safety. The provision of adequate protection is not dealt with in this chapter; it is emphasized however, that the operating procedures and conditions set out in ‘The Radioactive Substances Act (1960), and the ‘Ionizing Radiations (Sealed Sources) Regulations No. 808 (1969)’ must be observed at all times when radiography is used for aircraft inspection.

The importance of proper training is also evident in the interpretation of radiographs. Incorrect conclusions could result in the clearance of unsafe structures or components or, conversely, the scrapping of expensive items which are really sound.

SOURCES OF RADIATION

There are two forms of electro-magnetic radiations which can be used in radiography, namely X-ray and gamma rays. The main difference between the two is in the method of propagation. The radiations are of very short wavelength (0.001 Å to 2Å) and are capable of penetrating solids, the rays passing through a specimen being used to expose a sensitized film. X-rays also cause the fluorescence of certain chemicals and this reaction is sometimes used to produce an image on a phosphor screen; this technique is known as fluoroscopy.

X-Rays

This particular form of electro-magnetic radiation is produced when electrons, travelling at high speed, collide with matter in any form.

The basic requirements for the production of X-rays are a source of electrons, a means of accelerating the electrons to high speed and a target to emit the X-rays. A typical circuit of an X-ray set is shown in Figure 33.1. The X-ray tube is an evacuated chamber in which the electrons are derived from a filament, set in a focusing cup and heated to incandescence by a low voltage current; electrons are released and form a ‘space charge’ around the filament. When a high potential is applied, electrons accelerate from the filament (the cathode) to the anode and strike the target, which then emits X-rays.

Only approximately 1 % of the electron energy is converted into X-rays the rest being changed into heat and light . For this reason the anode consists of a substantial block of copper, in which the target is set, and is often cooled by the circulation of liquid. The target is made from tungsten to resist the high temperatures produced by the electrons at the focal spot.

X-rays are emitted in all directions from the target but the tube is normally shielded so that a beam is emitted in the shape of a 40 ^{o} cone. However, some X-ray tubes are designed to emit different shaped beams for particular uses.

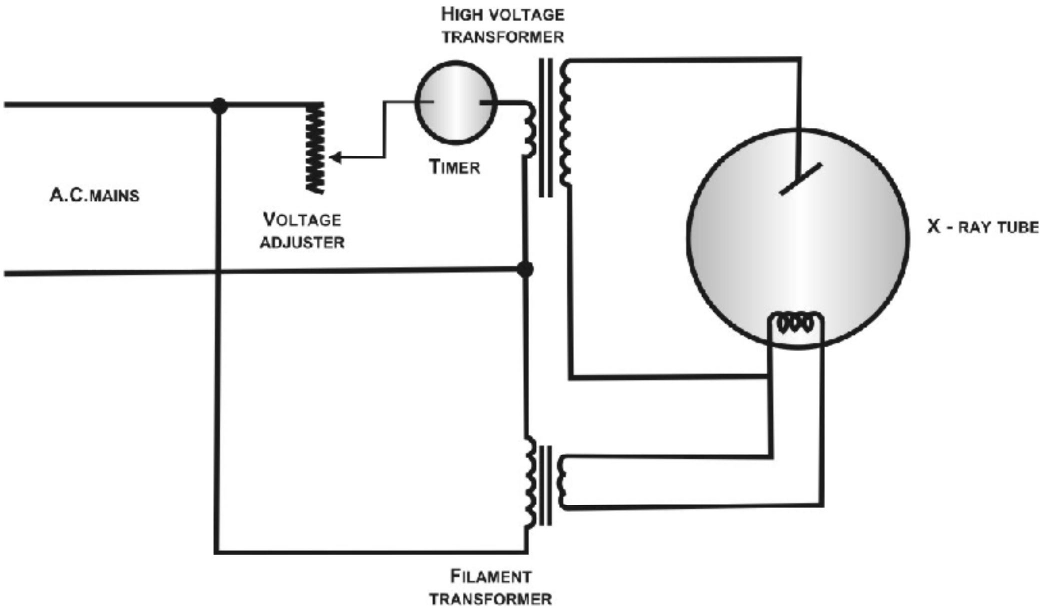


Fig. 33.1, Typical Circuit of An X-ray set

The electrical supply to an X-ray tube is normally from the a.c. mains through a transformer and, since electrons can only flow from the cathode to the anode, a pulsed tube current results. Some X-ray sets use complex electrical circuits to produce a constant potential in the tube, but they are generally very expensive and unsuitable for the type of portable equipment which is generally used on aircraft. The wavelength of the X-rays is inversely proportional to the voltage applied and the X-rays produced will vary in wavelengths down to a minimum value determined by the peak voltage. This is known as a 'continuous spectrum' and is a characteristic of all X-ray tubes. The penetrating power of X-rays increases as the wavelength decreases and high voltages are therefore used when radiographs of dense materials, such as steel, are required.

Penetrating Power

Although penetrating power is related to the voltages of the X-ray tube, it is often indicated by the 'half value layer' (H.V.L) of the beam. This represents the thickness of a given material (usually aluminium or copper) which will reduce the intensity of the beam to half its original value. This method is not completely accurate however, since the longer wavelengths, being less penetrating, are removed first and the quality of the beam is changed. If additional filtration (i.e. thicker aluminium or copper sheets) is provided it will be seen that the H.V.L. increases progressively until a constant beam quality is obtained.

Types of Equipment

X-ray equipment is normally graded according to the voltage range over which it is designed to operate. The portable sets used in aircraft work normally cover voltages between 10 k V and 250 kV, but no single set will cover this whole range. Tubes designed for high voltages possess inherent filtration properties, which, combined with space charge effects, will preclude the emission of an effective X-ray beam at low voltages. Typical ranges covered by portable sets are 10k V to 100k V and 100k V to 250k V.

Gamma Rays

Electromagnetic radiations resulting from the disintegration of radioactive materials are known as gamma rays. The isotopes now used in radiography are artificially produced and emit rays of similar wavelength to those produced in X-rays tubes. Gamma radiation is not in the same form as X-rays however, and consists of one or more discrete wavelengths in what is known as a 'line spectrum'. The relative intensities of each wavelength are always the same for a particular material. The four most commonly used isotopes are Cobalt 60, Iridium 192, caesium 137 and Thulium 170.

Radioactive Decay

Radioactive elements, whether natural or artificial, are subject to a specific rate of decay i.e. reduction in strength of the radioactivity. This decay is measured in terms of the time over which half the original activity is lost and is called the 'half life' of the material. The half life of radioactive materials varies considerably, for example, Aluminium 28 has a half life of 2.27 minutes whereas Uranium 238 has a half life of 4.5×10^9 years. Radioactive materials can be used for radiography through several half life periods provided that an adequate working strength remains, and some are capable of re-irradiation in an atomic pile.

Penetrating Power

It is customary to express the penetrating power of gamma rays in terms of the voltage which would be required to generate X-rays of similar penetrating power. The unit used, the mega electron volt (MeV), represents the energy required to accelerate an electron through 1 000 000 volts. The energy emitted by Caesium 137 is 0.66 MeV and this is equivalent in penetrating power to the X-rays generated at 660 k V by an X-ray set. Due to the differences in the radiation spectra of the two sources, however, gamma ray sources, which do not generally emit the longer wavelengths, have a mean penetrating power somewhat higher than X-rays.

Gamma Ray Sources

Radiographic gamma ray sources consist of a circular disc or cylinder of radioactive material encased in a sealed aluminium or stainless steel capsule. The capsule is kept in a container which acts as a storage safe and may also be used as a support during exposure. The container is made of a material, such as lead or depleted (non-radioactive) uranium, which will substantially reduce the emission of gamma trays. High intensity sources are kept in bulky, heavily shielded containers, exposure being achieved by positioning the source opposite a restricting aperture in the container. Some users employ an exposure head connected to the container by guide tubes, the isotope being positioned and controlled by a remote control device. Since gamma rays cannot be turned off, strict regulations have been devised to safeguard both operators and general public during the transportation and use of radioactive sources.

PHOTOGRAPHIC ASPECTS

X-ray Film

The films used in radiography are very similar to those used in photography except that the emulsion covers both sides of the flexible transparent base. The emulsion is sensitive to X-rays, gamma rays and light, and when exposed to those radiations a change takes place in its physical structure. When treated with a developer, a chemical reaction results in the formation of black metallic silver ; it is this silver which, comprises the image . Handling of the undeveloped film is normally carried out in a 'dark room' which is illuminated by subdued yellow light.

Film is supplied in two classes, depending on whether fluorescent intensifying screens are to be used or not. Within these classes, film is available in a wide range of speeds and grain sizes.

Where the high clarity of a normal film is unnecessary, for instance when searching for debris or checking for correct assembly of a component, certain types of photographic paper can be used, with a consequent saving in cost.

Film is normally prepared for exposure by placing in a cassette, which may be either rigid or flexible, or in a light-proof envelope. For many applications films is also prepared in roll from, an example of which would be the film use for taking radiographs of a complete fuselage former. An X-ray tube which emits a 360° beam is located in the centre of the fuselage, and a roll of film placed to encircle the fuselage.

Intensifying Screens

It is sometimes necessary to take a radiograph of thick or dense material, necessitating a very long exposure time. This time may be reduced by converting the energy of the X-rays or gamma rays into another form of energy to which the film emulsion is more sensitive.

Phosphor coated screens (known as 'salt' screens) will fluoresce in the presence of X-rays and, if in contact with the X-ray film, will supplement the image formed by X-rays during exposure. The disadvantage of this arrangement is that the screen imparts a granite appearance to the film and detracts from image formed by X-rays during exposure. The disadvantage of this arrangement is that the screen imparts a grainy appearance to the film and detracts from image sharpness. 'Screen' type film must be used in conjunction with fluorescent intensifying screens.

Metal foil screens are usually made of lead and assist the normal X-ray exposure by producing photo-electrons in the presence of X-rays. This intensifying effect is only evident at potentials above 120 k V, but since the lead screens also reduce scattered radiation and are not granular in construction , they are always used in radiography carried out at energies above this value.

It is essential that both types of screen are held in close contact with the film (on both sides), as any gap will result in a spread of light (or photo-electrons) and produce a blurred or fogged image. Absolute cleanliness of the screen is also essential, since any dust or grease between the film and screen will be reproduced on the radiograph.

Sensitivity

The darkness of a radiograph depends on the quantity of radiation penetrating the specimen, the lighter will be the image Defects such as a crack or gas hole will show up as dark areas on the radiograph, since they will give less resistance to the rays. However, the ability to recognize a defect will depend on its size and the quality of the radiograph. The sensitivity of the radiograph is normally measured by an image quality indicator (I.Q.I), also known as a penetrameter (Figure 33.2), but this should not be used as a means of calculating the smallest size of defect which may be detected. The shape of the defect and the plane in which it lies are most important ; if a crack runs in a plane normal to the X-ray beam it will probably not be detected, and this must be taken into account When establishing a technique for a particular inspection.

Ideally I.Q. Is should be made of the same material as the radiographic subject, but in practice mild steel is suitable for all steel specimens, pure aluminium is suitable for all aluminium alloys and copper is suitable for most bronzes and brasses. The I.Q.I. should be placed on the upper surfaces of the area undergoing radiography, i.e. nearest to the beam source, so that it will appear on the radiograph. The thickness of the last detectable step (or wire) should be ascertained and expressed as a percentage of the specimen thickness.

It will be appreciated that the difference in the sizes of the steps or wires in the I.Q.Is shown in Figure 33.2, must be very small for use with aircraft structures. In fact, although the use of I.Q.Is is essential with thick specimens, the very nature of aircraft structures, comprising skins, ribs, stringers, paint, sealant, etc., is an adequate form of I.Q.I. for most radiographic needs.

The step-wedge I.Q.I (Figure 33.2 (a)), consists of a number of steps ranging in thickness from 0.005 in to 0.1 in or greater as required . Each step contains a number of holes, varying in size according to the step thickness, and these are used both for identification of the step and as an indication of image sharpness.

The wire I.Q.I (Figure 33.2 (b)), consists of a series of short lengths of wire in graduated diameters, embedded in thin rubber or plastic sheet. This type of I.Q.I. is sensitive to both sharpness and contrast, particularly in the smaller sizes.

Variations of the standard I.Q.I. are sometimes used for special purposes, e.g., when searching for fatigue cracks an I.Q.I. containing a typical defect could be used (Figure 33.3). The I.Q.I. is placed on the surface of the member being examined and, provided that the simulated defect is clearly visible on the radiograph, it can be assumed that any other crack of similar size and orientation would also be visible.

Geometric Considerations

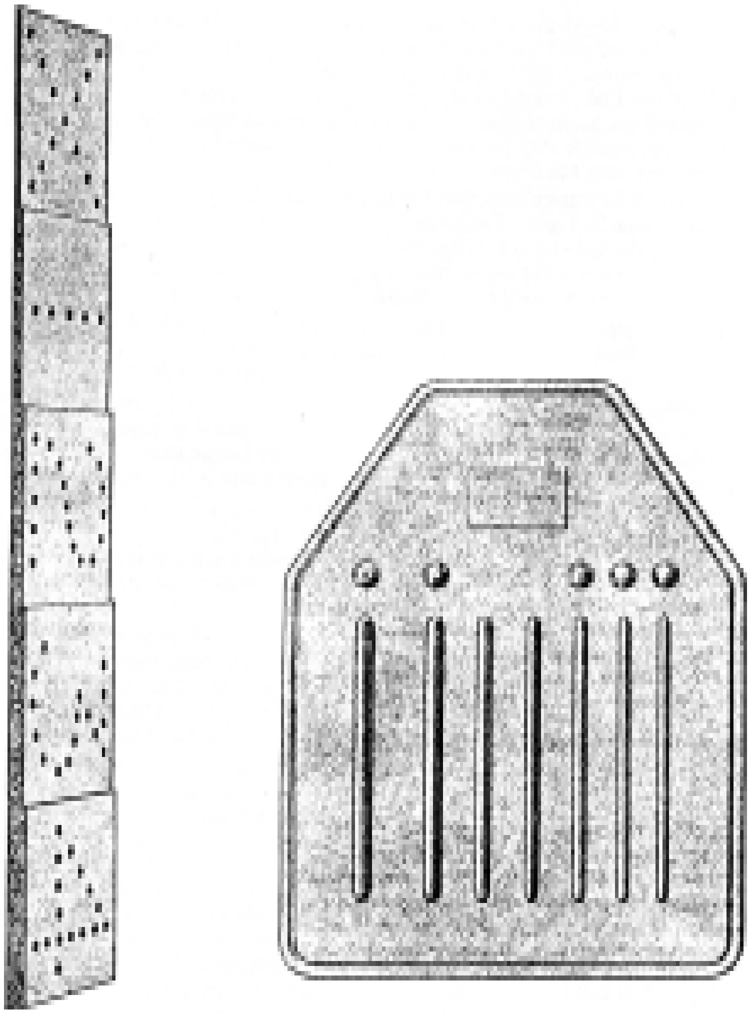
The sharpness of a radiographic image is influenced by the film characteristics and by geometric effects, which, since they are to a large extent under the control of the radiographer, are very important. The factors involved are the size of the radiation source, the distance between the source and the film, and the distance between the specimen and the film; these factors are illustrated in Figure 33.4.

It is generally accepted that a radiographic image viewed by the naked eye will appear to be sharp if the blurring of edges does not exceed 0.01 inches. The blurring, or sharpness, is caused by the finite size of the radiation source and this is quoted in the specification for the equipment concerned or can be found by experiment. From Figure 4 it can be seen that the closer the film is to the specimen then the sharper will be the image. However, practical considerations may prevent contact between the film and specimen and in this case acceptable sharpness can only be obtained by increasing the source-to-film distance. Alternatively, better coverage of a large or irregularly shaped part may be achieved by taking several radiographs from different angles, thus keeping the object-to-film distance to a minimum.

Exposure Conditions

The quantity of radiation affecting an area of specified size varies inversely as the square of the distance from the source; if the source-to-film distance is increased the exposure time must be increased accordingly. The ideal situation would obtain where the cone of radiation just covered the film area.

The required exposure conditions could be obtained by the use of exposure charts and calculations dependent on film characteristics. However, since a number of variables exist, it is more usual to establish a technique from knowledge of the structure involved, study of the aircraft manufacturing drawings and systematic trial and error methods. Once the geometric considerations have been determined a series of radiographs is usually taken, systematically varying the voltage, exposure time and, occasionally, the tube current or type of film, until an acceptable radiograph is produced; a double film technique is often used to reduce the number of exposures required. The lowest usable kilovoltage gives the highest contrast thus making recorded defects more distinct.



(a) STEP WEDGE TYPE **(b) WIRE TYPE**

Fig. 33.2, Standard Image Quality Indicators

Filtration

When a beam of radiation passes through a material, some passes directly through (the primary radiation) and some is scattered by collision with the atoms making up the material (the scattered radiation). The primary radiation is the true image forming energy, but the scattered radiation results in a fogging effect on the film, reducing contrast and impairing definition. While scattered radiation is always present, its effects can be reduced by the use of metallic screens, masks or backing.

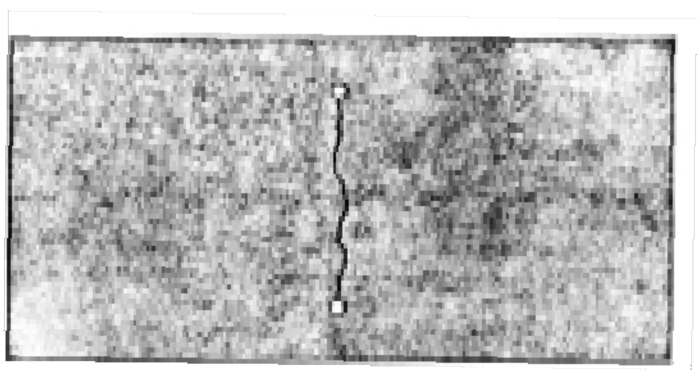


Fig. 33.3, I.Q.I. Simulating a Defect.

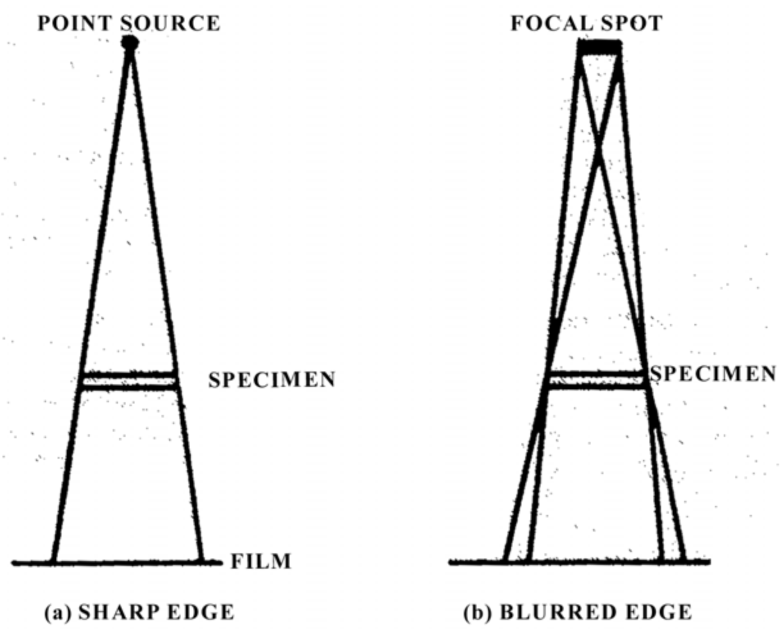


Fig. 33.4, Geometric Unsharpness

Primary Beam Filtration

X-rays consist of a wide band of wavelengths, the shorter of which are the image forming radiations. The longer wavelengths have little penetrating power but are a significant source of scattered radiation, and can normally be eliminated from the X-ray beam by placing a metal filter close to the X-ray source. The thickness of the filter is important since it affects the total material to be penetrated, and it is usually found by experiment; a copper filter 0.1 mm thick would normally be used with a 100kV to 200 kV set.

Scatter Within the Specimen

Some scattered radiation is generated within the specimen, particularly when it consists of a box-like structure, or dense material. This may be reduced by placing a filter, similar to that used for primary beam, immediately above the film. Particular care is necessary to ensure that this filter is clean, since any dirt will show up on the radiograph. In the case of light alloy structures a limitation of 2 minutes exposure time will usually eliminate such scatter.

Makes and Backing

Scattered radiation can be produced from any point within the area of coverage of the radiation beam and will, therefore , be produced by structure situated beside or behind the film. This radiation is reduced by placing lead sheets adjacent to the film and specimen, immediately at the back of the film, and, in permanent radiographic rooms, by covering the floor and table with lead. With irregularly shaped specimens an opaque paste mask is sometimes used.

RADIOGRAPHIC TECHNIQUES

The establishment of completely reliable techniques of examination is essential if confidence is to be placed in the resulting radiographs. It may be necessary to prove their effectiveness initially by dismantling the particular structure to ensure that no defects exist which have not been revealed in the radiographs, and to determine that the radiographs have been correctly interpreted.

The factors outlined in paragraph above should be taken into account in evolving a satisfactory radiographic technique, and a record should be kept of the conditions under which the technique was established. A typical Radiographic Technique sheet, as recommended in British Standard M34, is reproduced in Figure 33.5. This sheet should be given a number for identification purposes and should also include, in the 'Notes' section, such details as items which must be removed (including fuel from the fuel tanks, radiation sensitive items, sealant or paint, etc.), any jacking or trestling necessary and measurements from which the film, X-ray set or isotope may be positioned. A simple isometric drawing may also assist identification of an area under examination and the inclusion of photographs or drawings showing potentially defective items should also be considered.

It may often be necessary to penetrate a widely varying range of thicknesses and, if only a single radiograph is taken this may result in the appearance of greatly contrasting light and dark areas, making accurate interpretation almost impossible. In such circumstances the simultaneous exposure of two or three films without intervening wrapping in a common cassette or envelope may be employed; if the films and exposure time are carefully selected, each different thickness will be shown at a suitable density on one of the radiographs. The use of a lead screen separating two films is sometimes useful in achieving satisfactory radiographs of different material thicknesses and also gives greater flexibility in the selection of a film pack.

(Company name and address)

RADIOGRAPHIC TECHNIQUE SHEET	Sheet .... of ....sheeets	Technique sheet No.
Set used :		
Type of radiation :	Description	Part No.
Source size		
Film processing :	Purpose of inspection : Area to be inspected Acceptance standard :	Material and specification
Preparation :	Associated documents :	Prepared by : / Date :
	BS M.34	Approved by : / Date

Aspect or position	Exposure details: Angle of beam to film	s.f.d.	kV	mA	Time	Filters: on tube	on film	Screens	Ug	Film	Size and pattern	Radiograph No.	Figure reference

NOTES:

Fig. 33.5, Typical Radiographic Technique Sheet

GAMMA RAYS IN AIRCRAFT RADIOLOGY

In general it may be considered that the majority of radiographs of aircraft structures are taken with an X-ray set. This is due to the unsharpness and lack of contrast normally obtained with gamma sources and the gradual decrease in radiated energy. However, there are occasions when a gamma source is used, mainly due to lack of space or access for X-ray equipment.

Application

By the use of guide tubes or handling rods attached to containers, it is often possible to place isotopes in positions which would be completely inaccessible to X-ray equipment. An example of this is where an internal portion of a structure is to be examined, there being no means of access for the X-ray equipment and the complexity of the structure preluding the taking of X-ray pictures from the outside. Provided it is possible to place the film in position, the isotope can be inserted through a convenient aperture and a direct radiograph of the particular area may be obtained.

Isotopes are also often used for the examination of internal features of turbine engines, such as the main rotor shaft, and provision of access points is sometimes included in the engine design.

Isotopes

The types of isotope used will be determined by the thickness of the subject, the source-to-film distance and the source output in terms of exposure time.

FLUOROSCOPY

The luminescent property of phosphors enables them to transform X-rays into visible light. The effect is most pronounced with low energy x-rays, normal gamma ray sources are therefore unsuitable, being of too short a wavelength.

X-rays are passed through the specimen and impinge on a phosphor coated screen which emits light in proportion to the intensity of the X-radiations falling on it. A positive image is formed on the screen, showing internal details of the specimen in a similar manner to a radiograph.

Viewing cabinets are so constructed that the observer is protected from harmful radiations. Where low energy radiations are used the phosphor screen is viewed directly through a lead glass window but when high energy X-rays are necessary it is usual for an angled mirror to be interposed so that the screen is viewed at an angle tot he primary X-ray beam.

Due to the coarse grain of the phosphor screen and the poor geometric sharpness resulting from the need to place the screen close to the X-ray source, fluoroscopic images are greatly inferior to those produced by radiographs; for this reason fluoroscopy is seldom used in aircraft work. However, one big advantage of fluoroscopy is that there is no film to be developed and the method is suitable for checking the correct assembly of components or inspecting for debris in aircraft. In general engineering fluoroscopy is also used in conjunction with image intensifiers, for the examination of welded tube and other simple structures.

VIEWING CONDITIONS

In order to recognize all the indications available on a good radiograph, it is essential that suitable viewing conditions are provided.

Ideally, radiographs should be examined in a room set aside for this purpose and situated away from distracting conditions such as a high nose level. The room should be capable of being darkened but, during viewing, should have a low intensity background light which does not reflect on the film.

The viewing of radiographs requires a good deal of concentration. It is recommended that continuous viewing periods should not exceed 90 minutes and should be followed by a period of at least 30 minutes doing associated work away from the viewing area.

The radiograph itself should be placed on a special viewing box where it can be illuminated from the back, preferably by diffused lighting. Any light appearing round the edge of the radiograph should be masked off since it would tend to dazzle the viewer, possibly resulting in fine defects in the denser parts of the radiograph being overlooked. Controllable shutters are usually provide on the viewing box for this purpose. In addition, the masking of light areas of the radiograph while viewing dark areas will increase the apparent contrast of the image. Where the radiograph has areas of widely differing density the provision of a dimming control may assist the viewing of very light areas.

In some instances it may be advisable to make use of a magnifying glass for the examination of fine detail, but a glass with high magnification should not be used.

INTERPRETATION OF RADIOGRAPHS

The accurate interpretation of the defects indicated on a radiograph is a matter which requires considerable skill and experience and, if the maximum benefits are to be obtained from radiography it is essential that the viewer should have an intimate knowledge of the aircraft structure. Without such knowledge it would be possible to overlook faults which would be obvious to an engineer, if radiographs of a sound structure are available as standards, for comparison with radiographs on which defects are recorded. For simple structures on isometric drawing of the area might be suitable. Some of the indications obtained on radiographs are described in the following paragraphs.

Castings and Welds

Metallurgical defects in castings and welds generally produce characteristic patterns which may be recognized by an experienced viewer. Porosity, for example, will reduce the amount of material through which the X-rays or gamma rays must pass and result in dark spots in the film, whereas segregated constituents of alloys, or inclusions, may be light or dark, depending on their relative density.

Cracks in welds may be difficult to detect and knowledge of the defects associated with the particular type of weld is essential. The angle at which the radiograph is taken is of particular importance, since defects in a plane normal to the radiation beam would not result in any significant change of density in the emulsion. Surface blemishes produced by welding are recorded on the radiograph and produce a complex image liable to misinterpretation.

Corrosion

The detection of corrosion is invariably difficult, the difficulties often being aggravated by the presence of paint, jointing compound and surfaces fouling which, by their radiographic density, may compensate for the deficiency of material caused by corrosion or give rise to a suspicion of corrosion which does not exist. However, corrosion normally has an irregular and possibly 'fuzzy' outline, while compounds will usually have a regular and sharply defined one. Intergranular corrosion may not be detectable by radiography until it has reached an advanced state and affects the metal surface.

Under laboratory conditions, where scattered radiation can be effectively reduced and ideal exposure conditions obtained, it is possible to detect very small cavities. However, when radiographs of an aircraft structure are being taken, ideal conditions will not normally exist and the size of detectable cavities may be much larger. For example, fuel tank sealant is particularly dense, and it is doubtful if pitting less than 10 to 15 per cent of the total thickness, including the sealant, would be revealed.

A corrosion pit giving rise to a sudden change of thickness in a given specimen is more readily visible on a radiograph than a pit of the same depth in the form of a saucer-shaped depression. This is due to the fact that a sudden change in the density level on the radiograph is more easily seen than a gradual merging of two areas of different density.

A further difficulty in the detection of corrosion is that the corrosion products often adhere to the surface and the difference in density might be so slight as to be undetectable. In some instances the build up of corrosion products can be detected when the radiograph is taken at an oblique angle to the surface of the metal.

In aircraft structures, stress corrosion often has a characteristic appearance, showing up as lines of spots on the radiograph. With experience this condition can be identified from similar indications caused by debris or poor developing.

Corrosion can sometimes be detected where successive radiographs, taken over a period of time by an identical technique in each instance, reveal a gradual change in density in a particular area.

Cracks

There is a tendency to regard cracks as straight gaps perpendicular to the working surface, but this is not invariably so. Unless appropriate techniques have been used in taking the radiographs, it is possible for fairly large ' dog-leg' cracks particularly in the thicker sections, to remain undetected.

Stress cracks around rivets in aircraft structures often have a characteristic appearance, running along a line of rivets in a series of arcs. In certain circumstances the edge of the jointing compound used during wet assembly of rivets can give the appearance of hair line cracks of this type, but masking down to a very small area will reveal the true nature of the indication.

When cracks are being sought on the tension side of a wing it is sometimes possible to open up the cracks by applying a tension load, normally by jacking. This will result in a more positive indication on the radiograph.

While cracks will normally appear as a darker line on the radiograph, instances may occur when a lighter line is present. This may result from a part, such as a stringer, being cracked right across and overlapping at the point of fracture, thus presenting a thicker section for the rays to penetrate.

Many radiographs of structure bear evidence of what appears to be structural cracking but, when such areas are examined physically, the cracks have been found not in the structure but in the sealing or jointing compound used in the area. Such conditions may occur inside integral fuel tanks, but with experience it is possible to distinguish between the two types of cracks by reason of their distinctive shape. Some sealants are very opaque to X-rays and may completely hide a defect.

Leaded Fuel

It is often necessary to take radiographs where the primary beam of radiation passes through a fuel (e.g. the lower surface of a wing containing integral fuel tanks). Since lead offers considerable resistance to the penetration of X-rays and gamma rays, the presence of even the small percentage of lead contained in most aviation gasoline will restrict the quantity of radiation reaching the film. It is imperative, therefore, that the fuel tanks should be completely drained before the film is exposed. Pools of fuel left in the tanks may also give misleading indications on the radiograph. Less difficulty is experienced with kerosene but some scatter does occur and may impair the quality of the radiograph.

GLOSSARY OF TERMS USED IN RADIOGRAPHY

The following terms and abbreviations are used in radiological non-destructive testing and are taken from a complete list contained in British Standard 3683, part 3.

Ångstrom unit (Å)	Unit of measurement of the wavelength of X-rays and gamma rays. 1 Å = 10^{-8} cm.
Anode	The positive electrode of an X-ray tube which carries the target from which the X-rays are emitted.
Cathode	The negative electrode of X-ray tube.
Casette (or cassette)	A light-tight container for holding radiographic film, paper or plates during exposure. Screens may or may not be included.
Contrast	The relative brightness of two adjacent areas on an illuminated radiograph.
Definition	The sharpness of image details on a radiograph.
Density	The degree of blackening of a radiograph.
Focus-to-film distance (f.f.d)	The distance from the focal spot of an X-ray tube to a film set up for exposure.
Gamma (γ) rays	Electromagnetic radiation emitted by radioactive substances during their spontaneous disintegration.
Grainsize	The average size of the silver halide particles in a photographic emulsion.
Image Intensifier	A device used to give a brighter image than that produced by X-rays alone upon a fluorescent screen.
Isotopes	Atoms of a particular element which have the same chemical properties and atomic number, but a different mass number from those normally present in the element.
Penumbra (Ug)	Blurring at the edges of a radiographic image due to the radiation source being of finite dimensions.
Quality	The penetrating power of a beam of radiation.
Radiograph	The photographic image produced by a beam of radiations after passing through a material.
Resolution	The smallest distance between recognizable images on a film or screen.
Source-to-film distance (s.f.d.)	The distance from the source of primary radiation to a film set up for exposure.
Tube current	The current passing between the cathode and the anode during the operation of an X-ray tube.
Tube head	A type of X-ray shield which, in addition to the X-ray tube, may contain part of the high voltage generator.
Unsharpness	Image blurring caused by the penumbra, by movement, by grain size, or by light, electron or X-ray scatter.
X-rays	Electromagnetic radiation resulting from the loss of energy of charged particles (i.e. electrons).

■■■

CHAPTER-34
EDDY CURRENT METHOD

INTRODUCTION

This chapter gives guidance on the use of eddy current equipment for detecting cracks, corrosion or heat damage in aircraft structures, and also shown how the method can be used for the measurement of coating thickness or for sorting materials. Elementary theory of eddy currents is included to show the variables which are being measured and to indicate the interpretation of results which may be necessary for a particular application. Nothing in this chapter should be taken as overriding the information supplied by aircraft or engine manufacturers.

Eddy current methods can detect a large number of physical or chemical changes in a material, and the selection of the required parameter presents the equipment manufacturer with many problems; interpretation of the test indications would be very difficult if un desired parameters were not reduced or nullified. Conversely, equipment set up for a particular purpose is comparatively easy to use when indications are compared with a ' standard' or known defect. Eddy current equipment is normally built to perform only certain types of tests, these falling broadly into the categories of flaw detection, conductivity measurement and thickness measurement.

The main advantages of the use of eddy current methods are that they do not normally require extensive preparation of the surface or removal of the part to be tested, do not interfere with other work being carried out on the aircraft and, with surface defects, offer improved sensitivity over other non-destructive techniques. Small portable sets are battery powered and can easily be used in comparatively inaccessible place in aircraft structures.

Eddy current testing may be subject to certain difficulties, including depth of penetration and the effects of surface coatings and unseen changes in the geometry of the material under test. In addition the results of a test can only be related to the size of signal received, and are not necessarily an indication of the size of defect. Techniques are established after trials have shown a method which gives consistent results.

In aircraft work, eddy current testing is usually of the comparative type, a reference piece or standard in similar material containing an artificial defect, being used to compare indications from the part under test.

PRINCIPLES OF OPERATION

Eddy currents are induced in an electrically conducting material when the material is subjected to a changing magnetic field, and normally flow parallel to the surface of the material (Figure 34.1). In eddy current testing a coil is supplied with alternating current and held in contact with (or in close proximity to) the test specimen. The alternating magnetic field produced around the coil induces an alternating eddy current in the specimen, and the eddy current itself produces an alternating magnetic field which opposes and modifies the original coil field. The resultant magnetic field is the source of information which can be analysed to reveal the presence of flaws in the test specimen.

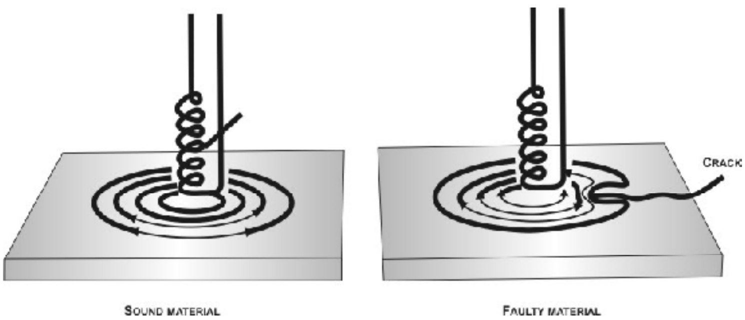


Fig. 34.1, Eddy Current Flow

Permeability

This quality is a measure of the ease with which a material will conduct magnetic lines of force and decides the density of flux which can be induced in that material. Permeability is a function of magnetising force and flux density; air and non-magnetic materials have, for testing purposes, a permeability (μ) of 1, while ferromagnetic materials have a permeability greater than 1. Permeability is not constant in magnetic materials, and varies with the magnetising force (coil current). Eddy currents are induced by flux changes in a material and are directly related to flux density; as permeability increases so the strength of eddy currents increases. Non-magnetic materials do not generate additional flux densities, but magnetic materials produce high flux densities which can mask all other measurements. During tests on ferromagnetic materials, that is materials with a permeability greater than 1, these effects can be suppressed or made constant by saturation with high D.C.. or AC. fields which, in effect, restore the permeability to 1.

Conductivity

Conductivity (σ) is a measure of the ability of electrons to flow through a material and is one of the main variables in eddy current testing. Each material has a unique value of conductivity and this fact enables changes in chemistry, heat treatment, hardness or homogeneity to be detected simply by comparing the conductivity with a specimen of known properties; increased conductivity gives increased eddy currents (although depth of penetration decreases). Conductivity is measured in either of two ways; it can be compared to a specific grade of high purity copper known as the International Annealed Copper Standard (IACS), which is considered as 100 % or it can be measured in meters per ohm millimetre^2 (58 $m\backslash\Omega \; mm^2$ = 100 % IACS).

Effects of Specimen on Test coil

A probe coil placed on the surface of a specimen will posses a particular value of impedance which can be found by measuring the voltage across the coil. The voltages due to resistance and reactance can also be separated and, if required, displayed on a cathode ray tube. Any change in conductivity, permeability or dimensions (d) of the specimen will, through the eddy current field, alter the coil 's impedance, either in magnitude or phase, and , depending on the parameter sought, can be indicated on a meter or cathode ray tube display. Changes affecting apparent conductivity, e.g. a crack, will be 90 ^{o} out of phase with changes affecting permeability or dimensions under certain test conditions.

Geometry

The size and shape of the test specimen may distort the primary magnetic field and mask defects in the affected area (Figure 34.2). The effects of geometry can be overcome by probe design, equipment calibration, frequency selection, or the use of jigs to maintain the probe in a particular relationship to the material surface, but must often be taken into account when conducting tests.

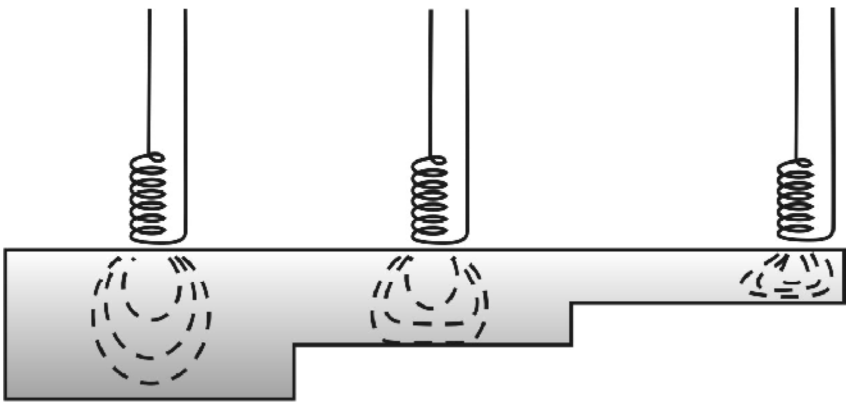


Fig. 34.2, Geometric Effects on primary magnetic field

Penetration

Eddy currents are strongest at the surface of a material and weaken with depth. This effect becomes more pronounced with increased frequency (f) of the alternating magnetic field and is known as 'skin effect'. Increases in permeability (μ) and conductivity (σ) in a material also decrease penetration depth. In practice the depth of penetration (P) of eddy currents is related to a depth where the current is reduced to 1/e (approximately 37 %) of the surface current and may be calculated from the formula, $P \approx \frac{500}{\sqrt{f\sigma\mu}}$ where P is in mm, and σ is in $m\backslash\Omega \, mm^2$.

Effects of Frequency

Any particular material possesses what is known as a characteristic frequency (f_g), which depends on its conductivity, permeability and dimensions. a practical use of the characteristic frequency is that samples of different materials tested at the same f / F_g ratio will give similar indications for similar defects. Actual test frequency is selected to obtain the best results from a particular test and depends on the type of defect sought, the depth of penetration required and the geometry of the specimen. When it is necessary to determine the phase of a signal, the frequency should be within the range where phase angle is greatest. When testing for conductivity only, to check hardness, heat treatment, etc., some penetration is required so a low frequency would be used, but when testing for surface cracks greater sensitivity would be obtained at a higher frequency.

In aircraft work testing is often concerned with thin sheet structure in aluminium alloy, and test frequencies between 5 kHz and 4 MHz are used, depending on the defect sought. However, frequencies as low as 50 Hz are used for checking material properties in ferromagnetic materials.

Lift-off

This may be defined as the change in impedance of a coil when the coil is moved away from the surface of the specimen. This produces a large indication on the test equipment . In some equipment the lift-off effect is nullified by applying a compensating current to the probe circuit, thus enabling rapid testing without the need for special jigs, but in other equipment the lift-off effect is analysed to measure, for example, the thickness of a non-conducting coating. This effect, when applied to encircling coils and bar specimens, is known as 'fill factor'.

COIL ARRANGEMENTS

A number of different coil arrangements may be used in eddy current testing, and some of the more common are discussed below. The types shown in Figures 34.3, 34.4 and 34.5 are not generally used during aircraft maintenance operations, but are widely used by material and component manufactures.

Single Primary Coil

Figure 34.3 shows the simplest arrangement. If a sound specimen is placed in the coil the impedance of the coil is modified and if a faulty specimen is placed in the coil the impedance is modified to a different degree.

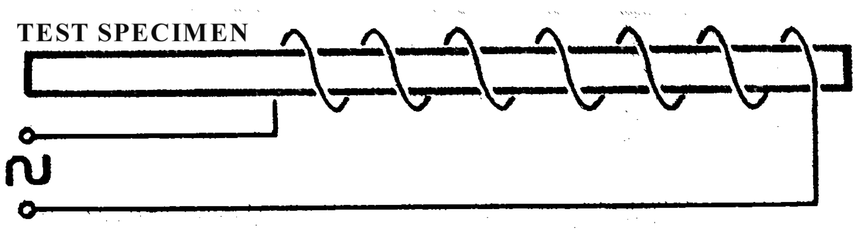


Fig. 34.3, Single primary coil system

Comparative Coil System

Figure 34.4 shows a coil arrangement which has two arms, one containing a flawless reference piece and the other the test specimen. Since the two sets of coils are identical any fault in the test piece will result in voltage across AB.

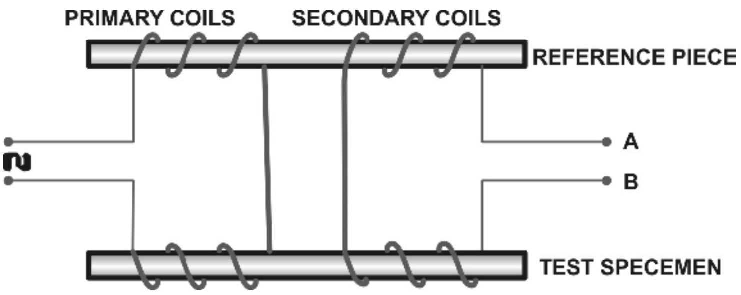


Fig. 34.4, Comparative Coil System

Differential Coil System

Figure 34.5 shows a coil arrangement which is also a comparison method, but in this case adjacent portions of the test specimen are compared with each other. The coil winding are, in effect, identical to the comparative coil system shown in Figure 34.4.

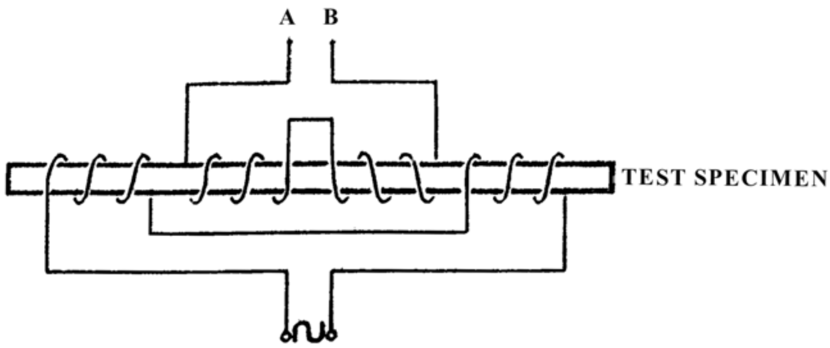


Fig. 34.5, Differential Coil System

Surface Coils

In aircraft work a single coil is generally used, with the axis of the coil normal to the surface being tested (Figure 34.6). A ferrite core is used to increase sensitivity to small defects, and the arrangement is used for detecting cracks in flat surfaces, curved surfaces or holes, by mounting the coil within a specially shaped probe. Impedance change obtained during a test are compared with those obtained from a defective part or a reference piece.

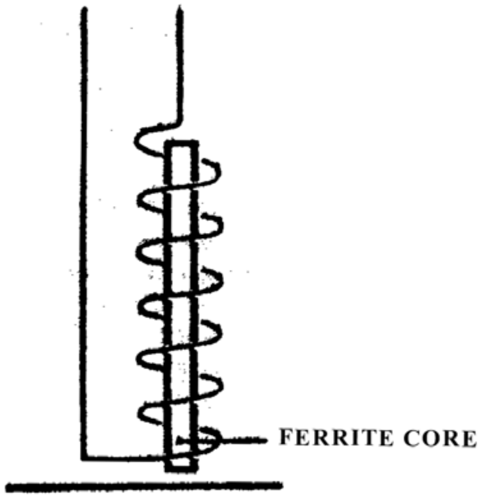


Fig. 34.6, Surface Coil

TYPES OF CIRCUITS

Bridge Circuits

Figure 34.7 shows a bridge circuit, one arm of which consists of two adjustable controls and a coil, and the other arm comprises the reference and test coils. The bridge is balanced initially (meter zeroed by adjustment of the variable resistor and inductor) with probe located on a flawless specimen. In use, any alteration in the impedance of the probe coil (due to faults in the test piece, or to lift-off) will unbalance the bridge and result in a deflection of the meter needle.

Resonant Circuits

The capacitance of a coil is usually small in relation to its inductance. However, if a capacitor is connected in the same circuit as a coil, since inductive reactance increases with frequency and capacitive reactance decreases with frequency, a condition will occur, at some frequency, when the effects are equal and opposite. This condition is known as resonance and circuit then behaves as if it contained only resistance, resulting in a large change in current flow.

Fig. 34.8, shows a typical eddy current circuit which operates on the resonance principle. The probe is a parallel tuned circuit connected to the grid of an oscillator and determines the frequency at which the circuit oscillates. If the flux density (and hence the impedance) of the probe coil is altered (e.g. by placing the probe on a metallic object) the oscillator frequency changes. Consequently, the frequency developed in the anode tuned circuit is no longer the frequency at which that circuit is tuned. This results in a change of impedance, which is recorded on the meter through the secondary windings of the anode coil.

Operation of the circuit shown in Figure 34.8 is dependent upon adjustment of the controls to suppress lift-off. With the probe located on the test specimen the anode circuit is tuned to a frequency in sympathy with the probe circuit by adjustment of the variable capacitor (i.e. the lift-off control) until the meter reads zero. If the probe is now removed from the specimen a change in impedance will again occur and result in deflection of the meter needle; this deflection can be counteracted by adjustment of the set-zero and lift-off controls. Further adjustment of these two controls will enable a zero meter reading to be obtained with the probe on or off the specimen. Any change in the specimen (e.g. a defect) will result in a change in the impedance of the probe coil and a deflection of the meter needle, regardless of the presence of, for example, a paint film of uneven thickness.

A different type of resonant circuit is shown in Figure 34.9, the probe coil and capacitor in this case being connected in series. Lift-off is suppressed by the addition of a compensating voltage.

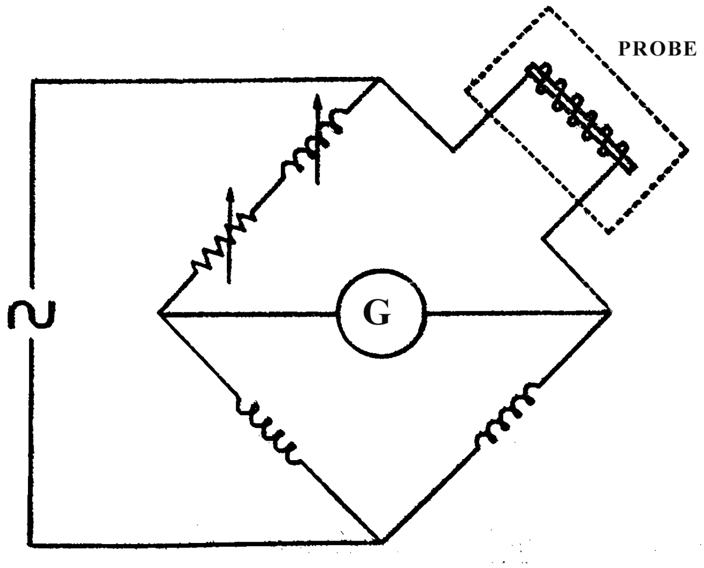


Fig. 34.7, Bridge Circuit

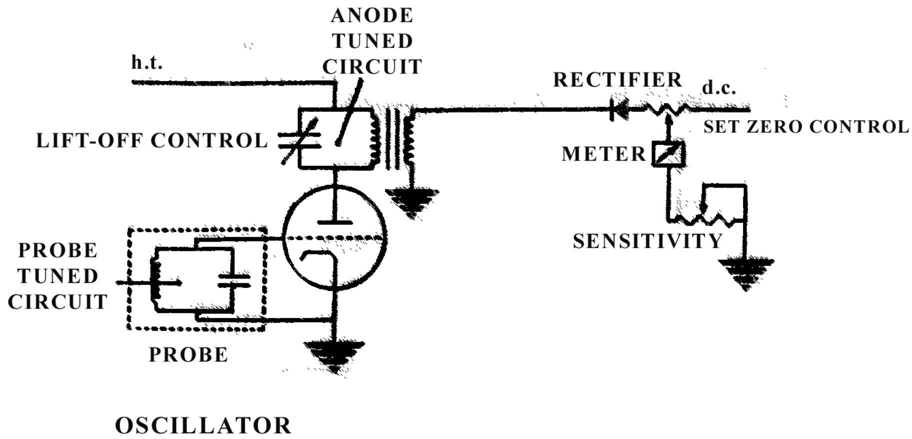


Fig. 34.8, Typical Tuned Circuit

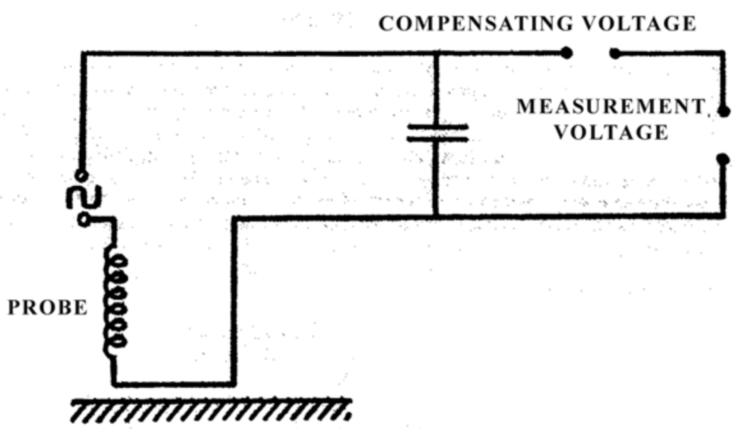


Fig. 34.9, Series Resonant Circuit

PHASE ANALYSIS

Where one of the parameters affecting impedance is required and all others can be assumed to be constant, the measurement of total impedance changes will satisfactorily reveal the presence of a defect or change in the unknown parameter, provided that a suitable reference piece is used for comparison. However, in many cases it is necessary to separate the reactive and resistive components of impedance in order to detect a particular type of defect and more sophisticated equipment becomes necessary.

Figure 34.10 shows the oscilloscope trace of a signal containing two voltages, V_1 and V_2, which are representative of the signal which could be obtained from eddy current equipment under certain test conditions. While the voltages are of the same frequency they can be seen to start at different points of the time scale, the difference resulting from the effects of reactance and being known as a phase change. Eddy current testing based on the use of phase changes is known as phase analysis.

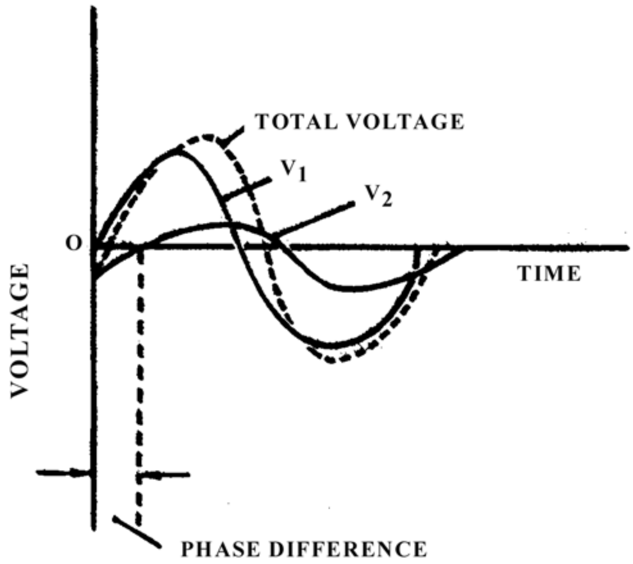


Fig. 34.10, Phase Difference

One method of suppressing the unwanted components of the measurement voltage (i.e. probe coil voltage) and presenting only the parameter required, is to include a phase sensing device in the circuit. This operates on the principle that only those components which are in phase with a reference voltage are passed to the meter. Figure 34.11 show a typical phase sensing circuit in which the measurement voltage is applied to one diagonal of a bridge and a reference voltage to the other. The rectifiers act as switches which pass current during one half of each cycle of the reference voltage only, but no reference current flows though the meter due to the symmetry of the bridge circuit. The measurement voltage is applied to the meter during those periods when the rectifiers are conducting, and , by varying the phase of the reference voltage, unwanted components of the measurement voltage can be eliminated.

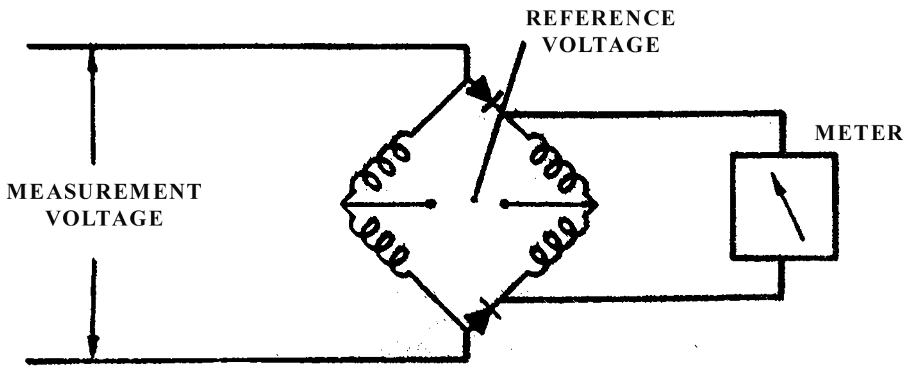


Fig. 34.11, Phase-Sensing Circuit

The resistive and reactive components of the measurement voltage (V_1 and V_2 respectively) can also be separated, fed to separate plates of a cathode ray tube (CRT) and presented as a two-dimensional display on the screen. By suitable phase controls the vertical and horizontal components can be made to represent, for example, conductivity variations and dimensional variations respectively. The most common types of display are the vector point, ellipse and linear time base.

Vectorpoint

A spot is projected on to the screen of the CRT, representing the end of the impedance vector (Z) (Figure 34.12) is adjusted to the centre of the screen when the test piece has the same properties as the reference specimen. Any anomaly in the test piece will result in movement of the spot, the direction of movement being an indication of the cause of the anomaly. If more than one variable is present, since the position of the spot indicates direction and magnitude, the cause can often be determined by vector analysis

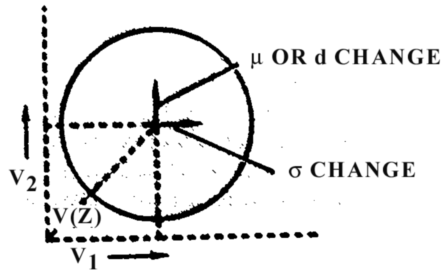


Fig. 34.12, Vector Point

Ellipse Method

A comparative coil arrangement is also used in this method. In the balanced condition a horizontal line is shown on the screen of the CRT whilst an unbalanced condition can be shown in either of two ways. One variable can be displayed by a change in the angle of the line and a second variable by the formation of an ellipse (Figure 34.13). By analysing the position and shape of the ellipse both variables can be evaluated.

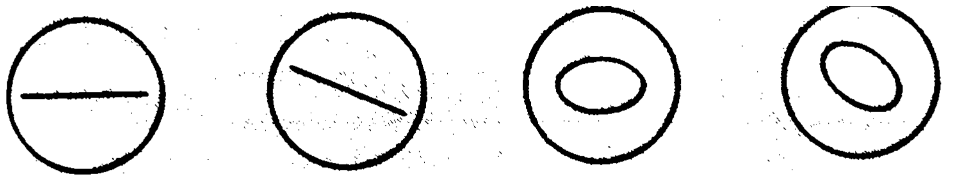


Fig. 34.13, Ellipse Method

LinearTime Base

A spot moving across the screen at a constant rate can be adjusted to show the wave-form of the voltage from a comparative coil system. A change in impedance will alter the wave-form and either of the components of impedance can be measured by adjustment of the phase shift controls. To assist in measuring any changes, the screen is often fitted with a slotted cursor (Figure 34.14).

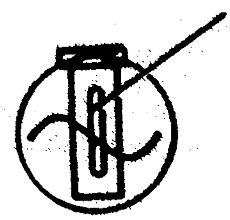


Fig. 34.14, Linear Time Base

PROBES

Unlike ultrasonic probes, the probes used in eddy current testing, because they are connected to the material by a magnetic field, do not require a coupling fluid, and no surface preparation is necessary other than the removal of any surface condition which would hinder free movement of the probe. Coils are also normally wound on a ferrite core, and this has the effect of concentrating the magnetic field and increasing sensitivity to small defects. Coils are often protected by enclosures in a plastics case, but the ferrite core is often left unprotected when required by particular test conditions. To maintain the coils in close proximity to the work it is often necessary to design a probe for one particular use only; some of the probes commonly used in aircraft work are discussed in below paragraph.

Surface Probes

Figure 34.15 shows two typical surface probes. (A) could be used for detecting surface cracks, and would be connected to a resonant circuit type of test set, whereas (B) could be used for coating thickness measurement or conductivity tests and would be connected in a bridge circuit type of test set. In the case of (A) a simple jig may be necessary to prevent spurious indications due to inadvertent probe angulation.

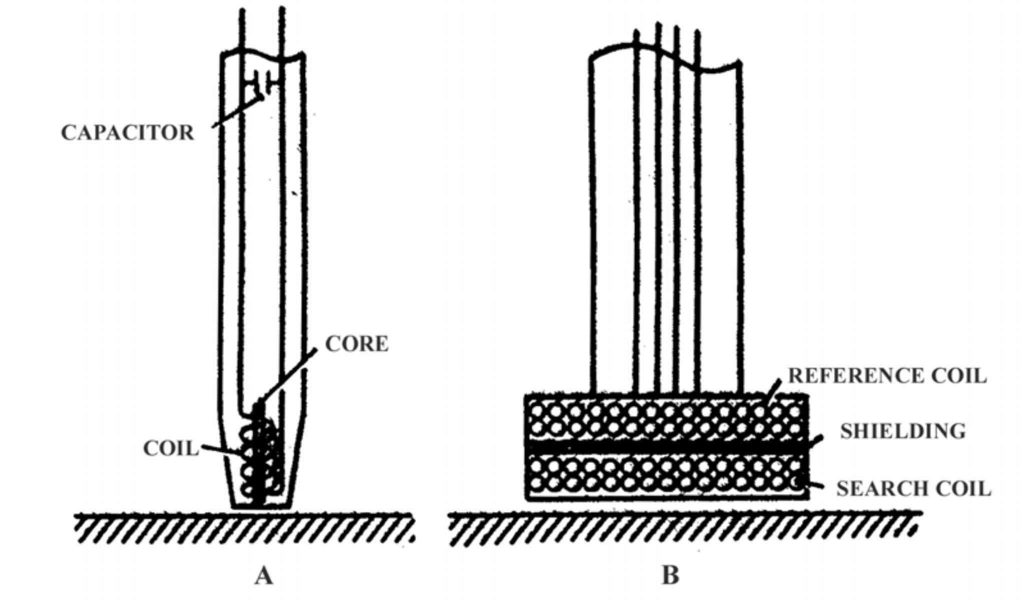


Fig. 34.15, Surface Probes

Hole Probes

Hole probes used during material manufacture would normally consist of a coil, the axis of which would be coincident with the axis of the tube under test, but in aircraft work a hole probe is normally located with the coil diametrically across the hole to achieve greater sensitivity. This type of probe is therefore a surface probe used for testing the surface of a hole. Figure 34.16 shows a typical hole probe of the latter type, the main use for which would be the detection of radial cracks round fastener holes.

The actual position of a crack can be determined by using an offset coil as illustrated, or by shielding one end of the coil.

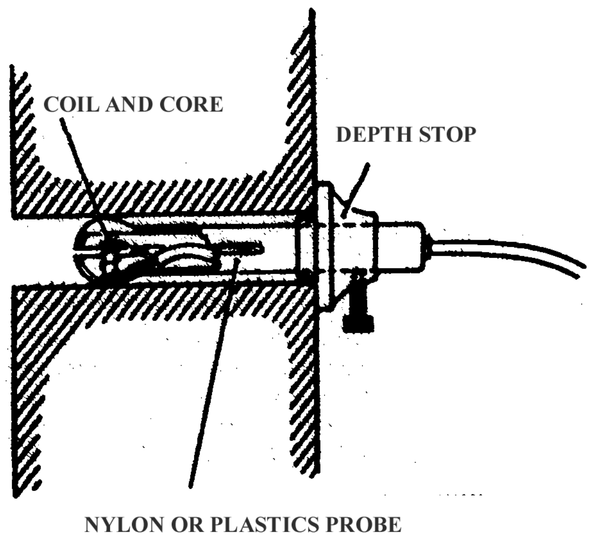


Fig. 34.16, Hole Probe

Special Probes

Probes may be designed to suit any application, the object being to present a coil at a particular position on a component, so that information can be obtained from changes in the coil's impedance. Examples of the use of special probes would be for the detection of cracks in wheel bead seats, turbine engine compressor or turbine blades, and each of these probes could be connected to a single test set of suitable frequency and complexity. Probes are also designed with a view to eliminating the need for disassembly when carrying out routine maintenance operations.

REFERENCE PIECES

In order to calibrate the equipment, standard reference pieces, manufactured from a material similar to that being tested, are necessary. These pieces should contain defects of known size and shape, so that the change in coil impedance against a known defect could be used as an acceptance limit.

A typical reference piece for surface cracks tests would contain, for example, three cuts of different depths, the depth being marked adjacent to each cut, and the block being marked with the material specification. The test acceptance level could then be related to a signal of the same amplitude as that obtained on a specified cut in the block.

Reference pieces are usually small in size and can be taken to the test location so that quick cross-reference can be made between the reference piece and the test specimen.

NOTE

Since the manufacture of a reference piece involves the removal of metal (by saw cut or spark erosion), the phase and magnitude of the impedance changes will not be identical with those obtained from a natural crack of similar depth. For this reason, actual defective aircraft components are sometimes used to give comparative readings.

TYPICAL APPLICATIONS OF EDDY CURRENTS

The eddy current equipment used in many material manufacturing processes is very sophisticated and completely automatic. Bar, tube and wire materials are normally passed through encircling coils of suitable size, and defects are both displayed on a cathode ray tube and recorded by tape or memory store. Audible warning, marking, and defective component rejection systems, actuated by the defect signal, are also often include. A recent innovation is the use of rotating probes through which bar material can be passed, the advantage of this method being an increase in the sensitivity to surface cracks. In aircraft maintenance work, however, eddy current equipment is usually restricted to conductivity tests and crack detection, mainly by the use of surface probes. Sophisticated equipment such as that described above is not normally required and equipment is usually portable and battery operated. The following paragraphs describe typical eddy current applications.

Checking Fastener Holes for Cracks

A suitable equipment for testing holes would be a simple impedance test set (i.e. not including phase analysing circuits) with lift-off control, and the probe would be similar to that shown in Figure 34.16, adjusted to be a snug fit in the hole. The reference piece should be of similar material to that being tested, and should contain holes of the same size as the probe with natural cracks or artificial notches at various depths in the hole to simulate cracks of maximum acceptable size.

The following procedure should be used when carrying out a test:-

i. Clean loose paint, dirt, burrs, etc. from inside and around the holes being checked.
ii. Calibrate instrument and adjust for lift-off in accordance with the manufacturer's instructions.
iii. Insert probe in hole in reference piece and adjust depth stop to obtain maximum needle deflection from a selected notch or crack. Adjust sensitivity to give the specified scale deflection from the crack.
iv. Insert probe in hole in test specimen and slowly rotate, noting and marking any holes producing needle deflections greater than that from the reference piece. Re-check probe in reference piece frequently.

NOTE

Any ovality in hole diameter will give a meter deflection which can be confused with the signal from a crack. Generally the indication from ovality shows a much slower change than that from a crack as the probe is rotated.

v. Repeat (iii) and (iv) at incremental depths to cover the hole surface completely.
vi. Ream out marked holes as recommended by aircraft manufacturer and repeat test with an appropriate sized probe and reference piece hole.

Checking Heat Damaged Skin

The conductivity of aluminium alloy sheet will increase with exposure to elevated temperatures up to approximately 500 ^{o} c, and above this temperature obvious sign of damage such as melted or charred metal become apparent. Tests conducted on the surrounding material will show the extent of the area in which the metal is below strength requirements and must be replaced.

The acceptable range of conductivity readings depends on the type of material and its heat treatment condition, and these readings may be stipulated in the appropriate Maintenance Manual. As a rough guide, the conductivity of unclad 7075-t6 material is 31 to 35 % IACS, but the important reading in relation to heat damage is the change in conductivity between sound and defective material

A conductivity meter should be used for this test, and this will normally be an impedance change instrument, with a meter and separate scale graduated in percentage IACS. This equipment is supplied with a surface probe and two test samples, one of high purity copper (with high conductivity) and the other a material of low conductivity, for calibration purposes.

The following procedure should be followed when carrying out the test:-

i. Thoroughly clean area to be inspected.
ii. Calibrate instrument in accordance with the manufacturer's instructions.
iii. Place probe on sound skin of similar material and thickness and remote from the heat affected zone, and adjust scale until meter is zeroed. Compare this reading with the expected conductivity.
iv. Check conductivity all round the affected area, noting any meter deflection, and marking the skin accordingly. By this means a demarcation line can be drawn round the damaged area, and material removed up to this line.

Detection of Corrosion

Corrosion on hidden surfaces can be detected by eddy current methods using phase sensitive equipment. If a reading at the normal thickness of a sheet material can be taken, since corrosion reduces the thickness of a sheet, when the probe is over corroded area of a different reading will be obtained. The equipment can be set up by noting the readings obtained from a sound material of, say, 90% of the thickness of the test specimen, and a rough estimation of the volume of corrosion beneath the probe can be obtained during a test.

Equipment is available which is specially designed for thickness measurement having a meter graduated in appropriate units, but any equipment operating at a frequency which would give a penetration depth at least equal to the sheet thickness could be used to give an indication of the presence of corrosion. Equipment designed for detecting surface cracks and operating at very high frequency would be unsuitable.

Care is necessary when checking for corrosion to ensure that underlying structure (stringers, frames, etc.), chemically contoured areas, and loose debris, do not cause misinterpretation of results.

Material Sorting

Provided that a known sample is available, eddy current equipment can be used to ensure that a batch of materials is correctly identified, or that a component is made from the correct material. Simple impedance equipment could be used for coarse sorting, but in order to differentiate between materials closely related in composition, equipment with phase sensing circuits is necessary. By placing the known sample in an encircling coil the characteristic trace of that material can be displayed on an oscilloscope and unknown samples accepted or rejected by comparison.

Coating Thickness Measurement

The thickness of conducting or non-conducting coatings on ferrous or non-ferrous bases can be measured using basic eddy current methods; although measurement becomes difficult where the conductivity of the coating and base metal are similar. It is possible to utilise crack detection equipment for measuring thick coatings, by comparing the readings obtained form the test specimen with the lift-off effect obtained when the probe is placed on slips of non-conducting material (e.g. mica) of known thickness. When measuring very thin coatings however (i.e. less than 0.12 mm (0.005 inch)), it is recommended that equipment designed specially for coating thickness measurement should be used.

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CHAPTER-35
ABNORMAL EVENTS

LIGHTNING STRIKES

Lightning is a discharge of electricity between highly charged cloud formations, or between a charged cloud and the ground. If an aircraft is flying, or on the ground in the vicinity of such a cloud formation, the discharge may strike the aircraft and result in very high voltage and currents passing through the structure. All separate parts of an aircraft are electrically bonded together to conduct a lighting strike away from areas where damage may hazard the aircraft, e.g. fuel tanks or flying controls, and during manufacture special precautions are often taken with non-metallic components such as wing tips, external fuel tanks and nose cones.

Lightning strikes may have two effects on an aircraft; strike damage where the discharge enters the aircraft, and static discharge damage subsequent to the strike. Strike damage is generally found at the wing tips, leading edges of wings and tail unit, and at the fuselage nose, but on some aircraft types other areas may be particularly susceptible, and this information should be obtained from the appropriate Maintenance Manual. Static discharge damage will usually be found at wing tips, trailing edges and antennae.

Strike damage is usually in the form of small circular holes in the exterior skin, either in clusters or spread out over a wide area, and often accompanied by burning or discoloration, blisters on radomes and cracks in glass fibre. Static discharge damage is usually in the form of local pitting and burning at trailing edges.

Structural Inspection

Since both lightning and turbulence occur in thunderstorms, an inspection for lightning damage will often coincide with an inspection following reported flight severe turbulence. The areas mentioned above should be examined for signs of strike or static discharge damage, and bonding strips and static discharge wicks should be examined for burning and disintegration. All control surfaces, including flaps, spoilers and tabs, should be inspected for damage at their hinge bearings; unsatisfactory bonding may have allowed static discharge and tracking across the bearings, unsatisfactory bonding may have allowed static discharge and tracking across the bearings, causing burning, break-up or seizure. A check for roughness and resistance to movement at each bearing, break in or seizure. A check for roughness and resistance to movement at each bearing, will usually indicate damage at such points. In addition, the following inspections should be carried out:-

i) Examine engine cowlings and engine for signs of burning or pitting. If a lightning strike is evident, tracking through the bearings may have occurred, and some manufacturers recommend that the oil filters and chip detectors should be examined for signs of contamination; this check should be repeated periodically for a specified number of running hours after the occurrence.

ii) Examine the fuselage skin and rivets generally, for burning or pitting.

iii) If the landing gears was extended when the lightning strike occurred, examine the lower parts of the gear for static discharge damage. Check for residual magnetism and demagnetize where necessary.

The inspections outlined in above paragraphs should be followed by functional checks of the radio and radar equipment, instruments, compasses, electrical circuit, and flying controls, in accordance with the relevant chapters of the approved Maintenance Manual. On some aircraft a bonding resistance check on radomes may also be specified.

HEAVY LANDING CHECKS

Wings

i) Examine the upper and lower skin surfaces for signs of wrinkling, pulled rivets, cracks and movement at skin joints. Inertial loading on the wing will normally result in wrinkles on the lower surface and cracks or rivet damage on the upper surface, but stress induced by wing-mounted engines may result in wrinkles on either surface.

ii) Check for signs of fuel leaks, and seepage from integral tanks.

iii) Examine root end fillets for cracks and signs of movement.

iv) Check flying controls for freedom of movement; power controlled systems should be checked with the power off.

v) Check balance weights, powered flying control unit mountings and control surface hinges for cracks, and the control surfaces for cracks or buckling.

vi) Where possible, check the wing spars for distortion and cracks.

Fuselage

i) Examine fuselage skin for wrinkling or other damage, particularly at skin joints and adjacent to landing gear attachments and centre section.

ii) Examine pressure bulkheads for distortion and cracks.

iii) Examine, for distortion and cracks, the supporting structure for heavy components such as galley modules, batteries, water tanks, fire extinguishers, auxiliary power units, etc.

iv) Check that the inertia switches for the fire extinguishers, emergency lights, etc., have not tripped.

v) Check instruments and instrument panels for damage and security.

vi) Check ducts and system pipes for damage, security, and fluid leaks.

vii) Check fit of access doors, emergency exits, etc., and surrounding areas for distortion and cracks.

viii) Check loading and unloading operation of cargo containers, and condition of cargo restraint system.

Inspection of Damaged Areas

If any superficial damage is found during the preliminary inspection, the supporting structure should be examined for distortion, loose rivets, cracks or other damage, and rigging and symmetry checks should be carried out to ascertain whether the damage has twisted or warped the main airframe structure. Where flying controls pass through supporting structure, cable tensions should be checked. On pressurised aircraft a cabin leak rate check should be carried out to ascertain whether the sealing of the fuselage is satisfactory and unaffected by the damage.

Empennage

i) Check flying controls for freedom of movement.

ii) Examine rudder and elevator hinges for cracks, and control surfaces for cracks and distortion, particularly near balance weight fittings.

iii) Examine tail plane attachments and fairings, screw jacks and mountings, for distortion and signs of movement.

Landing Gear

i) Examine tyres for excessive creep, flats, bulges, cuts pressure loss, and excessive growth.

ii) Examine wheels and brakes for cracks, other damage, and fluid leaks.

iii) Examine axles, struts and stays for distortion and other damage.

iv) Check shock struts for fluid leaks, scoring and abnormal extension.

v) Examine landing gear attachments for signs of cracks, damage or movement. In some instances this may require removal of certain bolts in critical locations, for a detailed magnetic crack detection test.

vi) Examine structure in the vicinity of the landing gear attachments for signs of cracks, distortion, movement of rivets or bolts, and fluid leakage.

vii) Examine doors and fairings for damage and distortion.

viii) Jack the aircraft and carry out retraction and nose wheel steering tests in accordance with the approved Maintenance Manual; check for correct operation of locks and warning lights, clearances in wheel bays, fit of doors, and signs of fluid leaks.

Engines nacell

i) Check engine controls for full and free movement.

ii) Examine engine mountings and pylons for damage and distortion. Tubular members should be checked for bow greater than prescribed limits, and cracks at welds. Mounting bolts and attachments should be checked for damage and evidence of movement.

iii) On turbine engines check freedom of rotating assemblies, and on piston engines check freedom of rotation with sparking plugs removed.

iv) Examine engine cowlings for wrinkling and distortion and integrity of fasteners.

v) Check for oil, fuel and hydraulic fluid leaks.

vi) Where applicable, check the propeller shaft for shock loading in accordance with the procedure in the Maintenance Manual.

Engine Runs

Provided that no major structural distortion has been found, engine runs should be carried out in accordance with the appropriate Maintenance Manual, in order to establish the satisfactory operation of all systems and controls. A general check for system leaks should be carried out while the engines are running, and on turbine the run-down time should be checked.

FLIGHT THROUGH TURBULENCE

Airframe structural Inspection

When an aircraft encounters a gust condition, the airload on the wings exceeds the normal wingload supporting the aircraft weight. The gust tends to accelerate the aircraft while its inertia acts to resist this change. If the combination of gust velocity and airspeed is too severe, the induced stress can cause structural damage.

Inspect all spar webs from the fuselage to the tip, through the inspection doors and other accessible openings. Check for buckling, in the area around the naceles and in the nacelle skin, particularly at the wing leading edge.

An aircraft landing gear is designed to withstand landing at a particular aircraft weight and vertical descent velocity (the maximum being 10ft/sec at design landing weight). If either of these parameters is exceeded during a landing, then it is probable that some damage may be caused to the landing gear or its supporting structure. Over stressing may also be caused by landing with drift or landing in an abnormal attitude, e.g. nose or tail wheel striking the runway before the main wheels.

Some aircraft are fitted with heavy landing indicators, which give a visual indication that specified ‘g’ forces have been exceeded, but in all cases of suspected heavy landings, the flight crew should be consulted for details of aircraft weight, fuel distribution, landing conditions, and whether any noises indicative of structural failure were heard.

The damage which may be expected following a heavy landing would normally be concentrated around the landing gear, its supporting structure in the wings or fuselage, the wing and tailplane attachments and the engine mountings. Secondary damage may be found on the fuselage upper and lower skin and structure, and wing skin and structure, depending on the configuration and loading of the aircraft. On some aircraft it is specified that, it no damage is found in the primary areas, the secondary areas need not be inspected; but if damage is found in the primary areas, then the inspection must be continued.

Upper & lower surface of wings

A special inspection should be performed after a flight through severe turbulence. Emphasis should be placed upon inspecting the upper and lower wing surfaces for excessive buckles or wrinkles with permanent set. Where wrinkles have occurred, remove a few rivets and examine the rivet shanks to determine if the rivets have sheared or were highly loaded in shear.

Fuel leak

Check for fuel leaks. Any sizeable fuel leak is an indication that an area may have received overloads which have broken the sealant and opened the seams.

If the landing gear was lowered during a period of severe turbulence, inspect the surrounding surfaces carefully for loose rivets, cracks, or buckling. The interior of the wheel well may give further indications of excessive gust conditions.

Bulk head

Inspect Bulkhead for any crack , damage or distortion.

Top and bottom fuselage

Inspect the top and bottom fuselage skin. An excessive bending moment may have left wrinkles of a diagonal nature in these areas.

Inspect the surface of the empennage for wrinkles, buckling, or sheared attachments, Also inspect the area of attachment of the empennage to the fuselage.

The above inspections cover the critical areas. If excessive damage is noted in any of the areas mentioned, the inspection should be continued until all damage is detected.

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CHAPTER-36
MAINTENANCE PROCEDURE

MAINTENANCE PLANING
The effectiveness of an inspection system depends to a great extents on how well the inspection and maintenance has been planed, for maintaining an aircraft in airworthiness condition it is necessary to subject an aircraft and components to approved maintenance schedule inspection, periodic inspection as approved by D.G.C.A.

Maintenance
Action or set of actions including inspection, servicing, maintenance and determination of condition required to active a desired aim which restores an aircraft parts equipments in serviceable and airworthiness condition.

Objective
To ensure continuous airworthiness of an aircraft

Maintenance Programme
It is a document which describes the specific schedule maintenance task, their frequency of completion and related procedure such as reliability programme necessary for safe operation.

Reliability Monitoring
All organisations will create a 'Reliability Monitoring Unit' (RMU) in the Quality Control Division which will be entrusted with the responsibility of gathering information from various sources for analysis in order to determine reliability trends of systems/Components/Structure of the aircraft operated by them.

The Reliability monitoring Unit will, in coordination with specialists, develop and introduce remedial measures to restore normal established trends within acceptable limits of performance.

Defect Monitoring/ Data Collection
Data (or more realistically, collected information) will vary in type according to the needs of each Programme. For example, those parts of the Programme based on data in respect of systems and subsystems will utilise inputs from reports by pilots, reports on engine unscheduled shut-downs and also, perhaps, reports on mechanical delays and cancellations. Those parts of the Programme based on data in respect of components will generally rely upon inputs from reports on components unscheduled removals and on workshop reports. Some of the larger Programmes embrace both 'systems' and 'component' based data inputs in the fullest of detail.

The principle behind the data collection process is that the information to be collected has to be adequate to ensure that any adverse defect rate, trend, or apparent reduction in failure resistance, is quickly identified for specialised attention. Some aircraft systems will function acceptably after specific component or sub-system failures; reports on such systems will, nevertheless, act as a source of data which may be used as the basis of action either to prevent the recurrence of such failures, or to control the failure rates.

Typical sources of data are reports on delays, in-flight defects, authorised operations with known defects (i.e. equipment in operative at a level compatible with the Minimum Equipment List), flight incidents, air turn-backs; the findings of line, hangar and workshop investigations. Other typical sources include reports resulting from On-Condition tasks and in-flight monitoring (Airborne Integrated Data Systems); Service Bulletins; other Operator's experience, etc. The choice of a source of data, and the processes for data collection, sifting and presentation (either as individual events or as rates of occurrence) should be such as to permit adequate condition assessment to be made relative both to the individual event and to any trend.

Pilot Reports
(a) Pilot Reports, more usually known as "Pireps", are reports of occurrences and malfunctions entered in the aircraft Technical Log by the flight crew for each flight. Pireps are one of the most significant sources of information, since they are a result of operational monitoring by the crew and are thus a direct indication of aircraft reliability as experienced by the flight crew.

(b) It is usual for the Technical Log entries to be routed to the Reliability Section (or Engineer/ Co-ordinator) at the end of each day, or at some other agreed interval, whereupon each entry is extracted and recorded as a count against the appropriate system. Pireps are thus monitored on a continuous basis, and at the end of the prescribed reporting period are calculated to a set base as a reliability statistic for comparison with the established Alert Levels e.g.Pirep Rate per 1,000 hr, Number of Pireps per 100 departures, etc.

(c) Engine performance monitoring can also be covered by the Pirep process in a Programme. Flight crew monitoring of engine operating conditions is, in many Programmes, a source of data in the same way as reports on system malfunctions.

Engine Unscheduled Shut-downs

(a) These are crew reports of engine shutdowns and usually include details of the indications and symptoms prior to shut-down. When analysed, these reports provide an overall measure of propulsion system reliability, particularly when coupled with the investigations and records of engine unscheduled removals.

(b) As with Pireps, reports on engine unscheduled shut-downs are calculated to a set base and produced as a reliability statistic at the end of each reporting period. The causes of shut-downs are investigated on a continuing basis, and the findings are routed via the Reliability Section to the Power-Plant Development Engineer.

Aircraft Mechanical Delays and Cancellations

(a) These are normally daily reports, made by the Operator's line maintenance staff, of delays and cancellations resulting from mechanical defects. Normally each report gives the cause of delay and clearly identifies the system or component in which the effect occurred. The details of any corrective action taken and the period of the delay are also included.

(b) The reports are monitored by the Reliability Section and are classified (usually in Air Transport Association of America, Specification 100 (ATA 100) Chapter sequence), recorded and passed to the appropriate engineering staffs for analysis. At prescribed periods, recorded delays and cancellations for each system are plotted, usually as events per 100 departures.

Component Unscheduled Removals and Confirmed Failures

At the end of the prescribed reporting period the unscheduled removals and/or confirmed failure rates for each component are calculated to a base of 1,000 hours flying, or, where relevant, to some other base related to component running hours, cycles, landings, etc.

NOTE: Reports on engine unscheduled removals, as with reports on engine performance monitoring, are also a source of data and are part of the Programme.

(a) **Component Unscheduled Removals.** Every component unscheduled removal is reported to the section which monitors reliability (the 'Reliability Section') and will normally include the following information.

i) Identification of component.
ii) Precise reason for removal.
iii) Aircraft registration and component location.
iv) Date and airframe hours/ running hours/ landings, etc. at removal.
v) Component hours since new/ repair/overhaul/ calibration.

Completed reports are routed daily to the Reliability Section for recording and for continuous monitoring for significant trends and arisings. Components exhibiting abnormal behavior patterns are brought to the attention of the engineering staff responsible, so that detailed investigations may be made and corrective action may be taken.

Component Confirmed Failures

(i) With the exception of self-evident cases, each unscheduled removal report is followed up by a workshop report in which the reported malfunction or defect is confirmed or denied. The report is routed to the Reliability Section. Workshop reports may be compiled from an Operator's own 'in-house' findings and/or from details supplied by component repair/overhaul contractors.

(ii) Where an unscheduled removal is justified the workshop reports will normally include details of the cause of the malfunction or defect, the corrective action taken and, where relevant, a list of replacement items. Many Programmes utilise the same type of report to highlight structural and general aircraft defects found during routine maintenance checks.

Miscellaneous Reports

Dependent upon the formation of individual Programmes, a variety of additional reports may be produced on a routine or non-routine basis. Such reports could range from formal minutes of reliability meetings to reports on the sample stripping of components, and also include special reports which have been requested during the investigation of any item which has been highlighted by the Programme displays and reports.

Statistical Measurement

To assist in the assessment of reliability, Alert Levels are established for the Items which are to be controlled by the Programme. The most commonly used data and units of measurement (Pireps per1,000 hours, Component Removals/ Failures per 1,000 hours. Delays/Cancellations per 100 departures, etc.) have been mentioned in previous paragraph. Too much importance should not be placed upon the choice of units of measurement. Provided that they are constant throughout the time the Programme runs and are appropriate to the type and frequency of the event. The choice of units of measurement will depend on the type of operation, the preference of the Operator and those required by the equipment manufacturer.

Reliability Alert Levels

A reliability alert level (or equivalent title, e.g. Performance Standard, Control Level, Reliability Index, Upper Limit) hereinafter referred to as an 'Alert Level', is purely an 'indicator' which when exceeded indicates that there has been an apparent deterioration in the normal behaviour pattern of the Item with which it is associated. When an Alert Level is exceeded the appropriate action has to be taken. It is important to realise that Alert Levels are not minimum acceptable airworthiness levels. When Alert Levels are based on a representative period of safe operation (during which Alert Levels are based on a representative period of safe operation (during which failures may well have occurred) they may be considered as a form of protection against erosion of the design aims of the aircraft in terms of system function availability. In the case of a system designed to a multiple Redundancy philosophy it has been a common misunderstanding that, as Redundancy exists, an increase in failure rate can always be tolerated without corrective action being taken.

Alert levels can range from 0.00 failure rate per 1,000 hours both for important components and, where failures in service have been extremely rare, to perhaps as many as 70 Pireps per 1,000 hours on a system basis for ATA 100 Equipment/ Furnishings, or for 20 removals of passenger entertainment units in a like period.

Workshop Reports

A summary of the results of defect investigations, based on the Workshop Reports is normally produced by component type for assessment by the Reliability Committee.

Problem Identification

Having collected the information, and having presented it in a timely manner it should now be possible to identify any problems and to assess the necessity for corrective actions. The information, having been sifted and categorised (normally in ATA100 Chapter order) as individual events and/or rates of occurrence, can be analysed using engineering and/or statistical methods. The analysis can be made at various stages in the handling of the data to differing degrees. Initially, reports on flight defects, delay causes, engine unscheduled shut-downs, workshop and hanger any immediate action is desirable. This initial individual analysis will highlight any need for immediate action is desirable. This initial individually to see if any immediate action is desirable. This initial individual analysis will highlight any need for immediate short term actions, e.g. the preparation of Mandatory Occurrence Reports, safety reports, fleet campaigns, with the long term corrective actions following after the later, collective, stages of analysis.

The Reliability monitoring unit will gather information from both scheduled maintenance and Un-scheduled Maintenance for Reliability control. The likely primary sources of information will be:

(i) Unscheduled removals.
(ii) Confirmed failures.
(iii) Deficiencies observed and corrected during scheduled services but otherwise nor reportable.
(iv) Pilot reports.
(v) Sampling inspections.
(vi) Shop findings/Bench check reports.

Corrective Action (Remedial Measures)

Corrective action taken to improve the reliability of systems and components, and ultimately that of the fleet, will vary considerably and may typically include one or more of the following:

(a) Changes in operational procedures or improvements in fault-finding techniques.
(b) Changes to the scope and frequency of maintenance processes which may involve servicing and inspection, system Tests or Checks, Overhaul, Partial Overhaul or bench testing or the introduction or variation of time limits, etc.
(c) Modification action.
(d) Non-routine inspections or adjustment.
(e) Change of materials, fuels and lubricant.
(f) Use of different repair agencies.
(g) Use of different sources of spares.
(h) Variations of storage conditions.
(i) Improvements in standards of staff training and technical literature.
(j) Amendments to the policy/ procedures of the programme.

Changes in Maintenance Control Reliability Method:

The programme furnished by the operator will include a procedure explaining in detail any change in the system which needs prior approval of the Airworthiness Authorities.

Following changes will require prior approval of DGCA:-

(a) Change in policy regarding method of computing performance number (Alert Value).
(b) Any upward change in TBO or 'service-time-increase' in schedule.
(c) Change in displays that would alter the type of information or frequency of information.
(d) Transfer of system/component from one type of control to other method of control.
(e) Data collection system.
(f) Data analysis method.

Definitions for the purpose of programme

Each Reliability Programme submitted by the operator to DGCA will contain definitions of the significant terms used therein. The definitions should include, but not limited to, "System Failure", "Component Failure", "Functional Check", "Unscheduled Removals" and any other terms which are basic to the particular system.

INSPECTION (Quality Management)

With the major issues of airworthiness and the economical allocation of vast sums of money being involved, it is essential that Quality Control should be applied as an overall control of the Maintenance Programme. Each Programme will describe the managerial responsibilities and procedures for continuous monitoring of the Programme at progressive and fixed periods. Reviews, to assess the effectiveness of the Programme, will also be prescribed.

There are various methods, both engineering and statistical, by which the effectiveness of the Programme may be evaluated, and these include:

(a) An assessment of the Programme Document and any subsequent amendment (e.g. with a view to possible extra activities).

(b) Surveillance of the Programme activities by the Quality Management Departments.

(c) Review by the Programme Control Committee to confirm that corrective action taken are correctly related to the performance trends and to the reports produced.
NOTE: Generally there would be two levels of committee activity, functional and managerial; the functional activity covering the practicality of corrective actions, and the managerial activity covering the overall Quality management of the Programme.

Repair

The restoration of an Aeronautical product to an airworthiness condition to ensure that aircraft continues to comply with the design aspects keeping in mined the cost factor. Repair is an operation that restores an item to a condition of practical operation or to original condition, divided into two parts. Major repair & Minor repair by using, welding, machining electro plating, Bench test are some of the technique employed during repair.

Major Repair

Means a design change that is intended to restore an aeronautical product to an worthiness condition is one if carried out improperly might appreciably effect weight and balance, structural strength performance, power plant operation, Flt. Characteristics or other airworthiness factors. It is also a repair that can not be performed by using elementary operations or that will be embodied in the product using non standard practices.

Minor Repair

A repair other than major repair which is not going to effect performance and air worthiness condition of the aircraft.

HARD TIME, ON CONDITION, CONDITION MONITORING

The DGCA recognises three primary maintenance processes. They are Hard Time, On-Condition and Condition Monitoring. In general terms, Hard Time and On-condition both involve actions directly concerned with preventing failure, whereas Condition Monitoring does not. However the Condition Monitoring process is such that any need for subsequent preventative actions would be generated from the process.

The Process

1. **Hard Time** : This is a preventative process in which known deterioration of an Item is limited to an acceptable level by the maintenance actions which are carried out at periods related to time in service (e.g. calendar time, number of cycles, number of landings). The prescribed actions normally include Servicing and such other actions as Overhaul, Partial Overhaul, Replacement, in accordance with instructions in the relevant manuals so that the Item concerned is either replaced or restored to such a condition that it can be released for service for a further specified period.

2. **On Condition** : This also is a preventative process but one in which the Item is inspected or tested, at specified periods, to an appropriate standard in order to determine whether it can continue in service (such an inspection or test may reveal a need for servicing actions). The fundamental purpose of On-Condition is to remove an Item before its failure in service. It is not a philosophy of 'fit until failure' or 'fit and forget it'.

3. **Condition Monitoring** : This is not a preventative process, having neither Hard Time nor On-Condition elements, but one in which information on Items gained from operational experience is collected, analysed and interpreted on a continuing basis as a means of implementing corrective procedures.

Where a Maintenance Steering Group Logic Analysis has not been applied to a particular aircraft to establish and allocate the primary maintenance processes for each item, the considerations of (a), (b) and (c) will be applied separately to all items to determine the acceptability of the primary maintenance process.

(a) Hard Time

(i) Where the failure of the item has a direct adverse effect on airworthiness and where evidence indicates that the Item is subject to wear or deterioration.

(ii) Where there is a Hidden Function which cannot be checked with the Item in-situ.
(iii)Where wear or deterioration exists to such an extent as to make a time limit economically desirable.
(iv) Where component condition or 'life' progression sampling is practised.
(v) Where limitations are prescribed in a Manufacturer's Warranty.

(b) On-Condition

Where an inspection or test of an Item to a prescribed standard (frequently in-situ) will determine the extent of deterioration, and hence the 'condition', i.e. any reduction in failure resistance.

(c) Condition Monitoring

Where a failure of an Item does not have a direct adverse effect on operating safety, and where (a) and (b) are not prescribed and no adverse age reliability relationship has been identified as the result of analysis of the data arising from a formalised monitoring procedure or programme.

CONDITION MONITORED MAINTENANCE

Introduction

Condition Monitored Maintenance, as a programme, is the formalised application of the maintenance processes Hard Time, On-Condition and Condition Monitoring to specific Items as prescribed in the Approved Maintenance Schedule. The controlling activity of Condition Monitored Maintenance is Condition Monitoring irrespective to whether Condition Monitoring is prescribed as a primary maintenance process in the Approved Maintenance Schedule or not. Condition Monitoring is repetitive and continuous, the key factor in its use being the introduction of aircraft embodying failure tolerant designs, which allow for replacement of some traditional failure preventative maintenance techniques by non-preventative techniques. Condition Monitoring is not a relaxation of maintenance standards or of airworthiness control; it is , in fact, more demanding of both management and engineering capabilities than the traditional preventative maintenance approaches. Each Condition Monitored Maintenance Programme is required to be approved by the CAA.

Maintenance Activities

There are three types of maintenance activity:-

(a) Maintenance applied at specified periods of time regardless of condition at that time. The maintenance activity may be a periodic overhaul, a bearing change, re-work, repaint, calibration, lubrication, etc. These result from Hard time requirements.

(b) Periodic examinations, mostly at specified periods of time, but sometimes on an opportunity basis (e.g. when an Item is removed for access) to determine not only the extent of deterioration but also that the deterioration is within specified limits. These result from On-Condition requirements.

(c) Actions applied in response to the analysis of condition clues produced by monitoring in-flight, hangar, workshop and other types of condition information sources. These result from Condition Monitoring requirements.

Condition Monitoring uses data on failures as items of 'condition' information which are evaluated to establish a necessity for the production or variation of Hard Time and On-Condition requirements, or for other corrective actions to be prescribed. Failure rates and effects are analysed to establish the need for corrective actions. Condition Monitoring can be used in its own right to identify the effects of deterioration, in order that steps may be taken to maintain the level of reliability inherent in the design of the item. Although Condition Monitoring accepts that failures will occur, it is necessary to be selective in its application. The acceptance of failures may be governed by the relative unimportance of the function, or by the fact that the unction is safeguarded by system Redundancy.

Maintenance of a particular Item could will be some combination of the three primary maintenance processes (Hard Time, On-Condition and Condition Monitoring). There is no hierarchy of the three process; they are applied to the various Items according to need and feasibility. Maintenance Schedules which are based on the Maintenance Steering Group principles will have Hard Time, On-Condition, or Condition Monitoring specified as the primary maintenance process for specific systems and sub-systems as well as for individual Maintenance Significant Items. Condition Monitoring can, therefore, be the primary maintenance process prescribed for an item, in which case it has also to be used for controlling the availability of those functions which are not directly controlled by a prescribed On-Condition or Hard Time Process; this control is provided by the statistical reliability element of Condition Monitored Maintenance. Items for which Hard Time and On-Condition are prescribed may, however, have the statistical reliability element of Condition Monitoring Maintenance applied, not as a primary maintenance process, but as a form of Quality Surveillances.

Staggering the aircraft operation

The operation should be planned in such away that all Aircrafts should not fall due for servicing/maintenance/ component change at a time. Planing should be such that one Aircraft comes back from maintenance then other should be due. So that the operational requirement is not effected and Aircrafts are always available for operational requirement.

DISCUSSION ABOUT MODIFICATION

What is Modification

A modification may be regarded as a change or alteration accomplished through re work by removal or installation of an item of equipment or by the substitution of an item of equipment for another approved item of equipment where the Director general of Civil Aviation finds as a result of service experience or other wise an unsafe condition exists with respect to a design feature or characteristic of the type certificated aircraft, component/ item of equipment, he may issue a directive specifying condition and limitations including inspections for continued operation in aircraft or may altogether prohibit the use of the same till the unsafe condition has been corrected. When design changes are considered necessary the holder of the type certificate shall submit appropriate design changes for approval as the DGCA.

(1) Written approval of DGCA shall be obtained which has not been previously done.
(2) At an early stage of modification brief particulars must be furnished to DGCA.
(3) Proposed modification should be such that the design of the Aircraft, Components, equipments when modified, satisfies the requirements.
(4) Modification should be classified as minor/major

Minor Modification
Has no appreciable effect on weight and balance, structure strength, reliability, operational characteristics or other characteristics effecting the airworthiness of an aircraft.

Major Modification
Not classified as minor modification. The design office shall be so organised that each design and drawing shall bear a description ditto, drawing Number, issue number, date of issue.

Why Modification is needed
Where the Director General of Civil Aviation finds, as a result of service experience or otherwise that an unsafe condition exists with respect to a design feature or characteristic of the type certificated aircraft, component/item of equipment, he may issue a directive specifying conditions and limitations including inspections for continued operation in aircraft or may altogether prohibit the use of the same till the unsafe condition has been corrected. When design changes are considered necessary, the holder of the Type Certificate shall submit appropriate design changes for approval of the Director General of Civil Aviation.

Procedure of documentation
The written approval as D.G.C.A. shall be obtained for a modification which has not been previously investigated and approved. At an early stage of modification, brief particular must be furnished to the director general of Civil Aviation. The proposed modification must be such that the design of the Aircraft, Component/equipment when modified, satisfies the requirements that were enforced at the time the type approval was originally granted, or such other requirement as the Director General of Civil Aviation may notify at that time modification must be classified as minor or major.

To meet operational requirements and to remove existing defect
The design organisation of the applicant should be sufficiently competent technically to undertake work on design of aircraft component/item of equipment, must be familiar with the relevant requirements and procedures and must maintain the highest standard as it may only be possible for the Director General of Civil Aviation to carry out percentage checks on reports and calculations submitted. The qualifications and experience of the senior staff of the design organisation shall be adequate to conduct the work involved in establishing the compliance with the requirements and ensure the good judgment is exercised with full appreciation of current aeronautical practice in design matters, whether specifically covered by the requirements or not. The design office shall be so organised that all calculations and drawings on which the airworthiness of the aircraft component/item of equipment depends are independently checked for numerical accuracy and validity of assumptions. Each design drawing shall bear a description title, drawing number, issue number and date of issue. All alterations to the design drawings shall be made in accordance with a drawing amendment system to ensure that the design records are suitably amended. If system to ensure that the design records are suitably amended. If an alteration is made to a drawing, a new issue number and date shall immediately be allocated to the drawing irrespective of whether the alteration is permanent or experimental. The applicant shall provide facilities of access to approved facilities or for making such tests as are necessary to establish compliance with the requirements. Design records shall be such that the proper correlation of drawings and maintenance with the design records is ensured. It is emphasized that the applicant is in a large measure, responsible for ensuring compliance with the requirements. The Director General of Civil Aviation would, however, exercise the right to check some or all technical reports including all points of doubt and to witness all important tests.

Completion & recording
All modification must be recorded in the appropriate log book and also when required in the modification record book, quoting the title and the authorisation. The letter can take the form of an Airworthiness Approval Note No. Issued by D.G.C.A. with reference No. an alert service bulletin, service bulletin or other document issued by an organisation taking design responsibility for modification. All supporting documents such as drawings, supplement type certificate etc. should be listed.

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CHAPTER-37
STORES PROCEDURES

GENERAL REQUIREMENT & CONDITION

The conditions of storage of aircraft supplies are important. The premises should be clean, well ventilated and maintained at an even dry temperature to minimize the effects of condensation. In many instances the manufacturer will specify the temperature and relative humidity in which the products should be stored. To ensure that these conditions are maintained within the specified range, instruments are used which measure the temperature and relative humidity of the store room.

Temperature and Relative Humidity

When required, the temperature and humidity should be checked at regular intervals by means of a hygrometer which measures the amount of humidity in the atmosphere. The wall-type of hygrometer is normally used and consists of wet and dry 'bulbs'; the dry bulb records the actual temperature, and a comparison between this reading and that registered by the wet bulb, when read in conjunction with a table, will indicate the percentage of relative humidity present in the atmosphere.

Protective Materials for Storage Purposes

Vapour Phase Inhibitor (VPI).

This is a method of protection against corrosion often used for stored articles made of ferrous metals.

(a) VPI protects by its vapour, which entirely covers any article in an enclosed space. Direct contact of the solid VPI with the metal is not required. Although moisture and oxygen are necessary for corrosion to take place, VPI does not react with or remove either of them, but operates by inhibiting their corrosive action.

(b) The method most commonly used is treated paper or board, the article to be protected being wrapped in paper which has been treated with VPI or, alternatively, enclosed in a box made of VPI treated board, or lined with treated paper.

NOTE: Protection of parts by the VPI process should only be used where it is approved by the manufacturer of the parts.

Protective Oils, Fluids, Compounds

Where oils, fluids or compounds are used as a temporary protection on metal articles, it should be ascertained that the material and the method of application is approved by the manufacturer of the article. Where protective oils, fluids or compounds have been used, deterioration of such fluids or compounds by handling can be minimised by wrapping in a nonabsorbent material (e.g. polythene, waxed paper), which will normally increase the life of such temporary protectives by inhibiting drying out. When parts or components are stored for long periods they should be inspected at intervals to ensure that the condition of the coating is satisfactory.

Use of Desiccants

The desiccants most commonly used in the protection of stored parts or components are silica-gel and activated alumina. Because of their hygroscopic nature desiccants are capable of absorbing moisture either inside a packaging container or a component, thereby preventing corrosion.

(a) Desiccants should be inspected and/or renewed at specified periods or when an air-tight container has been opened. It is important when inspecting or changing a desiccant that the prescribed method is used to avoid the entry of moisture into a dry container.

(b) **Tell-Tale Desiccant.** This indicating type of desiccant is prepared with a chemical which changes colour according to its moisture content. The following table gives guidance on the relative humidity of the surrounding air.

Colour	Surrounding Relative Humidity (%)	Moisture Content of Silica-Gel (%)
Deep Blue	0-5	0.2
Blue	10	5.5
Pale Blue	20	7.5
Pinkish Blue	30	12.0
Bluish Pink	40	20.2
Pink	50	27.0

(c) Silica-gel and activated alumina can be reactivated by a simple heat treatment process. The time and temperature required to effectively dry the desiccant should be verified with the manufacturer, but a general guide is 135ºC for at least two hours for silica-gel and 250ºC for four hours for activated alumina. The desiccant should then be placed in a sealed container until it has cooled, after which it should completely reactivated.

Racks and Bins

Open racks allow a free circulation of air and are preferable when the nature of the stock permits their use. The painted metal type of bins is more suitable than the wooden type, since with the latter there is a risk of corrosion due to mould or dampness. Polyethylene, rigid PVC, corrugated plastics or cardboard bins may also be used. Many moulded plastics bins can also be fitted with removable dividers which allow for the segregation of small parts whilst making economic use of the space.

Rotation of Issue

Methods of storage should be such that batches of materials or parts are issued in strict rotation, i.e. old should be issued before new stock. This is of particular importance for perishable goods, instruments and other components which have definite storage limiting periods.

Storage Limiting Period

The manufacturers of certain aircraft units impose storage limiting periods after which time they will not guarantee the efficient functioning of the equipment. On expiry of recommended storage periods the parts should be withdrawn from stores for checking or overhaul as recommended by the manufacturer. The effective storage limiting periods of some equipment may be considerably reduced if suitable conditions of storage are not provided. Therefore, storage limiting periods quoted by manufacturers can only be applicable if the prescribed conditions of storage are in operation, and users should develop suitable limiting periods from their own experience.

Flammable Materials

All materials of a flammable nature, such as dope, thinners, paint, etc., should be kept in a store isolated from the main buildings. The precautions to be taken vary with the quantity and volatility of the materials, and such stores should comply with the requirements of HM Inspector of Factories and the Area Fire Authority.

Issuance of certificate of Release (Stores)

1. All organisations approved or organisations otherwise required to have approved stores organisation, will issue aircraft parts/components or items of equipment form their stores under cover of Release Note for use by other organisations. The detailed working of such organisation is covered in CAR series 'E' part VII but the requirements regarding Release Note/Rejection Note are detailed below:
2. Release Notes shall be printed containing details given in the sample at Series 'E' Part VII and serially numbered. Distribution of copies of Release Note shall be made as follows:
   1st copy to the Consignee.
   2nd copy to the organisation's records.
3. Release Notes shall be signed by a person(s) approved by the Director General of Civil Aviation and whose name(s) is specified in the Organisation's Quality Control Manual or in the Terms of Approval.
4. Release Notes shall accompany the goods to which they relate or alternatively the Release Note and goods shall be identified in such a manner that they can be correlated with each other at any time.
   Note: The latter may be achieved by quoting in the space provided on the Release Note any identification markings on the aircraft goods such as their serial number or by forwarding with the goods and packing slip or label, identifying their related Release Note by Serial number.
5. If a Release Note is issued and subsequently varied or canceled both copies shall be suitably endorsed by the signatory.

RELEASE NOTE

Name of Approval Organisation..

Address...

....

Distribution

1st coy to consignee.
2nd copy to records.

RELEASE NOTE

Sl. No...
(to be included on document
at time of printing)

To M/s..Order No..

Advice No...

Indent Marks	Part No.	Description of goods	Qty	Spec No. drawing process	Batch or incoming Release Note	Remarks

This certificate is issued under approval granted by the director General of Civil Aviation and Aviation and it is certified that whole of the above mentioned material / good / components have been received from approved sources and are airworthy.

Signed ....

Quality Control Manager or
Release Note Signatory

Firms approval No...dated..

Category..............................F..................................... (Firm's Name)

REJECTION NOTE

Name of Approval Organisation...

Address...

Distribution :-
1st copy to supplier
2nd copy to record
3rd copy to Regional Airworthiness office

Serial No...

REJECTION NOTE

The undermentioned aircraft goods received under cover of:-

Release Note No...Date..

From...

have after inspection bee rejected for the reasons stated hereunder :-

Description of goods	Spec No. Drawing Pt No.	Qty. Received	Qty. Rejected	Reason for Rejection

The above goods are to be returned to the Supplier for Credit / replacement.

Quality Control Manager..
or
Release Note Signatory ....

(insert name of Organisation)

Certificate of maintenance and release

It is a certificate issued in respect of an aircraft, aircraft component/item of equipment by appropriately licensed AME, approved person or authorised person after carrying out servicing, modification, repairs, replacement, overhaul, process, treatment, test, operation and inspection, certifying that the work has been performed in accordance with the Airworthiness Requirements stipulated by DGCA.

Maintenance

Maintenance means performance of all work necessary for the purpose of ensuring that the aircraft is airworthy and safe for flight including servicing of aircraft and all modifications, repairs, replacements, overhaul, process, treatment, tests, operations and inspections of aircraft, aircraft component and item of equipment required for that purpose.

While carrying out inspection as per established inspection schedules or maintenance tasks the items of the inspection should be signed off simultaneously as the job progresses at each stage of inspection during maintenance, overhaul or repair. However, during transit/pre-flight inspections, an AME/ authorized person as in para 7 may be in possession of “inspection cards” to ensure that no items of inspection are missed, and a certificate to this effect will be made in the appropriate technical log book. The AME/authorized person shall explicitly certify on the satisfactory accomplishment of the pre-flight inspection giving reference to the inspection card. All entries made in the schedule/Taskcard or any additional sheet shall be in indelible ink. The inspection schedules/task cards should highlight the applicability of items of inspection, which may vary in different aircraft of the same type. Organisation using work order system to carryout and certify maintenance task may do so but maintain records of test values, physical parameters measured during maintenance with cross reference to the work order and vice versa.

All maintenance work other than routine, performed on the aircraft shall be entered in the additional/ off-job sheets and should be attached to the routine maintenance schedule/ Technical log book, for the sake of preservation. Additional/ off-job sheets so raised for recording additional work done should be serially numbered with cross reference to the maintenance task and vice versa to provide traceability.

Maintenance work carried out on the aircraft shall be certified in the relevant log books by appropriately licensed AMEs, approved or authorized persons who have issued Certificate of Release to Service for the work performed. However, DGCA may approve key persons for certification in the log books for the work done at outstations by others after satisfying that the work has been completed in accordance with the prescribed procedures.

Maintenance work on aircraft shall be recorded, signed and dated in the relevant log books within 48 hours of its completion by AMEs /Approved/ Authorised persons. If log books are not readily available because of aircraft being away from the base, then one copy of the log book entry should be kept with the Aircraft Technical log book. In such a case, a copy should be faxed/mailed to the main base so as to reach the person concerned with in the next calendar day for prompt entry in the log book.

Aircraft operated in an area where radio navigation/ communication equipment on board the aircraft is not required due to the absence of corresponding facilities on ground, need not be certified by an AME, provided the pilot is satisfied with the operation of the equipment. However, the onboard radio equipment shall be maintained and certified by an appropriately qualified AME or Approved Person immediately upon the aircraft returning to an area where corresponding ground facilities are available.

ISSUANCE OF CERTIFICATE OF RELEASE TO SERVICE

After satisfactory completion of each scheduled/ unscheduled maintenance work in accordance with applicable Maintenance data, a Certificate of Release to Service in respect of the aircraft (Annexure I) shall be issued by appropriately licensed AMEs, or authorized persons. The issuance of certificate of Release to Service implies that maintenance of the aircraft including that of its components and equipment has been carried out in accordance with applicable Maintenance data and it is airworthy in all respects and the aircraft is safe for release to service.

When extension maintenance is carried out on the aircraft, single certificate of release to service may be issued with a unique cross reference to the work package containing full details of maintenance carried out. Details of test values, physical measurements made while carrying out maintenance should be retained in the work package record.

An aircraft component, which has been maintained whilst off the aircraft, shall require the issuance of a certificate of release to service (Annexure II) for such maintenance. On installation of the component on an aircraft, a certificate of release to service in respect of the aircraft shall be required certifying its proper installation.

A certificate of release to service is necessary before flight, at the completion of any defect rectification, whilst the aircraft operates flight services between scheduled maintenance.

A certificate of Release to Service is not required to be issued after transit inspection.

Note: A certificate of release to service shall not be issued in the case of any non-compliance, known to the approved maintenance organization, which could seriously hazard flight safety.

CERTIFYING PERSONNEL

All aircraft maintenance work shall be carried out and certified by qualified licenced engineers/personnel approved by an AMO. An operator/AMO may approve following personnel to carryout and certify limited aircraft maintenance work subject to meeting specified requirements.

i. Persons holding a Basic AME Licence issued by DGCA in appropriate category
ii. Persons holding a valid CPL/ATPL on the type aircraft.
iii. Persons holding a valid AME Type Rated licence issued by DGCA on a similar aircraft, in appropriate category.

A certificate issued in respect of an aircraft or aircraft system or component or equipment by appropriately licensed AME, authorised or approved person, certifying that the same has been maintained, inspected and tested as per maintenance data and is airworthy in all respect and fit for release to service.

Note 1 Certificate of Release to service referred herein is synonymous to Certificate of Maintenance and Flight Release Certificate specified in Indian Aircraft Rules 1937 and in other sections/ series/ parts of Civil Aviation Requirements.

Not 2 AME used in this CAR refers to an appropriately qualified AME holding valid endorsement on the type of aircraft/ engine/ systems to be certified by him.

METHOD/PROCEDURE OF MAINTENANCE RELEASE CERTIFICATE

When issued must contain the following

1. Particular of work done or inspection completed.
2. The organisation and place at which work was done.
3. Details of aircrafts, types and registration number and mark.
4. The components used, their respective part number and Sl.no. recorded as applicable.

A copy of certificate of release to service shall be retained for one year an its associated maintenance record for 5 years from the date of certification.

CERTIFICATE OF RELEASE TO SERVICE

[APPROVED ORGANISATION NAME]

Organisation approval reference :

Certificate of release to service in accordance with CAR Section 2 Series 'F' Part VIII.

Aircraft:.. Type :............................Constructor No.:.........................

Registration No..has been maintained as specified in

Work Order :..

Brief description of work performed* :

Certifies that the work specified was carried out in accordance with CAR Section 2 Series 'F' Part VII and in respect of that work the aircraft is considered ready for release to service and therefore is in a condition for safe operation.

Certifying Staff (name):

(signature).

Licence / approval / authorization No.:

Location**:

Date:

* Reference to approved data used to perform the work

** Location where the work was performed

COMPONENT CERTIFICATE OF RELEASE TO SERVICE

1. **DGCA, India**	2. **AUTHORISED RELEASE CERTIFICATE** **CA-FORM ONE**	3. Form Tracking Number
4. Approved Organisation Name, Address and Approval Reference :		5. Work Order/ Contract/ Invoice

6. Item	7. Description	8. Part No.	9. Eligibility(*)	10. Quantity	11. Serial/ Batch No.	12. Status / Work

13. Remarks

14. Certifies that the item identified above were manufactured in conformity ☐ approved design date are in condition for safe operation' ☐ non-approved design data specified in Block 13		19. ☐ CAR 145.50 Release to Service ☐ CAR Section 2 Series 'E' Release to Service Certifies that unless otherwise specified in block 13, the work identified in block 12 and described in block 13, was accomplished in accordance with CAR 145/ Section 2 Series 'E' and in repect top that work the item are cosindered ready for release to service.	
15. Authorised Signature	16. Certificate/ Approval Ref no	20. Authorised Signature	21. Certificate/Approval Ref No.
17. Name	18. Date (D/M/Y)	22. Name	23. Date (D/M/Y)

(Strike off which ever is not applicable)

** Installer must cross-check eligibility with applicable technical data*

INTERFACE WITH AIRCRAFT OPERATION

It is a multisystem reliability in operation, where a system is backed up by an other system. In case of the failure of the system the other system will take over the operation automatically. For example as hydraulic system has system A, B, and stand by.

How to deal with operational requirement and trouble shooting

Trouble Shooting may be defined as the detection of fault indications and the isolation of the fault or faults causing the indication faulty. When the fault is isolated or identified the correction of fault is simply a matter of applying the correct procedures.

Manufacturers and operators work together to develop information and techniques regarding the operations and to establish the technique for trouble shooting. Numerous system have been developed by which faults are detected, analysed and corrected. The following procedure as an example may give some idea in trouble shooting chain.

Example chart

Trouble	Possible Cause	Correction
Motor Speed Slow	i. No lubrication	Lubricate as necessary
	ii. Applied Voltage low	Check Source of voltage
	iii. Motor wiring defective	Perform motor voltage continuity test for motor wiring

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CHAPTER-38
MAINTENANCE, INSPECTION/ QUALITY CONTROL/ QUALITYASSURANCE

QUALITY CONTROL AND ITS MANUAL

Quality Control

The approved organisation shall have a full fledged quality control department headed by a quality control manager, assisted by Deputy quality control manager (s) and adequate number of trained technical officers. Quality control is a procedure adopted by an A.M.O. in the light of manufacture requirement.

Quality control is a management system for programming and co-ordinating the on going quality and improvement efforts of the various groups in an organisation in accordance with the requirement of DGCA. Quality control has a cell of dedicated and well trained personnel to monitor the product and maintenance standard to ensure good maintenance practices stipulated by the aircraft rules and any instruction issued by D.G.C.A. time to time.

Quality Control Manual

It is a document, which describes the operator's procedures and practices in detail, the observance of which will ensure compliance with the airworthiness and safety requirements of DGCA and the manufacturer of the aircraft, aircraft component, item of equipment as per the scope of approval granted.

The Quality Control manual defines the quality policy followed by engineering department, adherence of which will ensure highest degree of airworthiness standards and safety of operations and forms the basis for maintenance approval. The quality control manual shall contain detailed policies, procedures, practices and quality control methods to be followed by organisations and its maintenance and inspection personnel in accordance with aircraft rules, also Civil aviation requirements, advisory circulars, manufacturers requirements and any other related requirements etc.

The purpose of this manual is to keep the inspection personnel posted with the inspection requirements, the procedure to be followed and their responsibilities to ensure the compliance of various requirements. The manual will be kept continuously updated by quality control department as and when there are changes to a manufacturers requirements, applicable aircraft rules, Civil aviation requirements and any instructions issued by D.G.C.A. from time to time.

QUALITY ASSURANCE AND ITS MANUAL

Quality Assurance

Quality assurance is a system to monitor, compliance with an adequacy of procedure as detailed in quality control manual to ensure safety and aircrafts safe maintenance practices.

It is an independent body with overall authority for the supervision of quality standards. The quality assurance department shall have a quality assurance programme to monitor adherance to maintenance programme laid down standards. Monitoring can be by means of spot checks and internal audit (surveillance) by the quality assurance team. Inter audit shall be carried out twice in a year and should meet the satisfaction of D.G.C.A.

Quality Assurance Manual

It is a document detailing the programme and procedures to monitor compliance with an adequacy of procedures as detailed in the quality Control Manual.

Practices and Methods

Quality Assurance unit which shall be an independent body with an overall authority for the supervision of quality standards, enabling the standards set by the system of quality control to be enforced. The Quality Assurance department shall have a quality assurance programme (internal audit system) to monitor adherence to the maintenance programme/laid down standards. Monitoring can be complied by means of spot checks and internal audit (surveillance carrying out internal audit should meet the satisfaction of DGCA. Internal audit shall be carried out twice a year covering the entire activities of the organization.

Quality Control Manager/ Dy. Quality Control Manager

A duly qualified and experienced person shall be nominated to function as **Quality Control Manager** who shall be approved by DGCA. Dy. QCM (s) who also requires to be approved by DGCA may assist the QCM. QCM/ Dy. QCM(s) shall be responsible to ensure that the organization is in compliance with CAR requirements. The QCM must be directly responsible to the Accountable Manager.

The scope of approval of an organization will depend on the capacity of the organization to undertake the job, the availability of equipment, and technical literature and will be commensurate with the qualification of Quality Control Manager and Dy. Quality Control Manager and the rest of the inspection staff employed on regular basis.

It shall be the responsibility of Quality Control Manager to seek prior concurrence of Regional Airworthiness Office before entrusting the work to temporarily hired AMEs.

Before approval is granted, the qualification and experience of QCM/Deputy QCM(s) will be examined by DGCA will satisfy itself about the suitability of QCM/Deputy QCM(s) by subjecting him to such examination as considered necessary. If the accepted QCM ceases to hold the position, the appointment of his successor must be simultaneously proposed by the approved organization for the approval by DGCA. QCM will have under his control number of approved organization for the approval by DGCA. QCM will have under his control number of approved personnel who will be experience knowledgeable and skill full in the specific activity of their respective scope of approval for the purpose of certification of the quantity of the product at various stage of manufacture/ maintenance/ inspection/ repair/ processing etc.

The QCM and Dy. QCM shall be individually/jointly fully conversant with the entire work covered by the scope of approval granted.

QCM and Dy QCM are nominated by the organisation and approved by D.G.C.A. after going through their qualification and experience. Following is their responsibilities

1. Monitoring of the effectiveness of the maintenance programme
2. Monitoring of continuous airworthiness/management activity
3. All the activity of maintenance is carried out by appropriate method.
4. QCM must be directly responsible to Accountable Manager.
5. Q.C.M. will have number of approved personnel who will be experience and knowledgeable/skillfull in the activity
6. The QCM/Dy QCM shall be fully conversant with entire work.

Quality System

Approved Organization shall establish:

(a) Procedure(s) acceptable to DGCA to ensure good maintenance practices and compliance with all relevant requirements specified in this CAR so that the tasks are accomplished and released to service after ensuring its Airworthiness.

(b) **Quality control cell**

QualityControl Cell to monitor

i) Product standards
ii) Compliance with adequate procedures to ensure good maintenance practices stipulated by the manufacturers and Aircraft Rules, applicable CARs and any instruction issued by DGCA from time to time.
iii) Airworthiness of aircraft, engine/ components

Quality assurance

Is a system to monitor compliance with an adequacy of procedures as detailed in Quality Control Manual to ensure safe maintenance practices and airworthiness of the aircraft

An approval maintenance organisation should have a quality assurance (Q.A.) system to monitor compliance with an adequacy of procedures as detailed in Quality Control Manual.

It is desired that suitable qualified an experienced person having adequate knowledge of the system and procedures policies and its implementation in the light of its approval granted by D.G.C.A. be appointed as Q.C.M.

Manuals

The organization seeking approval will prepare and submit to DGCA following manuals in triplicate:

a) Engineering Organization Manual;

b) Quality Control cum Assurance Manual (Operators Maintenance Control Manual)
c) Maintenance System Manual (Maintenance Organization's Procedures manual)
The manuals may be amalgamated (merged) provided details of aspects mentioned below under each of the manuals are not omitted

a) Engineering Organization Manual

This manual is not required to be approved by DGCA but its content may influence DGCA's decision concerning grant of approval.)

The manual shall contain:

i) A chart or description of the organization. The organizational chart must describe, at a minimum the management personnel and major functions. However, it is recommended that the chart cover the operator's entire organization.
ii) The duties and responsibilities and authority of management and inspection personnel.
iii) A general description of the facilities at every approved location.
iv) Scope of work authorized by DGCA.
v) A list of contract organizations. The list shall include organizations with whom the certificate holder has arranged to perform any of its maintenance, including a general description of the work and how quality is monitored.

b) Quality Control and Assurance Manual (Appendix G)

Regional Office shall approve Quality Control Manual in case of organizations based in the respective region, except for Indian Airlines, which will be approved by Headquarters.

Quality Control Manual - Volume 1

This Quality Control Manual defines the quality policy followed by Engg. Department, adherence of which will ensure highest degree of Airworthiness Standards and Safety of Operations and forms the basis for maintenance approval.

The Quality Control Manual shall contain detailed policies, procedures, practices and Quality Control methods to be followed by the organisation and its maintenance & inspection personnel in accordance with Aircraft Rules, AICs, Civil Aviation Requirements, Advisory Circulars, manufacturer requirement and any other related requirements etc. The purpose of this Manual is to keep the Inspection personnel posted with the Inspection requirements, the procedures to be followed and their responsibilities to ensure the compliance of various requirements.

This Manual is a dynamic document and will be kept continuously updated by the Quality Control Department as and when there are changes to manufacturers requirements, applicable Aircraft Rules. Civil Aviation Requirements and any instructions issued by DGCA from time to time. All pages of the Quality Control Manual shall be approved and stamped by DGCA. Similarly any amendments to the manual will be incorporated only after approval by DGCA.

Quality Assurance Manual - Volume II

This manual need not be approved by DGCA but the contents of this manual shall be in accordance with the Appendix enclosed.

An approved maintenance organization should establish a Quality Assurance System to monitor compliance with and adequacy of procedures as detailed in the Quality Control Manual to ensure safe maintenance practices and airworthiness of the aircraft.

The operator shall prepare a Quality Assurance Manual detailing the programme and procedures.

The Quality Assurance manual shall define the qualification and experience, duties and responsibilities of the Quality Assurance personnel. It is desired that the QA persons should be highly experienced and have the rating/ approval in the area of their work. They should be free from certification duties so that their decisions are not influenced by production/ certification considerations. The Quality Assurance personnel shall give feed back to Quality Assurance manager who in turn shall directly report to the Accountable Manager to ensure corrective action as necessary.

Quality Control System Procedure

Approval organisation shall have procedure(s) acceptable to D.G.C.A. to ensure good maintenance practices and compliance with all relevant requirements so that the task are accomplished and released to service after ensuring its airworthiness, must be compliance with adequate procedures, to ensure good maintenance practices stipulated by the manufacturers and Air Craft rules and any instruction issued by DGCA from time to time.

ONTHESPOTCHECK

Quality Assurance unit which shall be an independent body with an overall authority for the supervision of quality standards, enabling the standards set by the system of quality control to be enforced. The Quality Assurance department shall have a quality assurance programme (internal audit system) to monitor adherence to the maintenance programme/laid down standards. Monitoring can be complied by means of spot checks and internal audit (surveillance carrying out internal audit should meet the satisfaction of DGCA. Internal audit shall be carried out twice a year covering the entire activities of the organization.

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CHAPTER-39
ADDITIONAL MAINTENANCE PROCEDURES

PROCEDURE

To ensure continued airworthiness of the aircraft, owners/operators are required to comply with the Service Bulletins (SBs) requiring structural inspection of specific areas at certain intervals, Supplemental Inspection Document (SSID), Aircraft Repair and Modification Programme, Corrosion Prevention and Control Programme (CPCP), Repair Assessment Programme (RAP), etc.

DGCA at times declares mandatory the above inspections for compliance by owners/operators for continued airworthiness of the aircraft.

To ensure continued structural integrity of all aircraft including private aircraft, which have crossed 20 years, the following procedures is required to be followed:

a) The C of A be renewed every six months as against normal validity of twelve months. Test flight shall be carried out for the purpose of renewal of C of A as laid down in CAR Section 2, Series 'T' Part II.

b) The items of structural inspection as given in the (MPD) Manufacturer's Document and included in the approved routine schedule higher than flight release schedule be subjected to frequent inspection by reducing the inspection intervals by 20%.

c) All structural inspections required to be complied as per SSID, CPCP, Aging Aircraft Programme, DGCA mandatory modifications may continue to be carried out at the threshold given in the relevant document, such as, SBs/ADs, SSID, CPCP, Aging Aircraft Programme, etc.

d) Life of major components should be closely monitored to ensure that the life approved by DGCA is achieved. If it is observed that there is a wide variation between the approved life and the average life achieved, in which case, the approved life should be down graded to the average life achieved. Otherwise, the exact reason for reduction in the approved life should be analysed and appropriate steps taken in the form of compliance of SBs, procurement of spares from reputed sources, refresher training of personnel to improve the quality of workmanship etc. so that the approved life is achieved.

e) All minor and major defects should be thoroughly analysed and exact reason as to the cause of the defect established. Appropriate corrective action should be taken to ensure that the defects are not repeated and the occurrence of defects minimised. Major defects should be promptly reported to DGCA.

Service bulletins requiring additional structural inspection of specific areas at certain intervals

The scope and extent of various Maintenance Schedules must ensure that the entire aircraft, including its components and equipment, is thoroughly inspected, progressively and periodically, within the periods specified by the manufacturers and DGCA.

Aircraft are designed and built to provide many years of trouble free service. For the aircraft to remain airworthy and safe to operate for a long time in service life, it should be operated and maintained in accordance with the recommendations of the manufacturers and those stipulated by DGCA. Service experience has revealed that ageing aircraft needs special attention during the maintenance processes and at times require more frequent inspection of structural components for damage due to environmental deterioration, accidental damage and fatigue. To ensure structural integrity of ageing aircraft manufacturers have issued structural inspection programme and corrosion control prevention programme which must be supplemented with the existing maintenance programme to ensure continued airworthiness of these ageing aircraft. The operator should comply with Supplemental Structural Inspection Programme (SSIP) and Corrosion Prevention and Control programme (CPCP) where applicable by including in regular maintenance programme.

Aircraft which have reached or crossed their designed economic life develop, a number of associated problems due to fatigue, environmental corrosion and accidental damage are experienced during the service. These damages, if not properly detected and repaired in time, can cause catastrophe. To ensure continued airworthiness of aircraft, manufacturers of aircraft have issued documents prescribing additional structural inspections beyond design economic life. DGCA at times declares mandatory inspections for compliance by owner/operator for the purpose of continued Airworthiness of the Aircraft.

a) Service Bulletins (SBs) requiring structural inspection of specific areas at certain intervals.
b) Supplemental Structural Inspection Document (SSID)
c) Aging Aircraft Repair and Modification Programme

d) Corrosion Prevention and Control Programme (CPCP)
e) Repair Assessment Programme (RAP), etc.

Particular areas such as wingtanks, lavatory galley, bilge areas, require greater attention. Similarly aircraft used for insecticide spray requires much greater attention in this regard.

Suplimental structural inspection

Pressurised transport aircraft require regular assessment of their structure which degrade in strength due to fatigue, corrosion and accidental damages received during the maintenance. The operator should have a regular programme for assessing the condition of the aircraft structure. The operator has to identify the significant structural items (SSIs) and devise a means of regular inspection of these items. Initially for older aircraft, manufacturers would issue a document called 'Supplemental Structural Inspection Documents'. This document contains significant structural items, method of inspection and required corrective action. The documents when issued for an aircraft will be declared mandatory for continued airworthiness of the aircraft. Manual in respect of the particular aircraft mentioning the type of inspection and various prevention methods utilised for the purpose. It may be mentioned that aircraft had been designed and their strength had been assessed without considering impact of corrosion. Corrosion degrades strength considerably to the extent that catastrophic failure may occur.

REPAIR & MODIFICATION

The written approval of the Director General of Civil Aviation shall be obtained for a modification which has not been previously investigated and approved. At an early stage of the modification, brief particulars must be furnished to the Director General of Civil Aviation. The proposed modification must be such that the design of the aircraft/component/ equipment, when modified, satisfies the requirements that were enforced at the time the type approval was originally granted, or such other requirements as the Director General of Civil Aviation may notify at that time.

Modifications should be classified as minor and major. A minor modification shall be one which has no appreciable effect on the weight & balance, structural strength, reliability, interchangeability, operational characteristics or other characteristics affecting the airworthiness of the component/item of equipment. A major modification shall be one not classified as minor modification. Minor modification in the Type design may be provisionally approved by the design organisation of the constructory pending formal approval from the Director General of Civil Aviation. For this purpose, the applicant shall submit all necessary data, test reports etc. in support of the proposal for inclusion in the Type record.

CORROSION PRECAUTION AND CONTROL

Corrosion precaution

Much has been done to improve the corrosion resistance of aircraft: improvement in materials, surface treatments, insulation, and protective finishes. All of these have been aimed at reducing maintenance effort as well as improving reliability. In spite of these improvements, corrosion and its control is a very real problem that requires continuous preventive maintenance.

Corrosion-preventive maintenance includes the following specific functions:

(1) An adequate cleaning.
(2) Through periodic lubrication.
(3) Detailed inspection for corrosion and failure of protective systems.
(4) Prompt treatment of corrosion and touchup of damaged paint areas.
(5) Keeping drainholes free of obstruction.
(6) Daily draining of fuel cell sumps.
(7) Daily wipe-down of exposed critical areas.
(8) Sealing of aircraft against water during foul weather and proper ventilation on warm, sunny days.
(9) Making maximum use of protective covers on parked aircraft.

After any period during which regular corrosion preventive maintenance is interrupted, the amount of maintenance required to repair accumulated corrosion damage and bring the aircraft back up to standard will usually be quite high.

Corrosion Control

Among the controllable factors which affect the onset and spread of corrosive attack is foreign material which adheres to the metal surfaces. Such foreign material includes:

1. Soil and atmospheric dust.
2. Oil, grease, and engine exhaust residues.
3. Salt water and salt moisture condensation.
4. Spilled battery acids and caustic cleaning solutions.
5. Welding and brazing flux residues.

It is important that aircraft be kept clean. How often and to what extent an aircraft should be cleaned depends on several factors, such as location, model of aircraft, and type of operation.

REPAIR ASSESSMENT PROGRAM

Repair must be carried out in accordance with the appropriate Repair Manual or approved repair drawings relative thereto, in conjunction with any other related information contained in other documents recognised or approved by the DGCA.

General

Details of the inspections necessary before repair and the methods of assessing the extent of damage, supporting the structure, checking alignment and geometry, and assessing allowance for dressing of damage and limits of wear are generally given in the Repair Manual.

In the case of damage not covered by the Repair Manual but which, nevertheless, is thought to be repairable, a suitable repair scheme can often be obtained by application to the aircraft constructor (or to a Drawing Office holding the appropriate Design Approval). When supplying information of the damage to the constructor, photographs showing details of the damage are often helpful and may save both time and expense.

Preliminary Survey of Damage

A preliminary survey enables the damage to be classified (e.g. negligible, repairable or necessitating replacement) and a decision to be made as to the preparation necessary before commencing the repair. How the aircraft was damaged or overloaded should be determined as accurately as possible, and perusal of the pilot's or ground staff's accident report will give guidance to the necessary checks.

Structure distortion which can be evident at the site of the incident, may not be apparent when the aircraft is lifted and the locally imposed loads have been removed. Therefore, the aircraft should normally be inspected on the site where the damage occurred and the damage and distortion plotted on a station chart and ideally photographed before the aircraft is moved, providing a valuable indicator as to areas that require a more detailed inspection.

Depending on the results of the preliminary survey, the expected duration of the repair work and the precautions necessary as a result of local conditions, it may be necessary (among other things) to remove the batteries, drain the fuel system and/or inhibit the engines.

Cleaning

When the structure requires cleaning, this should be carefully supervised, otherwise useful evidence may be lost (e.g. the products of corrosion will help in locating corroded parts and the presence of a dark dusty substance at a structural joint will indicate fretting). Where mud, oil or other extraneous matter has to be removed, the cleaning solutions should be those given in the Repair or Maintenance Manual. Where a fire has occurred, it is important to remove all traces of fire extinguishant and smoke deposits as soon as possible, as some of these products promote rapid corrosion.

Cracks

Care should be taken that cracks, however minor they appear to be, are not overlooked. Where visual inspection is not completely satisfactory, especially at points of concentrated stress, one of the methods of non-destructive examination should be used.

Corrosion

Particular attention should be given to evidence of corrosion. Guidance on the methods of assessing the damage and of carrying out any rectification necessary is given in Leaflets. In cases of doubt, the use of one of the non-destructive testing methods.

Scores and Abrasions

Where a score or abrasion in a stressed part is within the limits specified in the Repair Data for blending out into a smooth surfaced shallow depression, it is often necessary to submit the part to one of the non-destructive testing processes described. This will ensure that minute cracks are detected and included in the assessment of damage.

Bolted Joints

Checks should be made on all bolted joints in the locality of the damaged area, or where overstressing is suspected, for evidence of bolt and associated hole damage. Where no obvious sign of movement is detected, sample inspection by removal of bolt(s) is often advised.

Skin Panels

Where buckling of a skin panel is apparent, a careful check of the area and related structure should be made for loose bolts, loose or sheared rivets, cracks and distortion. This should include any remote positions where the loads induced by the particular incident may have spread. In some instances where buckling is within limits specified in the Repair

Manual, schemes are provided for fitting a strengthening member, otherwise a new panel should be fitted after any associated structure has been repaired.

Internal Inspection

The internal inspection of a structure is particularly important since damage or defects can often be present without any outward indication. In instances where the damage is extensive, the whole structure should be inspected. Guidance on the internal inspection of structures, together with the various aids which may be used to facilitate the inspection.

Removal of Damage

In some instances it will be necessary to cut away the damaged material and dress back the surrounding structure. Although it should be ensured that no more material than is necessary is removed, it is necessary to make sure that the adjacent structure to which the repair is to be applied is in a sound condition.

Control of life limited components

Life of major components should be closely monitored to ensure that the life approved by DGCA is achieved. If it is observed that there is a wide variation between the approved life and the average life achieved in which case, the approved life should be down graded to the approved life should be analyzed and appropriate steps taken in the form of compliance of SBs, procurement of spares from reputed sources, refresher training of personnel to improve the quality of workmanship etc. so that the approved life is achieved.

Control by reliability method

The maintenance Control by Reliability Method will alert the organisation in time and help it in identifying the potential problems existing on its aircraft engines and accessories and will thus enable it to take preventive/curative measures expeditiously.

The method permits an organisation having sizable fleet of aircraft to amend and refine its existing system of maintenance in respect of each type of aircraft and its major components, in its fleet, in consultation with Regional Airworthiness office of DGCA, so as to improve the service reliability of its fleet.

All organisations will create a ‘Reliability Monitoring Unit’ (RMU) in the Quality Control Division which will be entrusted with the responsibility of gathering information from various sources for analysis in order to determine reliability trends of systems/components/structure of the aircraft operated by them.

The Reliability Monitoring Unit will gather information from both Scheduled Maintenance and Un-scheduled Maintenance for Reliability control. The likely primary source of information will be:

(i) Unscheduled removals.
(ii) Confirmed failures.
(iii) Deficiencies observed and corrected during scheduled services but otherwise not reportable.
(iv) Pilot reports.
(v) Sampling inspections.
(vi) Shop findings/Bench Check reports.

Unschedule removal

This is another factor which would help the operator to assess the condition of the component maintenance behaviour after proper investigation of confirmed failures. Such components are to be investigated by the operators reliability control section and necessary corrective action taken.

Confirmed Failures

(i) With the exception of self-evident cases, each unscheduled removal report is followed up by a workshop report in which the reported malfunction or defect is confirmed or denied. The report is routed to the Reliability Section. Workshop reports may be complied from an Operator’s own ‘in-house’ finding and/or from details supplied by component repair/ overhaul contractors.
(ii) where an unscheduled removal is justified the workshop reports will normally include details of the cause of the malfunction or defect, the corrective action taken and, where relevant, a list of replacement items. Many Programmes utilise the same type of report to highlight structural and general aircraft defects found during routine maintenance checks.

Reported failure per 1000 hr.

The various data collected are reduced to 1000 per hrs. of operation or thousands of flight hours and numerical rate derived. The pilots reports as well as the confirmed failures are to be taken as complementary to each other as sometimes unscheduled removal of components may not be a confirmed failure.

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