STTN

AP 3421

ERECTION OF ANTENNAE
(Aerial Erector)

By Command of the Defence Council

Ministry of Defence   For use in the Royal Air Force   November 1972

Record of Amendments

The amendments promulgated in the undermentioned Amendment Lists have been incorporated in this Publication.

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FOREWORD

This Air Publication has been prepared by Headquarters Training Command (Ed 1c) under the direction of the Ministry of Defence, Directorate of Training (Ground) (Royal Air Force).

It is published primarily to assist those under training as Aerial Erectors. Aerial Erectors require knowledge on subject matter relating to the installation of masts and aerials (antennas) and to the maintenance of aerial systems. It is with the intention of helping to provide the necessary information that this STTN (Standard Trade Training Notes) is written. It is not intended to form a complete textbook, but is to be used as required in conjunction with lessons and demonstrations given at the training school.

This Air Publication may also prove useful to trained Aerial Erectors studying for Promotion Examinations at other RAF stations. It contains, within one cover, sufficient information on appropriate subjects to the minimum standard required by Part I of an Airman's Promotion Examination in the trade of Aerial Erector.

The subject matter in this STTN may be affected by the contents of Defence Council Instructions (DCIs) and by amendments to other official publications. When this occurs, suitable amendment lists will be issued as soon as practicable to correct the STTN. In the meantime, any mandatory document that contradicts information contained in this publication is to be taken as the overriding authority.

The subject matter of this STTN has been based on material gathered from numerous sources, both Service and civilian. An acknowledgement is extended to all who have contributed to its preparation—particularly to the staff of the Aerial Erector School and Trade Standards Centre, RAF Digby who supplied the bulk of the original material.

Footnotes will be found on every page of this publication. At the bottom left-hand corner of each left-hand page the footnote consists of two numbers; the first number refers to the chapter number, and the second number refers to the page number within that chapter. The publication number appears as a footnote at the lower right-hand corner.

At the bottom left-hand corner of each right-hand page the footnote consists of the chapter title. Immediately underneath this title will be found the appropriate Amendment List number and date. The footnote at the bottom left-hand corner refers to the chapter and page number.

Readers of this publication are asked to report any unsatisfactory feature that they may notice. Such unsatisfactory features may include omissions, factual errors in words or illustrations, and ambiguous, obscure, or conflicting instructions. All such unsatisfactory features should be reported to Headquarters Training Command (Ed 1c) on RAF Form 6734.

MINISTRY OF DEFENCE (AIR) November 1972

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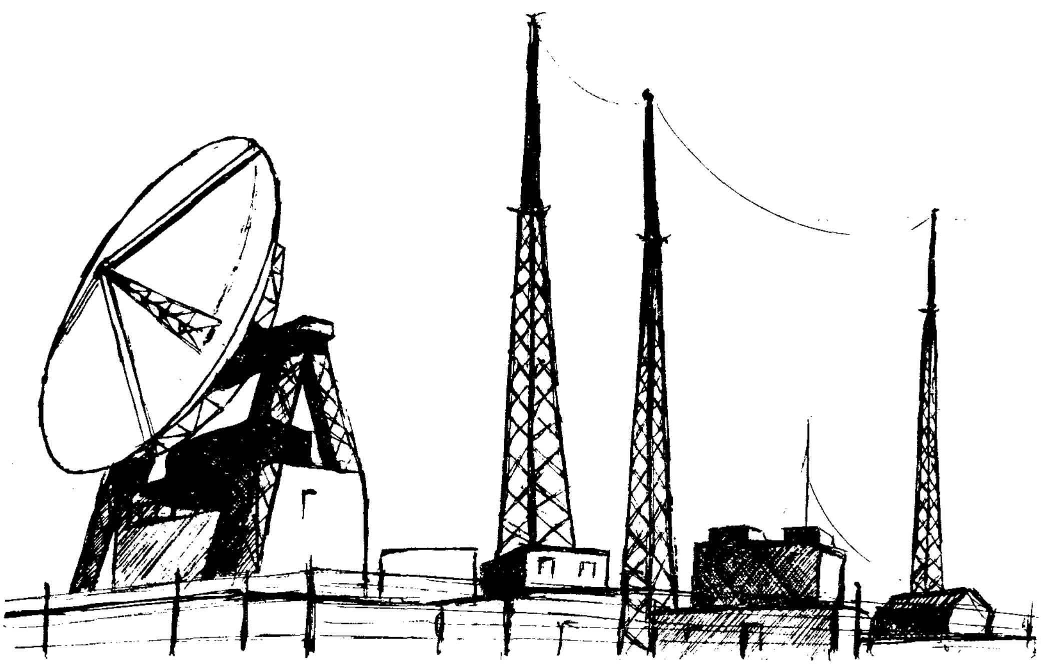
CHAPTER 1

COMMUNICATIONS AND THE AERIAL ERECTOR



Communications

The word 'communication' means the giving or exchanging of information by any means. Communication has always played an indispensable part in the everyday life of the human race. Imagine the chaos that would result if the present-day means of communication, ie radio, television, telephone etc, were suddenly no longer available to us. Effective and efficient means of communication are vital to our whole way of life, as is the role of those whose responsibility it is to maintain them.

Early Methods of Communication

The simplest method of communication, and one that has been in use from the earliest times, is of course, the human voice. Some two thousand years ago the Persians developed a communications system consisting of men positioned on hilltops and specially constructed towers placed close enough for shouted messages to be passed from one to the other. This method was later improved upon by using torches arranged in patterns to represent letters of the alphabet. This increased the speed at which messages could be transmitted by reducing the number of 'relay stations'. During the French Revolution a similar system was used to send messages from Paris to Toulon, a distance of over 400 miles, in twenty minutes. Other examples of early long-range communication systems were the smoke-signals of the North American Indian, the 'jungle-drum', and the beacon fires widely used to warn communities of impending enemy attacks (Fig 1.1).

Fig 1.1 Signal Beacon

One important fact was soon discovered by those early communicators: the higher the point from which 'signals' were transmitted and received, the greater was the distance over which the message could be relayed, and the less was the interference from obstacles on the ground. This fact is just as valid today as it was for the early methods of communication.

The first electrical communications system was devised by an American, Samuel Morse, in 1836. In this system a code consisting of dots and dashes was used to represent letters of the alphabet (the Morse Code) (Fig 1.2). Messages were transmitted along wires in the form of short and long electrical impulses representing the dots and dashes of the Morse Code.

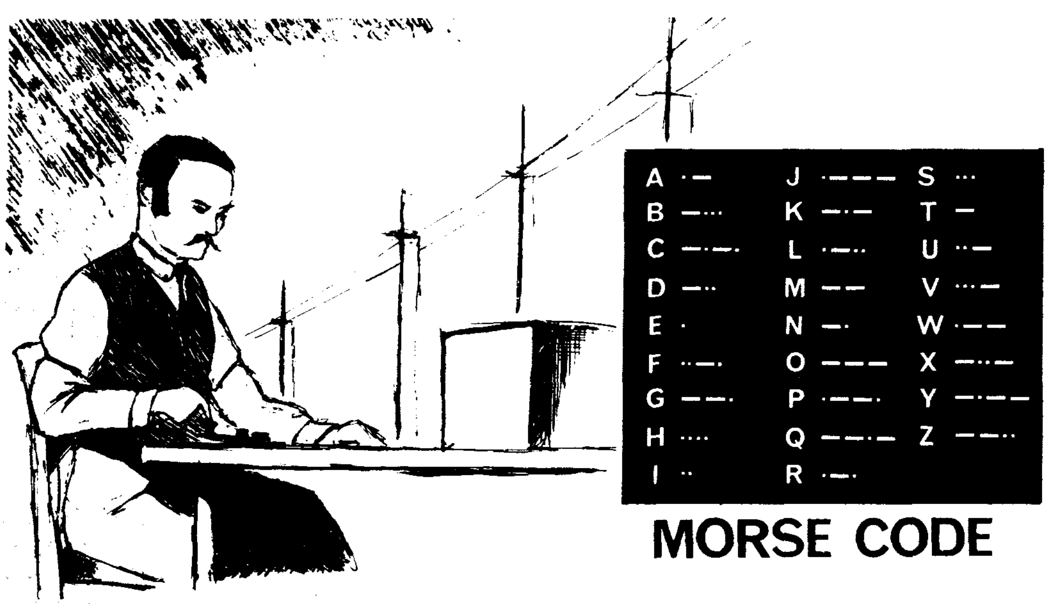


Fig 1.2 1836 Samuel Morse first electrical communications system

Wireless Communication

In 1895, an Italian inventor named Marconi demonstrated a completely new method of communication. Instead of sending morse signals along a wire, he showed that the same signals could be sent through the air by means of electromagnetic waves. The electromagnetic waves were *radiated* through the air from a wire suspended in the air (an aerial) and were therefore called *radio* waves. Since there were no wires joining the 'sending' end of the system to the 'receiving' end, the system was called 'wireless' telegraphy. Although this demonstration established communications over the very short distance of just over a mile, it set the pattern of modern day communications.

In the preceding paragraph the word 'aerial' is used. In modern terminology the word '*antenna*' is used to describe the same thing, and will, therefore, be used throughout this book.

By 1898 wireless telegraphy was being used to communicate between ships and shore over the then-great distance of 12 miles. In the same year, communications were established between England and France and, for the first time, wireless telegraphy was used in naval manoeuvres between ships 75 miles apart (Fig 1.3). These achievements were soon followed by the transmission of messages across the Atlantic, and this laid the foundation for worldwide wireless communications.

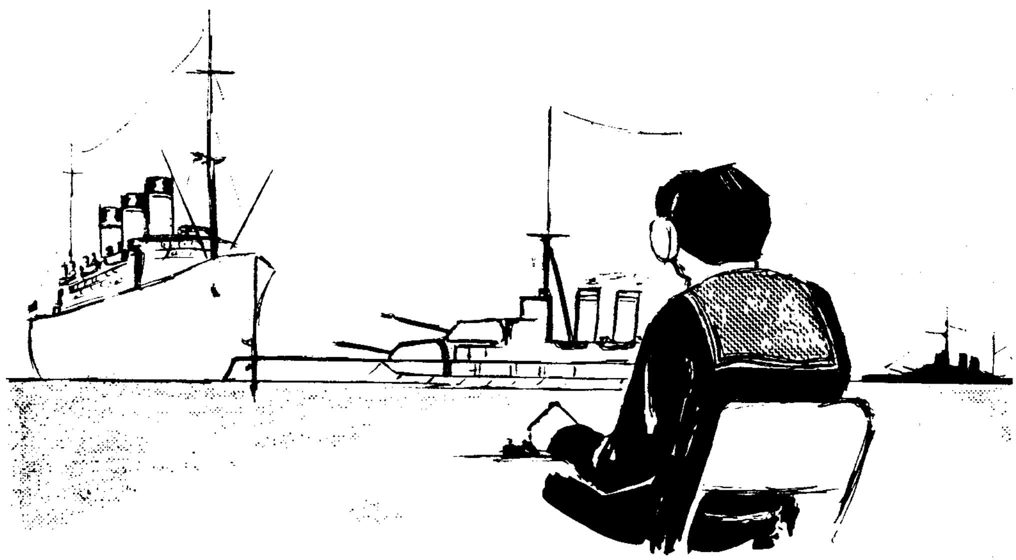


Fig 1.3 1898 Wireless Telegraphy used in Naval Manoeuvres

Initially the antennas used were crude and inefficient and tended to hinder progress. However, as time passed, antennas and antenna systems were improved to provide greater efficiency and increased reliability. Without efficient transmitting and receiving antennas, even the most sophisticated communications system would not give satisfactory results. Antennas are, therefore, an important feature in any wireless communications system.

Communications in the Royal Air Force

The RAF relies on efficient, up-to-date communications systems in order to maintain its effectiveness as a modern fighting force. Many systems are in use, including telephone networks. However, we are concerned here with *wireless communication* systems. All such systems rely on efficient antennas to maintain a high degree of communication reliability. This reliability needs to extend over distances varying from a few miles to many thousands of miles and is necessary so that a commander can control his forces and apply their maximum fighting strength. To achieve this, the commander or his subordinates must be able to communicate effectively between various ground stations, between ground stations and aircraft, and between aircraft in flight (Fig 1.4).

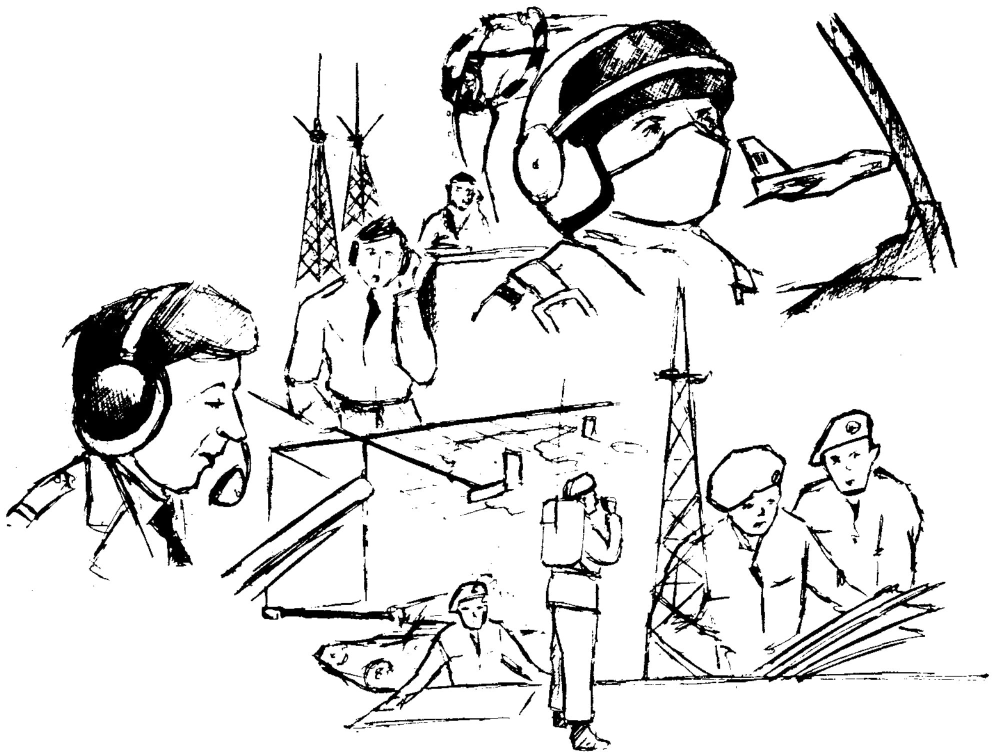


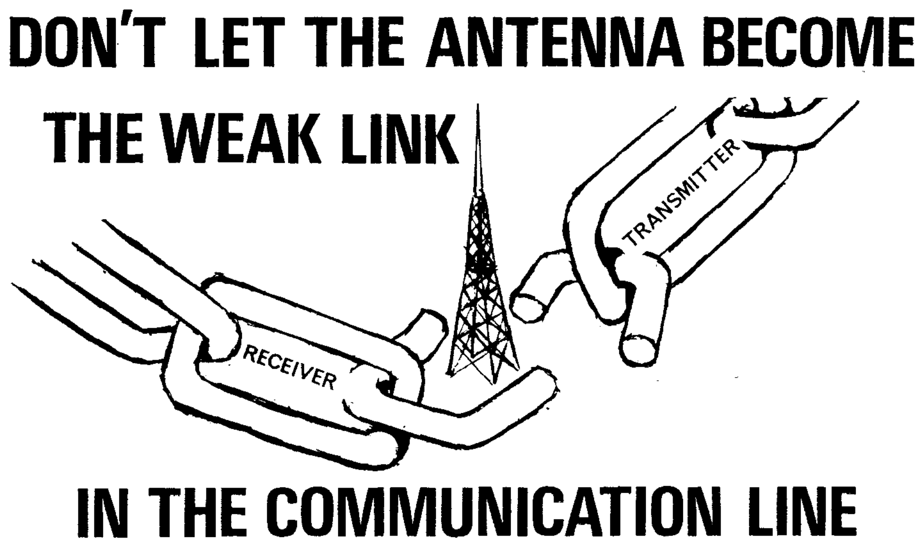
Fig 1.4 Communications in the Royal Air Force

Aerial Erector Trade

Between World Wars 1 and 2 maintenance of antenna systems was the responsibility of radio tradesmen. With the rapid introduction of radar at the beginning of World War 2, and the use of more sophisticated antenna systems in the field of communications the trade of Aerial Rigger was evolved to undertake the maintenance tasks. Subsequently a new trade of Aerial Erector was introduced into the RAF trade structure and has remained independent of, but closely associated with, the Electronic Engineering trade group.

The ground trades of the RAF are arranged in broad trade groups, numbered 1 to 22 inclusive, each trade having a specific field of employment within its appropriate group. The Aerial Erector trade is in Trade Group 5 (General Engineering Trade Group).

In general terms, the Aerial Erector is responsible for installing the masts and antennas for the many different types of installations, and for maintaining these to a high degree of efficieny. It has already been mentioned, and it is worth repeating, that antennas are a key feature in any wireless communications system. Without correctly installed antennas, maintained to the highest level of efficiency, the communications system needed by the Royal Air Force could not exist. The role of the Aerial Erector is, therefore, of the greatest importance. Shoddy workmanship on the part of an Aerial Erector could result in a complete breakdown of a vital communications link, with disastrous consequences. Make sure, therefore, that you learn your trade, and learn it thoroughly, so that your link in the chain remains sound.



Promotion Structure

The trade of aerial erector is a 'list 2' trade, and is one of the very few trades in the RAF where an airman passes out of basic training as a Senior Aircraftman (SAC). The reason for this is that the trained aerial erector is expected to work with the minimum of supervision; in some single-manned (digital) posts, he works with no immediate supervision.

We are all, no doubt, interested in promotion. Fig 1.5 shows that promotion prospects in the trade of Aerial Erector exist up to the rank of Flight Sergeant (FS).

There are two factors that determine whether an Aerial Erector can progress up this career ladder:

- Vacancies have to be declared in the appropriate higher rank.
- The airmen has to be eligible for promotion; that is, he must be *qualified.*

An airman has no control over the first of these factors. The number of establishment vacancies in any given rank in the trade is determined by higher authority, who decide what the future requirements will be over, say, the next six months.

The second factor is, to a large extent, up to the airman himself. To become eligible for promotion, an airman must have passed appropriate examinations. For example, as shown in Fig 1.5, for an airman (SAC) to become eligible for promotion to Corporal (Cpl), he must have passed Promotion Examination No 1 and also the RAF Education Test Part 1.

Promotion Examinations. These are normally in two parts: Part I tests a candidate's knowledge of the principles and procedures of the trade; Part II is a practical test to assess the capability of a candidate in applying his trade knowledge and skill in the performance of tasks appropriate to the next higher rank in the trade. For the higher promotion examinations, supervisory capability and knowledge of administration and organization are also tested.

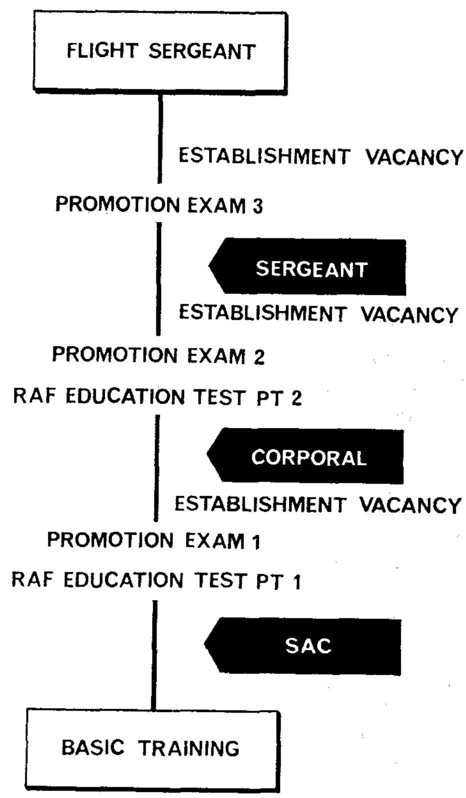


Fig 1.5 Career Structure—Aerial Erector

RAF Education Tests. As shown in Fig 1.5, the two parts of the RAF Education Tests are taken at different points in the career ladder. In general, these tests check whether an airman has the basic educational qualifications required for appropriate ranks in the trade. Part I is required for promotion from SAC to Cpl, and Part II for further promotion. Note that a pass in English and any two other subjects in the General Certificate of Education (GCE), or equivalent passes in the Certificate of Secondary Education (CSE), give exemption from both parts of the RAF Education Test.

Use of STTN

It is clear from what has been said that to do his job properly, and in order to advance in rank, the Aerial Erector must know every facet of his trade. He must also ensure that he keeps abreast of modern trends so that he can keep up to date. Only by doing so can a candidate hope to pass the appropriate promotion examination. It is here that Standard Trade Training Notes (STTN) can help.

In the chapters that follow, the appropriate principles, procedures and knowledge required by the Aerial Erector are considered in some detail. These chapters will be amended from time to time to cater for new developments and changes in the trade. Thus, the STTN provides the basic information you need. Make sure that you use it.

CHAPTER 2

FIRE AND FIRE EXTINGUISHERS

Introduction

Every year many lives are lost, serious injuries are sustained and property to the value of millions of pounds is damaged or destroyed by fire. If we were all fire conscious and strictly observed fire regulations many of the fires could have been avoided. *Fire precaution is everyone's business.* You must know what precautions to take in order to prevent a fire starting, and also how best to deal with a fire should one break out, so that you are able to minimize its effect. It is also important that you should know which type of equipment to use against a particular type of fire, and be able to recognize readily the various types of equipment and flammable materials.

> **Note.** Although, in the past, 'inflammable' was invariably used to describe materials that are 'easily set on fire', modern usage tends towards the use of 'flammable' to mean the same thing.

Causes of Fire

There are many and varied ways in which fires may be started, and fire orders and regulations are framed as preventive measures. A few direct causes of fire are:

- Careless disposal of lighted cigarettes and matches.
- Smoking near a vehicle whilst it is being refuelled.
- Failure to obey orders regarding the disposal of rags impregnated with flammable materials such as petrol, oil or kerosene.
- Misuse of petrol and other cleaning solvents.
- Failing to wipe up flammable liquids that may have been spilled.
- Lack of care with portable heaters.
- Defective electric cables. Never ignore the smell of burning rubber.
- Sparks from various sources.

Regulations

None of us are keen on rules and regulations, but if we give a little thought to them we usually have to admit that they are really necessary. In fact, with reference to fire regulations, *vital* would be a better description. But not only must we know what the fire rules and regulations are, we must be able to apply them.

Fire regulations and orders are issued for the various areas and applications with which you may come into contact. A detailed account of these is outside the scope of this book, but you must make yourself familiar with such regulations and orders so that you will automatically put them into practice when the need arises. The following points have a general application:

- **Cleaning materials.** Waste petrol, oils, and lubricants from drip trays and degreasing tanks must not be allowed to accumulate in hangars or workshops. They should be removed at the end of each day's work and destroyed in an authorized disposal pit or an incinerator. Any rags impregnated with these fluids, paint or wax, must be kept in a metal container fitted with a lid when not in actual use and destroyed in the same manner.

- **Naked lights.** Smoking is not permitted in the vicinity of aircraft, hangars, fuel installations, or near areas or buildings where explosives are stored.

- **Explosives.** Buildings containing explosives have a specific fire class symbol prominently displayed on or near the building. Each symbol consists of a black geometrical shape on a yellow square. In the centre of the symbol is the fire class number. Details of these symbols, and their meanings are illustrated in Poster 76 (Markings on Buildings containing Explosives).

- **Electrical equipment.** All portable electric tools must be properly earthed. Flexible cables should be inspected frequently to ensure that the insulation is undamaged. Portable electrical lighting equipment must be of the safety type, with wire cages fitted over the bulbs to prevent accidental damage.

Combustion

Combustion, or burning, takes place when material or fuel combines chemically with oxygen, causing a rapid rise in temperature. For the material to combine readily with oxygen it must either be in a gaseous state or be converted into a gas by the presence of heat. The amount of heat required varies according to the type of material involved, as does the amount of heat produced during combustion. Among the materials that produce considerable heat when burned, and which require little heat to become gaseous, are explosives; so rapid is their combustion it is almost impossible to control.

As fires are caused by the chemical combination of fuel and oxygen from the atmosphere, it follows that a fire can be extinguished by separating the fuel and the oxygen. A fire can also be extinguished if the temperature of the burning material can be lowered sufficiently to prevent gases from being released from the material. *For electrical fires it is essential that a non-conducting extinguishant is used.* Thus a fire can be extinguished by:

- Isolating the fire from the oxygen in the atmosphere.

- Cooling the burning material sufficiently.

Extinguishants

Every extinguishant is not suitable for use against every fire. As stated earlier, fires are of different types, depending mainly upon the material that is burning. It is, therefore, necessary to use the correct extinguishant. The following paragraphs describe some of the common extinguishants and indicate the types of fires they may be used against.

Water. Water is a very good cooling agent and can be used effectively against fires involving solids such as timber, textiles, paper and plastics.

Water must not be used against 'electrical' fires or against fires involving flammable liquids such as gasoline, oil or kerosene.

Water is a very good conductor of electricity, and its use against fire in a 'live' piece of electrical equipment is dangerous because the electricity may be conducted back to the fire-fighter.

The use of water against fires involving flammable liquids is both dangerous and ineffective. This is because the density of water is greater than that of most liquids, and so the burning liquid tends to float on the surface of the water, thus extending the area of the fire.

- *Use water against 'solid' fires.*
- *Do not use it against 'electrical' or 'liquid' fires.*

Sand. Sand is very effective for instant action on small domestic, liquid or electrical outbreaks of fire. It is also used to confine and reduce the possibility of ignition when spillage of flammable liquid occurs.

Foam. Water can be made to float upon and blanket the surface of oil or other liquids by reducing its density to below that of the burning liquid.

Remember—liquids—do not use against 'electrical' fires.

A suitable foaming agent is added to the water which is then aerated (charged with air or gas). Two types of foam are in general use for fire-fighting:

- **Chemical foam.** Aeration of the water occurs as the result of chemical reaction when acid is allowed to mix with a solution of water and a suitable alkali; each bubble of foam is filled with carbon dioxide (CO_2). This gas, being inert, will not support combustion and is heavier than air. Thus the close-textured blanket of gas-filled bubbles displaces the oxygen in the fire zone and smothers the fire.
- **Mechanical foam.** Water containing a foaming agent can also be converted into foam by mechanical agitation, but in this case the bubbles are filled with air. The blanketing effect of mechanical foam is less than that of chemical foam because of the presence of air in the bubbles, and a much greater mass of foam is required to achieve comparable results.

Dry powder. The powder is usually potassium sulphate, and is expelled from a container under gas pressure. The discharge forms a dense cloud of powder, occupying the space immediately above the surface of the fire and replacing the oxygen available for combustion. In addition, the powder particles themselves rapidly absorb heat and reduce the temperature in the fire zone. Dry powder is primarily intended for use against liquid fires, but may be used on 'electrical' fires.

Inert gases. The blanketing effect of carbon dioxide gas in chemical foam has already been mentioned. *Any inert gas*, provided it is heavier than air, will produce similar results when applied to the seat of a fire. This type of extinguishant is particularly useful for electrical fires, and where there is a requirement to deal with small-scale fires in the cleanest possible way. Some extinguishers are supplied in container form with gas under pressure; others use vaporizing liquids which are transformed into inert gases when sprayed into the fire zone.

First Aid Fire-fighting Appliances

Many fires are found early enough to be extinguished by first aid fire-fighting appliances. These appliances, such as fire buckets containing water or sand, asbestos blankets, hose reels for connection to the water supply, and several types of extinguishers (Fig 2.1), are provided at fire points throughout the Station building and areas.

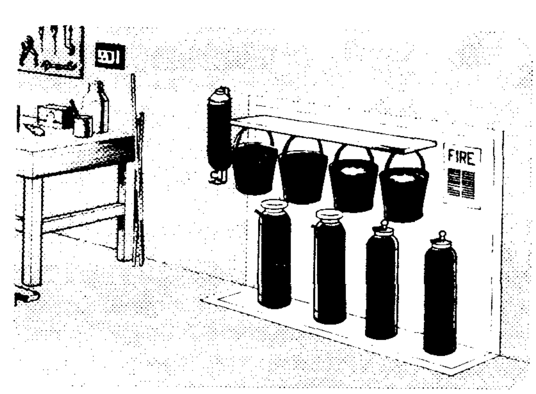


Fig 2.1 Fire-fighting Equipment

Despite the variation in size and content of these various items, they are designed for instant use by persons in the vicinity of an outbreak of fire; thus, they are portable and simple to use. Instant identification of the types of extinguishers with reference to the type of fire for which they are to be used is, of course, vital. Consequently they are painted in accordance with a national colour code which identifies their contents (Fig 2.2).

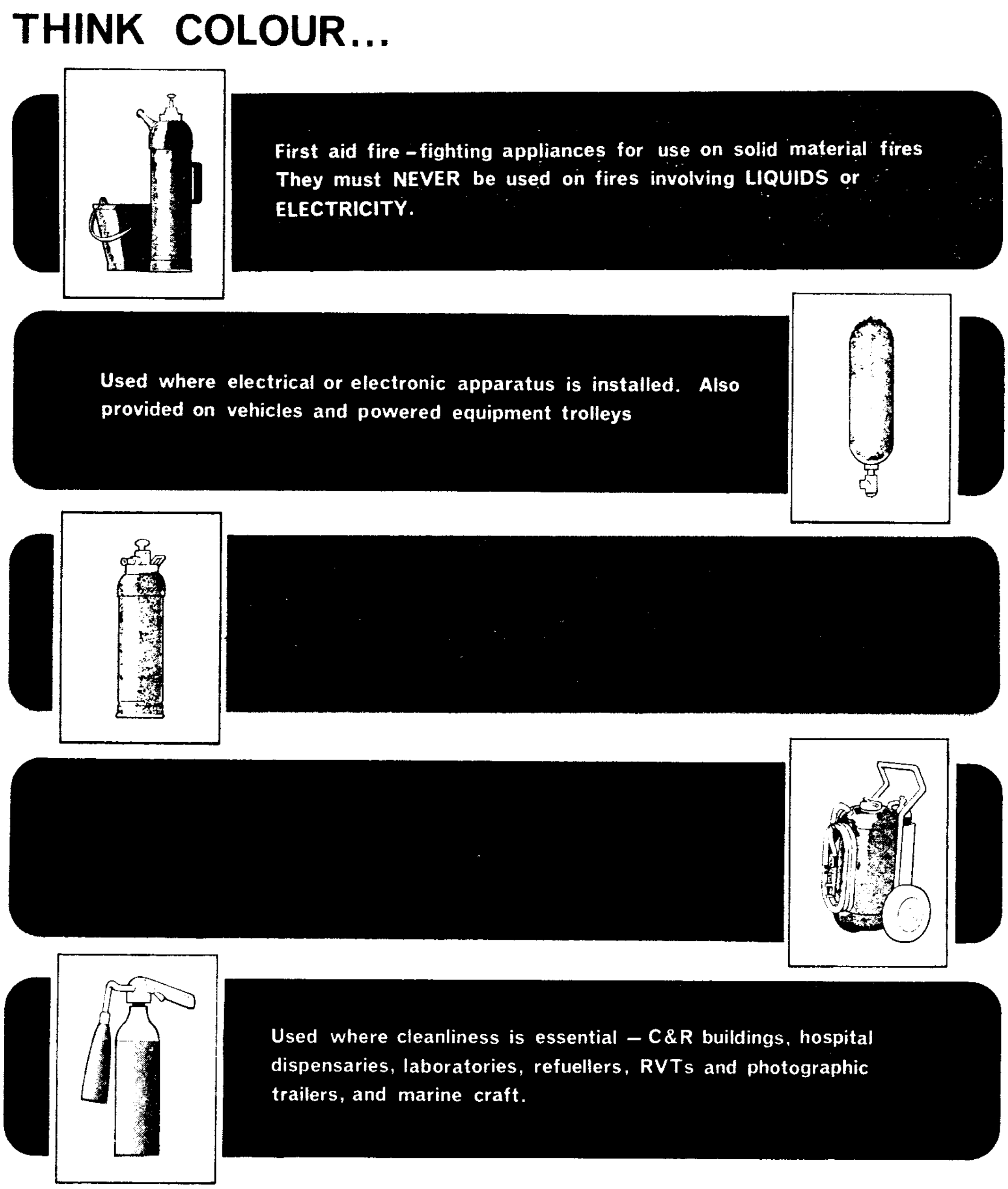


Fig 2.2 Colours Identify Contents

Soda acid. This type of extinguisher (Fig 2.3) is a handy method of storing water for immediate use under pressure, and applying it in the most effective manner. It is used on solid material fires such as wood, paper or clothing, which can be quenched effectively by cooling the burning mass below the ignition point of the material. This type of extinguisher is painted **RED**. *It must not be used on liquid fires or those involving electricity.*

- **Operation.** Remove the safety clip and strike the plunger a sharp blow. This breaks the glass bottle and the acid mixes with the alkaline solution. The carbon dioxide (CO_2) gas which is formed expands rapidly and forces the contents of the cylinder out of the nozzle.

- Maximum effect is obtained by directing the jet of water from the nozzle as close to the seat of the fire as possible.

Water gas. Soda acid extinguishers are now obsolescent and are being replaced as they become unserviceable by water/gas extinguishers. The water in this improved type of extinguisher (Fig 2.3) is forced out when required by piercing a CO_2 cartridge fitted inside the cylinder. The standard body colour for these extinguishers is **RED.**

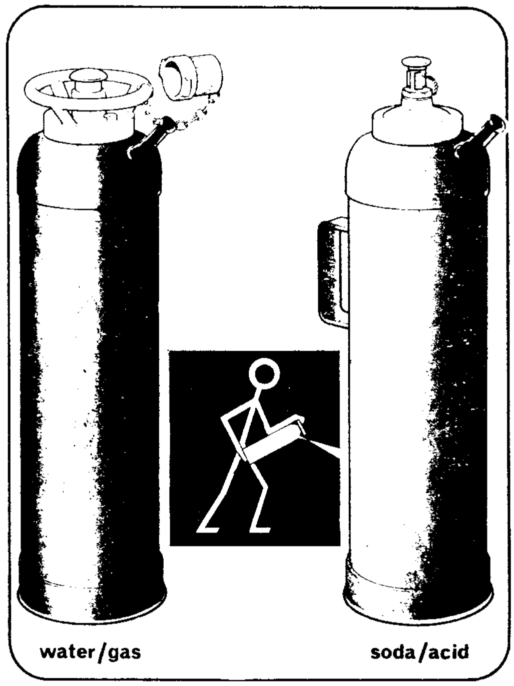


Fig 2.3 Domestic Fire Extinguishers

Chemical foam. The 2 gallon foam extinguisher (Fig 2.4) is primarily for use on burning liquids, but may be used effectively against solid material fires (not electrical). The cylindrical body of the extinguisher, painted **PALE CREAM,** contains an alkaline solution of bicarbonate of soda and water and a foaming compound. An inner container holds an acid solution of aluminium sulphate and water. A sealing mechanism in the headpiece of the extinguisher prevents the two solutions mixing when the cylinder is upright.

- **Operation.** The key-handle must first be pulled upwards and then turned clockwise.

- Place a finger over the nozzle outlet and invert the extinguisher using the handgrip across the base. Shake vigorously and keep the finger over the nozzle for at least five seconds whilst the pressure builds up.

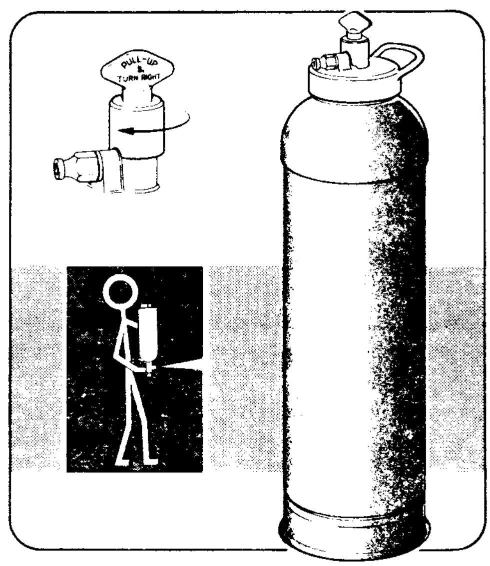


Fig 2.4 2 gallon Foam Extinguisher

- Work from a position where the nozzle can be elevated slightly so that the jet travels its full range before falling onto the surface of the liquid. The volume of foam produced is enough to cover 10 square feet when applied evenly.

- *This is the only type of extinguisher which is turned upside down for operation* (as distinct from those which have a nozzle in the base).

Dry powder trolley. The 150 lb dry powder trolley (Fig 2.5) is provided to supplement the foam extinguishers at fuel installations and fuel and lubricant compounds. The 150 lb filling of dry powder is contained in the cylindrical body of the extinguisher, standard body colour is **BLUE.** A 5 lb cylinder of compressed CO_2, standard colour **BLACK** with an **ALUMINIUM** or **WHITE**

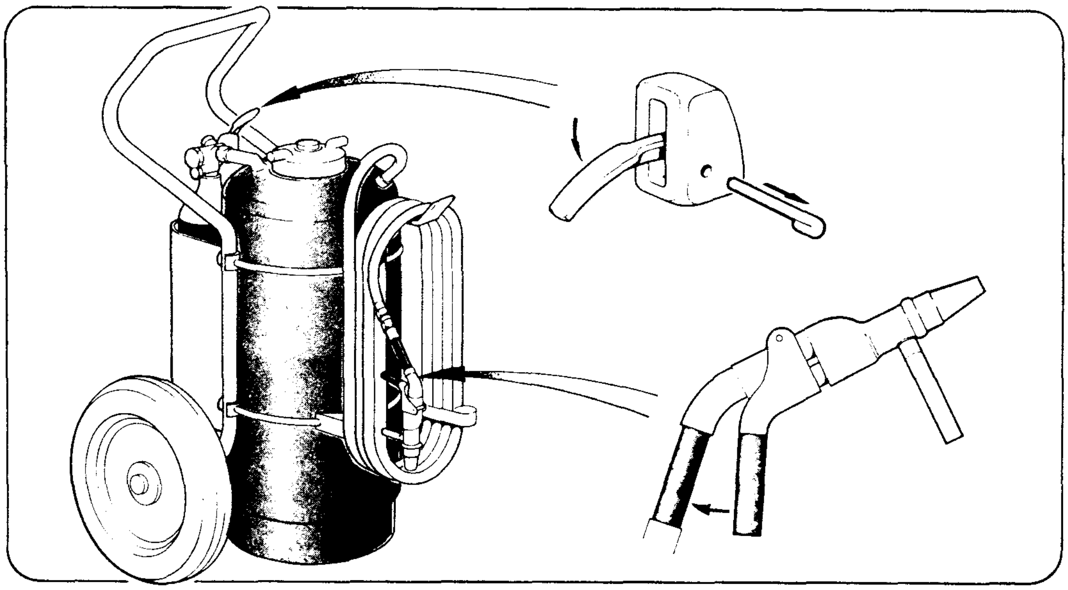


Fig 2.5 Dry Powder Trolley

neckband, is connected to the powder container. The applicator is trigger-operated, and the gas/ powder mixture is discharged as a conical jet which then expands into a dense cloud of powder.

- **Operation.** Remove the safety pin from the CO_2 cylinder head and push down the lever; this pressurizes the powder container.
- Take the applicator from its socket and uncoil the hose towards the fire.
- You should position yourself upwind of the fire, or as nearly upwind as possible.
- When in position, squeeze the applicator trigger. Hold the applicator at a low level, parallel to the ground, and sweep it slowly from side to side to ensure that the cloud of powder covers the whole of the flame zone.

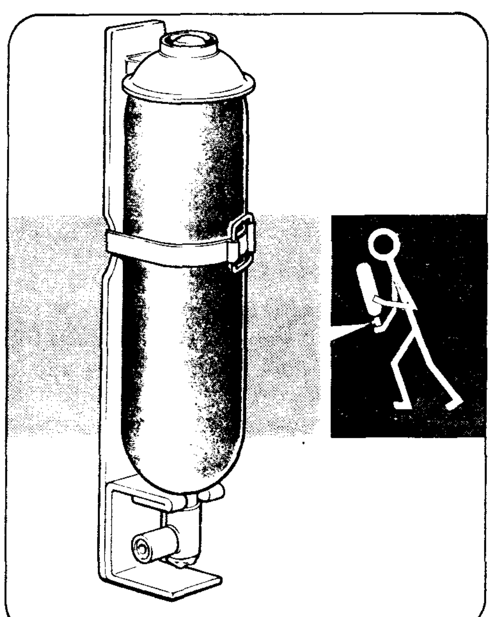


Fig 2.6 Extinguisher for Electrical Fires

3 lb BCF (Bromochlorodifluoromethane). This type of extinguisher (Fig 2.6) is provided mainly for use on fires in electrical or electronic apparatus, but can also be used effectively against small liquid fires. It is also provided as an accessory for MT vehicles and powered ground equipment trolleys. BCF does not conduct electricity nor leave behind a solid liquid or residue.

The standard body colour for this type of extinguisher is **GREEN**. The discharge outlet is situated in the base of the body, and fitted over it is the discharge assembly which is free to slide upwards. The white disc at the top of the extinguisher is a pressure indicator. If it is pressed in, the internal pressure should ensure that it regains its normal shape immediately. In fact, it is almost impossible to depress it while the extinguisher is fully charged. The safety clip prevents accidental discharge during transit or storage, but it must be removed when the extinguisher is positioned in its bracket ready for use.

- **Operation.** Remove the extinguisher from its bracket.

- Move into position to attack the fire. This is necessary because the discharged BCF vaporizes very rapidly and the discharge is completed in a few seconds.

- Keep the extinguisher vertical and strike the striker plate against the floor or the top of a table or bench. The discharge is immediate.

- When used on an engine fire in a vehicle or powered trailer, discharge through the radiator grill of the vehicle is unlikely to be effective. Therefore, the bonnet should be opened to allow accurate placing of the discharge, and then closed again as soon as discharge ends.

- When used against an exposed fire, discharge should be at a range of not more than a few feet and moved fairly quickly to ensure that all the flames are enveloped by the vapour before discharge ends.

- Although BCF has little toxic effect, it is possible that harmful products might be released by the combustion. Therefore, if the incident occurs in a room or compartment, the room should be ventilated when it is certain that the fire is extinguished.

Improved type BCF. This improved type of BCF extinguisher (Fig 2.7) consists of a plastic operating handle and a detachable container which can be of 1.5, 2.5 or 3.5 kg capacity.

Operation. Unlock the safety catch by pushing it forward as directed by the red arrow. Holding the extinguisher upright, aim at the base of the fire and squeeze the operating lever. This action will cause the vaporizing liquid to spurt from the nozzle in the handle; the same action breaks a red plastic disc at the base of the handle, thus indicating that the extinguisher has been used.

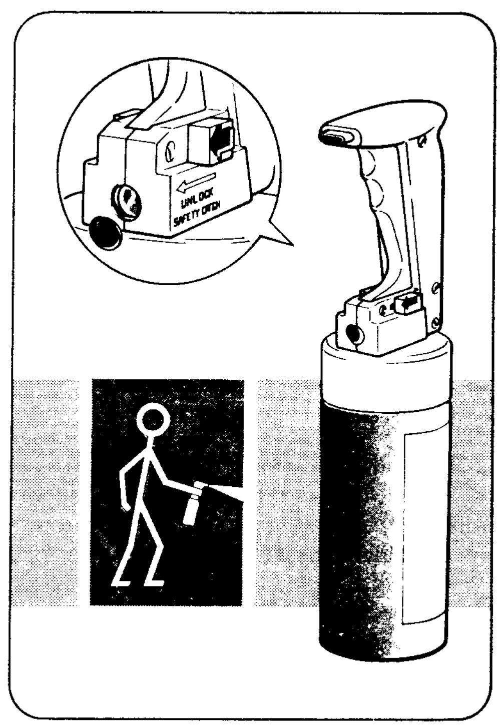


Fig 2.7 1.5 kg BCF Extinguisher

CO_2 hand fire extinguisher. Four sizes of these are provided—1.1 kg, 2.2 kg, 4.5 kg, and 6.8 kg. These figures indicate the weight of liquefied CO_2 which each type of extinguisher contains. Generally, such extinguishers are provided in buildings only where there is a requirement to deal with small-scale fires in the cleanest possible way.

Such locations would be photographic centres, hospital dispensaries or chemical laboratories. They are also carried, in addition to the 3 lb BCF extinguisher, on certain specialist vehicles such as refuellers and photographic trailers, and on marine craft. The 6.8 kg type may be an item of ancillary equipment on crash/fire trucks and domestic fire trucks.

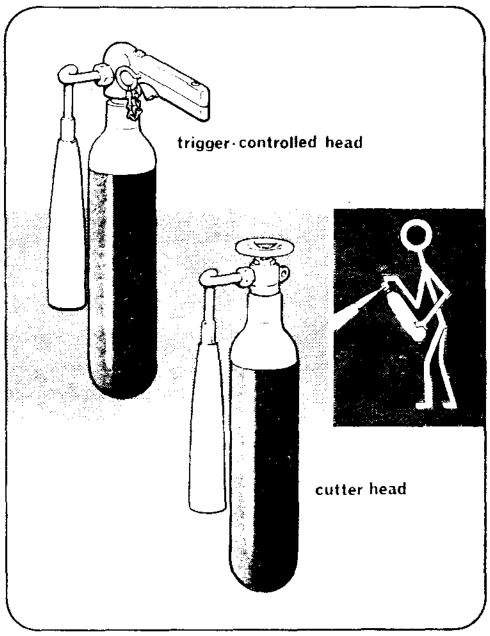


Fig 2.8 CO_2 Hand Types

These extinguishers consist of a CO_2 cylinder, standard colour **BLACK** with an **ALUMINIUM** or **WHITE** neckband, of appropriate size to type. The operating head is fitted with a short length of discharge tubing and a discharge horn, and may be either one of two principal types (Fig 2.8):

- **Cutter head.** Used on cylinders sealed by a copper disc.
- **Trigger-controlled head.** This is an integral part of cylinders sealed by a valve.

The cylinders may be mounted in brackets equipped with quick-release buckles. The flexible tubing allows the horn to be aimed at various levels or in any direction without being encumbered by the extinguisher which is comparatively heavy for its size.

- **Operation.** The horn must be positioned for discharge before the extinguisher is operated.
- Remove the safety pin.
- With a cutter-head, turn the hand wheel anti-clockwise. Turn the hand wheel clockwise to stop operation.
- With a trigger-controlled head, squeeze the trigger; this action fixes the trigger in the operating position. The discharge can be stopped by pressing the button at the top end of the cancelling lever, provided the trigger is not being held by the user's hand.
- The discharged gas forms a white cloud, and the object is to make the cloud envelop the whole of the base of the flames by sweeping the horn steadily from side to side. If used in the open, it must be directed from upwind.
- When a CO_2 extinguisher is discharged, there is an abrupt hissing roar.

Conclusion

You will, of course, receive instruction regarding Station Fire Orders, which will cover the local action to be taken in the event of fire and also fire prevention. This will include practical operation of equipment, and will occur early in a tour of duty at a new station. This is necessary because there are detailed differences between stations in, for example, the procedure for raising an alarm of fire.

Meantime, make sure that you know the colours of the various fire extinguishers and also the type of fire against which they may be used (Fig 2.9).

- **RED** Used only against solid fires.
- **PALE CREAM** Primarily on burning liquids—also solid fires.
- **GREEN** Mainly on 'electrical' fires—also small liquid fires.
- **BLUE** Used against liquid fires.
- **BLACK—ALUMINIUM** or **WHITE** neckband. Used where operational cleanliness is required.

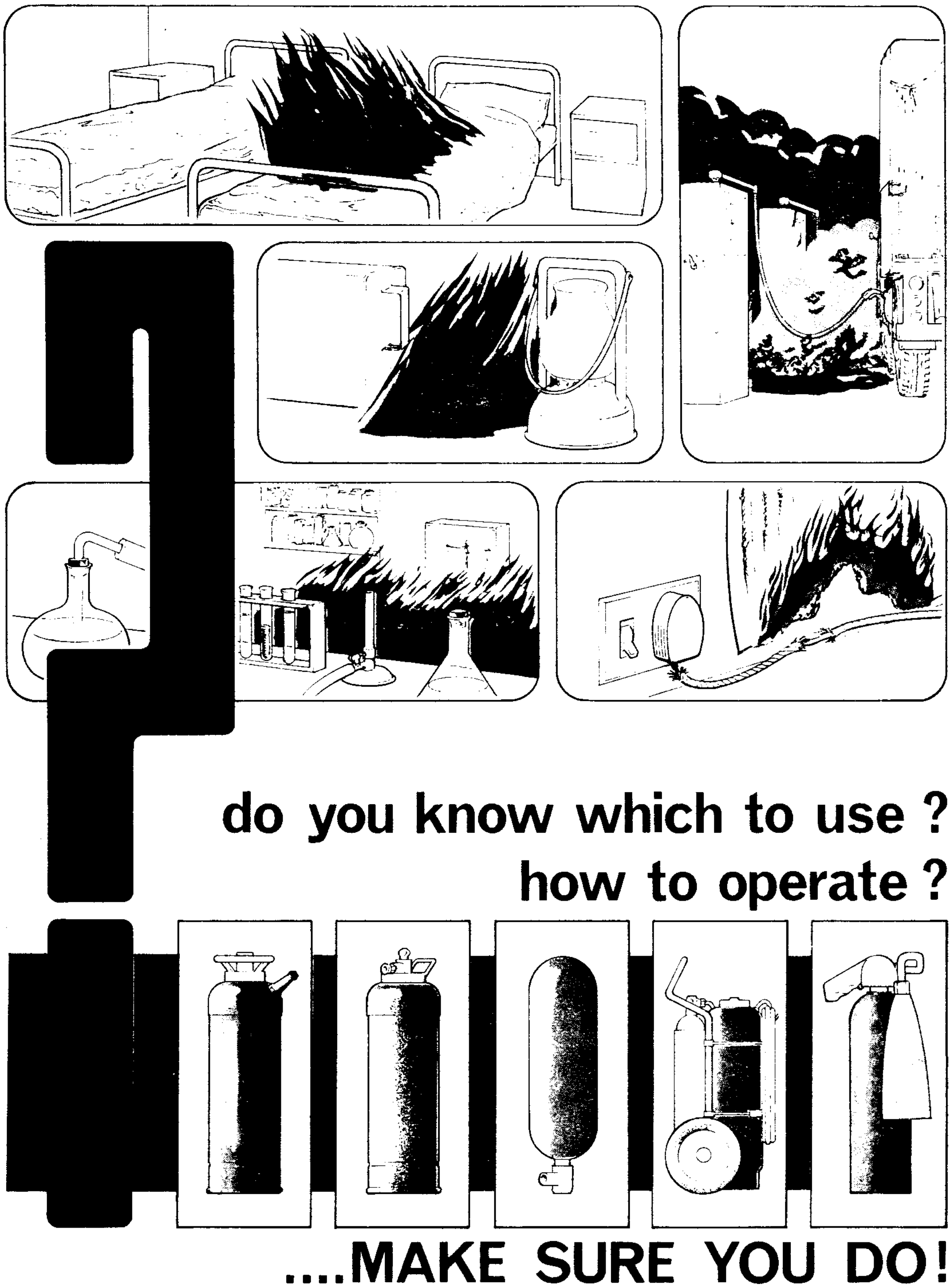


Fig 2.9 Fires and Extinguishers

Never forget that effective fire protection depend on:

- Detection of outbreaks at an early stage.
- Raising the alarm promptly and correctly.
- Speedy and correct suppression.

If a fire breaks out—make sure that you are prepared.

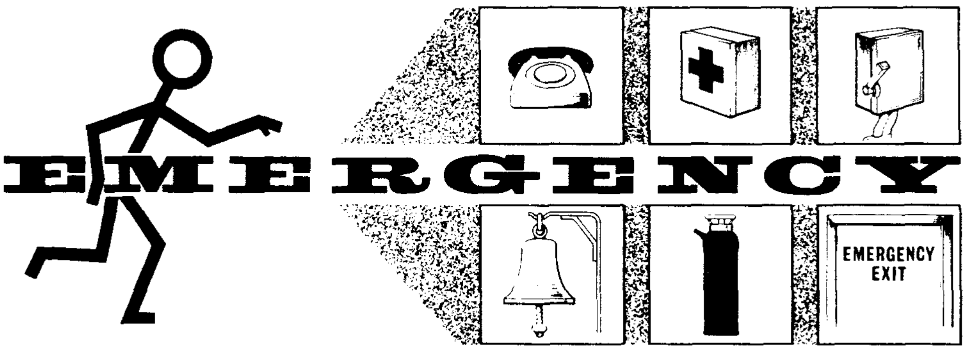


Fig 2.10 Where and Why ?

DO YOU KNOW (Fig 2.10):

- How to raise the alarm?
- The sound of the fire alarm?
- Where the nearest fire point is?
- How to use the fire-fighting equipment?
- The nearest emergency exit?

If not—**FIND OUT NOW!**

SUMMARY—REVIEW

Fire

The consequences of fire are such that we must all be fire conscious. This entails strict observance of fire orders and deletion of all carelessness.

Q What do the words 'inflammable' and 'flammable' mean? (p 2.1).

Causes of Fire

Fires may be started in a variety of ways

Q Give some 'causes of fire' (p 2.1).

Combustion

Oxygen is necessary to sustain burning. To enable chemical combustion of material and oxygen, the material must be in a gaseous state or be converted to a gas by heat.

Q What are the two methods of extinguishing fires? (p 2.2).

Extinguishants

Water can be used effectively against fires involving solids, provided they are not electrically 'alive'.

Q Why would you not use water on a liquid fire? (p 2.3).

Q When would you use sand as a first aid extinguishant? (p 2.3).

Foam can be used to cover the surface of oil or other liquid fires (p 2.3).

Q What types of foam are in general use for fire-fighting? (p 2.3).

Dry powder discharged above the surface of a fire replaces the oxygen necessary for combustion and also reduces the temperature in the fire zone (p 2.3).

Q What type of fire is dry powder intended to be used against? (p 2.3).

Any inert gas which is heavier than air will have a blanketing effect when applied to the seat of a fire (p 2.3).

Q For what type of fire is this type of extinguishant particularly useful? (p 2.3).

First Aid Fire-fighting Appliances

First aid fire-fighting appliances are provided at various locations throughout the station; they are designed for instant use.

Q Why is instant identification important? (p 2.4).

The soda acid type of extinguisher is for use on solid material fires and must not be used on liquid fires or those involving electricity.

Q How would you obtain maximum effect from a soda acid extinguisher? (p 2.5).

Water/gas extinguishers are now replacing soda acid types and on this new equipment the water is discharged under CO_2 gas pressure.

Q How is accidental discharge of a water/gas extinguisher prevented? (p 2.5).

The 2 gallon foam extinguisher is primarily for use on burning liquids but may also be used on solid material fires.

Q State your working position when using a 2 gallon foam extinguisher (p 2.5).

Q How does the operation of 2 gallon foam extinguisher differ from all other types (p 2.5).

The dry powder trolley is intended for use mainly where flammable liquids are stored in bulk. The gas/powder mixture which is discharged expands into a dense cloud of powder.

Q Where would you position yourself with regard to the fire? (p 2.6).

Q How would you achieve complete coverage of the flame zone (p 2.6).

The 3 lb BCF extinguisher is provided mainly for use on fires in electrical and electronic apparatus, but can also be used effectively against small oil and other liquid fires.

Q Why is it necessary to get into position before operating the 3 lb BCF extinguisher (p 2.7).

An improved type BCF extinguisher consists of a plastic operating handle and one of three different capacity containers.

Q How would you operate one of these extinguishers? (p 2.7).

Four sizes of CO_2 hand fire extinguishers are provided for use in buildings where they may be required to deal with small-scale fires in the cleanest possible way. They are also carried on certain specialist vehicles, such as refuellers, in addition to the 3 lb BCF extinguisher. The 6.8 kg type may also be provided on crash/fire trucks and domestic fire trucks.

Q What are the two principal types of operating head? (p 2.8).

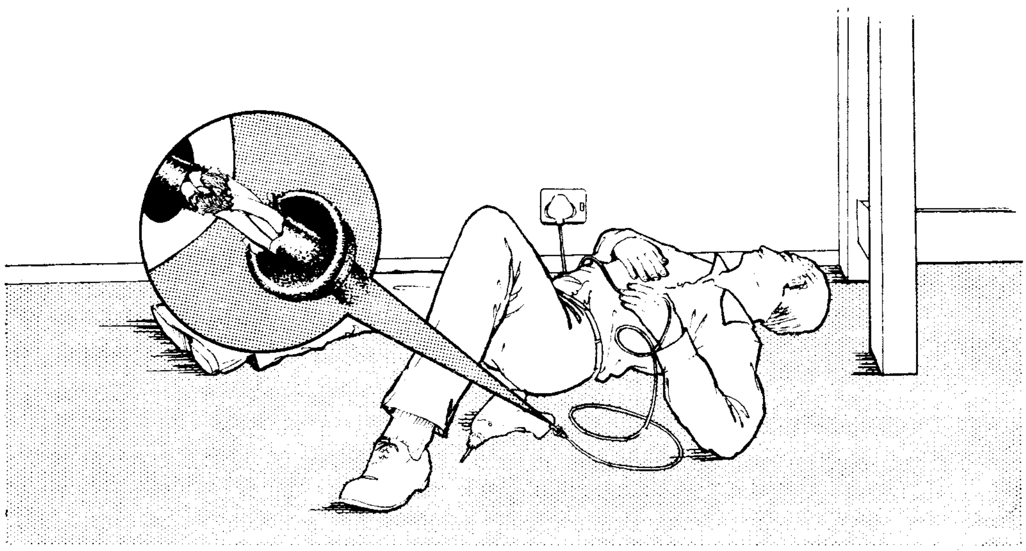
Q The discharged gas forms a white cloud. What is your objective and how do you operate the horn to achieve this? (p 2.8).

Q You discover a fire in each of the following situations. What colour of extinguisher would you use for each particular incident?

- In the clothing store.
- In the workshop—a receptacle containing gasoline for cleaning purposes is on fire.
- An electric cooker in the cookhouse.

CHAPTER 3

PERSONAL SAFETY AND FIRST AID IN THE WORKSHOP



Introduction

Certain compulsory rules are displayed in every workshop. These are workshop safety precautions which are based upon the Factories Act of 1961, and are designed to safeguard the activities of everyone employed in the workshop. They are mainly concerned with levels of cleanliness, ventilation, heating, lighting, use of electric and pneumatic power, for protection, accident prevention, and first aid. In some jobs there are special risks for which additional local instructions are needed; these instances attention is drawn to the risks involved by a poster, or notice, displayed near the particular danger spot.

Accidents rarely just happen. They are more often caused by carelessness, or by deliberate disregard of the workshop safety rules. Since the precautions are intended to minimise the risk of injury, anyone who ignores them not only endangers his own life but also the lives of others around him. Furthermore, it should be remembered that, in law, a person may in some circumstances be held responsible for an accident if he has not taken the necessary protective measures. However, despite all warnings and reasonable caution, accidents still happen. It is therefore important that eryone should have an elementary knowledge of first aid and be able to help in an emergency.

Personal Safety

Every reasonable safeguard is incorporated in the design of modern workshop equipment but no safety device or set of rules can control a person's behaviour. A careless act, a moment of over-confidence, can prove very costly in terms of working hours lost and damage to personnel and equipment. The lesson is simple! Think—before doing anything. However, there are occasions, such as an emergency, when there is little time for thought, when the right actions must be instinctive. In these circumstances everyone must be able to act promptly and efficiently from any part of the workshop. So, for your own safety and that of your workmates, make certain that you are thoroughly familiar with your surroundings and KNOW THE WHEREABOUTS OF EACH OF THE ITEMS SHOWN IN FIG 3.1.

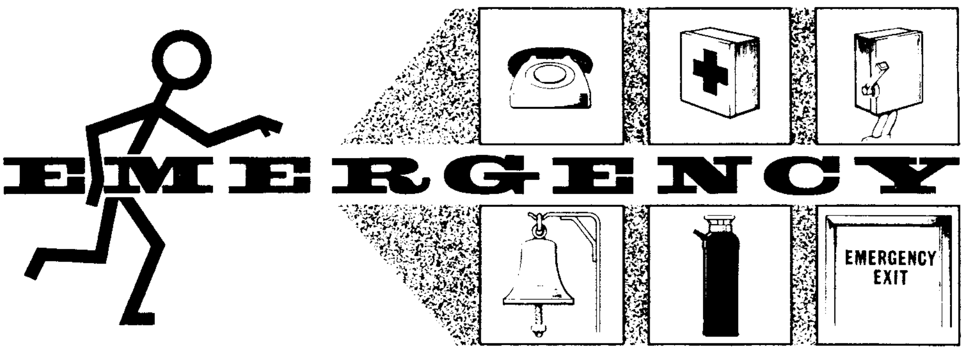


Fig 3.1 Where are they ?

Workshop tidiness. All persons who work in, or have cause to enter, a workshop or servicing bay should be conscious of the need for tidiness and the simple measures needed to avoid accidents. A tidy workshop is usually a safe place. The floor should be kept clean, free from patches of oil and grease, and not littered with equipment over which people may trip and fall. Equipment should be tidily stacked, leaving adequate work space and gangways for escape in case of emergency. General refuse, including oily rags and packaging materials, should not be allowed to accumulate and so become a fire hazard. Metal containers are provided for combustible waste; these should be emptied at the end of a working day and the rubbish burned in a safe place. This regular disposal is important, for if oily waste is allowed to build up and become tightly packed in these containers, there is a danger of spontaneous combustion taking place. Fuels and lubricants that have become contaminated in any way must be collected in containers and returned to the supply squadron for disposal; they are not to be poured into drains to become a fire hazard and a menace to life in the surrounding farms and streams.

Cleanliness. Personal hygiene is always important. In a workshop it is essential, not only to health, but to the safe production of good work. Overalls are provided and must always be worn. Correctly fastened and laundered at regular intervals, they avoid contamination of your normal clothing and provide a reasonable protection against industrial dermatitis, a skin infection which is caused by continual contact with oils, fuels, paints, and solvents. The hands can be protected by using 'barrier' cream and cleansing gel. The correct procedure is: BEFORE starting work, wash with water and rub in the barrier cream; AFTER work, remove with gel and wash again. Since no protective film of barrier cream can last a whole working day, this procedure must be followed at each break from work; this includes breaks for going to meals, visits to the toilet, or any other occasion. If the hands are likely to be exposed to solvents, or similar cleaning materials, for long periods then suitable gloves or gauntlets must be worn. The surface of the work bench should be kept clean and without any sharp edges or projections which could cause an injury; use a brush when cleaning down, not your hand.

Hand tools. Hand tools such as files, screwdrivers, pliers, hammers, and spanners are so commonplace that they are seldom considered to be dangerous. But they ARE dangerous, particularly if misused and not properly maintained (Fig 3.2). In the workshop, hand tools should be arranged so that they are readily to hand and able to be checked easily. A 'shadowboard' (see p 4.1), or similar device, can help to safeguard tools and avoid the loss of temper and time searching for mislaid items.

- **Files.** Never use these tools without a sound, tight-fitting handle. These handles should always have a metal ferrule which helps to secure the tang in the handle, and minimises the risk of the wood splitting.
- **Hammers.** Loose-fitting hammer heads are liable to fly off and cause serious injury. Before using a hammer be sure that the shaft is without cracks, and securely wedged in the hammer head.
- **Screwdrivers.** Always select the screwdriver that is the right size and shape for the screw, and check that the tip of the blade is in good condition. The tip of the common screwdriver should be ground or filed square and kept thick enough to fit the screw snugly. For electrical work use a screwdriver with an insulated handle. Do not carry screwdrivers, or similar sharp-ended tools, in your pockets.
- **Punches.** Punches with 'mushroomed' heads are a danger to users and passers-by. Keep the head ground or filed to its original shape; this applies to any similar tool that is repeatedly struck by a hammer.
- **Spanners.** Remember that for every nut or bolt there is a spanner of the correct size—USE IT! Ring and socket spanners are less likely to slip off the nut and are to be preferred to the common open-ened spanner; use an adjustable spanner only as a last resort. Whenever possible PULL a spanner rather than push it. In pushing you are more likely to lose your balance when the nut suddenly slackens; the result is usually very painful to the knuckles.
- **Pliers.** Pliers are liable to pinch the skin if grasped too near to the close-fitting hinge; grip the plier handles near the ends. When using pliers for clipping wire, hold them so that the ends of the wire, when snipped, are directed towards the ground. NEVER use pliers to tighten or slacken nuts, bolts or screws.

Do not place tools where they may be accidentally dislodged, particularly if they are being used above head level. Moreover, do not 'throw a spanner in the works' by leaving tools behind when a job has been completed.

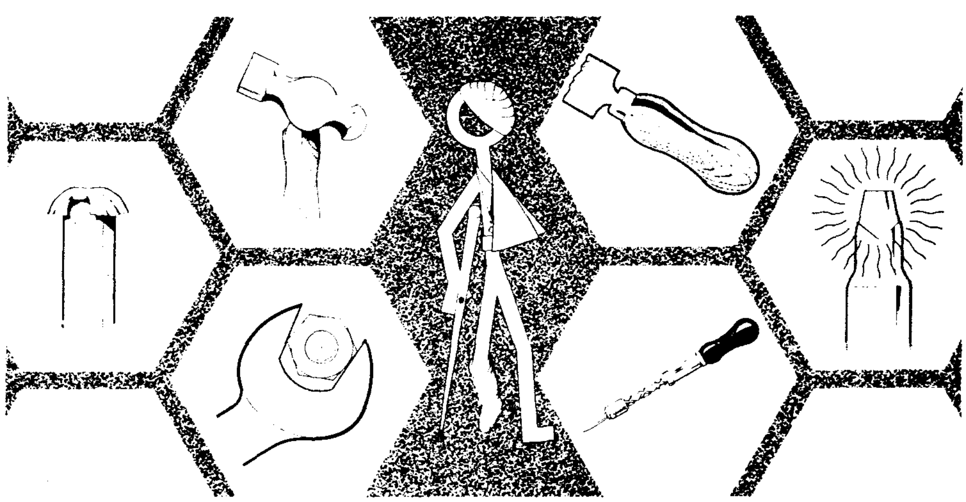


Fig 3.2 Misuse of Tools

Powered tools. Extra care is needed where electric or pneumatic power is used to operate tools and machines. Such tools are designed to be powerful and once started cannot be stopped immediately. Before using a powered machine be sure that the appropriate guards or fences are securely in place and that no part of your body or clothing can come in contact with the moving parts. Ensure that your overalls are correctly fastened and that your tie is either removed or safely tucked away. It is advisable to wear a cap if your hair is long, and to remove any rings from your fingers. Always protect your eyes when using a grinding machine; wear safety goggles even though the machine may have a perspex shield.

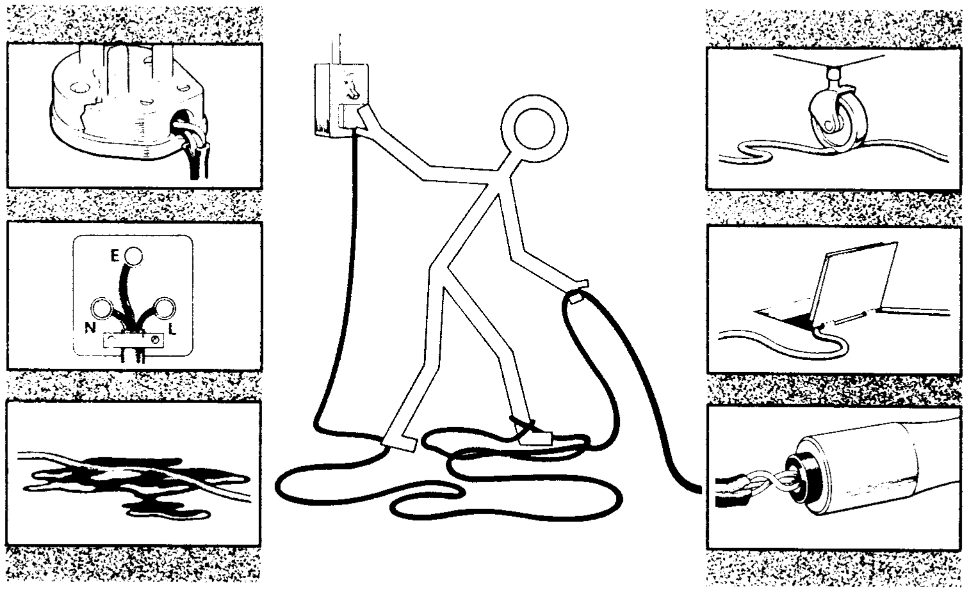


Fig. 3.3 Situations to be avoided with Electrical Equipment

When about to use a portable electrically-operated tool, such as a drill or a soldering iron, inspect the connecting cable for damage and ensure that an earthed (3-pin) plug is securely fitted to its end (Fig 3.3). BEFORE 'PLUGGING IN' TO THE MAINS SUPPLY SOCKET BE SURE THAT THE POWER IS SWITCHED OFF. If a lengthy run of cable is used, allow sufficient slack to avoid any strain being placed upon the cable connections; and take care that the cable is not trodden upon, laying in oil, or likely to be chafed by any sharp edges such as those of aircraft inspection panels and hatches. After use, or at any time when the tools are left unattended, switch off and remove the electric plug from the supply socket. When returning the tool to its stowage, coil the connecting cable carefully to avoid any kinks. Portable electrically-operated tools should be regularly and frequently tested, particular attention being paid to the flexible cable and its connections and to the continuity of the earth conductor.

Compressed air which is used to operate other portable power tools and lubricating equipment can, if misused, be extremely dangerous. Air pressure lines must be handled with care and the nozzles of such equipment must never be pointed towards a person's body. It must be realized that, apart from the obvious exposed danger spots such as the eyes, and ears, the air blast available at the nozzle can easily penetrate clothing and cause serious injury if the air enters any part of the body. It may be considered amusing to direct a jet of air at another person, but pressures as low as 10 to 15 lb per square inch have been known to produce severe internal injury, so—DO NOT PLAY ABOUT WITH COMPRESSED AIR—any accidental injection of air, oil or grease into the skin must receive immediate medical attention.

Handling equipment. Despite all the mechanical aids that are available we still rely on our hands for a great deal of the everyday lifting and carrying. When you have to manhandle equipment do it correctly (Fig 3.4). Remember that most back injuries are caused by incorrect lifting; that is, failing to keep the back straight and not using the leg muscles to take most of the strain. If it is necessary to manhandle larger articles, this must be done by a group of persons under the supervision of one individual. He alone must give clear, concise moving instructions.

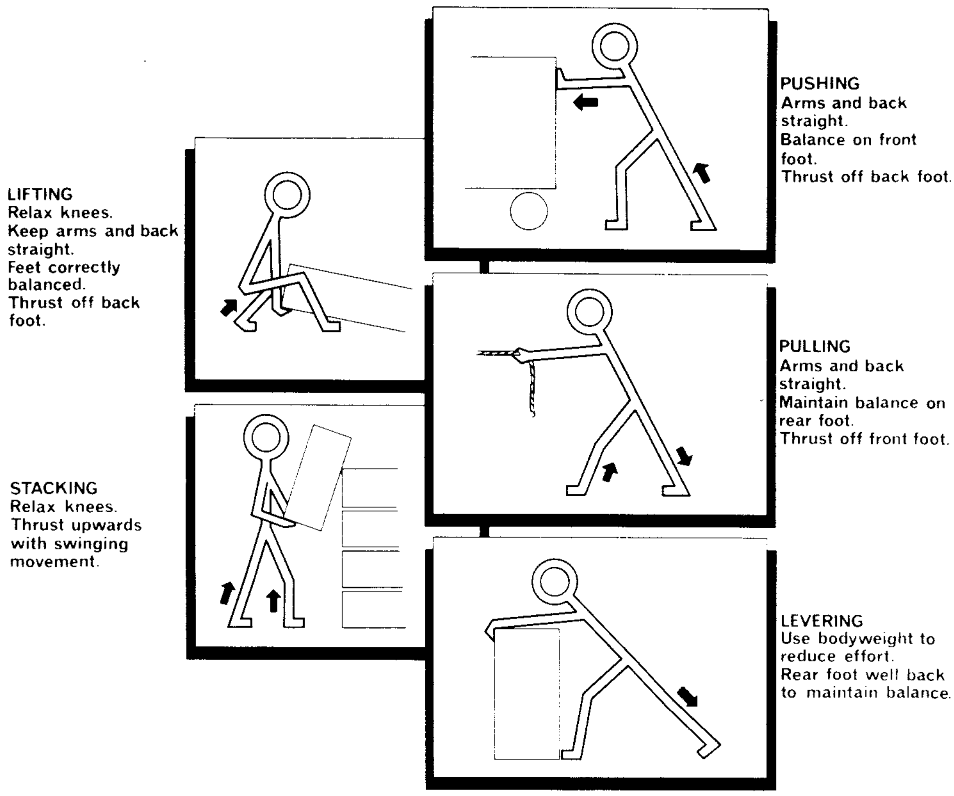


Fig 3.4 Correct handling techniques

For heavier work, mechanical lifting tackle must be used; check before use that the equipment bears a tag to show that it is capable of lifting the load and also that it is currently serviceable. Ensure the load is safely held using the appropriate hooks and slings; lift just clear of the ground and check security of the load before taking the full lift. DO NOT STAND BENEATH A SUSPENDED LOAD.

When using trolleys make sure the load is tidily stacked and unable to fall off. See that the way ahead is clear and watch that fingers are not trapped in doorways. When using fork lift trolleys be careful to stand clear when the forks are being raised or lowered.

Storage racks and benches need to be rigid to be safe; a loose bolt may result in dangerous movement, or even collapse, which could trap limbs and cause serious injury. Such equipment must be kept clean, particular attention being paid to the tread surfaces of ladders and servicing platforms which are made treacherous by grease spots and spillage of oil.

When engine-driven ground equipment is used in enclosed surrounds, there must be sufficient ventilation to avoid the build-up of poisonous exhaust fumes.

Toxic fluids. Many of the chemical solvents used for cleaning and degreasing give off fumes which, if inhaled, can cause loss of consciousness. They are in fact anaesthetics and can be very dangerous if used in a poorly ventilated area. Never attempt to work in any confined space which may contain dangerous fumes unless you are wearing suitable breathing apparatus. Continued exposure to toxic degreasants will produce a condition similar to intoxication which could gradually deteriorate to unconsciousness; any person who is employed on degreasing and seen to be showing these symptoms must be quickly taken out into the open air. Smoking, eating, and drinking are forbidden in any areas where chemical solvents are being used.

Fire prevention. Every person employed in the workshop must know what to do in the event of a fire. Be sure that you are conversant with the Fire Instructions applicable to the building and are able to use the fire-fighting equipment available. A variety of first aid fire appliances are sited at strategic points in the workshop. In addition to the extinguishers described in Chapter 2, there are often fire buckets, asbestos blankets, and hose reels for connection to the water supply.

Ordinary fires involving the common combustibles such as paper, wood, and plastics, can be put out with water from buckets, hoses, and the portable water/gas extinguishers. Foam extinguishers and buckets filled with sand are provided for dealing with liquid fires. Fires in electrical equipment can be put out in the cleanest possible way by using the 3 lb BCF extinguisher (Fig 3.5).

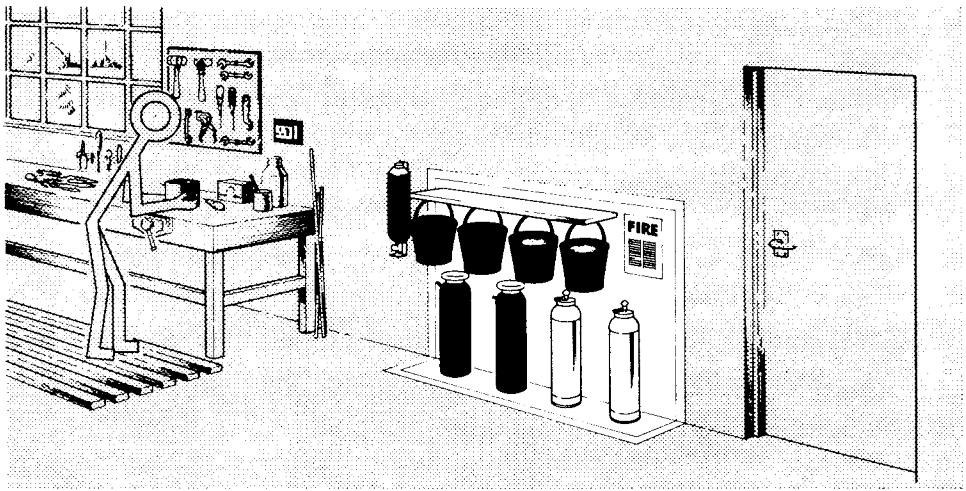


Fig 3.5 Fire-fighting equipment in the workshop

If a fire breaks out—make sure you are prepared for it. DO YOU KNOW:

- How to give the alarm?
- The sound of your fire alarm?
- Where the nearest fire point is?
- How to use the fire-fighting equipment?
- The nearest emergency exit?

If not—FIND OUT NOW!

First Aid

Introduction

Safety regulations in force in the RAF are designed to prevent accidents and should be strictly obeyed, but an accident can still happen any time, anywhere. A minor accident can be worsened by the lack of attention shown to the casualty or by the misplaced efforts of an over-enthusiastic helper. Some knowledge of first aid is always an asset; the ability to perform artificial respiration is essential to ALL whose work involves the use of electricity. Remember the two 'golden rules' of first aid:

- Perform immediately only those actions necessary to save life or to prevent the emergency from worsening.

- Send for medical aid as soon as possible.

Fortunately, first aid on most RAF units is largely concerned with minor injuries and ailments. With any other condition, the 'first aider' has only to know what to do to keep the injured person alive until medical help arrives. It must be remembered, however, that the effectiveness of first aid often depends on the ingenuity of the individual and his ability to improvise his materials from articles at the scene of the accident—*eg* scarves may be used as broad bandages, clean handkerchiefs for dressings, broom handles as splints, coats for blankets.

Priorities in First Aid

It is of vital importance when rendering first aid that the correct actions are carried out *in the correct order*. These are:

- Removing the casualty from any source of danger, at the same time ensuring that, whilst in the process of rescuing, you yourself do not become a casualty.
- Checking that the casualty is still breathing, and if he isn't, taking *immediate action* to try and restore his breathing.
- Stopping any bleeding.
- Recognise and treating shock.
- Covering all wounds, burns or scalds.
- Immobilising broken or suspected broken bones.
- Obtaining medical help without delay.

Removing Casualty from Danger

The casualty's condition must not be aggravated, nor his life endangered, by unnecessary handling or hurried evacuation. It may be better to treat the casualty where he is, as a helper acting alone could well cause more damage attempting evacuation than treating him at the site of the accident. However, a casualty must be removed if he is in danger from fire, poisonous fumes, collapsing buildings *etc*.

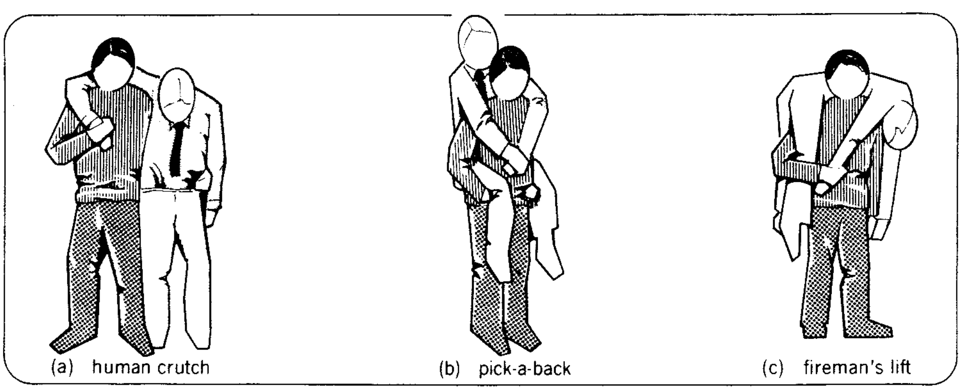


Fig 3.6 Removing a casualty (single person methods)

Removal by one man. There are three widely used methods whereby an unaided helper can evacuate a casualty and these are shown in Fig 3.6. If help is available do not attempt to evacuate a casualty single-handed.

- **The human crutch.** This is useful for leg injuries. Stand at the casualty's injured side. Place his arm over your shoulders and hold it in position with your outside hand. Assist the casualty by putting your inside arm around his waist, grasping his clothing at the hip (see Fig 3.6a).
- **Pick-a-back.** If the casualty is conscious and able to help he can be carried in the same way as a child riding pick-a-back (see Fig 3.6b).
- **Fireman's lift.** This method is difficult with a heavy casualty. Help the casualty to stand up and grasp his right wrist with your left hand. Bend down with your head under his right arm so that your right shoulder is just below the casualty's waist and place your right arm between

his legs. Taking the weight on your right shoulder, straighten your legs and rise to the upright position. Pull the casualty into a comfortable position across your shoulders and transfer his right wrist to your right hand (see Fig 3.6c).

Removal by two (or more) persons. There are two widely used methods of evacuating a casualty when two (or more) persons are available.

- **The 4-handed seat.** This method is used when the casualty is conscious and can assist with his arms. The two helpers face each other behind the casualty, grasp their own left wrists with their right hands and each other's right wrists with their left hands as shown in Fig 3.7a. They stoop down and tell the casualty to place one arm around the shoulders of each helper so that he may raise himself to sit on their linked hands. The helpers rise rise together, and, stepping off with their *outside* feet, walk in a normal manner with the casualty steadying himself with his arms (see Fig 3.7b).

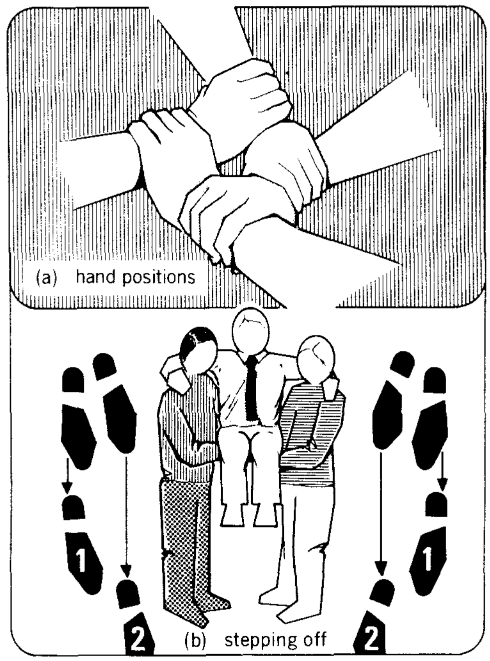


Fig 3.7 The four-handed seat

- **The 2-handed seat.** This method is used to carry a casualty who is unable to steady himself by using his arms. The two helpers stand facing one another on either side of the casualty. They stoop and place their forearms behind the casualty's back and, if possible, grasp the casualty's clothing (see Fig 3.8a). They raise the casualty's back from the floor and then link their free hands under the middle of the casualty's thighs. The hands are linked using a hooked grip as shown in Fig 3.8b and a handkerchief or piece of rag is useful to prevent the finger nails from digging in. The helpers rise to their feet and step off together with the *outside* feet as shown in Fig 3.8c.

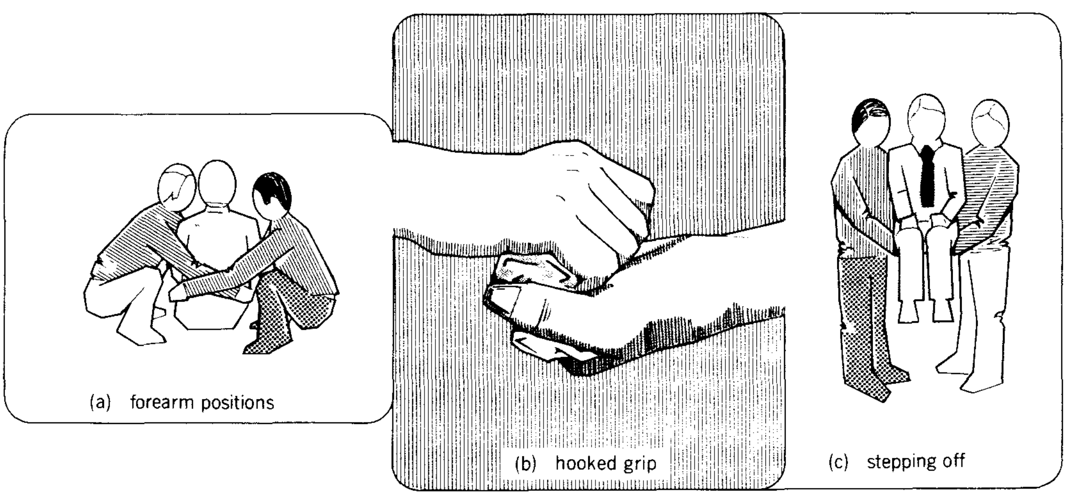


Fig 3.8 The two-handed seat

Unconsciousness

Loss of consciousness occurs when the brain ceases to work correctly. This may be caused in many ways. A person rendered unconscious may have suffered a blow on the head, he may have received an electric shock, or he may have been overcome by fumes. The treatment given to an unconscious person depends upon whether or not he is breathing.

a. **Unconscious person who is breathing.**

- Stop any serious bleeding.
- Roll him over into the 'recovery' position (Fig 3.9). The rear arm ahould be drawn gently backwards to extend slightly behind the person's back.
- Clear his mouth of any obstructions, including false teeth, if any.
- Bend his head and neck backwards and pull his chin forward; this prevents his tongue blocking his air passage (*see later*).
- Loosen his clothing at neck, chest and waist.
- Protect him with blankets, coats or rugs.
- Send for medical help.

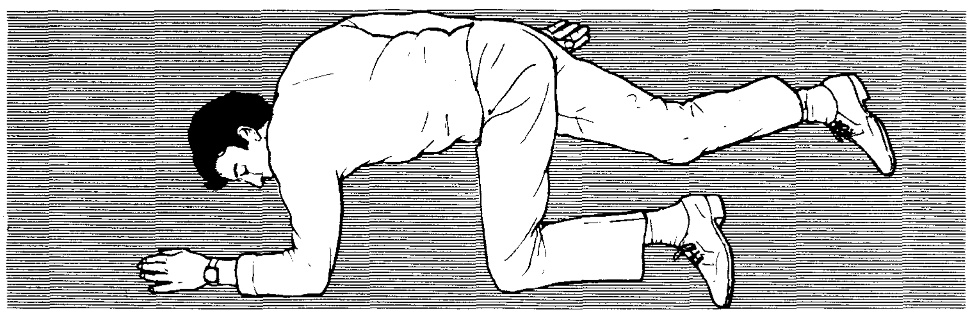


Fig 3.9 The recovery position

b. **Unconscious person who is not breathing.** It is important to determine very quickly whether or not a person is breathing so that there is *no delay* in applying artificial respiration should it prove necessary.

- If this is not done, *a person who is not breathing can die within a few minutes.*

So if you are faced with an unconscious person whom you suspect is not breathing, listen very carefully for sounds of breathing and watch for chest movements. If you find no signs of breathing, then:

- Clear the casualty's airway.
- Start artificial respiration IMMEDIATELY.

Clearing the Airway

To provide and maintain a clear airway:

- Put your finger in the casualty's mouth and remove any obstruction (including false teeth).
- Tilt his head well back and push his lower jaw forward.

Fig 3.10 shows that when an unconscious person is lying on his back, his tongue is likely to fall backwards, blocking the space between his mouth and windpipe. By pushing his head back, as shown, the tongue moves forward and the air passages are fully open.

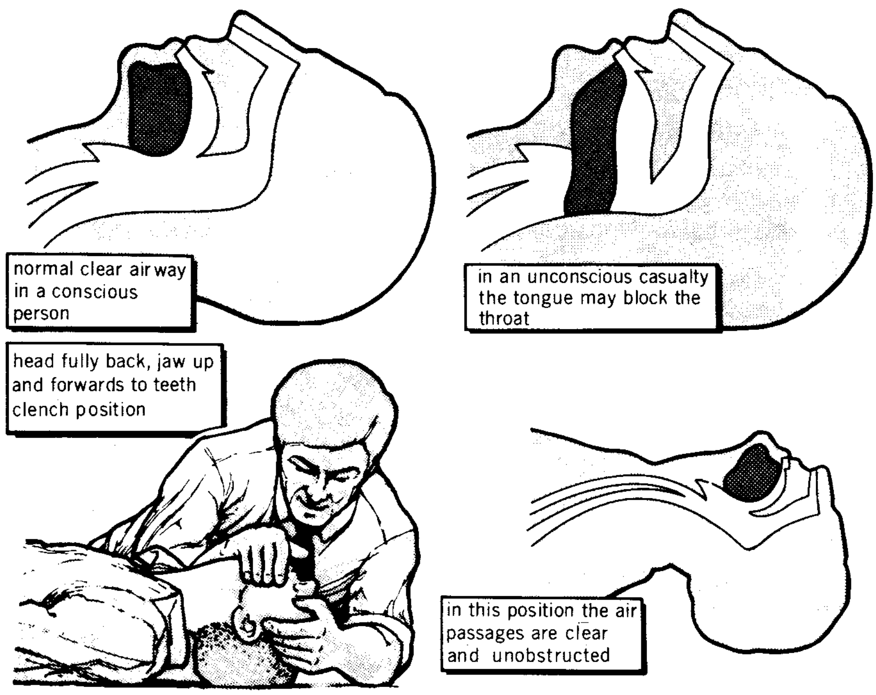


Fig 3.10 Clearing the airway

Artificial Respiration

If the brain is deprived of oxygen for four minutes irreversible changes take place in it; the aim of artificial respiration is to forestall these changes by the immediate oxygenation of the blood. Therefore, the importance of beginning artificial respiration AT ONCE and continuing it *without interruption* cannot be over-emphasized. All other treatments or considerations must be implemented only if they in no way interfere with the immediate, efficient and unremitting application of artificial respiration. There are two recognised methods for use by RAF personnel:

- The mouth-to-mouth (or mouth-to-nose) method.
- The Holger Nielsen method.

Mouth-to-mouth resuscitation. This is the most effective way of applying artificial respiration and should be used whenever possible. It is easy to apply and, since no movement of the patient's limbs is required, it avoids worsening any injuries he may have. In this method, you breathe air from your own lungs through the patient's mouth (or nose) into his lungs. The method is illustrated in Fig 3.11.

- Turn the casualty on his back.
- Ensure a clear airway.
- Apply artificial respiration as illustrated in Fig 3.11.

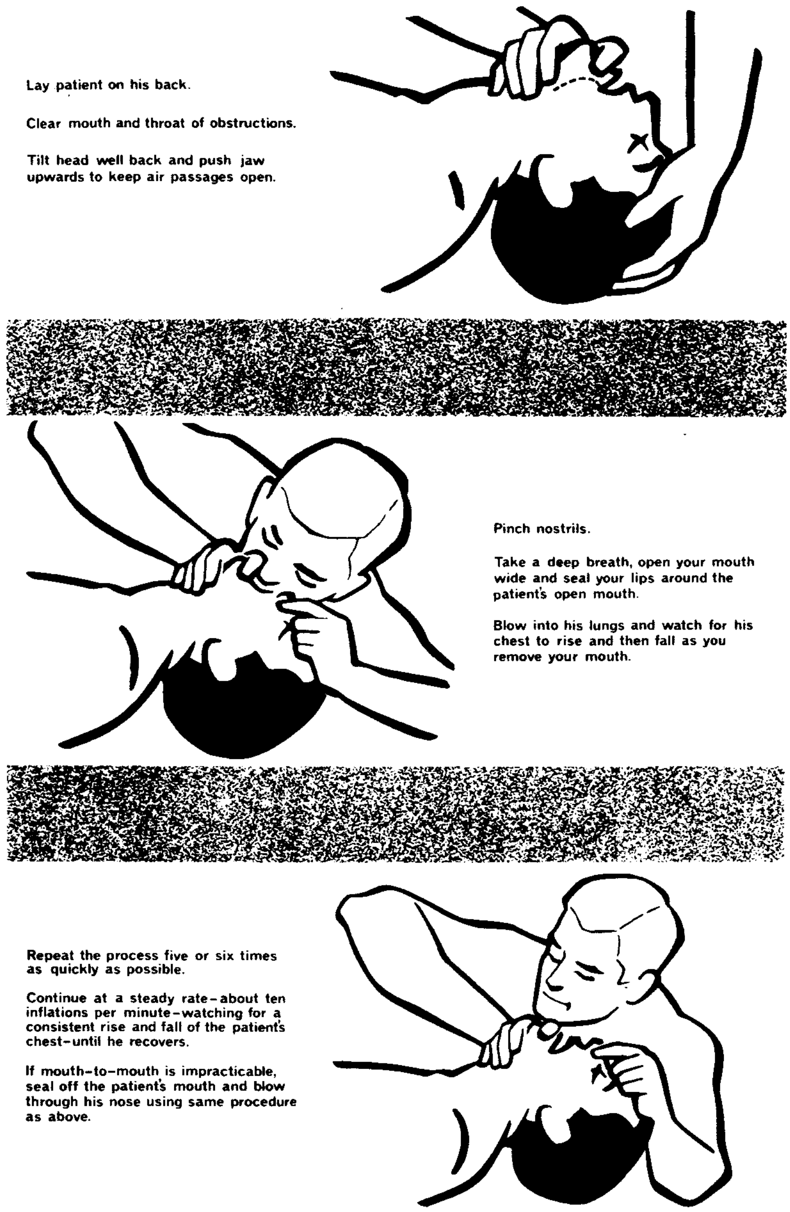


Fig 3.11 Mouth-to-mouth resuscitation

- Loosen the patient's clothing at neck, chest and waist.
- Continue artificial respiration until the patient is breathing normally or until medical help arrives. DO NOT GIVE UP.
- If breathing continues unassisted but the patient remains unconscious, place him in the 'recovery' position (Fig 3.9).

Note. Medical assistance should be sent for as soon as possible without interfering with *the immediate application of artificial respiration.*

The Holger Nielsen method. This method of applying artificial respiration is used when the injuries to the casualty prevent the mouth-to-mouth (or mouth-to-nose) method from being used. However, the Holger Nielsen method cannot be used when the casualty has severe arm or chest injuries. Proceed as shown in Fig 3.12 and described below:

- Place the casualty face downwards with his arms under his head and the elbows bent so that one hand rests on the other.
- Turn his head to one side so that his cheek rests on his uppermost hand.
- Kneel on one knee at the casualty's head and put the foot of your opposite leg near his elbow (Fig 3.12A).
- Place your hands on his back just below his shoulder blades and rock forward with your elbows straight, until your arms are approximately vertical. In this way, a steady pressure is applied to the casualty's chest (Fig 3.12B). Do this once, and then:

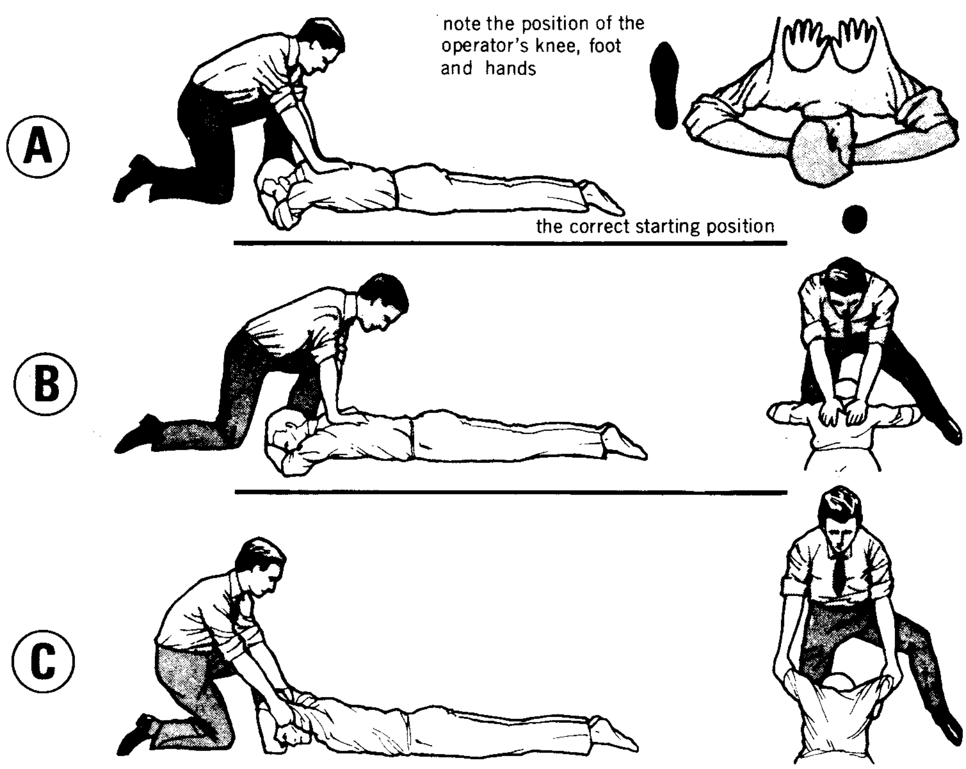


Fig 3.12 The Holger Nielsen method

- Grip his arms just above the elbows and rock backwards, raising his arms until resistance and tension are felt at his shoulders; then lower his arms (Fig 3.12C).
- Repeat the actions shown in B and C about 12 times each minute until the casualty is breathing normally.
- Medical help must be obtained as soon as possible.

Bleeding

Minor wounds. With most small cuts and abrasions, the bleeding stops fairly quickly. Nevertheless, it is important that all cuts and abrasions are *thoroughly cleaned by washing under a running tap.* Cover the wounds with a sterile dressing from the first aid box held in the section. Take care not to touch either the wound or the sterile surface of the dressing (see Fig 3.13). Where it is considered necessary, further treatment must be obtained from the Station Medical Centre.

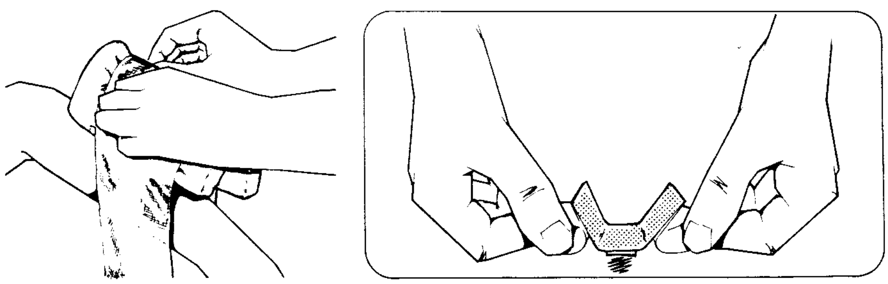


Fig 3.13 Keep dressings sterile

Major wounds. These injuries need expert medical attention. Until this help arrives, avoid further infection and stop the bleeding:

- Seat the injured person or lay him down.
- Raise the part that is bleeding above the level of the rest of the body, if possible, and support it (Fig 3.14).
- Place a sterile dressing, or clean pad, over the wound and bind it firmly into place. Do not try to remove anything embedded in the wound.
- If bleeding continues, and blood comes through the dressing, add further dressings and bandage firmly.
- Send for medical help as soon as possible.

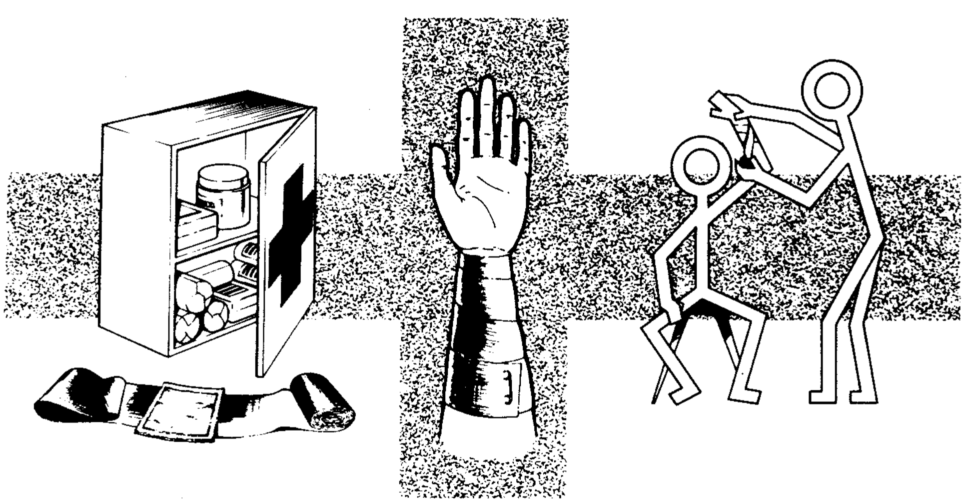


Fig 3.14 Treating major wounds

Shock

Shock is a dangerous state of collapse which may develop after a serious injury. When a person is shocked:

- He is very pale.
- His skin is cold, yet moist with sweat.
- His pulse is weak, but fast.
- His breathing is rapid, but shallow.
- He may complain of thirst.
- He is restless at first but may lapse into unconsciousness.

A person in this condition needs URGENT medical attention.

Until medical help arrives:

- Stop any bleeding.
- Move the patient as little as possible; lay him down, turn his head to one side and, provided they are not fractured, raise his legs above the level of his head (Fig 3.15).
- Loosen any tight clothing.
- Protect him with blankets, coats or rugs.
- Stay with him and do all you can to relieve anxiety and to reassure him until medical help arrives.
- Do not give anything to eat or drink.

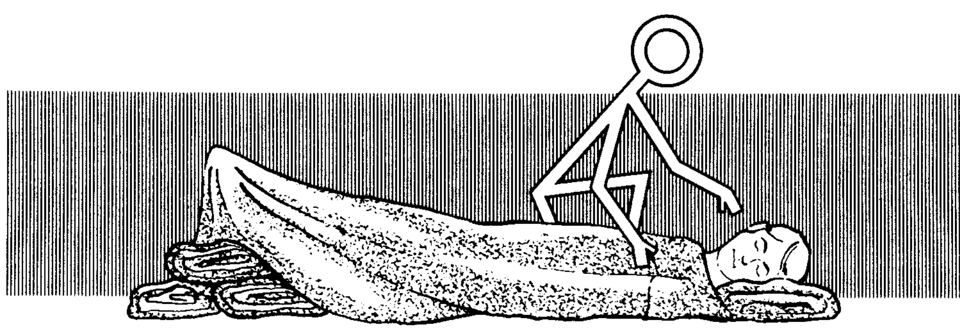


Fig 3.15 Treatment for shock

Electric Shock

Precautions. Electricity strikes without warning; the only safeguards against it are to observe all safety regulations and to ensure that *you* and *all your colleagues* can perform artificial respiration. Safety regulations are published in AP3158 Vol 2 and AP100B but the following points should be borne in mind:

- Safety interlocks on equipment should not be over-ridden unless it is necessary for servicing or adjustment purposes.
- Two or more persons must be present at all times when work is being carried out on 'live' equipment.
- The person doing the work must stand on a rubber insulating mat and should work 'one-handed' if at all possible.

Treatment for electric shock:

- Switch off the current at once. If this is not possible the victim should be removed from contact by using any available insulator such as a broom. Be careful to avoid contact with live conductors, or the patient, with bare hands. Stand on a rubber mat while moving the patient from contact if this is possible.
- START ARTIFICIAL RESPIRATION IMMEDIATELY. Speed is vital; any known method of respiration is better than a delay.
- Loosen the patient's collar and any tight clothing *without interrupting the artificial respiration.*
- If as a result of electric shock the patient is suffering from burns they should be covered with a sterile dressing if this can be done *without hindrance to the artificial respiration.*
- Send for medical aid. Even after apparent recovery the victim should be seen by the medical officer as victims of electric shock sometimes suffer a relapse.

Burns

Causes. A burn is an injury caused by dry heat or chemicals, as a result of which the skin goes red and blisters may form. In severe cases the skin may be destroyed and the tissues underneath damaged. They are commonly caused by:

- Dry heat, such as fire or contact with hot metals.
- Friction, such as contact with a moving wheel or rope.
- High tension electricity, lightning strikes, or high power *rf* fields.
- Severe cold *eg* contact with liquid oxygen, dry ice *etc.*
- Corrosive chemicals such as the acid or alkaline electrolyte from storage batteries.

Fluid loss. The danger from a burn increases with its surface area, and medical aid should be obtained without delay in serious cases. Burns are always extremely painful and are usually accompanied by shock due to loss of plasma. This fluid leaks out as a yellowish sticky fluid from the burned areas and may either form blisters or leak away from damaged skin areas. In burns of large surface area this loss of fluid can soon become dangerous. Conscious casualties should be given drinks of (warm) water, tea or milk (BUT NOT ALCOHOL) in quantities of about half a cup every 10 minutes or so until medical help arrives. DO NOT give fluids to an unconscious patient.

Treatment for general burns:

- Cool the area by immersion in clean cold water (or under a running cold water tap) for a period of 10 minutes.
- *Do not prick blisters or attempt to remove clothing stuck to the affected area.*
- Dry the affected area and then apply a clean dry dressing, sterile if possible.
- Do not apply any antiseptics, creams, oils or powders to burns.
- Treat for shock (see p 3.14).

Treatment for chemical burns. Always take reasonable precautions against burning by contact with contaminated clothing, particularly if strong sulphuric acid (used in most batteries) is involved.

- Flush the burn AT ONCE using plenty of water—warm if possible.
- Eyes should be held open and flushed for at least 15 minutes. The MO should be called to all eye injuries.
- Contaminated clothes should be removed while flushing continues.
- If the burn is serious, flushing should be continued until the MO arrives.

Broken Bones

Accidents resulting in broken bones are commonly caused by slipping on an oil or grease patch on a workshop or hangar floor. The floor should be kept clean at all times and should not be used as a storage place for objects which could cause someone to trip and fall. If heavy objects are being handled the proper lifting tackle must be used. Do not walk under suspended loads or place your limbs in a position where a slipped load could cause an injury.

The treatment of broken bones should always be carried out by medical personnel, as an injury may be aggravated by well meaning but misplaced attention. The following rules apply:

- *Do not attempt to straighten the injured part.*
- If the patient *must* be moved for his own safety, the injured part should be supported.
- Reassure the patient.
- *Do not give the patient fluids* as an anaesthetic will almost certainly be required.

Radioactivity

Some of the electron tubes used in modern equipments contain radioactive materials and dangerous radiations are given off by some modern inspection techniques which use X-rays. Serious injury to health can be caused by:

- Contamination of wounds by fragments of broken radioactive valves.
- Effects of the vapour released from broken valves either by inhaling fumes or eating foods contaminated by this vapour or dust from the immediate area.
- Exposure to radiation due to incorrect use of X-ray equipment.

All safety regulations (AP4678A) must be obeyed, and all radioactive items must be handled with extreme care.

Treatment:

- Cuts or abrasions must be reported to the MO who *must* be told that the injury was sustained while in contact with radioactive material.
- If the MO is not available:

  (1) Wash the wound with soap and large quantities of clean water.

  (2) Stimulate mild bleeding by applying manual pressure around the wound.

Frostbite

Frostbite affects the exposed parts of the body, particularly those parts where blood circulation is poor *eg* the nose, ears, hands and feet. Frostbite first appears as a small patch of white (or cream coloured) frozen skin which is firm to the touch. A prickling sensation may be felt by the victim as the skin freezes. To avoid frostbite:

- Keep moving—exercise fingers and toes—wrinkle the skin on your face.
- Never handle cold objects, particularly metals, with bare hands.
- Avoid exposure of flesh in high wind conditions.
- Avoid spilling fuel on bare flesh—the flesh will freeze almost at once as the fuel evaporates.

Treatment for frostbite. Personnel suffering from any of the ill effects of exposure should have medical treatment. Frostbite, however, also needs immediate attention:

- Slight cases may be treated by getting out of the wind. A small area may be warmed up by placing a bare hand over it, covering the outside of the hand with a glove or mitt. Woollen pads on backs of gloves may provide enough warmth.
- Frostbitten hands should be thrust inside your clothing against your body.
- Keep the frostbitten part covered with *dry* clothing until you reach shelter.
- *Never* rub frostbite—especially with snow.
- If blisters appear, do not burst them.
- Never warm up frostbite quickly by holding the affected part before fire or radiators, or by dipping in hot water. Use body-warmth heat only.

Excessive Heat

Personnel who are not accustomed to high temperatures can develop heat exhaustion due to a salt and/or water deficiency. In more severe cases heat stroke may occur.

Heat exhaustion. This is a similar condition to shock, and is commonly found in newcomers to very hot climates. Excessive sweating causes salt and fluid losses which are often further aggravated by diarrhoea or vomiting.

- **Symptoms:**
  - The casualty is exhausted but may be restless.
  - The face is pale and cold but sweating.
  - The breathing and pulse are rapid.
  - The casualty may complain of dizziness or nausea and may have a headache.
  - Muscular cramp may occur, particularly in the abdomen.
- **Treatment:**
  - Place the casualty in cool surroundings and *keep him there.*
  - If he is conscious give him cold water to drink. If there is a lot of sweating it is best to add a half-teaspoonful of salt to each pint of water.
  - Obtain medical assistance.

Heat stroke. The onset of heat stroke is often quite sudden and the casualty may collapse unconscious. The casualty is unable to control his body temperature by the normal sweating process.

- **Symptoms:**
  - A body temperature of 40°C (104°F) or more may occur.
  - The face is flushed and the skin hot and dry to the touch.

- ■ Breathing may be noisy.
- ■ There may be confusion or stupor and unconsciousness may result.

- **Treatment.** Medical attention is vital. The purpose of first aid is to reduce the casualty's body temperature as quickly as possible.
  - ■ Strip the casualty and wrap in a wet, cold sheet or blanket. Keep this wet until the casualty's temperature is lowered to 38°C (101°F).
  - ■ Place the casualty in the recovery position.
  - ■ If fans are available direct the air on to the casualty to assist cooling by evaporation.
  - ■ If the casualty's temperature rises again before medical help arrives repeat the treatment.

What To Do In an Emergency

If an emergency does arise in your section, in-as-much as that someone is injured, you should take the following actions:

- Make sure that the patient is breathing properly; remove any obstruction in the mouth and, if necessary, start artificial respiration immediately.
- Stop any bleeding.
- Do not move the injured person until you know what is wrong—unless his life could be further endangered if you don't move him.
- Give what treatment you can, but do not attempt too much.
- Treat for shock; uncover the patient as little as possible.
- Keep spectators away and send for the medical officer, giving accurate details of what happened.

SUMMARY—REVIEW

Workshop Tidiness

All persons who work in, or have cause to enter, a workshop or servicing bay should be aware of the need for tidiness and the simple measures needed to avoid accidents.

Q Name the simple measures necessary to avoid accident in the workshop (p. 3.2).

Cleanliness

Personal hygiene is always important.

Q What is the correct procedure for using barrier cream and cleansing gel? (p. 3.2).

Powered Tools

Extra care is needed where electric or pneumatic power is used to operate tools and machinery.

Q List the precautions necessary when using an electrically powered drill (p. 3.4).

Handling Equipment

Despite all the mechanical aids that are available we still rely on our hands for a great deal of the everyday lifting and carrying.

Q What is the correct way to lift a load? (p. 3.5).

Toxic Fluids

Q Why is smoking, eating and drinking forbidden in areas where chemical solvents are being used? (p. 3.5).

Priorities in First Aid

In rendering first aid it is vital that certain actions are carried out in the correct order.

Q What are these actions and in what order must they be carried out? (p. 3.7).

Removing a Casualty from Danger

A casualty must be removed if he is in danger from fire, poisonous fumes, collapsed buildings etc.

Q What are the five methods of removing a casualty? (p. 3.7).

Unconsciousness

The treatment given to an unconscious person depends upon whether or not he is breathing.

Q What is the treatment to be given to an unconscious person who is:

a. Breathing? (p. 3.9). b. Not breathing? (p. 3.9).

Artificial Respiration

There are two recognised methods of artificial respiration—mouth-to-mouth resuscitation and the Holger Nielsen method.

Q Describe how you would carry out the mouth-to-mouth method (p 3.10).

Q Describe how you would carry out the Holger Nielsen method (p. 3.12).

Bleeding

Major wounds need expert medical attention.

Q One of your workmates is badly injured and losing a lot of blood. What would you do to try and help? (p. 3.13).

Shock

Shock is a dangerous state of collapse which may develop after a serious injury.

Q A person suffering from shock has various symptoms. List three of these symptoms. (p. 3.14).

Electric Shock

Most electrical accidents are due to faulty electrical apparatus.

Q It is stated in the text that you must not touch a person suffering from electric shock whilst he is still in contact with the source of electricity. Why is this important? (p. 3.15).

Q How, then, do you disconnect him from the source of electricity? (p. 3.15).

Q If the patient has stopped breathing, what is your first action once he is clear of the electrical supply? (p. 3.15).

Burns

Dry burns are caused by fire or contact with hot metals and by friction such as contact with moving rope.

Q How would you render first aid to someone suffering from a rope burn? (p. 3.15).

Broken Bones

The treatment of broken bones is the job of the medical expert.

Q Until this help arrives what should your action be? (p. 3.16).

Frostbite

Frostbite effects the exposed parts of the body.

Q How can frostbite be avoided? (p. 3.17).

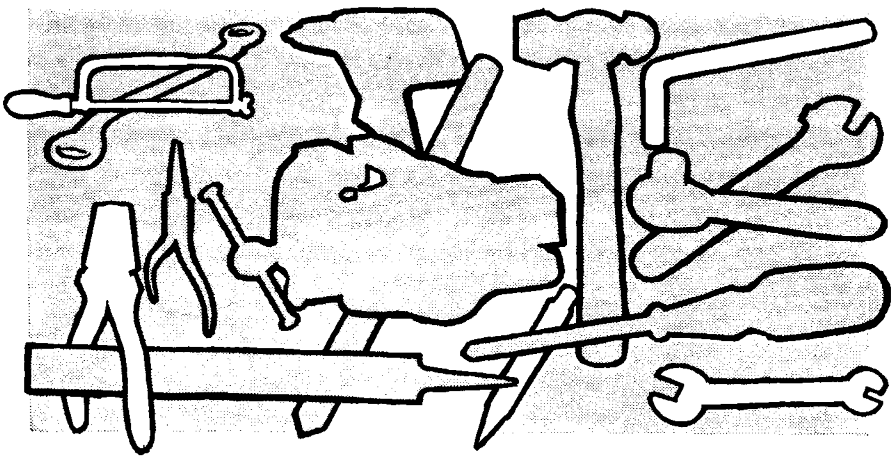
Q What is the treatment for frostbite? (p. 3.17).

What to do in a Emergency

Q What action should be taken should an emergency arise in your section, such as someone being injured? (p. 3.18).

CHAPTER 4

HAND TOOLS



Introduction

Most of the work that an aerial erector does in the field or in the workshop requires the use of hand tools. The quality of work depends very much upon how these tools are used and the care and consideration they receive afterwards. Skill with tools is a matter of continual practice, whilst taking care of them is just plain common sense. Even the most expensive tools quickly become second rate when ill-used, thrown into tool boxes, or left lying about after use. Tool boxes, holdalls, transit cases, and shadowboards, are all designed to protect tools, not merely to contain them.

Fig 4.1 shows a shadowboard, a device commonly used in workshops. The outlines of the tools are painted on a contrasting background and tools covering their appropriate 'shadows' are held on the board by hooks and clips. When a tool is removed from the shadowboard it is replaced by the personal disc of the tradesman removing it. In this way a check of the board quickly shows the tools in use, who is using them and, at the end of a task, the tools that are missing.

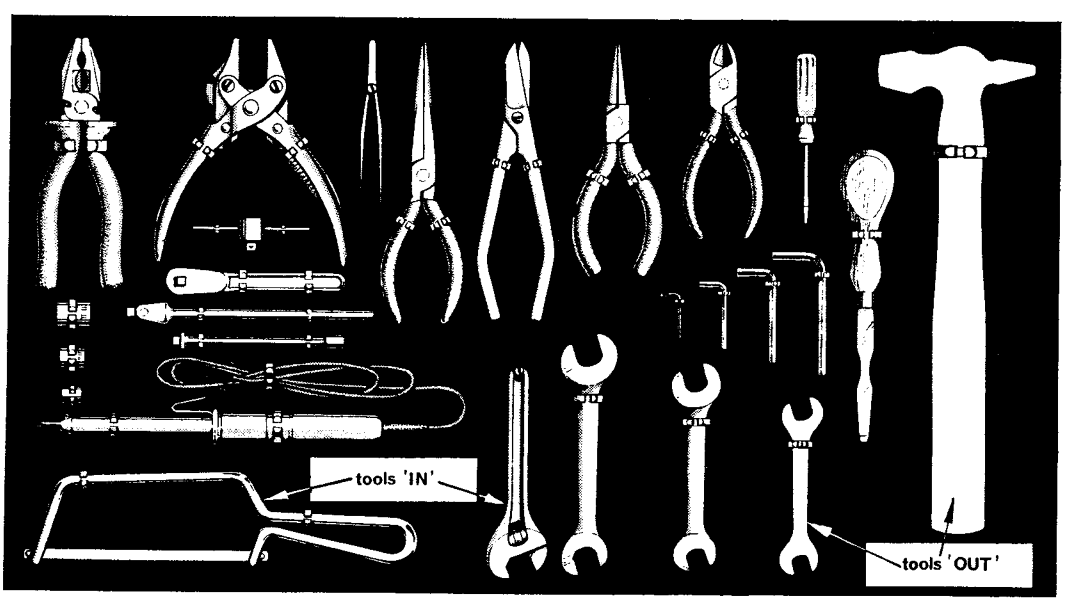


Fig 4.1 Shadowboard and Tools

Before accurate work can be done with any hand tool, the work must be held steady. A rigid bench is essential, and the most important fixture on it is the vice (Fig 4.2). Securely bolted to the bench, the vice is able to hold work firmly and in its most suitable position. The jaws of the bench vice are detachable and are serrated to help grip the work. When it is necessary to hold work which has smooth finished surfaces, clamps made of soft material are placed over the jaws. The sliding jaw is normally operated by a screw moving in and out of a nut in the stationary part of the vice; by moving the quick release lever the screw can be disengaged and the sliding jaw pushed or pulled into any required position. The height of the vice should be such that the top of the vice is level with the fitter's elbow as he stands beside the bench.

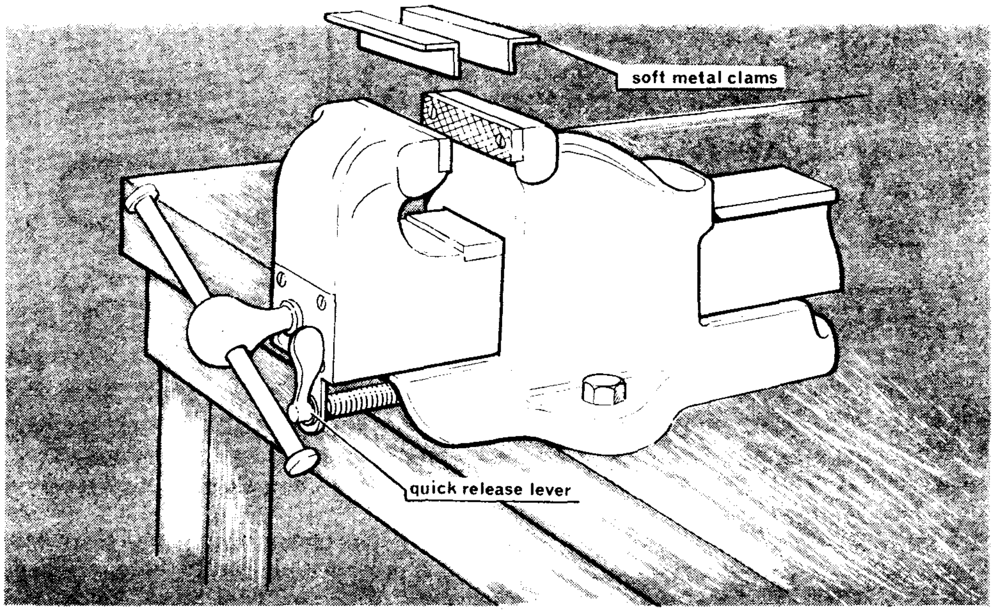


Fig 4.2 Bench Vice

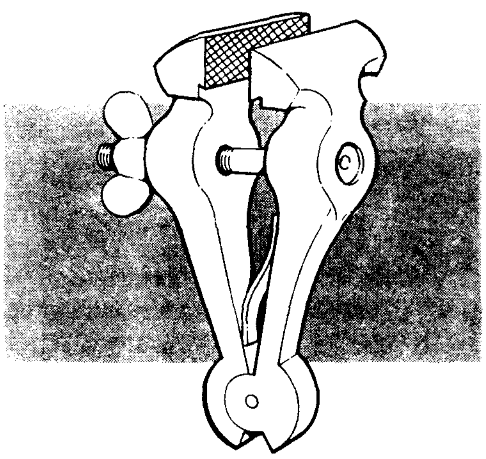


Fig 4.3 Hand Vice

A hand vice (Fig 4.3) is used for holding small work which cannot be conveniently held in the bench vice. It is also useful as a 'G' clamp for holding parts together while an adhesive sets hard.

Hacksaw

The hacksaw is used for cutting material to approximate size. It consists of an adjustable frame and a narrow, hardened steel blade. The blade fits over two pegs projecting from mountings which slide in and out of the frame-ends, and is tensioned by turning the wing nut at the forward end. The blade is fitted to the frame with the teeth pointing away from the handle so that the saw cuts on the forward stroke (Fig 4.4). The blade can be set at right angles to the frame enabling long narrow strips to be cut from a sheet of material.

Hacksaw blades are made in a variety of grades. Fine-toothed blades (24-32 teeth per inch) are used to cut hard material and metal of thin section, whilst coarse blades (14-18 teeth per inch) are used to cut softer, bulkier materials. A progressive pitch blade on which the teeth are finely-spaced at the front end and become gradually coarser towards the rear, can be used to cut a wide range of materials. Blades are fragile and are easily damaged by rough usage. Best results are obtained by cutting with the full length of the blade using steady even strokes, pressure being applied as the saw is pushed forward. Short rapid strokes are inefficient, cause overheating, and shorten the life of the blade.

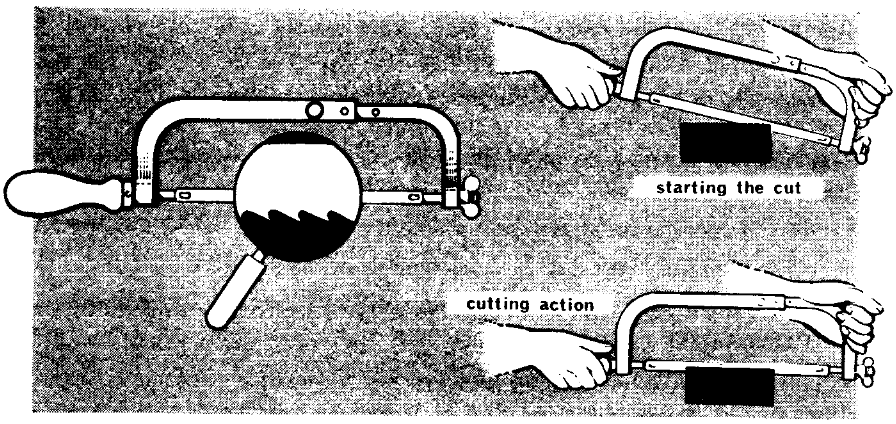


Fig 4.4 Using a Hacksaw

Files

Files are used to reduce metal accurately to the required size. The blade is made of hardened steel, and the tang, to which the wooden handle is fitted, is left soft. Files are made in various lengths, shapes, and grades of cutting edge, and are classified by these important features. The standard cross-sections and shapes are shown in Fig 4.5.

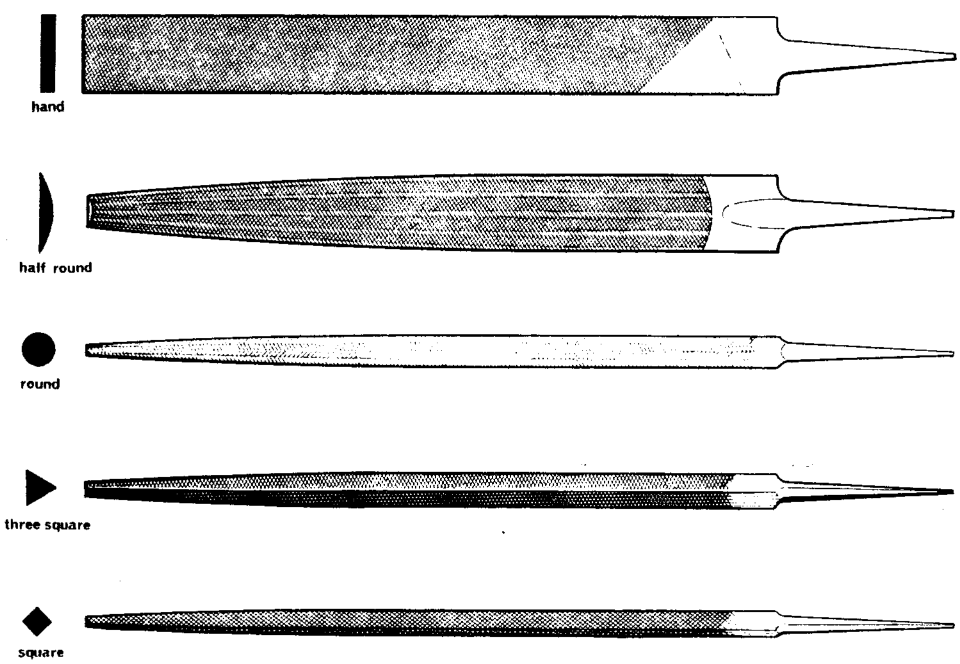


Fig 4.5 Common Types of File

- **Hand.** This is a general purpose file, used mainly for filing flat surfaces. One edge of the blade is usually smooth or 'safe' which allows one surface in a corner to be filed without causing damage to the other. The abbreviation HSE is used to describe this file in tool checking lists and catalogues and simply means a *Hand File* with a *Safe Edge.*
- **Half round.** Used for filing irregular shaped work and large radii.
- **Round.** Sometimes called a "rat-tail", the round file is used for enlarging holes and filing small internal radii.
- **Three-square.** A file of triangular section, used for filing angles of less than 90°.
- **Square.** Used to file small flat surfaces where the hand file is inconvenient.

The cut of a file is the pattern of the teeth on the faces of the blade. Various cuts are provided, designed to give the most satisfactory results when working on different materials (Fig 4.6).

- **Single cut.** This cut is used on the softer metals, such as brass, copper, and aluminium. Since there is only one set of teeth the file is less likely to become clogged. Round files and the curved face of half round files are normally single cut.
- **Double cut.** Double cut files are normally used to cut iron and steel. As its name implies, it is a pattern in which two sets of teeth cross each other.
- **Dreadnought.** The curved teeth are ideal for heavy cutting on broad soft metal surface.
- **Rasp.** A cut used on very soft materials such as wood or plastic.

A file is graded by the pitch of the teeth which governs the rate of cutting and the quality of the finished surface. The common grades are:

- **Bastard.** This is a coarse fast-cutting grade used for rough preliminary filing.
- **Second cut.** A semi-rough grade which gives a better finish than a bastard file.
- **Smooth.** This produces a good finish; a very slow cutter.

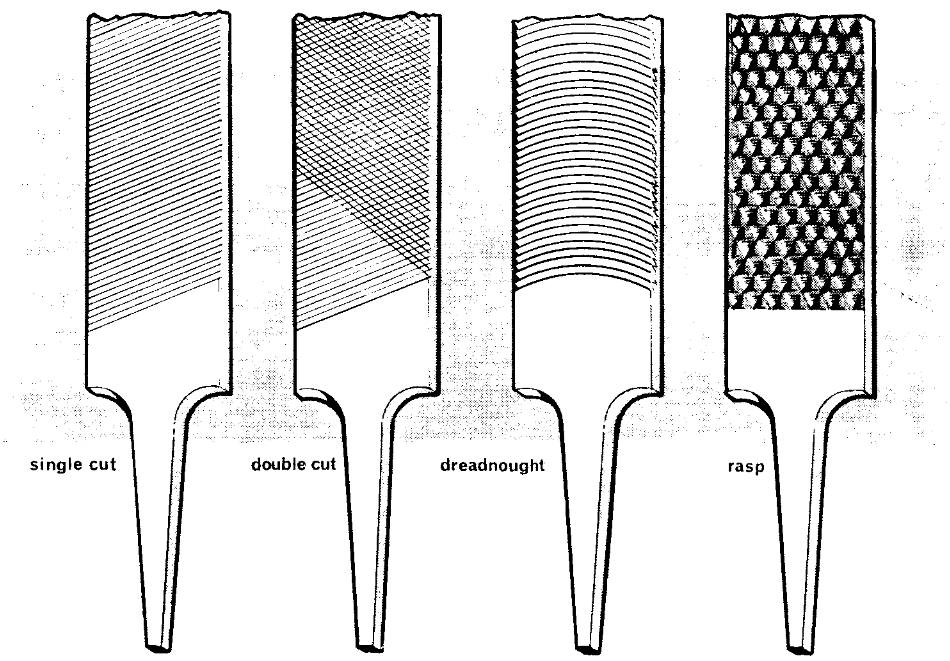


Fig 4.6 File Cuts

Files are quickly ruined by misuse and lack of care. In a tool box they should never be mixed with other tools but kept separate, even from each other, in a file hold-all. Alternatively, in a workshop, they should be stowed separately in rack. It is important to keep the file teeth clean, dry and free from corrosion. Filings which collect in the teeth during use can be removed by frequently brushing the face of the file with a wire brush; oil and grease can be absorbed by rubbing chalk into the teeth. Always choose the correct file for the job, and ensure that the handle is the right size and fixed securely to the tang.

Punches

Punches are used to localize the blow of a hammer and to prevent damage to the area surrounding the working point. Various types are available, but the only type you will be concerned with is the *centre punch* (Fig 4.7).

The centre punch is used, amongst other things, to make small indentations or "pops" to locate the point of a drill. They are made of hardened steel ground to a point at one end.

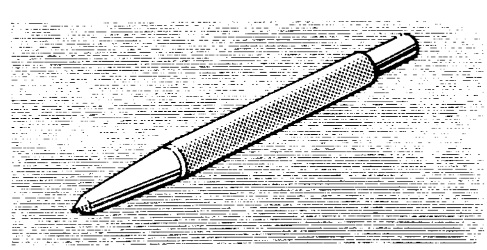


Fig 4.7 Centre Punch

Drills

Drills are used for cutting circular holes in materials, the most efficient type of drill used for general metal work being the twist-drill (Fig 4.8). The spiral fluting presents the cutting edges to the work at the correct angle and provides an exit for the waste metal, or swarf; it is also a path down which lubricant can be fed to the cutting edges. The two grades of drill are known as "carbon steel" and "high speed steel"; the abbreviation CS or HSS is stamped upon the drill shank. High speed drills have the advantage of being able to cut at much higher speeds than carbon steel drills without damage to the cutting edges.

The size of a twist-drill is marked on the shank in the form of a fraction, a number, or a letter. On small drills where marking is impracticable, the size can be checked by using a drill gauge. Metric drills have now superseded the numbered and lettered series and there is a metric size to replace each drill of these obsolete ranges. The minimum metric drill size is 0·35 mm diameter, but the general purpose range runs from 1·00 mm diameter upward in steps of 0·5 mm.

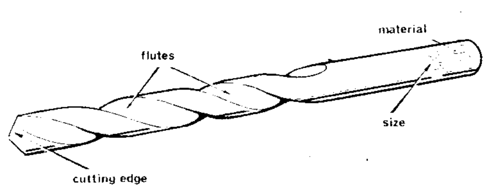


Fig 4.8 Twist Drill

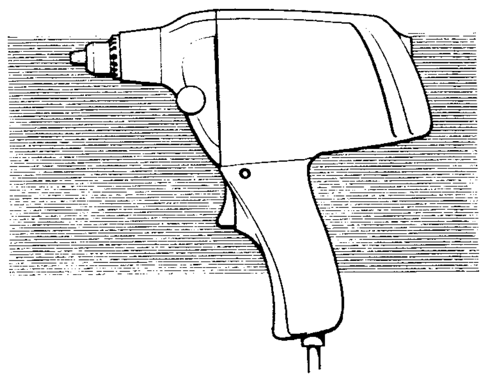


Fig 4.9 Portable Power Drill

Portable Drilling Machines

It is often more convenient to take the drill to the work than it is to take the work to the drill. In this way the use of hand or portable power drills can save valuable servicing time by avoiding any dismantling. The hand drill is used for small drilling operations and can house drills up to 6·35 mm ($\frac{1}{4}$ inch). Where electric power is available, it is preferable to use a power drill (Fig 4.9).

Before using any portable power tool always check that the power supply lead and its connections are in sound condition.

When electric power is not available, a hand drill of the type shown in Fig 4.10 will have to be used.

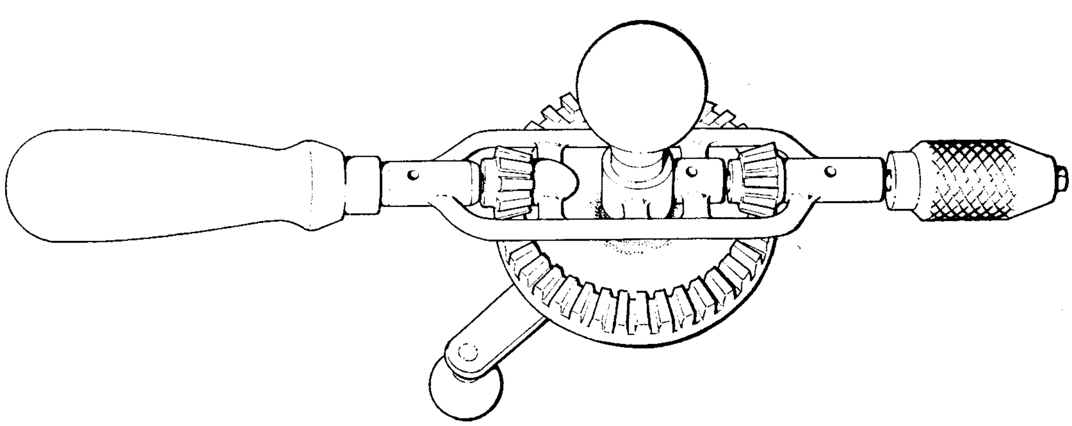


Fig 4.10 Hand Drill

Drilling Procedure

The following procedure applies whether drilling is done using a hand-operated drill or power-driven portable drill.

- Mark the centre position of the hole to be drilled by using a centre punch to make a "pop" mark.
- Fit the correct size drill into the chuck and rotate the drive to check that the drill is correctly centred.
- Secure the work in a vice when appropriate.
- Place the top of the drill in the centre pop. Keep the drill perpendicular to the work surface and, if using a hand-operated drill, turn the drive slowly until the drill bites into the surface. If using a power-operated hand drill apply only a light pressure on the drill.
- Increase the speed of the hand drive (or apply more pressure if using a power drill) until the correct feed is obtained. Apply a lubricant if necessary to keep the drill cool.
- If a hole of limited depth is required make a pencil or chalk mark on the body of the drill at the required distance from the point. Pause several times during drilling, stop the drill, and clear any swarf from the hole.
- When drilling right through a material the pressure should be reduced towards the end of the job to prevent breaking of the surface as the drill emerges.
- Continue rotating the drill clockwise whilst withdrawing it from the hole.

Chisels

Metal-cutting chisels are used in conjunction with steel-headed hammers. They are forged from high-carbon steel with the cutting edge hardened and tempered; alternatively they may be made of nickel-alloy steel, specially treated to procure a long-lasting cutting edge. Chisels are classified by their overall length and shape, but the only one that you as Aerial Erectors will use is the flat chisel (Fig 4.11).

After considerable use the end of the chisel struck by the hammer will become ragged and must be removed by grinding.

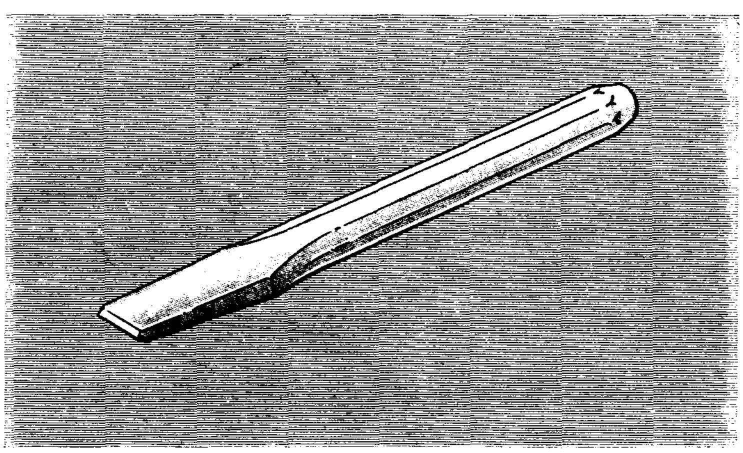


Fig 4.11 Flat Chisel

Screwdrivers

A screwdriver consists of a hardened steel blade fitted with a suitable handle, usually made from an insulating material. Screwdrivers are classified by the length of the blade, *eg*, screwdriver common 6 in. Some screwdrivers have a ratchet mechanism in the handle to permit speedy operation (Fig 4.12).

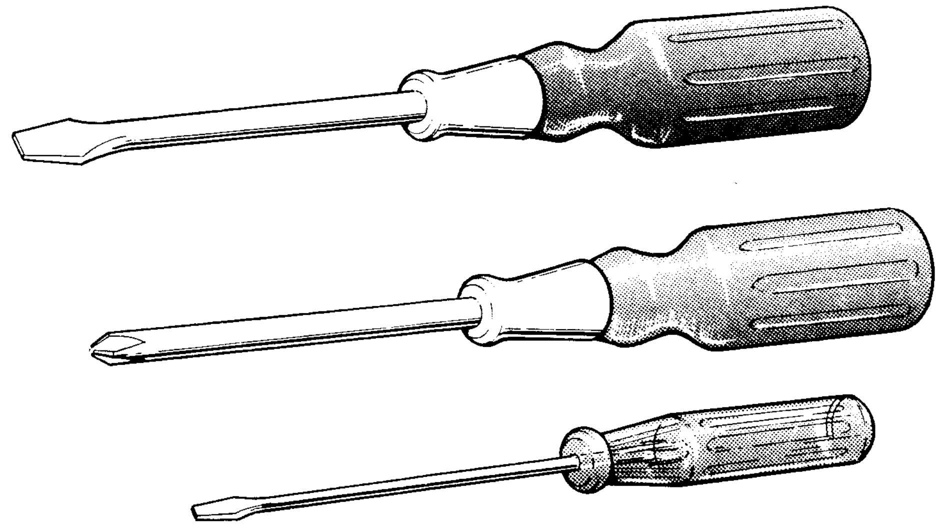


Fig 4.12 Screwdrivers

The use of the screwdriver demands the utmost care. To avoid damage and possible personal injury, ensure that the screwdriver you use is the right size and that its blade is a snug fit in the recess of the screw (Fig 4.13).

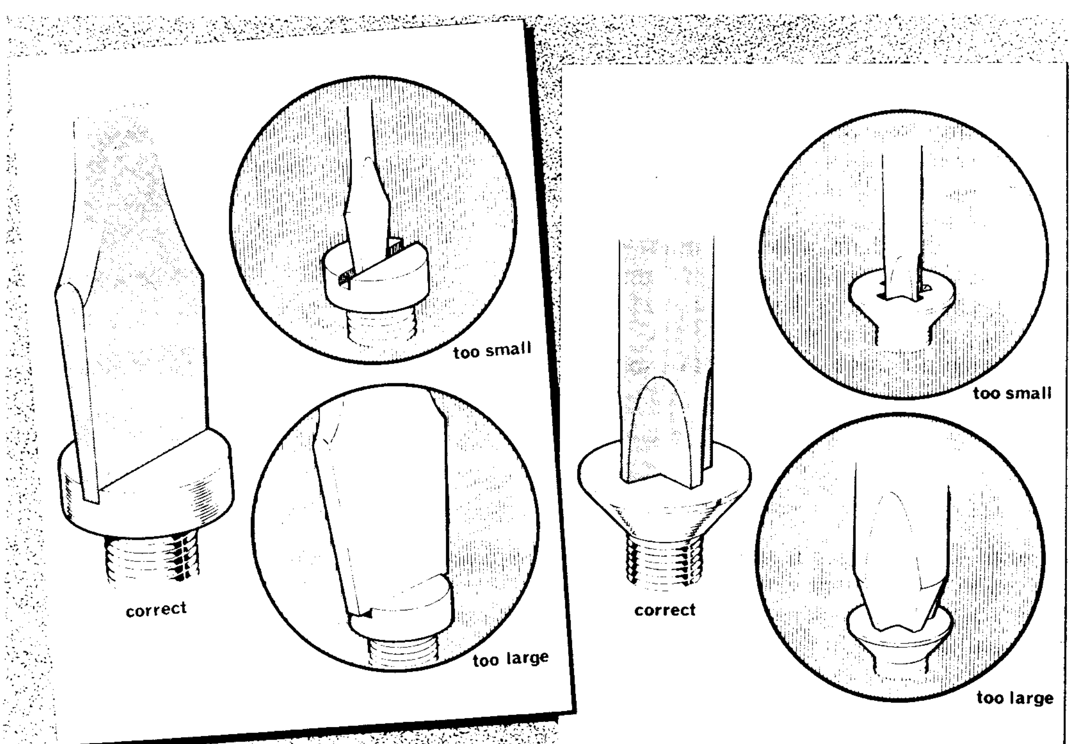


Fig 4.13 Choice of Screwdrivers

Pliers and Cutters

Pliers. Pliers are used for gripping small objects which cannot easily be handled with the fingers. They can be used in places where the fingers will not go and for holding objects which are too hot to touch. Typical uses are holding components during soldering, removing split pins from locknuts and pulling wires through small holes. The jaws of different types of pliers are shaped to suit their normal applications. Two common types are shown in Fig 4.14.

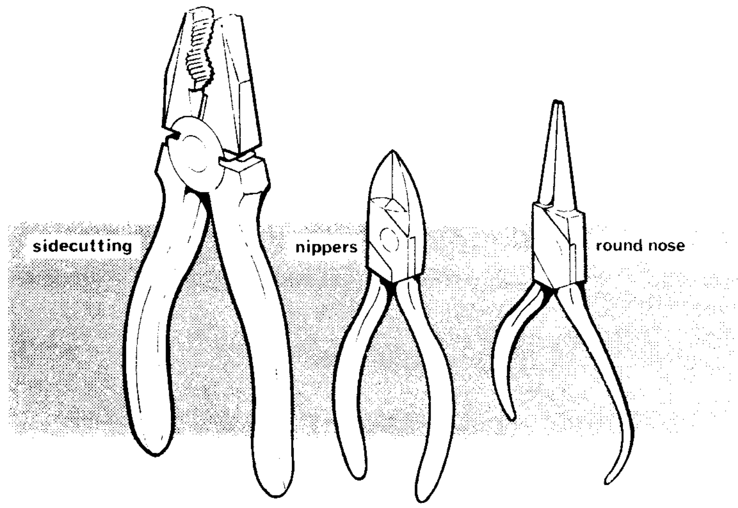


Fig 4.14 Pliers and Nippers

Nippers. Nippers are used for cutting wires or small bolts and are often incorporated as part of a pair of pliers. One common type of nipper (nippers diagonal) is shown in Fig 4.14.

Hammers

A hammer consists, with certain exceptions, of a high carbon steel head, hardened on the working faces and attached to a wooden shaft. The head must be wedged securely to the shaft with a wedge lying parallel to the axis of the head. A hammer should be held close to the end of the shaft to obtain maximum control (Fig 4.15).

Hammers are classified by type and weight of the head (Fig 4.16).

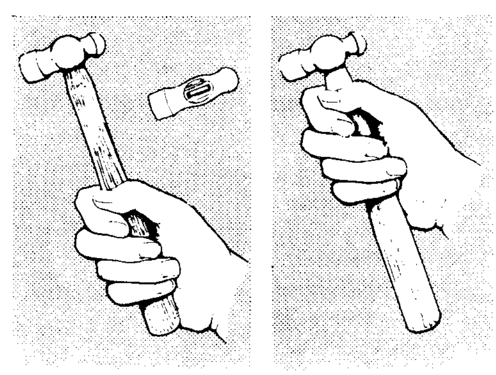


Fig 4.15 Use of a Hammer

Ball pein. This hammer is used for all normal engineering work; the ball enables a blow to be delivered to a very small working area.

Cross pein and straight pein. These hammers are also in general use, the narrow pein being convenient for working in a narrow space.

Nylon faced. Used when damage to the surface of a soft material must be avoided.

7 lb and 14 lb hammers. These are heavy duty hammers used for driving in marking pegs and pickets.

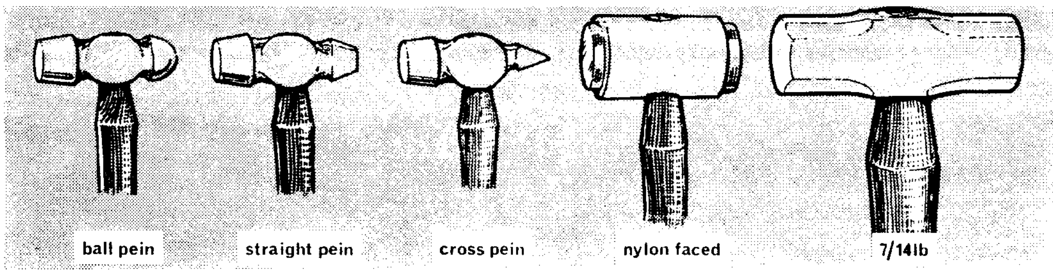


Fig 4.16 Types of Hammer

Spanners

Spanners are used to tighten or loosen nuts and bolts. The leverage provided by the length of the normal spanner enables a nut or bolt to be tightened sufficiently by hand. The use of a hammer or spanner-lengthening device is bad practice and will certainly damage the screw-thread and probably fracture the bolt.

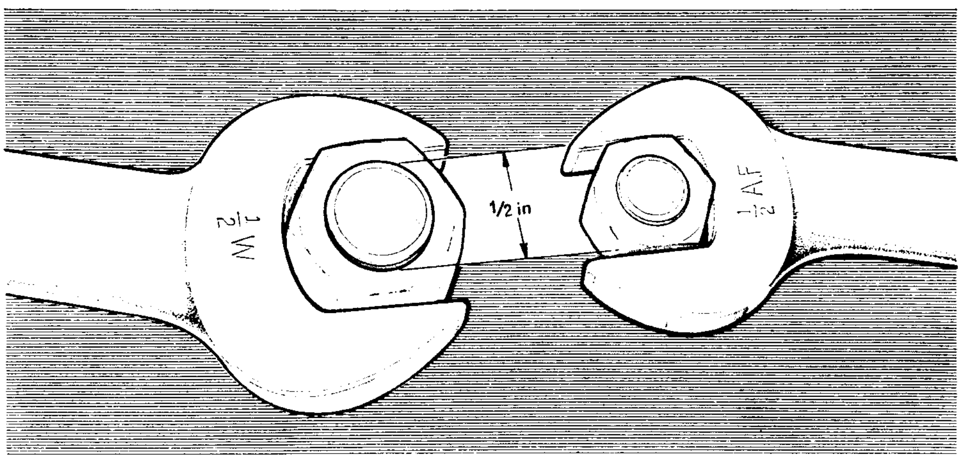


Fig 4.17 Spanner Size

Spanner sizes are marked on the jaw face or on the shank (Fig 4.17). Unified spanners are marked with distance across the flats of the nut or bolt that they fit. The mark is either a number representing the distance correct to two decimal places, or a simple fraction followed by the abbreviation AF (across flats). Whitworth standard spanners are marked with a similar fraction followed by a W (Whitworth), but with an important difference: in this case the mark refers to the diameter of the bolt whose head the spanner fits. A Whitworth standard spanner will fit a British Standard Fine (BSF) nut or bolt, one size larger. For example, $\frac{1}{4}$W will fit $\frac{5}{16}$ BSF, and so on.

Set or open-jaw spanners. These are usually double-ended with a different size at each end (Fig 4.18). The jaws are normally set at an angle to the shank, a useful feature when tackling nuts and bolts in awkward places. By turning the spanner over, the nut can be approached from a different angle.

Ring spanners. Ring spanners grip the nut on all faces and for this reason are preferable to open jaw spanners. The ends are usually made with twelve points (bi-hexagonal) to make it easier to operate when spanner movement is restricted (Fig 4.18).

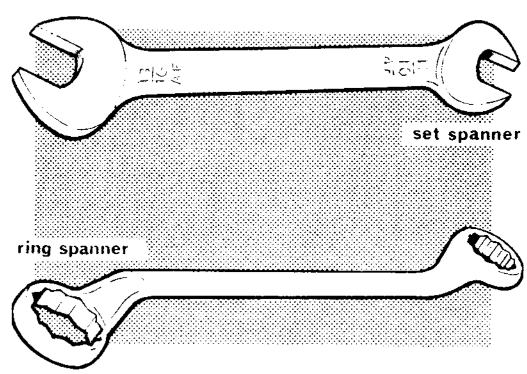


Fig 4.18 Common Spanner

Adjustable spanners. These are handy tools (Fig 4.19) which are able to fit many sizes of nut and bolts. Owing to the tendency for the slack-fitting movable jaw to spring open when force is applied, the adjustable spanner should only be used when a fixed spanner of the correct size is not available.

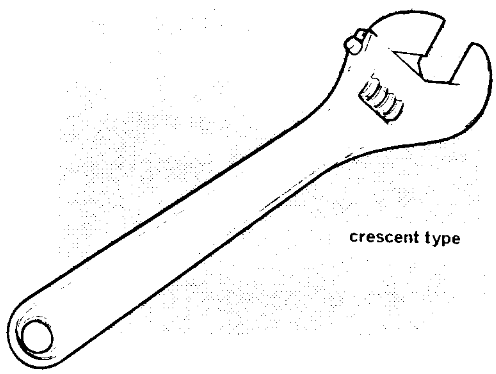


Fig 4.19 Adjustable Spanner

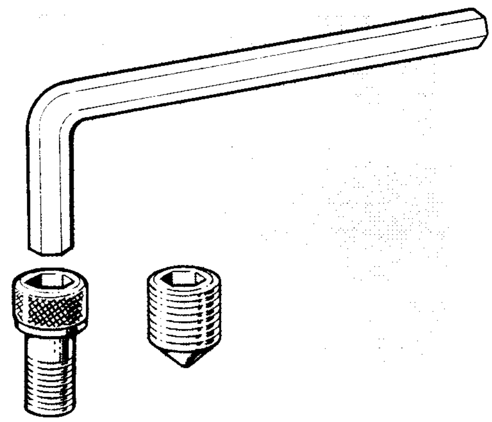


Fig 4.20 Allen Key qnd Screws

Allen keys. Some set bolts and grub screws have circular heads with a hexagonal recess in the centre. These parts are tightened or slackened with an Allen Key (Fig 4.20). The keys are made of hardened steel and supplied in sets, the size of each key being the distance across the flats of the hexagon. Alternatively the key may form part of a special socket attachment (Fig 4.22).

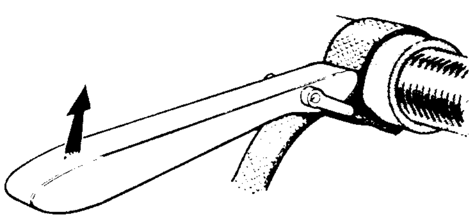


Fig 4.21 Strap Wrench

Strap wrench. The strap wrench (Fig 4.21) is used only for *slackening* knurled nuts on plugs and sockets. When the strap length is correctly adjusted, any increase of load on the handle tightens the strap on the nut.

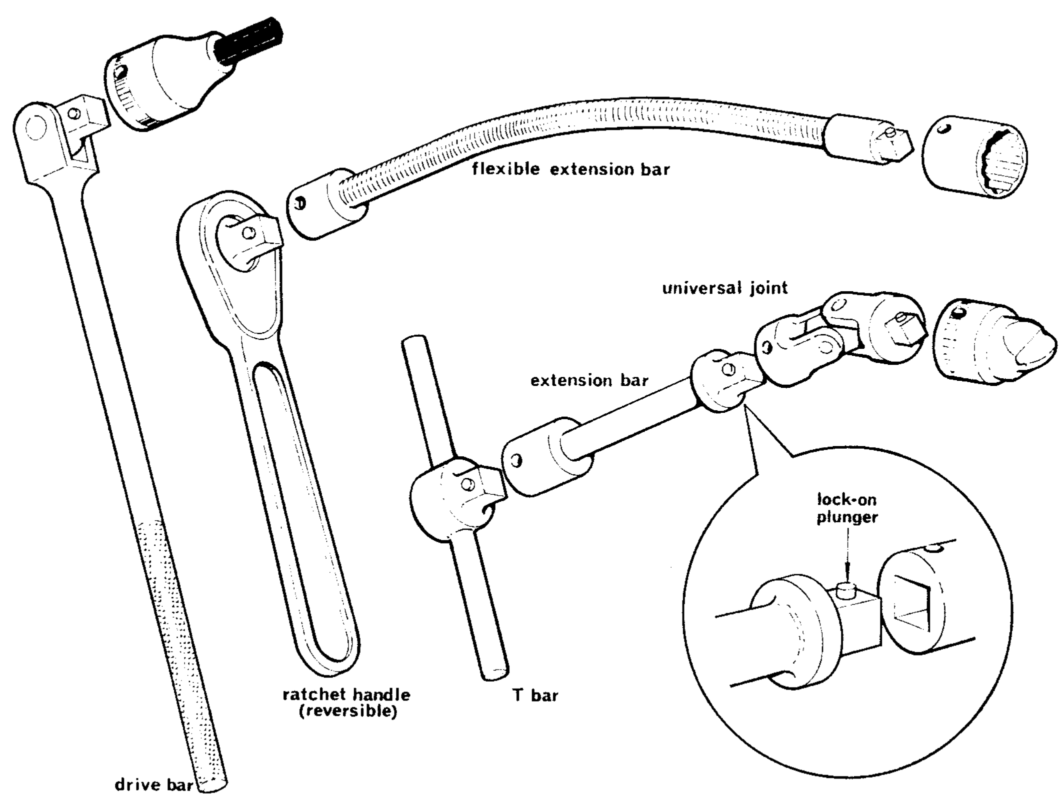


Fig 4.22 Socket Set

Socket spanners. These spanners combine the advantages of both the ring and set spanner. They are usually supplied in sets with a variety of fitments including ratchet handles, rigid and flexible extension bars, T-bars, and a universal joint (Fig 4.22). Fitted to these various components and retained by a spring ball or pin, the socket spanner can be used in almost any position.

Taps

Taps are used for cutting *internal* screw threads (Fig 4.23). They are short screws made of hardened steel and fluted to form cutting edges. The end of the tap shank is made square to fit into a hand wrench. Taps are supplied in sets consisting of two or three taps depending upon the type of thread. They are used in the following order:

- **Taper tap.** Used to start the thread cutting, this tap is tapered gradually leaving only six or seven complete threads near the shank.
- **Second tap.** This tap is used to deepen the thread begun by the taper tap and is tapered for the first two or three threads only.
- **Plug tap.** Used to finish the threads in a blind hole; this tap has no taper.

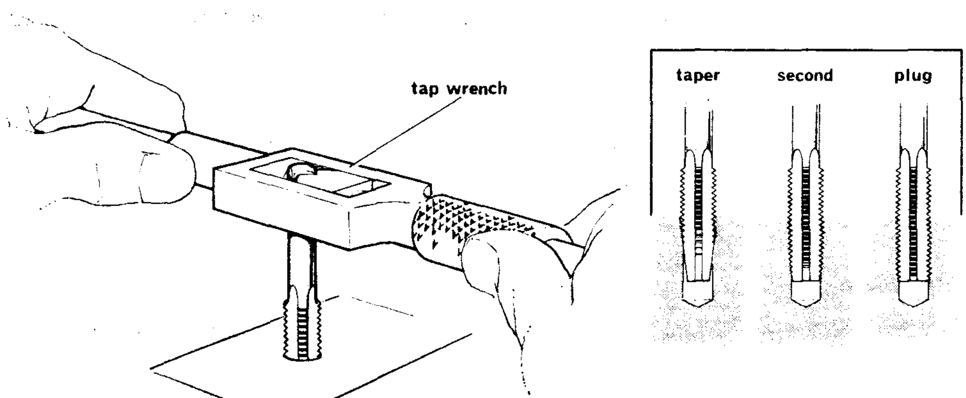


Fig 4.23 Cutting an Internal Thread

Dies

Dies are used for cutting *external* threads and consist of an internal thread of hardened steel which is fluted to form several cutting edges.

The circular die has a standard outside diameter so that a range of sizes are able to fit into a standard stock to form a complete tool. The die is held in the stock by a knurled screw that beds into a split in the die. This split allows a slight decrease of size to be made by two further screws on the stock. The thread on one side of the die is tapered for easier starting and this side should be farthest away from the stock shoulder (Fig 4.24).

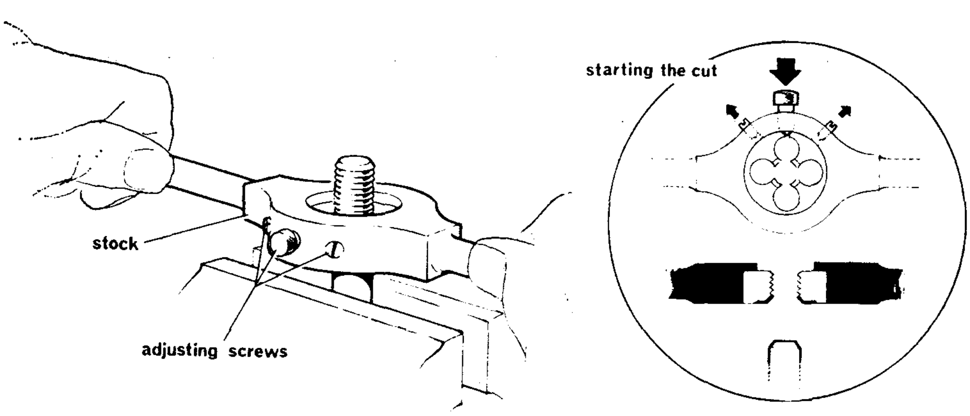


Fig 4.24 Cutting an External Thread

Conclusion

In this chapter the various tools that you will be using have been described, together with the use to which they are put. It is important that tools are used only for the purposes for which they are designed. Failure to do this is not only bad practice but can often be dangerous both to you and the equipment on which you are working.

SUMMARY—REVIEW

Hacksaw

The hacksaw is used for cutting material to approximate size.

Q What is the correct way to fit a blade in a hacksaw? (p. 4.2).

Q How are the best results obtained when using a hacksaw? (p. 4.2).

Files

The cut of a file is the pattern of the teeth on the face of the blade.

Q Name the four cuts and their application (p. 4.4).

Drilling Procedure

Q What precaution should be taken when drilling through a material? (p. 4.6).

Spanners

Spanner sizes are marked on the jaw face or on the shank.

Q What is the difference between the meanings of the marks $\frac{1}{2}$W and $\frac{1}{2}$ AF? (p. 4.9).

Taps

Taps are used for cutting internal threads and are supplied in sets of two or three taps depending on the type of thread.

Q In what order are taps used? (p. 4.11).

Dies

Dies are used for cutting external threads. The thread on one side of the die is tapered for easier starting.

Q How is a die fitted in a stock? (p. 4.11).

CHAPTER 5

LOCKING DEVICES

Introduction

Vibration can cause a nut to slacken or even separate from its bolt. Nuts and bolts are widely used in the construction of aerial masts and towers, and it is essential, therefore, that precautions are taken to ensure that each nut and bolt remains securely tightened so that the mast or tower does not become a weak link in the communication chain.

Various methods of locking a nut in position have been devised, some of which are described in this chapter. You will find that some of these devices can only be used once; it is important that care is taken not to re-use these devices.

Lock Nut

A lock nut is a thin nut which is tightened down firmly on top of the main nut. This action wedges the threads and prevents the main nut slackening (Fig 5.1).

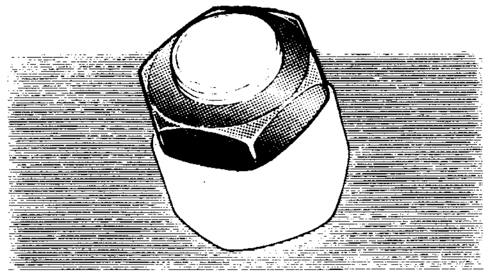


Fig 5.1 Locknut

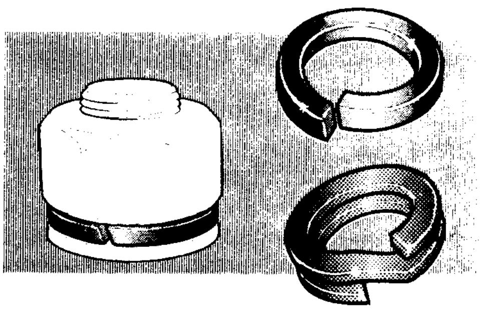


Fig 5.2 Spring Washer

Spring Washer

This is either a single or double coil spring that is fitted beneath the nut, as shown in Fig 5.2. When the nut is tightened and the spring compressed, considerable friction is set up between the faces of the screw threads and this is sufficient to prevent the nut or bolt from turning. Provided the spring washer retains its springing action it may be re-used. To prevent damage to the surface finish of a component, it is common practice to fit a plain washer beneath the spring washer.

Tab Washer

This is a metal washer with two or more tabs and is suitable for use with standard nuts (Fig 5.3). One tab is bent against one of the flats of the nut and the other over an edge. Some tab washers have a tab which fits into a slot or a hole in the component.

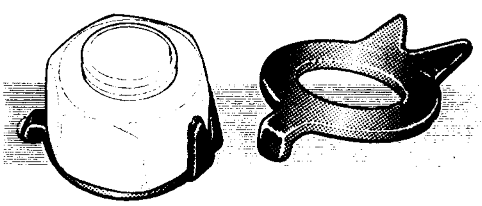


Fig 5.3 Tab Washer

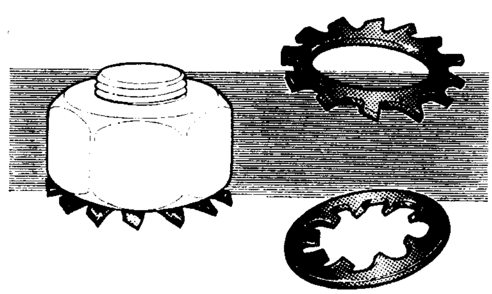


Fig 5.4 Shakeproof Washer

Shakeproof Washer

This is a spring washer which has slanting serrations on its internal or external edges (Fig 5.4). The angle of the serrations is such that the nut is able to ride over them when being tightened, but any tendency to unscrew will be resisted by the sharp edges of the serrations biting into the underside of the nut.

Locking Plate

This is a thin metal plate fitted over the nut after tightening. The plate is then screwed to the component surface (Fig 5.5). A locking plate may be used repeatedly, providing it is a good fit on the nut.

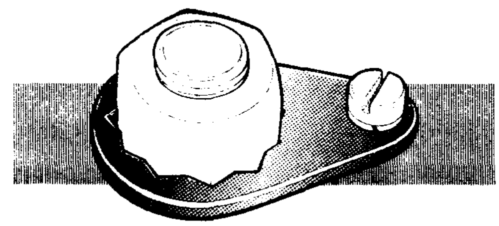


Fig 5.5 Locking Plate

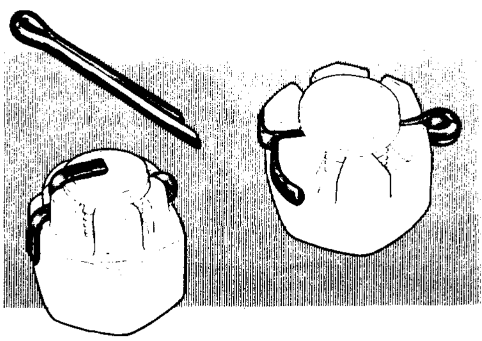


Fig 5.6 Split Pin

Split Pin

A split pin is used with a slotted or castellated nut. The steel pin lies in a slot in the nut and passes through a hole in the bolt. The pin is secured by bending the legs as shown in the two examples in Fig 5.6. Either method is acceptable in locking slotted or castellated nuts. *A split pin must be used once only.*

Stiffnuts

A stiffnut is a one-piece self-locking nut. It is designed so that when it is assembled to a stud or bolt, the friction between the screw threads is so great that the nut is securely held in position. The friction is produced at one end of the nut by a built-in locking device which can be either a nylon insert, shaped slots and projections, or an elliptical collar. When assembled, the end of the bolt must protrude from the end of a stiffnut by at least one complete thread. The nuts can be used repeatedly until the friction produced is insufficient to lock the nut.

Stiffnuts made of steel and aluminium alloy are widely used since, having no separate parts, they can be rapidly removed and replaced and so save time. In addition to the normal hexagonal type of stiffnut, anchor stiffnuts are used when access to both sides of a structure is not possible. These are riveted to the "blind" side of the component so that the bolt can be inserted or removed easily from the other side. Where a row of anchor stiffnuts is needed it is often convenient to use strip nuts; in the arrangement the stiffnuts are fitted at equal intervals along a channel strip which itself is riveted to the structure. The common types of stiffnut and a variety of anchor stiffnuts are shown in Figs 5.7, 5.8 and 5.9.

Nyloc. This nut has an unthreaded nylon insert permanently housed at one end. As the bolt threads engage the insert, the nylon is compressed to the shape of the bolt threads setting up considerable friction between the load-carrying faces of the engaged threads. The Nyloc cap nut (Fig 5.7) has an insert which completely seals the end of bolt to which the nut is fitted.

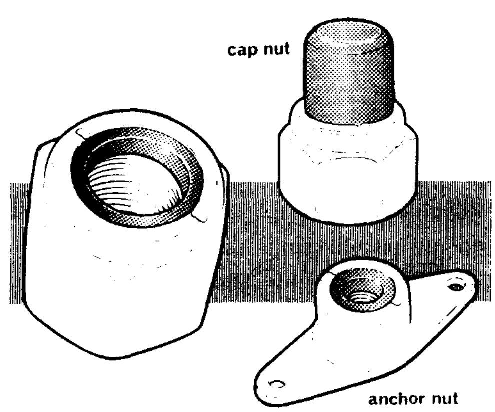


Fig 5.7 Nyloc Stiffnuts

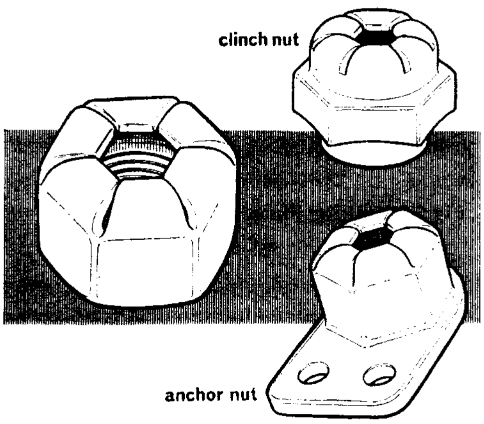


Fig 5.8 Oddie Stiffnuts

Oddie. The top of this stiffnut has six tongues depressed inwards to form a circle whose diameter is slightly smaller than the minor diameter of the bolt (Fig 5.8). The tongues are pushed upwards by the bolt as it passes through the nut, applying a load on the contacting thread faces.

Aerotight and Philidas. By closing the slots cut in the tops of these stiffnuts the upper threads of the nut are caused to run slightly out of track. As the bolt engages the "de-pitched" threads, pressure is required to open the slots and re-align the threads. The friction produced by this effort provides an adequate locking effect (Fig 5.9).

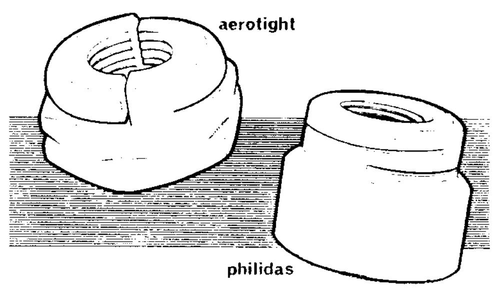


Fig 5.9 Aerotight and Philidas Stiffnuts

Varnish

Small screws and bolts can be locked by the application of a thin coating of a varnish shellac.

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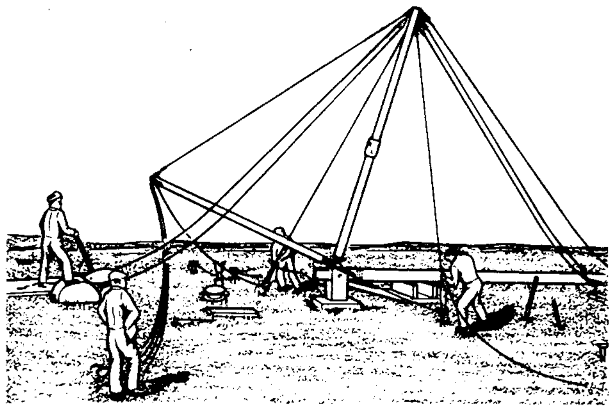


CHAPTER 6

SPECIALIST TOOLS

Introduction

In Chapter 4 the tools described are in common use by many trades. In this chapter the tools described have a special importance to the Aerial Erector, hence the title 'Specialist Tools'.

Tirfor Winch

The Tirfor winch (Fig 6.1) is a hand-operated lifting or pulling machine with an unlimited rope travel. It works by pulling directly on the rope, the pull being applied by two pairs of smooth jaws which exert a grip on the rope, the grip being in proportion to the load being lifted or pulled. The jaws are operated by two levers, one lever providing a forward motion to the rope, the other lever providing a backward motion to the rope. There are three versions of the Tirfor winch, the T7 and T13 (Fig 6.1) and the T35 (Fig 6.2), all of which must be used in conjunction with the Tirfor Maxiflex wire rope. On the T35 winch the forward operating lever is fitted with a two-speed change. In the high speed position the winch is limited to a lifting and pulling effort of 2.95 tonnes (3 tons) and in the low speed position to a lifting effort of 2.95 tonnes (3 tons) and a pulling effort of 4.72 tonnes (5 tons). The two speeds of operation are selected as follows:

- **High speed.** Lift the button on the top of the forward operating handle and turn the speed crank pin through a half turn (*see* Fig 6.2).
- **Low speed.** Reverse the above operation.

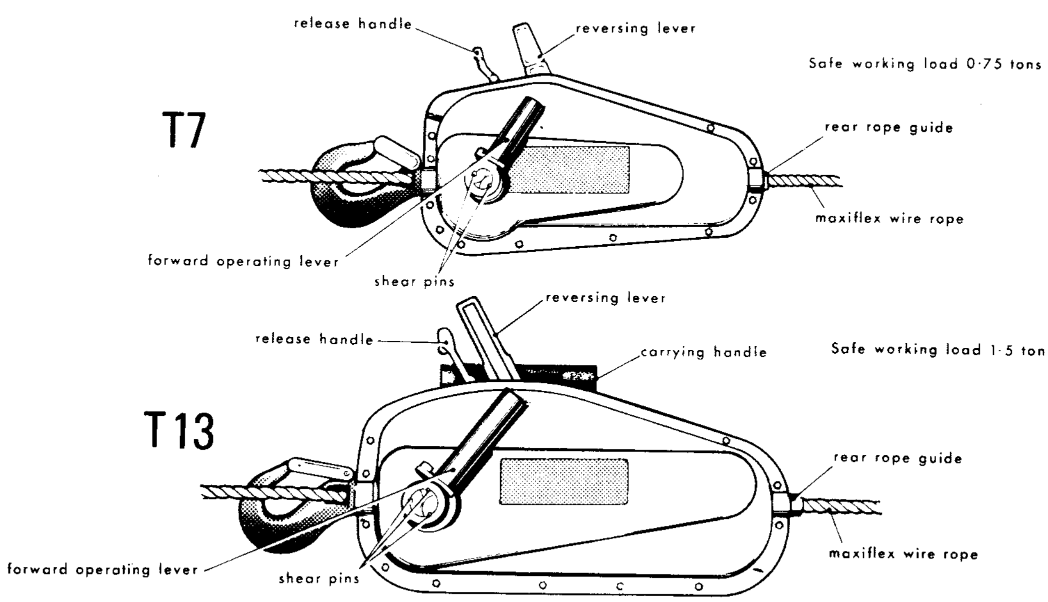
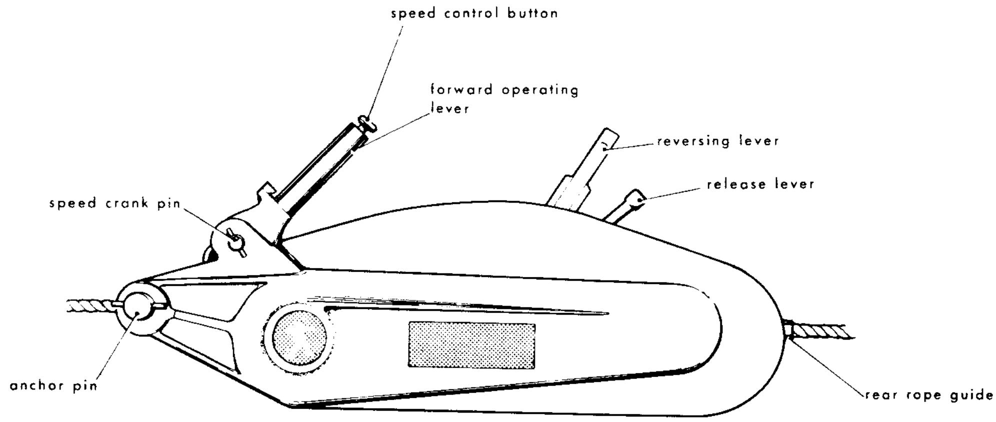


Fig. 6.1 T7 and T13 Tirfor Winches



Safe working load 3 tons high speed
5tons low speed

Fig. 6.2 T35 Tirfor Winch

Overloads

The safe working loads indicated in Figs 6.1 and 6.2 can be lifted by these winches by one man using normal effort. If more than normal effort is required when using either the T7 or T13 versions, shear pins in the forward operating lever (*see* Fig 6.1) will shear and prevent further forward or upward movement. Reverse action is still available using the reversing lever, so that the load may be slackened or lowered to the ground.

The damaged shear pins should be removed by removing the forward operating lever; new shear pins can then be fitted. In the T7, two spare pins will be found in the forward operating lever; in the T13, the spare pins are kept in the carrying handle.

Should you have to use these spare pins, remember to obtain replacements and put them in their correct stowage place.

Sheave Blocks

Loads in excess of those shown in Figs 6.1 and 6.2 may be lifted or pulled by using the Tirfor winches in conjunction with sheave blocks. The minimum diameters of the pulley wheels used in sheave blocks are given in Table 1 for the different Tirfor winches, together with the suitable Tirfor Maxiflex steel wire rope.

TABLE 1

Tirfor Winch	Minimum pulley dia	Suitable for steel rope of dia
T7	6 in (150mm)	$\frac{5}{16}$ in (8mm)
T13	8 in (200mm)	$\frac{7}{16}$ in (11mm)
T35	9 in (225mm)	$\frac{5}{8}$ in (16mm)

When using multi-sheave blocks, always ensure that the blocks are suitable for the total load to be lifted, and that the top anchorage for the combination is sufficient to carry the total load of the winch rope tension, the weight of the blocks, and the load to be lifted. Examples of how sheave blocks can be used in conjunction with the Tirfor winch are shown in Fig 6.3. The values given in this illustration are calculated taking friction into consideration.

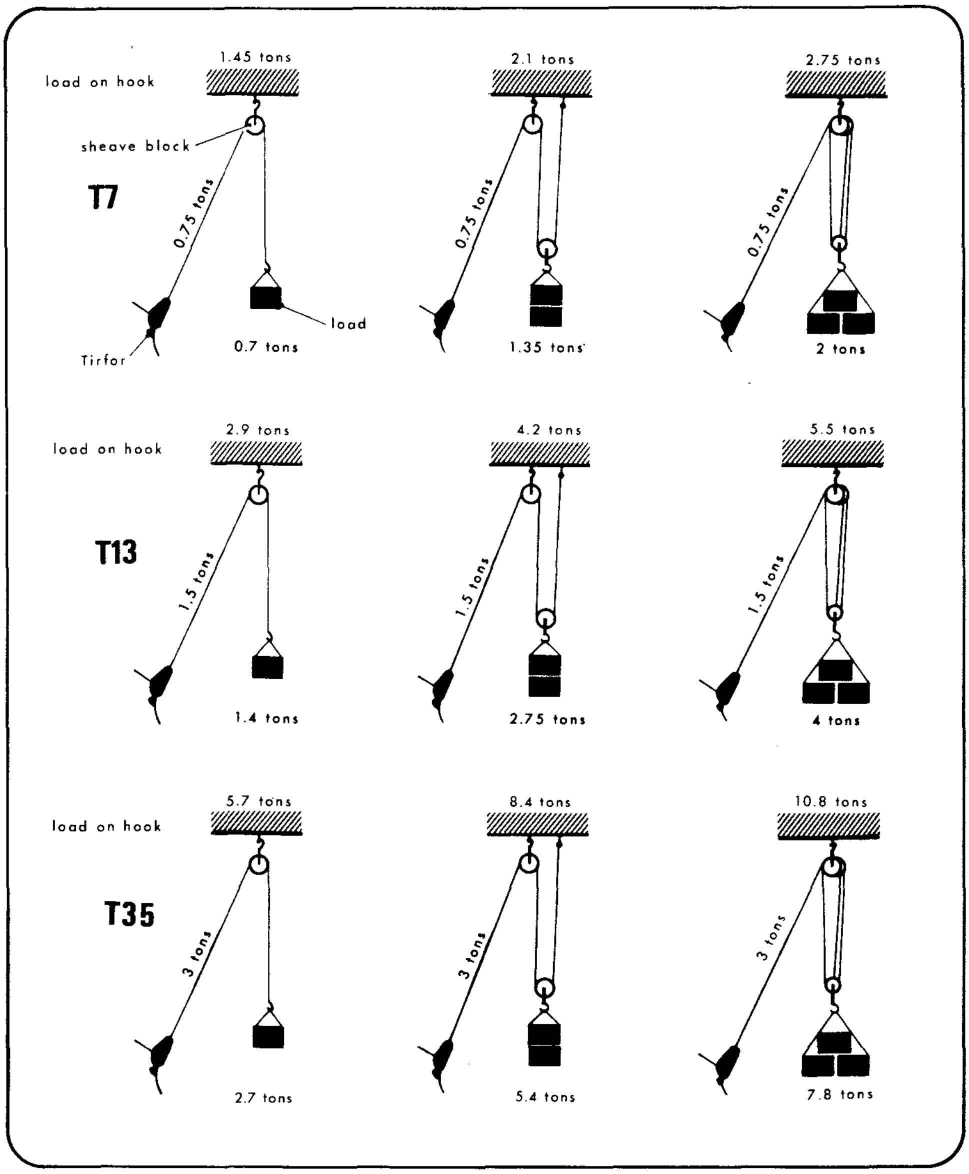


Fig. 6.3 Use of Tirfor Winch with Sheave Blocks

Use of Tirfor Winches

Precautions. Before using a Tirfor winch the following precautions must be taken:

- The winch and wire rope are well lubricated with heavy gear oil (excessive lubrication will not cause the wire rope to slip).

  Note

  Do not use oils or greases containing additives such as molydenum disulphide.

- The pulley wheels used in sheave blocks are the correct size for the Tirfor winch in use (*see* Table 1).
- The lifting or pulling load to be exerted is within the rated capacity of the winch (*see* Figs 6.1 and 6.2).
- There are no obstructions that could prevent the rope, winch and anchor from operating in a straight line.
- The forward and reversing operating levers operate freely.

Preparation for use. After checking the precautions listed above, proceed as follows:

- Uncoil the rope in a straight line to prevent loops that might untwist strands or form kinks when under tension.
- Push the release handle towards the hook (anchor pin in T34) into the notched position to open the jaws.
- Lay the winch on the ground and insert the tapered end of the wire rope through the winch rear rope guide (Fig 6.1) and feed it through until it emerges at the front of the winch.
- Anchor the winch and the cable hook with the correct slings (*see* Fig 6.4).
- Pull the wire through the winch by hand until it becomes tight on the load.
- Remove the release lever from the release position.
- Select the speed required when using the T35 winch.
- Fit the telescopic operating handle on the forward operating lever.

Pulling and lifting. With the operating handle on the forward operating stub, a to-and-fro lever action is employed to move the rope through the winch. As the machines do not have ratchets, the operating handle need not be used through its full stroke; if space is confined, short strokes can be made. The handle can be left in any position of its strokes without danger of 'flying'.

Slackening the rope or lowering the load. Fix the operating handle on the reversing lever and move to-and-fro.

Releasing or disengaging the rope. It is impossible to operate the release lever when there is a load on the winch, because the jaws are locked by the tension in the rope. Therefore, before the rope can be released or disengaged, any load on the winch must be removed by operating the reversing lever until the rope is slack. The release lever can now be pulled into the notch and the rope removed from the winch.

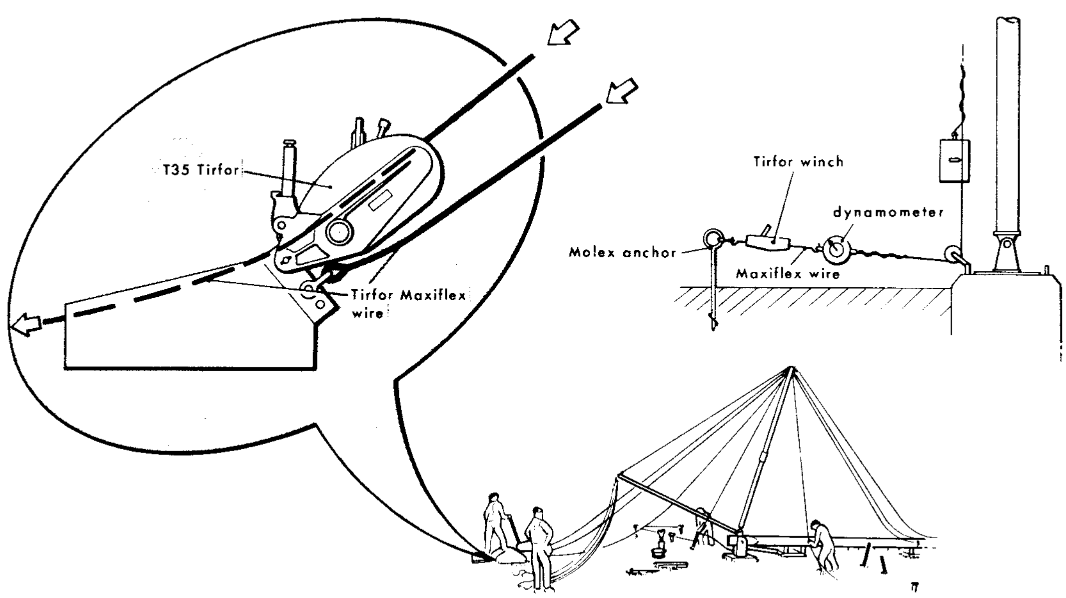


Fig. 6.4 Anchoring the Winch

Checking Wear on Jaws

A periodic inspection to ensure that overwork has not caused any wear on the jaws should be carried out every three or six months, depending upon the amount of use.

a. Mark on the side of the casing the position of the release lever in its closed position with no rope in the winch (Fig 6.5).

b. Push the release lever to the release position and insert the wire rope through the winch.
c. Allow the release lever to move rearwards to grip the rope and again mark the position of the release lever on the side of the casing.
d. If the distance between the two marks is less than 12.5mm (½ in) for the T7 and T13 winches or 25.4mm (1 in) for the T35 winch, the faces must be renewed.

Maintenance and Lubrication

Lubrication should be carried out at regular intervals to ensure that all the rope gripping mechanisms work freely. Before putting a new winch into service, lubricate generously and, if convenient, lubricate each time before use. A symptom of lack of lubrication is jerkiness when lowering a load.

To lubricate, either pour heavy gear oil into the winch through the slot in the top of the machine, then shake the winch and allow to drain, or squirt plenty of oil into the winch using an oil gun.

If the winch is very dirty, or contains earth or clay, allow the winch to soak in an approved solvent and then shake vigorously. After all foreign material has been removed, lubricate liberally with heavy gear oil (*see note*), then shake the winch and drain off the surplus oil.

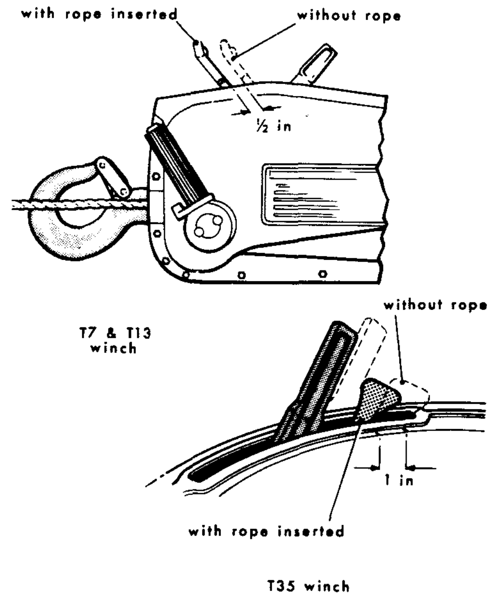
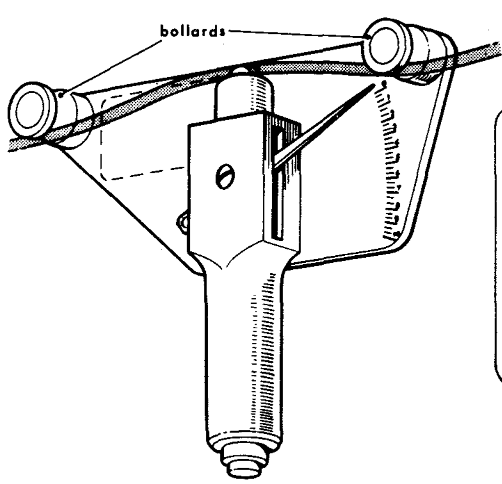


Fig. 6.5 Checking Wear on Jaws

Note
Greases and oils containing additives such as molybdenum disulphide must not be used.

Tensiometer

The tensiometer (Fig 6.6) is used to measure the tension in various ropes and wires up to a maximum tension of 300lb. Only static tension can be measured (*ie* a steady tension), although the tension in a rope or wire may be adjusted with the tensiometer in position and a subsequent reading taken when the rope or wire is again in a static condition.



	CIRC	DIA	1	2	3	4	5	6	7	8	9	10
TERYL.	5/8		45	65	90	120	170	220				
	3/4		42	62	86	110	152	196	270			
	7/8		39	59	82	106	145	188	250	288		
	1		38	56	79	102	136	168	224	285		
	1 1/8		37	54	76	100	135	170	223	255		
	1 1/4		35	52	70	94	122	153	200	202		
	1 1/2		33	48	60	80	102	128	160		255	328
CU	LBS/MILE 100	0·079		70	105	140	185					
	LBS/MILE 300	0·137										
CU/PLY		0·050		84	92	127	184	256				

POUNDS TENSION

conversion chart located on reverse side of tensiometer

Fig. 6.6 The Tensiometer

Description

The tensiometer consists of a 6mm ($\frac{3}{16}$ in) thick aluminium plate with a stainless steel bollard screwed on at either end at the top of the plate. A plunger assembly actuating a pointer is secured centrally between the bollards, allowing the line under test to pass under the two bollards and rest in the groove cut in the spring-loaded plunger. This plunger deflects the line upwards, the deflection depending upon the tension in the line.

An indicator attached to the plunger moves across a scale indicating a reading that may be converted, by means of a chart on the back of the plate, to a tension in pounds depending upon:

a. The material of which the line under test is made;

b. The diameter of the line.

Measuring the Tension in a Line

Before attempting to measure the tension in a line you must ensure that:

a. The supports for the line are at least 4·6 metres (fifteen feet) apart.

b. The material from which the line is made, and its diameter or poundage, are known.

c. The identified line appears on the conversion chart label on the back of the tensiometer.

To determine the tension proceed as follows:

a. Position the tensiometer at least five feet from either end of the line so that the line passes under the left-hand bollard, over the top of the plunger (resting in the groove) and under the right-hand bollard as shown in Fig 6.6. A levering action may be required to achieve this position.

b. Move the tensiometer to and fro a short distance along the line in order to even the tension in the line.

c. Note the reading on the scale as indicated by the pointer.

d. Referring to the conversion chart label on the back of the tensiometer, identify the line under test and convert the reading obtained in the previous operation to a tension in pounds.

Setting Up a Tension in a Line

To set up a given tension in a line, proceed as follows:

a. Set up the tensiometer on the line as in a and b in the preceding paragraph.

b. Refer to the conversion chart on the back of the tensiometer and, for the line under test, obtain a scale reading in divisions for the desired tension in pounds.

c. Adjust the tension in the line until the required scale reading is obtained. The line is then at the required tension.

Note

After adjusting the tension in the line it is necessary to move the tensiometer to and fro a short distance along the line to obtain the correct reading.

Servicing

The plunger should be wiped clean and a few drops of thin oil applied to the plunger through the hole exposing the special screw securing the indicator to the plunger (Fig 6.6). The oil may be worked in by operating the plunger a few times. The frequency of oiling depends entirely on how often the tensiometer is used.

Dynamometer

The dynamometer (Fig 6.7) is a spring operated scale calibrated to record the tension in pounds being applied to a line (*dynamic tension*). It is used during lifting, pulling or antenna erection operations, and is installed between the winch or source of effort and the system under tension by shackles attached on either side of the dynamometer. It has two pointers, one to record the actual tension at any time, and the other to record the maximum tension applied during the lifting, pulling or antenna erection operation.

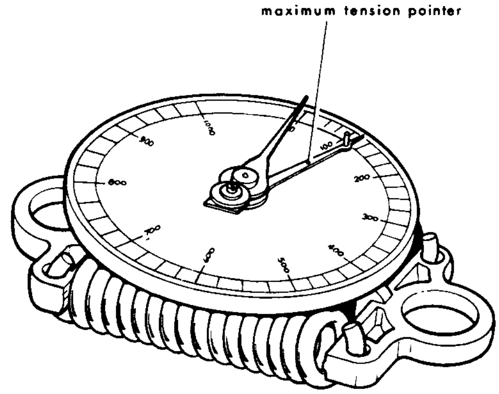


Fig. 6.7 The Dynamometer

Hand-operated Drum Winch (Drawvice)

This tool is used to apply tension to wire ropes up to 1 in circumference. It consists of a pair of vice jaws (Fig 6.8) which can be closed or released by means of a butterfly nut, and a ratchet-controlled drum to which is attached a length of wire rope. The wire rope can be winched on or off the drum by the rotation of a handle which fits over the squared end of the drum shaft. One end of the handle is specially shaped to act as a spanner for tightening and releasing the butterfly nut.

Operation

The vice jaws are placed over the wire to be tensioned and the butterfly nut securely tightened by using the special slot cut in the winch handle. The drum wire is then attached via an eye and shackle to a suitable anchorage point. The handle is then attached to the drum and rotated until the required tension is obtained. Care must be taken to ensure that the wire winds evenly onto the drum and that one turn does not override another.

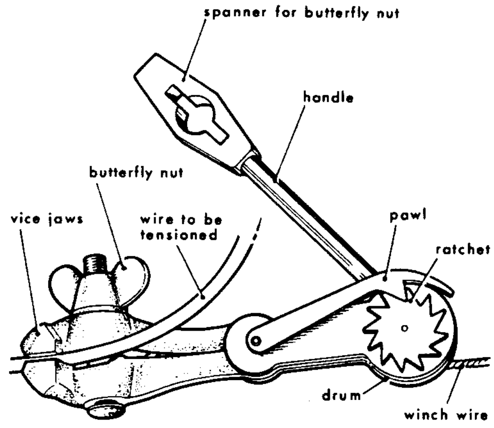


Fig. 6.8 Hand-operated Drum Winch (Drawvice)

Safety Precautions

- *Before use:*

  a. Inspect the terminations of the wire rope to the winch drum for security of attachment.

  b. Examine the fit of the pawl into the ratchet. The tool is not to be used if the ratchet is worn.

- *Preparation for use:*

  a. Ensure that at least two turns of the wire rope remain on the winch drum in every operating position.

  b. Anchor the draw vice so that when the tension is applied the pull is in a straight line.

- *Operation:*

  a. When applying tension, care must be taken to ensure that the pawl is engaged in the ratchet. Experience has shown that the best method to use is to hold the pawl in position with one hand while turning the handle with the other.

b. To release the tension:

1. Place the handle in a position most convenient to the user.
2. Take the strain on the handle.
3. Lift the pawl and allow the handle to rotate one quarter of a turn. *It is important to keep a firm grip on the handle during this operation. Failure to do so can result in serious personal injury.*
4. Replace the pawl in the ratchet.
5. Remove the handle and return it to the first position.
6. Repeat the operations 1 to 5 until all the tension is off.

Wire Tensioner (Ratchet Strainer and Tongs)

The wire tensioner (Fig 6.9) is used for tensioning single filament copper nichrome or stainless steel wire. It consists of a pair of jawed tongs and a spring-loaded ratchet-controlled drum to which is attached a length of wire rope. The body of the tool incorporates a spring-operated scale calibrated in pounds to record the approximate tension being applied. A tensiometer is to be used to obtain an accurate measurement of the required tension.

Operation

Attach the tensioner to the wire to be tensioned making sure that the correct jaws are used to suit the size of wire (*see* Fig 6.9) *ie* 100lb copper wire, nichrome and stainless steel wire in the jaws marked 100lb, and 200lb and 300lb copper wire in the jaws marked 200lb.

Secure the drum wire to a suitable anchorage point using the eye and shackle on the wire, then fit the handle to the drum and rotate the drum to winch on the wire rope until the required tension is obtained. Whilst rotating the drum ensure that the drum wire winds on evenly and that one turn does not override another.

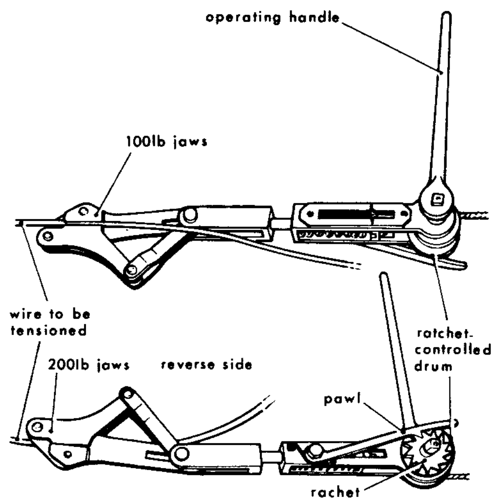


Fig. 6.9 Wire Tensioner

Clamping Tool

The clamping tool (Fig 6.10) is used to clamp brass or steel collets to copper, nichrome or stainless steel wire.

Operation

Assemble the collet on the wire and then place the clamping tool over the wire by means of the slot cut along one side of the tool (*see* Fig 6.10). Ensure that the externally tapered inner section of the collet is between the clamping tool and the threaded outer section of the collet as shown in the illustration.

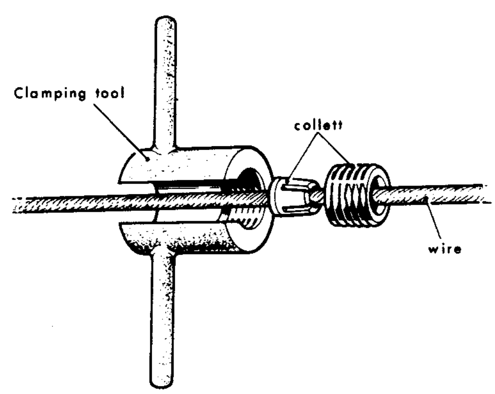


Fig. 6.10 Clamping Tool

Hold the clamping tool firmly in one hand and screw the threaded outer section of the collet into the threaded end of the clamping tool using an OBA open ended spanner. Continue turning the spanner until the two sections of the collet are firmly clamped together then remove the clamping tool.

Helical Membrane (HM) Cable Bending and Straightening Machines

During the installation of helical membrane coaxial cables it is important that they should not be kinked; also, the construction of these cables is such that it does not permit them to follow acute bends. To ensure the smooth bending, at suitable radii, of HM cables a special installation kit must be used.

The complete kit is contained in two carrying cases and consists of the following:

- Two bending and straightening machines; one (the smaller of the two) is for use with HM4 and HM9 cables, in which it will manufacture smooth bends of up to 90 degrees at 305mm (12 in) radius. The larger machine is for use with HM7 and HM11 cables, in which it will manufacture smooth bends of up to 90 degrees at 457mm (18 in) radius.
- One 'ENERPAC' single speed hydraulic hand pump, Type 39, and associated 3·05 metres (10ft) long 'ENERPAC' hose, Type H927, both of which are common to the two bending and straightening machines.
- A tool kit for the hydraulic pump.
- An oil refill.
- Cutting and flaring tools for terminating and jointing HM cable (these items are not discussed in this chapter).

The smaller machine is illustrated in Figs 6.11 and 6.12. In Fig 6.11 the machine is shown set up for bending operations and in Fig 6.12 it is set up for straightening operations. Apart from its size and two small constructional details, the larger machine is identical to the smaller machine and it is not illustrated in this chapter.

Each machine consists of the following (Figs 6.11 and 6.12):

- A backplate.
- 2 block formers } for bending operations
- 1 radial former } for bending operations
- 1 fixed straight former } for straightening operations
- 1 driving straight former } for straightening operations
- 1 'ENERPAC' cylinder and housing, RC-55 for the smaller machine and RC-1010 for the larger machine.

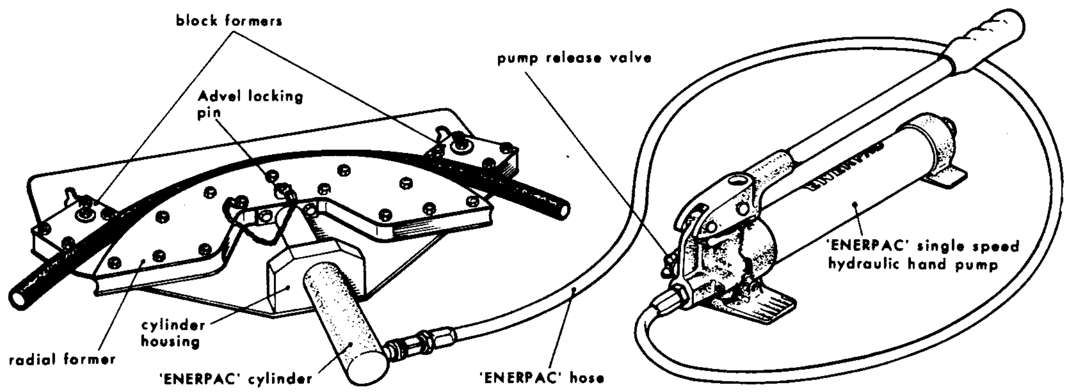


Fig. 6.11 Bending Operations

Assembling and Using the Machines (Bending)

To assemble and use the smaller machine (Fig 6.11) for bending operations proceed as follows:

- Take the 'ENERPAC' cylinder RC-55 from the smaller of the two cases and remove the two bolts from the cylinder housing. The housing should not be removed from the cylinder unless required for servicing.

- Secure the backplate to the cylinder and tighten the two bolts.
- Fit the radial former to the cylinder plunger and lock it in position using the Advel locking pin.
- Fit the two block formers to the lower keyhole slots in the backplate, ensuring that when the knurled nuts are tightened, the formers are free to swivel on their mountings. The formers are marked L and R and must be fitted to the keyhole bearing the same marking.
- Connect the hand pump to the cylinder using the 3·05 metres (10ft) long 'ENERPAC' hose. The pump handle can be screwed into the pump beam either vertically or horizontally.
- Screw the pump release valve finger tight.
- Fit the cable to be bent between the machine formers. Ensure that the backplate lies in the plane of the bend, with the cable between the radial and block formers.
- Operate the pump, the bending machine being firmly supported, and apply as much pressure to the cylinder as the task requires. When the required bend is obtained release the pressure by opening the pump release valve. The cylinder plunger will now retract, releasing the cable.

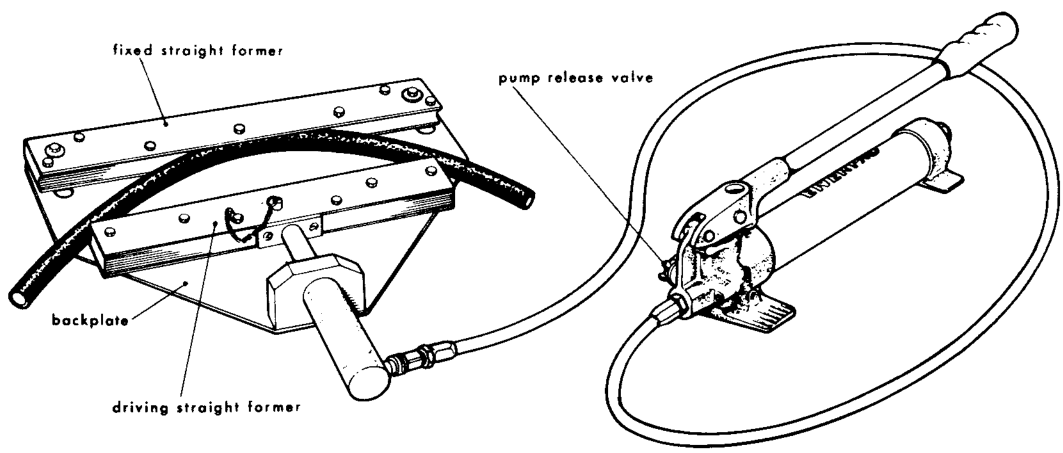


Fig. 6.12 Straightening Operations

Assembly and Use of the Machines (Straightening)

To assemble and use the smaller machine (Fig 6.12) for straightening proceed as follows:

- Assemble the backplate to the 'ENERPAC' cylinder RC-55 as described for the bending operations.
- Mount the driving straight former to the cylinder plunger and lock it in position using the Advel locking pin.
- Secure the fixed straight former to the backplate using the upper keyhole slots of the backplate.
- Fit the cable to be straightened to the machine so that the driving straight former bears on the inside of the bend.
- Operate the pump as for the bending operation.
- Release pressure by opening pump release valve.
- Final straightening is carried out by moving the fixed straight former to the lower set of keyhole slots and repeating the straightening procedure.
- Release pressure and remove cable.

When the machine is dismantled it is not necessary to drain the pump, hose or cylinder of oil since the hydraulic joints are self-sealing.

Variations in Procedure for Larger Machine

When using the larger machine it will be seen that there is only one set of three keyhole slots along the upper edge of the backplate. The block formers are fixed in the two outer slots for cable bending. The fixed straight former used in cable straightening procedure is attached to the three keyhole slots by extension lugs which are secured in the normal manner by knurled nuts. Apart from these differences, the method of assembly and use is identical to that described for the smaller of the two machines.

Maintenance

To ensure trouble-free operation of the hydraulic equipment, always keep the pump, hose and cylinders clean. Always cover the couplings with their dust caps when the assembly is dismantled, and guard against the entry of dirt, particularly when working in or near trenches or excavations.

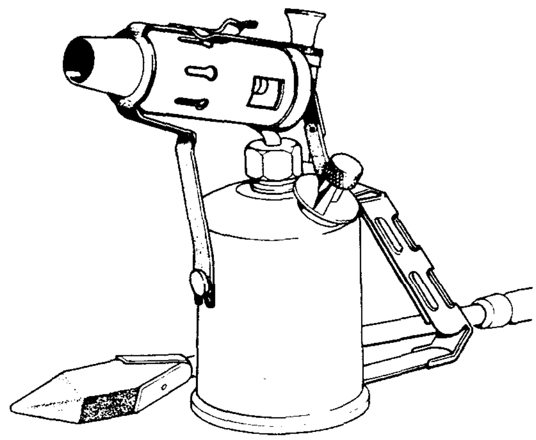
Do not kink the hose or allow heavy or sharp objects to fall across it, and never drag or carry the assembly by the hose.

Avoid over-extending the plungers of the cylinders—so much pressure is available that it is possible to push these out of their housings. The spring retaining screws of the cylinders should never be adjusted.

A periodical check should be made on the oil level of the P-39 pump. For this test no oil should remain in the cylinders, whose plungers should be fully retracted after use by opening the pump release valve in the normal way. After the relief valve has again been made finger tight the hose and cylinder can be disconnected.

The pump should be held vertically by gripping its foot bracket in a vice, the filler screw being uppermost. When the filler screw is removed it will be found to incorporate a dip stick, on which the correct oil level is indicated by a notch. Topping up should be done using ENERPAC HF47 only.

The pump should occasionally be drained of oil and flushed out with paraffin, then refilled. When this has been done, couple up the hose and a cylinder and test the pump operation to check that there is no air in the system. If air has to be removed, pump until the cylinder plunger is fully extended then open the release valve on the pump. Place the end of the plunger on a wooden pad on the floor and press down on the cylinder body until the plunger is fully retracted. Pump rapidly for 8 to 10 strokes, when the system should work correctly. Repeat the process if necessary.



CHAPTER 7

SOLDERING

Introduction

The process of soldering consists of joining metals (which may or may not be similar) by flowing an alloy, known as *solder*, between the surfaces to be joined. A material called *flux* is used to clean the surfaces to be joined. Two forms of soldering will be described in this chapter —*soft soldering* and *silver soldering*.

SOFT SOLDERING

General

In soft soldering a tin-lead solder is used. The tin in the solder combines with the metal of the joint, this occurring only when the metal and solder brought into contact are thoroughly clean. The comparatively low temperature required to make the solder flow enables joining to be achieved without adverse effect upon the physical properties of the joined metals, and minimizes the damage to adjacent materials such as paint, insulation, *etc.*

Most metals can be soft soldered, but specialized knowledge or equipment is sometimes required. The basic equipment required for soft soldering consists of a soldering iron, solder, flux and a source of heat.

Soldering Irons

A soldering iron consists of a copper 'bit' secured to a holder, to which is fitted a heat-resistant handle. The bit varies in size according to the nature of the work for which the iron is intended; because the bit is the heat reservoir it must be large enough to heat the work adequately. The following types of soldering iron are available:

Common soldering iron. This type of iron is available in various shapes and weights. Two typical forms are shown in Fig 7.1; the bits, which are renewable, are usually heated by a brazing lamp.

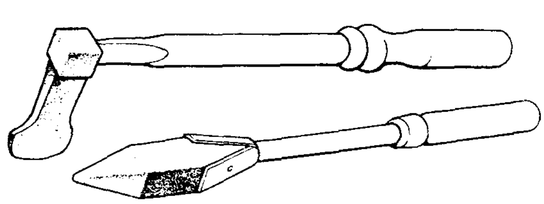


Fig 7.1 Common Soldering Iron

Electric soldering iron. This type of iron is also available in various shapes and sizes, and heated by means of built-in electric heating elements. Fig 7.2 shows typical examples of electric soldering irons. The two smaller irons are intended for light work, such as soldering small electrical connections; the other two are suitable for general workshop use.

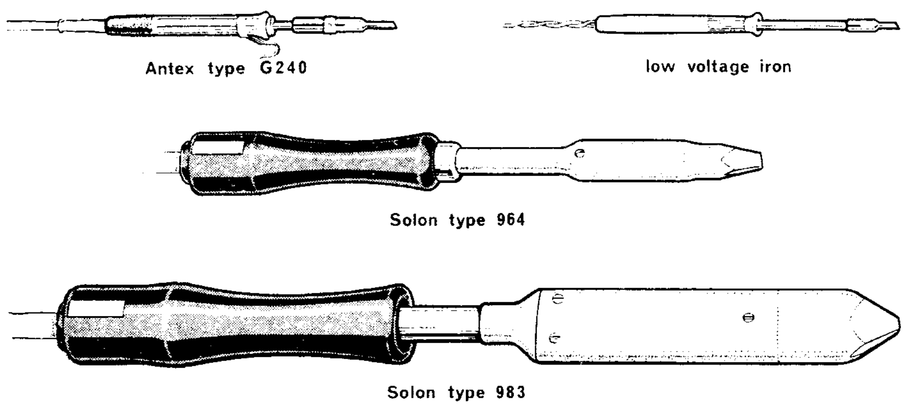


Fig 7.2 Electric Soldering Irons

Care and maintenance of soldering irons. When properly used, a soldering iron has a very long life. The bit should be kept clean and tinned at all times (see p 7.4). Any oxides which form on the bit should be removed using a wire brush, and the bit retinned immediately. Overheating can cause a bit to become pitted and oxidized. To prevent this, electric soldering irons should be switched off when not required. Care should be taken to avoid putting down a hot soldering iron where it can cause a fire, and with electric soldering irons special care must be taken to ensure that the hot bit does not come into contact with the mains lead, as melted insulation may allow a short circuit to occur and start a fire.

Soft Solder

Soft solders are mainly alloys of tin and lead. A small percentage of antimony is sometimes added to give a harder and stronger joint. Some of the standard grades of soft solder and their uses are as follows:

- **Tinman's.** This is a solder composed of 58% lead, 40% tin, and 2% antimony. It is supplied in sticks and is used for both fine and general work.
- **Electrician's.** This solder is composed of 40% lead and 60% tin; it is supplied in the form of resin-cored wire which eliminates the need to use corrosive fluxes. It is intended mainly for instrument, radio and electrical work.

Fluxes

The main barrier to success in soldering is the oxide film which forms on any metal exposed to the oxygen in the atmosphere. The primary purpose of flux is to dissolve the oxide film and provide a chemically clean area immediately beneath the soldering iron. As a result, when the molten solder contacts the bare metal it immediately 'wets' the surface and alloys with it. Fluxes also allow the solder to spread more rapidly. Fluxes are classified as being either of the 'active' or 'safety' type. Active fluxes are basically acids and include hydrochloric acid, and zinc and ammonium chlorides. They are effective in removing oxides, but leave a corrosive residue which must be carefully removed after soldering. Safety fluxes, although not so effective as active fluxes, have none of their corrosive properties.

Brazing Lamp

Much of the soldering you will have to do will be carried out under field conditions where there will be no electrical supply available to allow the use of electric soldering irons, and the common soldering iron such as shown in Fig 7.1 will have to be used. Since this type of iron requires a separate means of heating, some portable heating device will be required. The most commonly-used method of heating the common soldering iron is by means of brazing lamps (or blow-lamps, as they are more generally called) which are available in 5 pint and 1 pint sizes. In this chapter we shall discuss the 1 pint size.

Construction and operating principle. The main constructional features of a brazing lamp are shown in Fig 7.3. Kerosene from the container is forced under pressure through the vaporizer to the jet. On leaving the jet, the vapour becomes mixed with air in the burner chamber and when the resulting mixture is ignited it burns with a blue flame of fairly high temperature. The burner chamber is so designed that the flame also heats the vaporizer. Pressure is applied to the container by a hand-operated pump embodying a non-return valve, and is released through an air release valve.

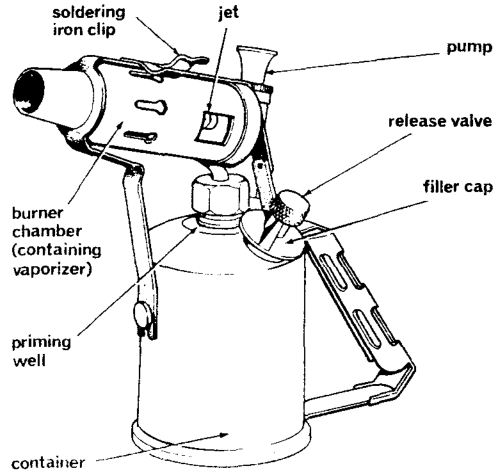


Fig 7.3 1 Pint Brazing Lamp

Preparing and lighting the brazing lamp. To obtain the best results from a brazing lamp it must always be maintained in a clean and serviceable condition. The method of preparing and lighting the 1 pint brazing lamp is as follows:

- Remove the filler cap and fill the container ¾ full with clean kerosene, using a funnel and a fine gauge strainer; then replace and tighten the cap and dry the outside of the lamp.

- Clean the jet with the correct cleaning needle or pricker.

- Open the air realease valve.

- Fill the priming well (Fig 7.3) with methylated spirits and ignite the spirit to heat the vaporizer. The capacity of the priming well is such that when practically all the spirit has been burnt the vaporizer should be hot enough to function correctly.

- Close the air release valve and operate the pump. If the vaporizer is hot enough the vapour will ignite and burn with a blue flame. If the vaporizer is not hot enough, liquid kerosene will be ejected through the jet, or the vapour will burn with a yellow flame. If this occurs, open the air release valve and repeat the lighting procedure.

A sudden reduction in the size of the flame when the lamp is in use is an indication of a partially-blocked jet. This can usually be rectified, without extinguishing the lamp, by careful use of the cleaning needle or pricker. The lamp can be extinguished at any time by opening the air release valve.

Precautions. In view of the highly flammable nature of the fuel and the fact that it is burning under pressure, the following precautions must be strictly observed when using brazing lamps:

- Foam or dry powder fire extinguishers must be available. Water must not be used (*see* Chapter 2).

- Lighted lamps must not be taken within 15 metres (50 ft) of aircraft, mechanical transport or flammable stores.

- Lamps must not be used in excessive heat; for instance, near furnaces.

- Brazing lamps, when in use, must be stood upon incombustible material—never upon wooden floors or benches.

- The flame, when not being used for heating work, must always be directed against a metal or asbestos sheet, or a brick hearth.

Method of Soft Soldering

Preparation of the iron. Preparation of the bit for soldering is most important and entails covering the working surfaces of the bit with solder. This is the process of *tinning* referred to earlier. The bit is filed until it is clean and smooth; then, with the iron heated, the bit is dipped into a flux to remove any oxides, and solder is applied to the bit. Any excess solder is wiped off with a clean cloth.

Precautions. The following precautions should be observed when using soldering irons:

- The ideal working temperature of the iron is just high enough to melt the solder easily. Overheating causes chalkiness in the solder, resulting in unsatisfactory joints, and it also encourages the formation of oxide on the bit, thus necessitating repeated cleaning and re-tinning. Systematic use of the heater switch enables an electric iron to be kept at optimum temperature, while frequent slight re-heating of a common iron is always preferable to less frequent but more protracted re-heating.

- When heating a common iron, always direct the flame of the brazing lamp towards the *base* of the bit, not at the point.

- Excessive use of soldering fluid or flux should be avoided, as this tends to lower the temperature of the iron and also promotes corrosion of the bit.

Soldering process. Skill in soldering can be developed only by practice. The basic steps in making a soldered joint are as follows:

- Clean and tin the bit of the soldering iron. Allow sufficient time for the iron to reach its working temperature.

- Clean the surfaces to be soldered and apply a suitable flux.

- Tin the joining surfaces by running the iron along each surface in turn, adding solder until a thin, even flow is spread over each surface.

- Assemble parts and, after applying a small quantity of flux to the joint, run the bit along the joint, allowing time for the tinned surfaces to fuse together. Add more solder as necessary to finish the joint.

- Remove any surplus flux; clean the bit, switch off if using an electric soldering iron, and allow the iron to cool.

Soldering is not a difficult process, and good results can be obtained by exercising care and paying attention to the following points:

- Ensure that the solder and flux chosen for the work in hand is of the correct type and that the flux is clean.

- Be very careful over the cleaning of surfaces prior to tinning; thorough cleaning is always important, but is absolutely vital when a safety flux is used.

- Molten solder will not adhere properly to cold metal, and it may be found necessary to preheat work of large dimensions. In this case avoid excessive pre-heating as this may cause the formation of a film of oxide on the previously cleaned surfaces.

- If it is necessary to secure the work to be soldered in a vice, place wooden blocks between the jaws and the work so as to minimize the heat loss.

- Use the minimum amount of solder between the joint faces, but make sure that it is evenly distributed. Solder has little strength and the strongest joint is produced by a thin film adhering perfectly to the joint faces.

SILVER SOLDERING

General

As its name suggests, silver soldering involves the use of a solder containing a proportion of silver, and in fact the type of silver solder you will be using is cadmium free, containing 42-44% silver. Because silver solder melts at a much higher temperature than lead/tin solder, a method of heating other than the soldering iron must be used. In the Aerial Erector trade, the method used is to burn a gas called propane using a calor gas blowlamp (Fig 7.4).

Propane Cylinder

Propane is stored in a portable cylinder (Fig 7.4), made of a high quality mild steel and painted red. The flow of propane is controlled by a simple ON-OFF valve.

Method of Silver Soldering

The only difference between silver soldering and soft soldering is in the equipment and the materials that are used, *ie* the solder and flux. The solder, as mentioned earlier, is cadmium free, and containing 42-44% silver, and the flux used is either Easi-Flow or Flux, Brazing, Low Temperature. Both these fluxes are active fluxes (*see* p7.2) and any residue must be washed off on completion of the soldering operation.

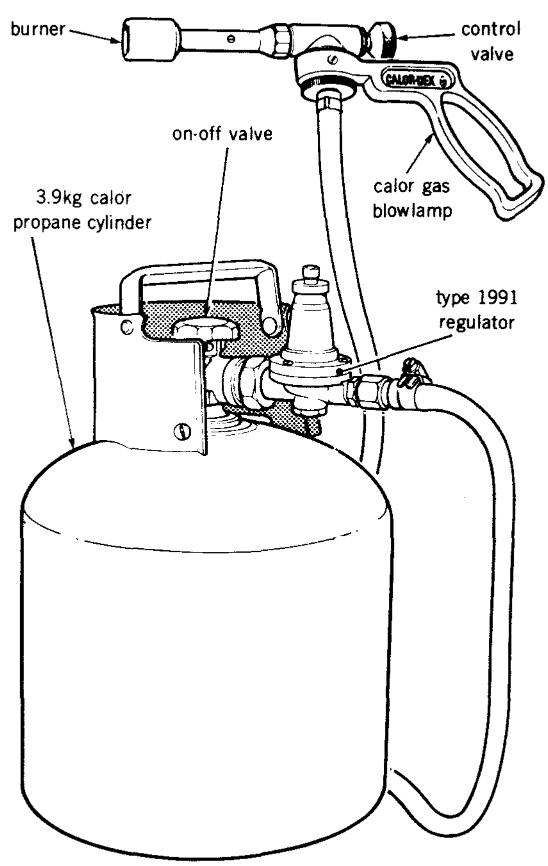


Fig 7.4 Propane gas cylinder and blowlamp

Propane Cylinders — Safety Precautions

Propane is a highly-flammable gas which will ignite and burn instantly from a spark or a piece of hot metal. If it is allowed to mix with air a highly explosive mixture is created, and a relatively small amount of the gas in a badly-ventilated room or other confined space may cause a serious accident if a flame, heat or spark is brought near.

High Pressure Gas Cylinders

Propane cylinders should be stored away from damp, heat and dust. Never store them near oil or grease or other combustibles, and do not place them where oil may drop on them from overhead bearings or machines. Do not store propane cylinders alongside oxygen or other fuel gas cylinders. Propane cylinders, full or empty, in store, or in use, must always be kept in the vertical position. When moving cylinders be careful not to drop or jar them. Never hoist them by a rope of chain sling or by an electro-magnet.

NEVER

- Use oil, grease or lubricant of any kind on cylinder valves or connections.
- Attempt to use equipment for gases other than those for which it is supplied.
- Test for leaks with a naked flame — use a solution of soap and water. Place leaking cylinders in the open air, remove from heat or flame, until the leak can be stopped.
- Thaw frozen cylinder valves by using a naked flame. Thaw them by the use of hot water.

Torches

Keep the connection joints tight, as leaks are dangerous as well as wasteful. Never use a torch as a lever or hammer.

Keep the torch nozzle clean by the occasional use of a wood splinter or piece of copper wire. Never use drills, reamers or steel welding wire for this purpose, as they tend to enlarge the gas passage in the nozzle.

Only skilled personnel should dismantle torches.

General Precautions

Do not work over a boarded floor unless it is covered with sheet metal or asbestos.

If work has to be suspended for more than a few minutes the flame should be extinguished or the torch placed in a suitable rest. It must never be hung on cylinders, or placed with the flame playing on the ground or on any items of equipment.

SUMMARY REVIEW

Soldering

Fluxes allow the solder to spread more rapidly.

Q What are the two classifications of solder and their properties? (p7.2).

The most common method of heating the common soldering iron is by means of the brazing lamp.

Q Name the component parts of the 1 pint brazing lamp (p7.3).

Q What is the method of preparing and lighting the 1 pint brazing lamp (7.3).

Q Name the precautions to be observed when using a brazing lamp (p7.3).

Soldering is not a difficult process, and good results can be achieved by exercising care and paying attention to certain points.

Q What are the points to be paid attention to? (p7.4).

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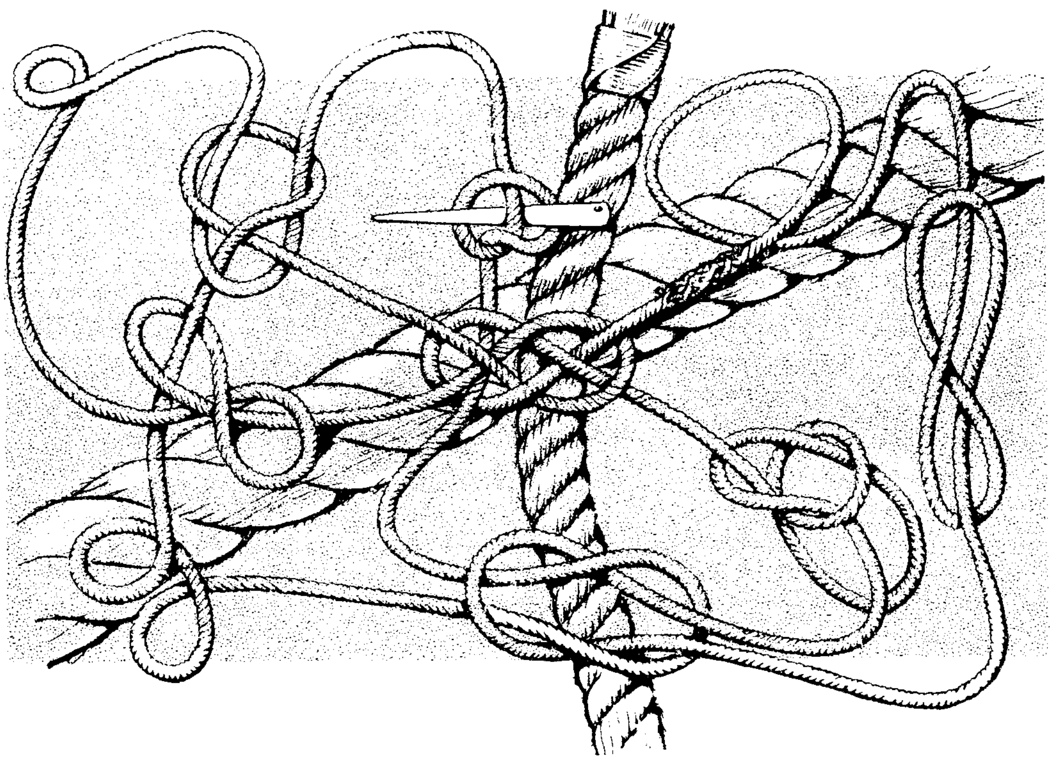
Acetylene Cylinders

Q What is the correct method of transporting acetylene cylinders? (p 7.6).

Q What is the procedure for dealing with a hot acetylene cylinder? (p 7.6).

CHAPTER 8

FIBRE ROPE AND ITS USAGE



Introduction

Rope is widely used in the erection of aerials and aerial systems. It is used as a means of supporting the aerial system, as a temporary lifting or haulage accessory, and as a lifeline.

You will be using three types of rope in your work:

- Natural fibre rope.
- Synthetic or man-made rope.
- Wire rope.

Since wire rope differs considerably both in its structure and in the way in which it is handled, this chapter will be confined to dealing with the first two types of rope, and wire rope will be dealt with separately in the following chapter.

Natural Fibre Rope

Over the years since man learnt how to make rope, many different materials have been used in its manufacture. Today the materials you are most likely to come across are hemp, cotton, flax, jute, manilla, sisal, and coir. Of these the most commonly used for erecting aerials are *manilla* and *sisal.*

Manilla. This rope is made from the fibre of the abaca plant, which grows extensively in the Philippine Islands and is shipped from the port of Manilla (hence its name); it is also found in Central America, Sumatra and Borneo. Manilla rope is a strong, smooth, hard fibre rope which does not rot when wet. It is normally used for lifelines, safety suspension chairs, or whenever the safety of equipment is of the utmost importance. It can be recognised by its deep golden brown colour when new and untreated.

Sisal. This rope is made from the leaves of the agave plant, which is grown in East Africa and Haiti. When new and untreated, sisal is hairy and of a pale straw colour. It is not as reliable as manilla and should not be used for any purpose where the parting of the rope would endanger life.

Construction of Rope

Ropes are made from vegetable fibres, each of which is between two and four feet long. These fibres are spun into *yarns* (Fig 8.1) to bind the fibres firmly together so that they hold by friction when the yarn is subjected to strain. A number of yarns are then twisted together to form a *strand* 150 fathoms long (1 fathom = 6 feet or approximately 2 metres).

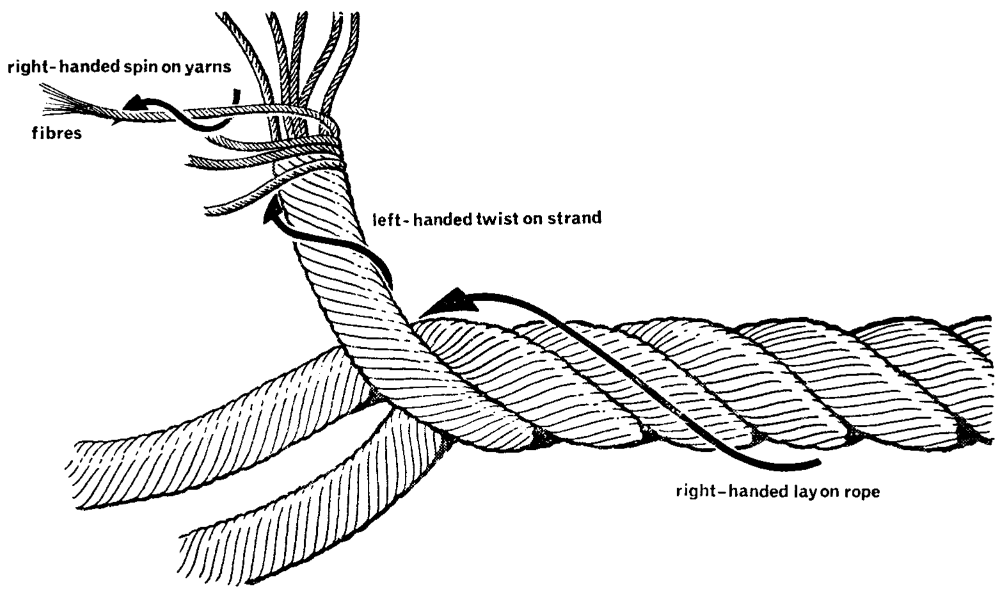


Fig 8.1 Hawser-laid Rope

Three or four strands are now made up into a left- or right-handed rope. This process is called 'laying' and is always carried out in the opposite direction to that used in the previous stage of twisting the strands. As the rope is laid up, its length contracts like a coiled spring, giving it a certain elasticity, and in practice, three strands of 150 fathoms lay up into a rope 120 fathoms (220 metres) in length. Three strands laid up in this way constitute a *hawser-laid rope* (Fig 8.1) and is the type of rope most commonly used.

Rope is normally described by reference to its circumference measured in inches and to the material from which it is made: for example, 3 inch manilla. The length of a rope is measured in fathoms.

Man-made Fibre Rope

Man-made (synthetic) fibre ropes have been available commercially in Great Britain since 1948. Examples of this type of rope are Nylon, Terylene, Polypropylene and Polyethylene. These ropes have characteristics which, in some instances, are superior to those of natural fibre ropes. Their construction is the same as for natural fibre ropes.

Qualities

Some of the qualities which have helped the swing towards the use of synthetic ropes are:

- **Breaking strength and stretch.** Nylon rope is approximately three times as strong as a natural fibre rope of the same size; terylene rope is nearly twice as strong. Nylon rope will extend to 45 per cent, and terylene rope 38 per cent, of its length before breaking.
- **Lightness in weight.** All synthetic ropes are lighter than either sisal or manilla.
- **Immunity to rot.** Synthetic rope is not attacked by mould, bacteria and insects. It can be stored for long periods without fear of deterioration.

Limitations

- **Sunlight.** All synthetic ropes lose strength when exposed to strong sunlight for long periods, but the loss is not enough to reach significant proportions. Even so, when not being used, they should be stored away or covered over.
- **Friction.** If synthetic rope is subjected to excessive friction it may develop glazed areas at the points at which the friction occurs. This glazing is caused by the fusing of the fibres by the heat generated by the friction. Glazing weakens the rope and if the glazed area is extensive, and no other rope is available, the damaged length should be removed and the parts of the rope *spliced* together (*see later*).

Safe Working Load

The tables of safe working loads for sisal, manilla and nylon ropes given below are reproduced from AP 3817A, Vol 1, Sect 11, Chap 1. Until tables of safe working loads for such synthetic ropes as terylene, polypropylene and polyethylene are incorporated in the AP 3817A, the advice of the appropriate manufacturer should be sought.

TABLE 1 Safe working loads of natural fibre ropes

Circumference of rope (in)	Safe working loads (cwt)		Circumference of rope (in)	Safe working loads (cwt)	
	Sisal or Manilla	Tarred Sisal		Sisal or Manilla	Tarred Sisal
1	1½	1¼	3	13¼	10
1¼	2¼	1½	3½	17½	13
1½	3¼	2½	4	22½	16½
1¾	4½	3¼	4½	28¼	21½
2	5¾	4½	5	34	26¼
2½	9	6½	—	—	—

TABLE 2 Safe working loads of nylon fibre ropes

Circumference of rope (in)	Breaking load (min)	Safe working load (1/6 of breaking load)
1	2240 lb	370 lb
1¼	3500 lb	580 lb
1½	5000 lb	830 lb
1¾	7000 lb	1160 lb
2	4·00 tons	0·66 tons
2½	6·25 tons	1·04 tons
3	9·00 tons	1·50 tons
3½	12·00 tons	2·00 tons
4	15·50 tons	2·58 tons
4½	19·00 tons	3·16 tons
5	23·50 tons	3·91 tons

KNOTS, BENDS AND HITCHES

Introduction

Long before the Ancient Egyptians used ropes to haul heavy stones into position whilst building the pyramids, man had developed methods of fastening ropes. Over the centuries, seamen—whose survival depended upon reliable methods of joining and fastening ropes—have developed these methods in the form of knots, bends and hitches, into a precise skill. In many ways the erection of masts or antenna systems is similar to the rigging methods used on ships. It is essential that you learn the correct uses of a selection of knots, bends and hitches and the correct method of making them. Your life, and the lives of your colleagues, and the efficiency of the mast or antenna systems, depend on your ability to do so.

Strength of Knotted Ropes

All knots, bends and hitches reduce the strength of a rope in that part of the rope where the knot, bend or hitch is made. This reduction varies from 40 to 60 per cent, and it should be borne in mind when putting a load on a knotted rope.

Parts of a Rope

The following terms, illustrated in Fig 8.2, are used to describe the various parts of a rope. These terms should always be used when you wish to describe or direct a particular aspect of the use of a rope.

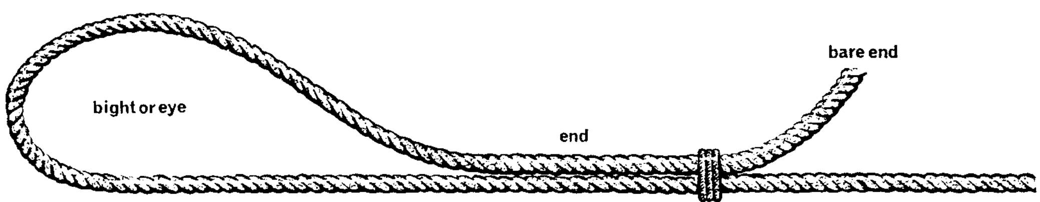


Fig 8.2 Parts of a Rope

Bight. This is the middle part of a length of rope. This term also refers to a loop of rope, and to make a bight is to form a loop.

End. This is the short length at either end of a rope, which may be formed into a bight, or used for making a knot, bend or hitch.

Bare end. As distinct from above, this is the extreme end of a length of rope.

Standing part. This is that part of a rope which is not already termed as the end or bight.

Stop. A stop is used to fasten two ropes, or two parts of the same rope together, to prevent them moving in relation to each other.

Elements of Knots, Bends and Hitches

Most knots, bends and hitches consist of a combination of two or more of the elements illustrated in Fig 8.3.

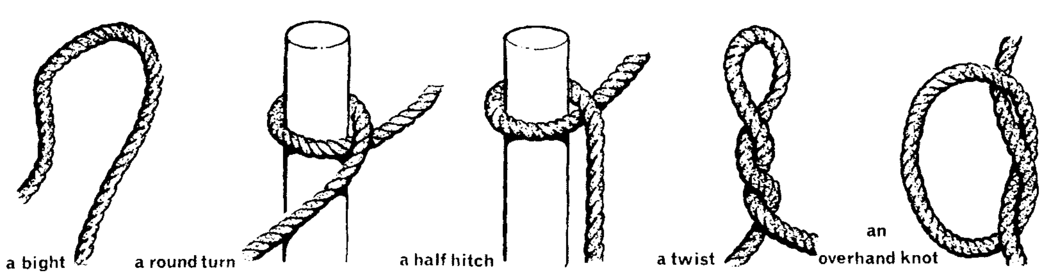


Fig 8.3 Elements of Knots, Bends and Hitches

Reef Knot

The reef knot (Fig 8.4) consists of two overhand knots made consecutively, and is used as a common tie for joining two ropes of equal circumference. It is not liable to come undone when there is no strain on the knot, but is unreliable if the ropes are of unequal circumference or very slippery, unless the ends are seized back to their standing parts.

When forming a reef knot you must take care to cross the ends opposite ways each time they are knotted (*ie* right over left, then left over right, or *vice-versa*), otherwise the result will be a granny knot. A granny will either slip or jam depending on whether it is made with, or against, the lay of the rope; a granny is also liable to come undone where there is no strain on the knot, and for these reasons *it is never used by Aerial Erectors.*

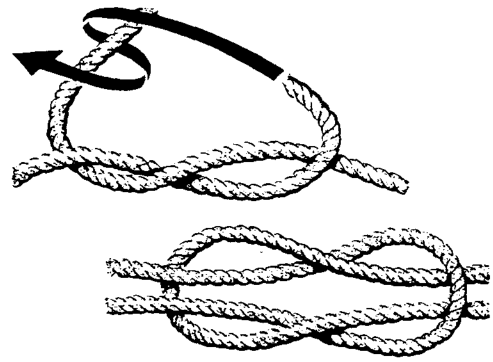


Fig 8.4 Reef Knot

Figure-of-Eight Knot

This knot is one of a group of knots known as stopper knots. It is used to stop the end of a rope unravelling or to prevent the rope slipping through a block.

The figure-of-eight knot is made by taking the end of the rope over and then behind the standing part (Fig 8.5a) and passing the end down through the loop thus formed (Fig 8.5b).

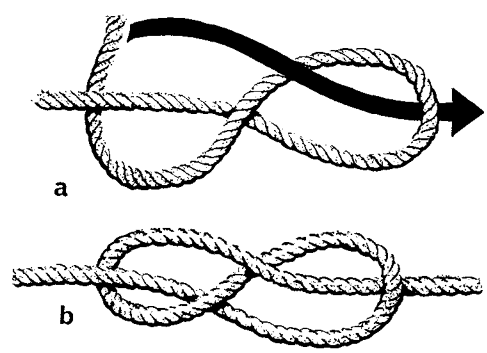


Fig 8.5 Figure-of-Eight Knot

Crown Knot

When finished, the crown knot leaves the three strands of a three-strand rope pointing back along the rope. It is used to begin a back splice (*see later*) and as a basis for more complicated knots but is seldom used on its own. To form a crown, unlay the strands a distance equal to three to four times the size of the rope, whip their ends (not shown) and spread them out in the form of a star, with the centre strand furthest away from the body (Fig 8.6a) and then:

- Bring strand C to the front to form a loop (Fig 8.6a).
- Place A over C and behind B (Fig 8.6b).
- Thread strand B through the loop of C (Fig 8.6c).
- Pull all strands taut until the knot is tidy and uniform (Fig 8.6d).

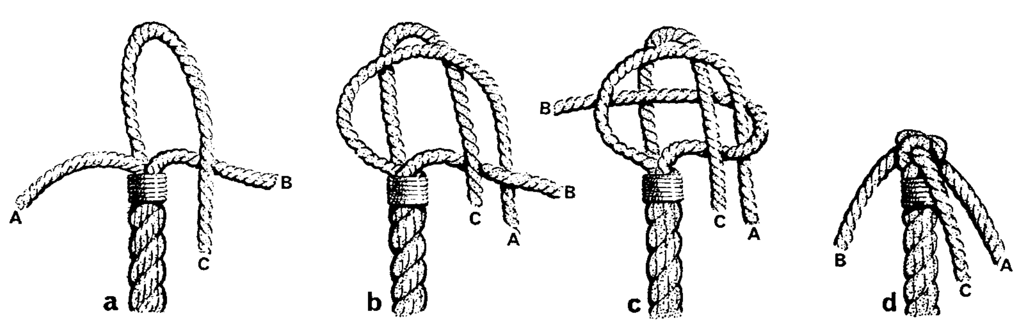


Fig 8.6 Making a Crown Knot

Marline Spike Hitch

This hitch, originally designed to obtain a better grip on a small cord, can be used to secure tools *etc* to a rope for hauling aloft. It is formed by making a loop either in the bight or the end of a rope (Fig 8.7a) then placing the loop over the standing part of the rope (Fig 8.7b). The object to be hauled aloft is placed across the loop but under the standing part (Fig 8.7c).

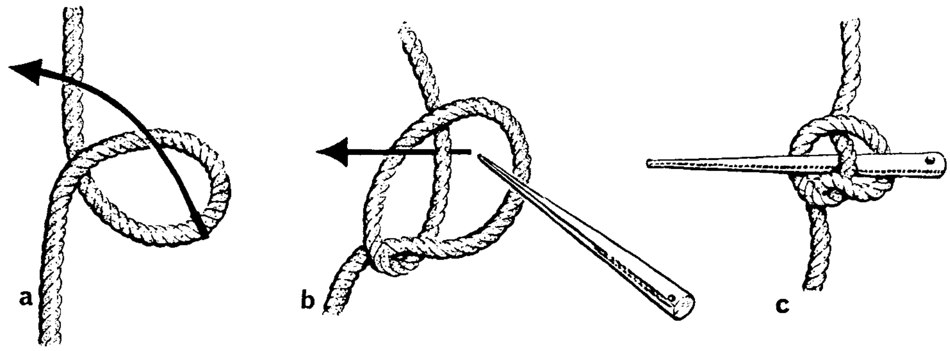


Fig 8.7 Marline Spike Hitch

Clove Hitch

A clove hitch is used to secure a rope to a spar, rail or similar fitting. It can be made in the end or on the bight of the rope, as illustrated in Fig 8.8a and b respectively. A clove hitch will slip along the spar or rail if subjected to a sideways pull.

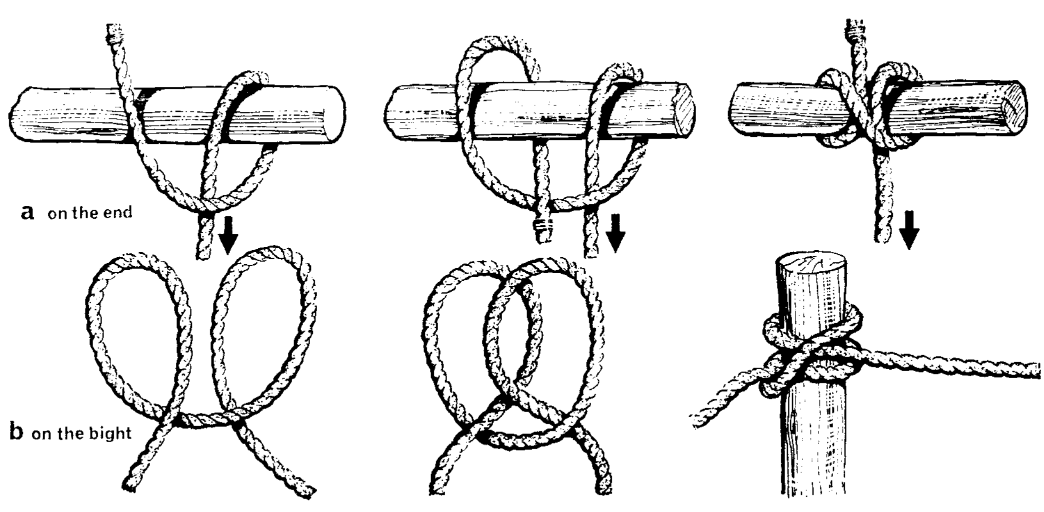


Fig. 8.8 Clove Hitch

To make a clove hitch on the end of a rope (Fig 8.8a) take a round turn on one side of the standing part, followed by a second round turn on the other side. The hitch is then completed by tucking the end of the rope through the second round turn and pulling it taut.

To make a clove hitch on the bight two loops are made as shown in Fig 8.8b. One loop is then placed on top of the other and this is passed over the end of the spar.

Rolling Hitch

This hitch (Fig 8.9) is also used for securing a rope to a spar when the pull is expected to be from one side or the other; it is also used for securing to another rope under strain. It is made by passing the end twice around the spar or rope, each turn crossing the standing part. A half hitch on the opposite side of the standing part completes the hitch. Always pass the two turns on the side from which the pull is expected. Unlike the clove, hitch this hitch will not slip along the spar or rope when subjected to a sideways pull.

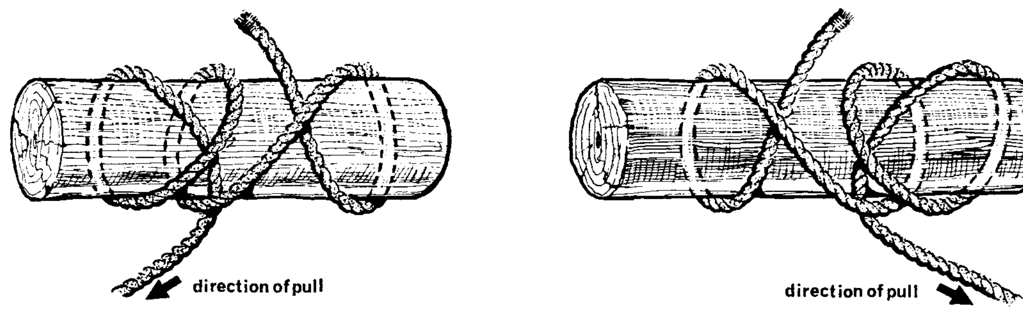


Fig 8.9 Rolling Hitch

The rolling hitch is also used as a temporary method of securing guylines. When used for this purpose the hitch is made on the standing part of the rope as illustrated in Fig 8.10.

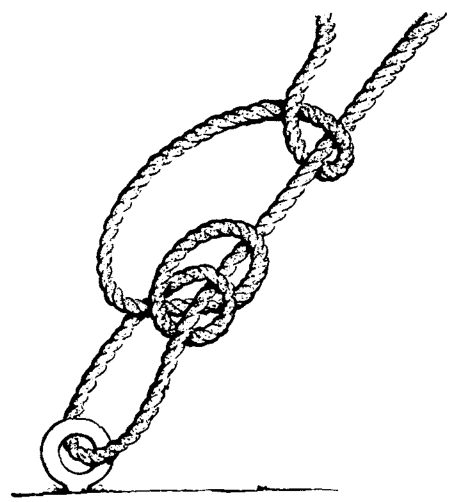


Fig 8.10 Rolling Hitch used to secure a Guyline

Round Turn and Two Half-hitches

This combination (Fig 8.11) is used to secure a heavy load to a hook or ring. It will never jam and can be cast off quickly. The end should be stopped to the standing part.

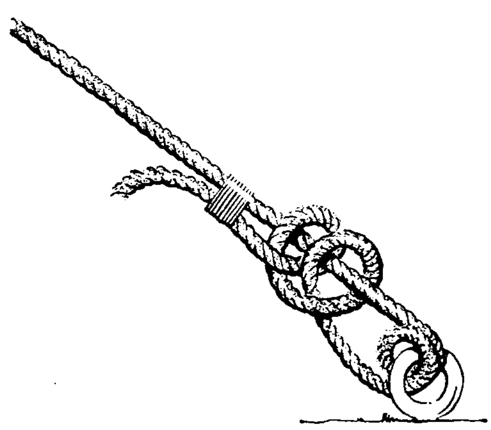


Fig 8.11 Round Turn and Two Half-Hitches

Sheet Bend

This is used to secure a rope to an eye or for joining two ropes of unequal thickness. When joining ropes of unequal thickness a loop is made at the end of the thicker rope; the end of the thinner rope is then passed through the loop from behind, brought round the back of the loop, and downwards under itself in front (Fig 8.12a).

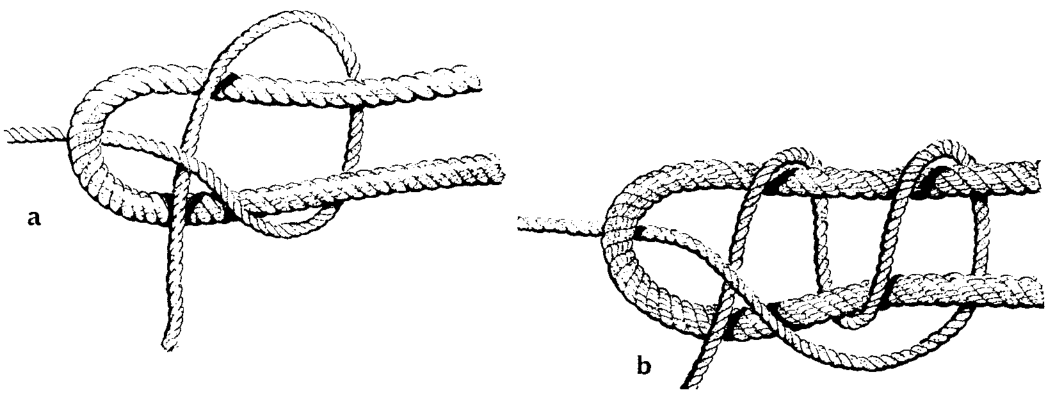


Fig 8.12 Sheet Bend

If the two ropes differ considerably in thickness or if they are wet, the *double sheet bend* should be used. To make the double sheet bend, begin as for the single sheet bend and, after passing the thinner rope around the back of the loop, take a second turn round the back before running it downwards under itself (Fig 8.12b).

Sheepshank

This is used to shorten the bight of a rope without cutting it. The strain on the rope will usually prevent the sheepshank from slipping but, if necessary, the loops can be stopped to the standing parts or secured with a toggle.

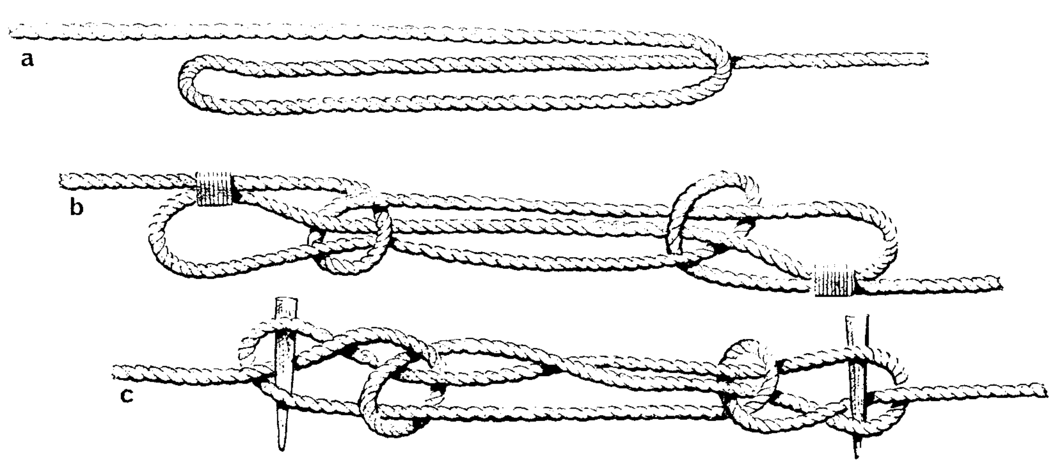


Fig 8.13 Sheepshank

To make a sheepshank, measure how much of the rope is to be taken up and lay this length into three (Fig 8.13a). With each standing part take a half hitch round the corresponding bight (Fig 8.13b). Fig 8.13b shows the sheepshank secured with a stopping and Fig 8.13c shows it secured with toggles.

Bowline

This is the most useful knot for making temporary eyes in ropes of all sizes. It is also used to form a lifeline around a man's waist and for a great variety of similar purposes.

There are many ways of making a bowline, but the method illustrated in Fig 8.14 is probably the simplest:

- Make a small loop (this loop is sometimes called a *gooseneck*), in the standing part of the rope (Fig 8.14a), taking care to leave a sufficiently long end to make the main loop of the required size, *eg* to pass around a man's waist if making a lifeline.
- Form the main loop by passing the end of the rope up through the gooseneck (Fig 8.14b).
- Pass the end of the rope behind the standing part and back down through the gooseneck (Fig 8.14), thus forming the completed bowline.

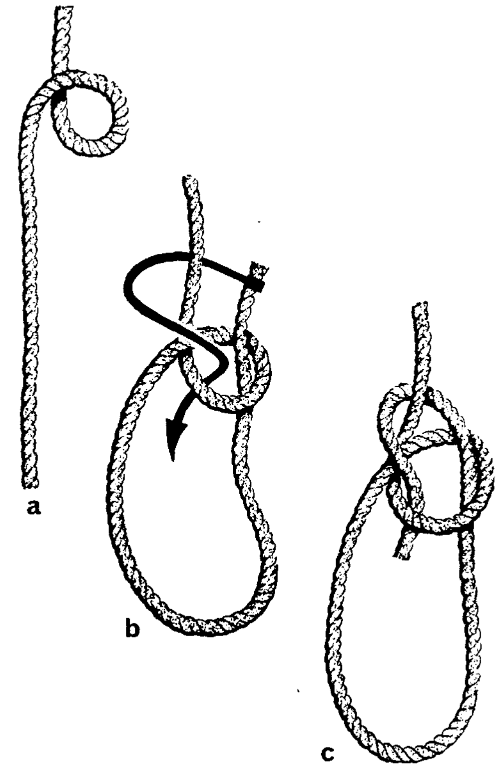


Fig 8.14 Bowline

Bowline on the Bight

As its name says, this bowline is made on the bight. It is used for raising or lowering a person.

To make this knot, make a bight in the rope and using both parts together follow the first two stages given for making the simple bowline. Then, holding the gooseneck firmly, bring the loop projecting through it down towards you and up behind the two standing parts as shown in Fig 8.15a to complete the knot (Fig 8.15b).

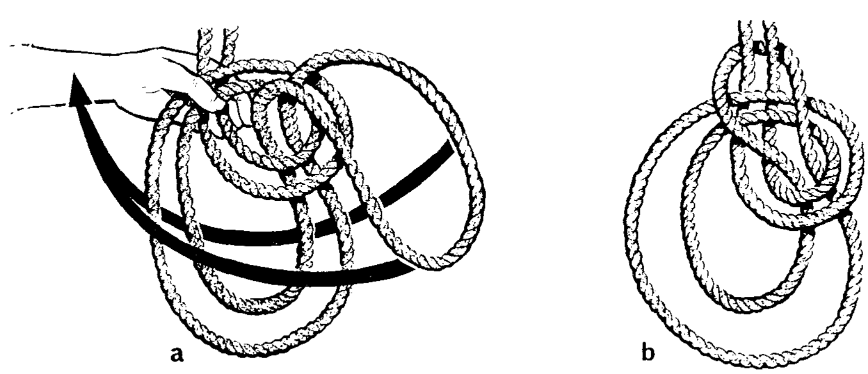


Fig 8.15 Bowline on the Bight

Marline Hitch

The marline hitch (Fig 8.16) is used for locking long objects or bundles together and is made as follows:

- Make an eye in the end of a rope using a timber hitch (*see below*) or small bowline.
- Pass the other end around the bundle and pass it down through the bight and pull taut.
- Continue along the bundle with a series of half hitches which should be in line, pulling each half hitch taut as it is made.
- Finish with a clove hitch.

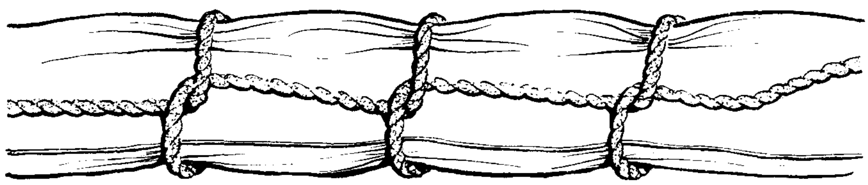


Fig 8.16 Marline Hitch

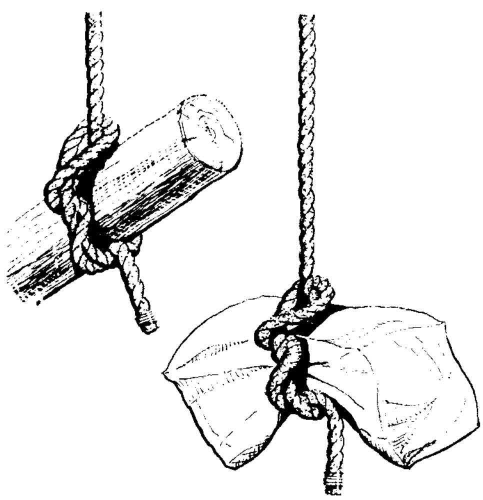


Fig 8.17 Timber Hitch

Timber Hitch

This hitch is used to secure a rope's end to a spar or bale. It is made by taking a rather long loose end which is then twisted back round itself with the lay (Fig 8.17). The hitch is tightened by pulling on the standing part.

Catspaw

A catspaw is used to make a temporary loop in a rope for hooking on (Fig 8.18). To make a catspaw turn back a bight on itself as shown in Fig 8.18a and twist the two loops away from each other (Fig 8.18b). The two eyes that are formed are then brought together and passed over the hook (Fig 8.18c).

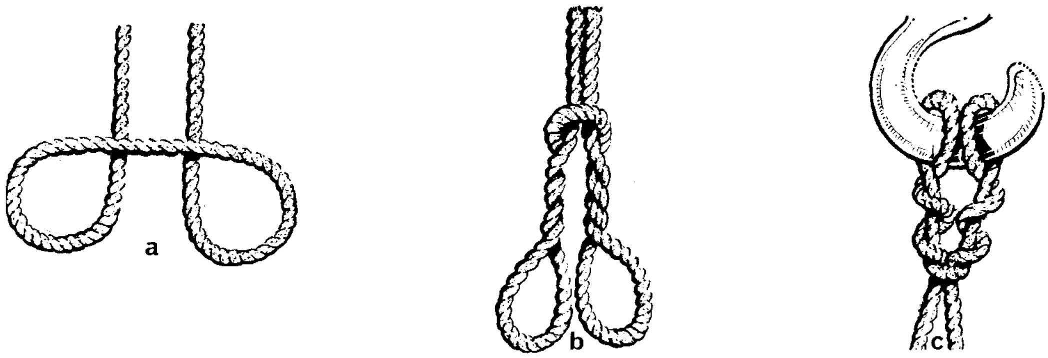


Fig 8.18 Catspaw

WHIPPING

Introduction

At the beginning of this chapter we saw that ropes are manufactured in lengths of 120 fathoms (220 metres) or in the case of man-made fibre ropes 1000 feet (305 metres). It is most unlikely that the ropes will be used in such lengths and you will have to cut them into more practical lengths.

When a rope is cut, its fibres, yarns and strands are free to unlay and the ends of the rope become frayed, weakening that part of the rope and making it extremely difficult to work with. It is evident, therefore, that a method of preventing the rope ends from unlaying is required before the rope is used. The method used is called *whipping* and consists of binding the end of a rope with twine. Lengths of twine used for whipping must be weatherproofed by the application of beeswax. It is sufficient to draw the twine over a block of beeswax so that it cuts into the wax which will adhere to the twine and prevent it from rotting.

Common Whipping

The common whipping is quickly and easily made. It is not so strong as other forms of whipping and will normally be used as a temporary measure when time is more important than strength or quality. It can be made on any part of a rope.

- Place the end of the twine along the rope as shown in Fig 8.19a.
- Using the other (working) end of the twine, pass six turns around the rope against its lay, working towards the end of the rope, each turn being pulled taut as it is made. Ensure that turns do not ride one over the other and that there are no gaps between the turns.
- Lay the working end of the twine along the rope as shown in Fig 8.19b and pass a further five or six turns over it, taking the bight over the end of the rope with each turn.
- When the bight becomes too small to pass over the end of the rope, pull the working end of the twine through the turns you have passed over it, thus completing the last turn round the rope (Fig 8.19c).
- Complete the whipping by cutting off the ends of the twine close to the turns (Fig 8.19d).

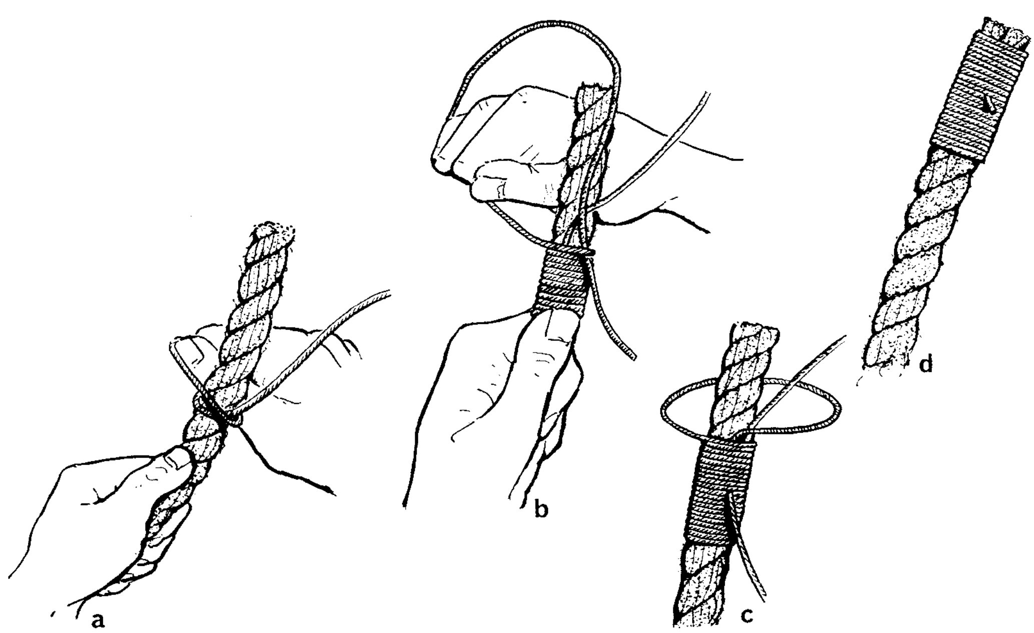


Fig 8.19 Common Whipping

An alternative finish, which can be used when the whipping is on the bight of the rope, is to take the last five or six turns loosely over one finger and pass the end back through them (Fig 8.20). The turns are worked taut, and the end pulled taut.

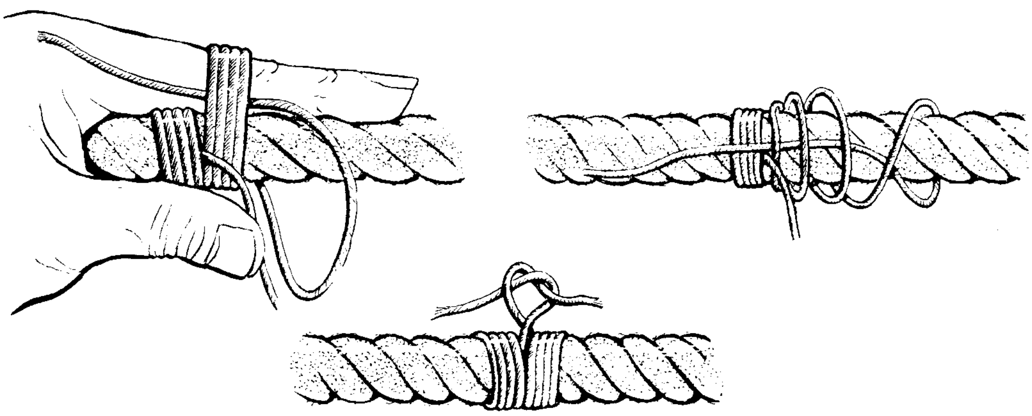


Fig 8.20 Alternative Finish to Common Whipping

West Country Whipping

The west country whipping is extremely strong, and when properly made will not slip. It is generally used when splicing fibre and wire ropes and can be made on any part of a rope.

- Middle the twine on the rope in the position required, pass the two ends round the rope in opposite directions and tie them with an overhand knot (Fig 8.21a).
- Pass the two ends back round the rope and tie a second overhand knot (Fig 8.21b).
- Continue this procedure, ensuring that the overhand knots are in line on either side of the rope, until the whipping is approximately ¾" long.
- Finish off with a reef knot and cut off the spare ends leaving about ⅛" either side of the reef knot.

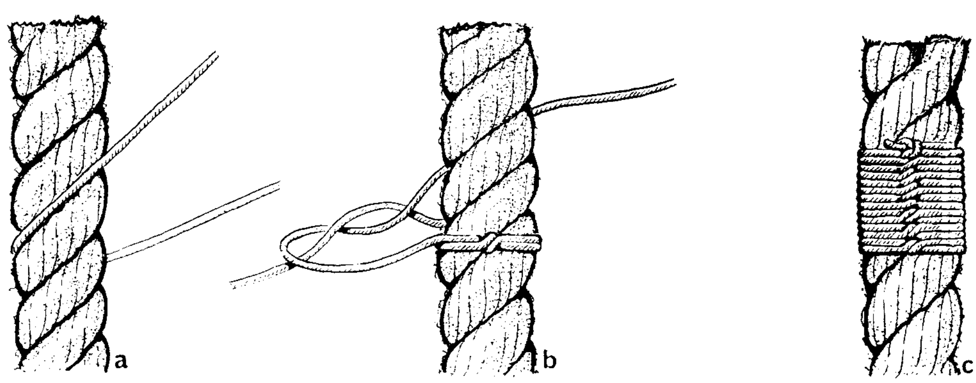


Fig 8.21 West Country Whipping

American Whipping

The American whipping is similar to the common whipping except that both ends of the twine are left clear at the centre of the whipping. This makes it slightly stronger than the common whipping so that it can be used as a quick temporary measure, but where strength is more important:

- Carry out the first two stages of the common whipping.
- Take the non-working end of the twine and fold it back over the first six turns (Fig 8.22a).
- Carry out the last two stages of the common whipping (Fig 8.22b).
- There should now be two loose ends of the twine at the centre of the whipping. Tie these off with a reef knot and cut off the ends ⅛" either side of the knot (Fig 8.22c).

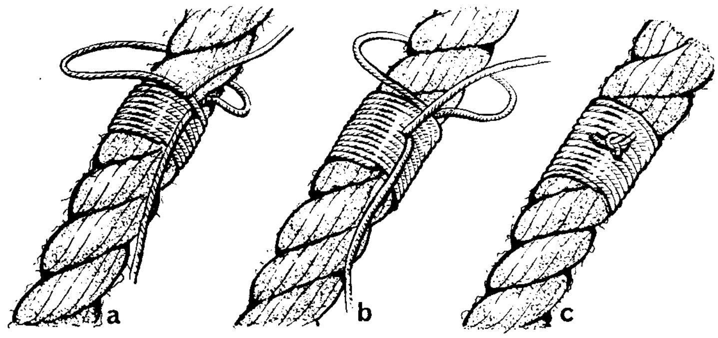


Fig 8.22 American Whipping

Sailmaker's Whipping

A sailmaker's whipping is the strongest and most secure of all whippings and should be used whenever the ends of a rope are subjected to considerable movement or use.

- Unlay the rope for about 3 inches (any frayed portion of the strands are not included in this measurement as they will be cut off after completion of the whipping). Hold the end of the rope in the left hand pointing upwards with the middle strand farthest away.
- Make a bight in the twine about 16 inches long and pass the bight over one strand and bring the two ends back towards you between the other two strands, making one end longer than the other (Fig 8.23a).
- With the bight hanging about 8 inches down the back of the rope, hold the bight and the two ends back along the rope, and lay up the rope with the right hand.
- Leaving the short end where it is, take up the long end and make about twelve turns of the whipping or until the whipping is ¾ inch long, working towards the end of the rope (Fig 8.23b).
- As with all whippings, pull each turn taut and ensure the turns do not override and that there are no gaps between the turns.
- Pass the bight over the whipping and the end of the strand it already encircles (Fig 8.23c). Pull on the short end so as to shorten the bight until it is tightened hard between the strands (Fig 8.23d).
- The short end comes from between two strands; locate the ends of these strands and pass the short end between them. Tie the short end to the long end with a reef knot ensuring that all the slack is taken up and that the knot is hard down between the strands (Fig 8.23d).
- Cut off the ends of the strands and the twine about a ¼″ from the end of the whipping (Fig 8.23e).

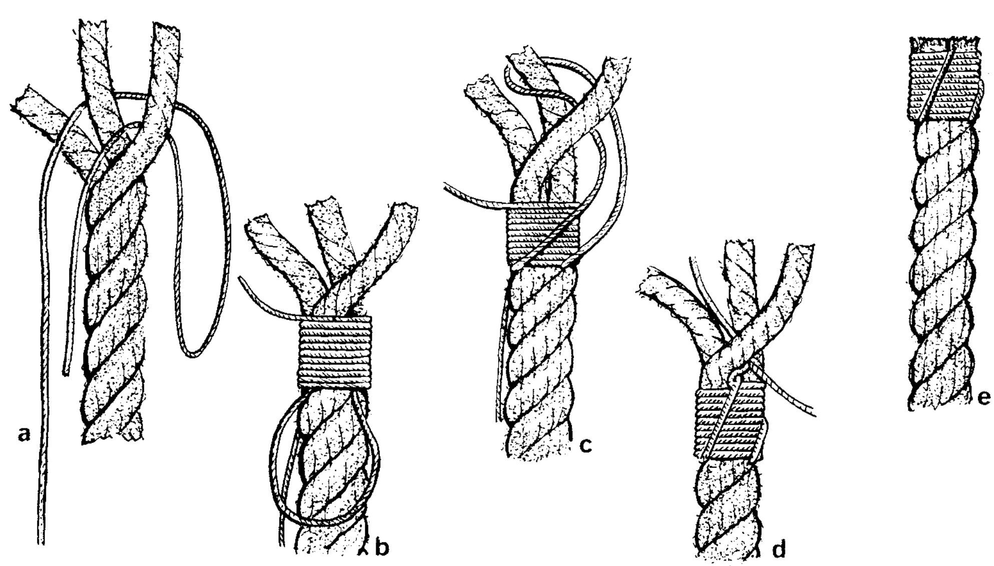


Fig 8.23 Sailmaker's Whipping

SPLICING

Introduction

Splicing is a method of joining two ropes together, of making an eye in the end of a rope, or of preventing the end of a rope from fraying. In the following paragraphs one example of each of these applications will be described:

- The back splice—used to prevent fraying.
- The eye-splice—used to make a permanent eye.
- The short splice—used for joining two ropes.

Back Splice

The back splice (Fig 8.24) is made as follows:

- Unlay the strands a distance equal to five times the circumference of the rope and whip the end of each strand (Fig 8.24a).
- Make a crown knot (*see* page 8.5).
- Then tuck each strand in turn, against the lay, over one strand and under the next as shown in Fig 8.24b.
- After each strand is tucked, pull the strands taut and tidy up this first tuck until each strand is uniform.
- Continue this tucking until 4½ tucks are made.

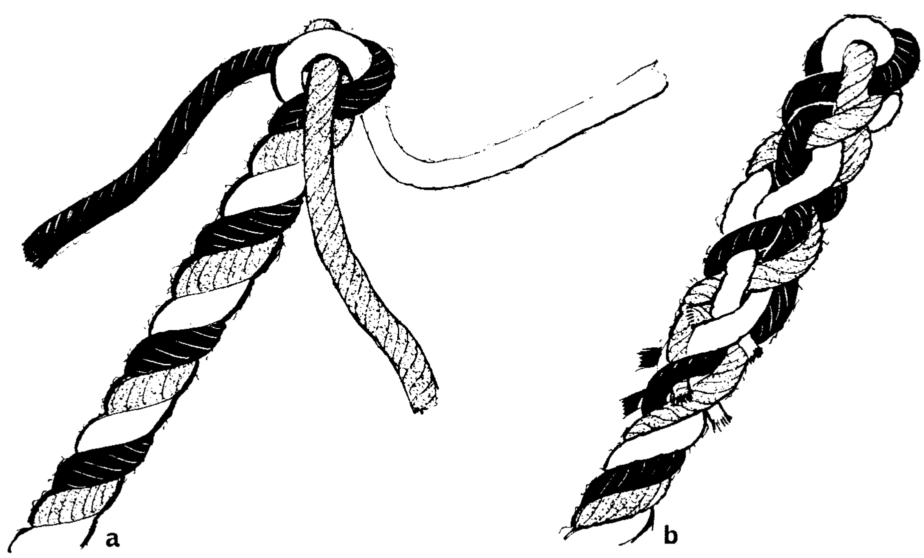


Fig 8.24 Making a Back Splice

To make the last half tuck, divide each strand into two equal parts. Take one of these parts from each strand and tuck it over and under as for a normal full tuck (Fig 8.25).
The splice is then completed by cutting all six ends leaving approximately ½ inch protruding from the splice (Fig 8.25).

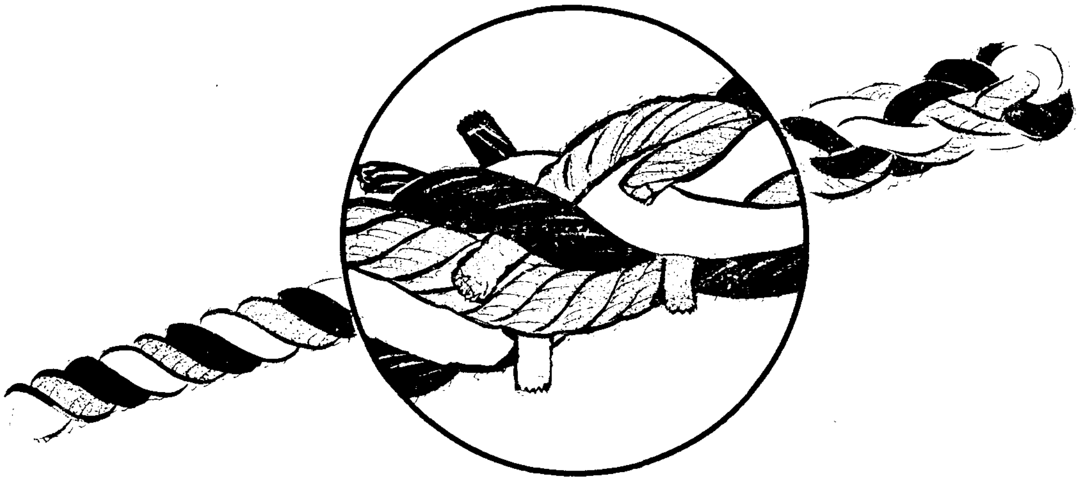


Fig 8.25 Details of Half Tuck

Eye Splice

Whip the rope at a distance from its end equal to five times the circumference of the rope, then unlay the rope to the whipping and whip the end of each strand. Mark the place intended for the crown of the eye (Fig 8.26), and bend the rope back from there so as to bring the unlaid strands alongside the place where the splice is to be made, with the left and middle strands lying on top of the rope.

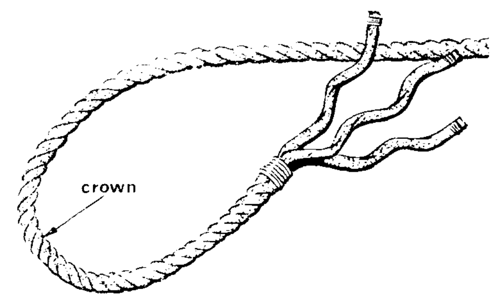


Fig 8.26 Start of an Eye Splice

Now refer to Fig 8.27 (in which the middle strand is marked A, the left hand strand B, and the right hand strand C) and make the splice as follows:

- Tuck A, from right to left, under the nearest strand of the standing part (Fig 8.27a).
- Tuck B, from right to left under the next strand on the standing part (Fig 8.27b).
- Now turn the rope right over so as to bring the remaining strand C on the top (Fig 8.27c) and then tuck C from right to left under the unoccupied strand on the standing part. Care must be taken to retain the lay of the rope in the last strand, as this enables it to lie closer (Fig 8.27d).

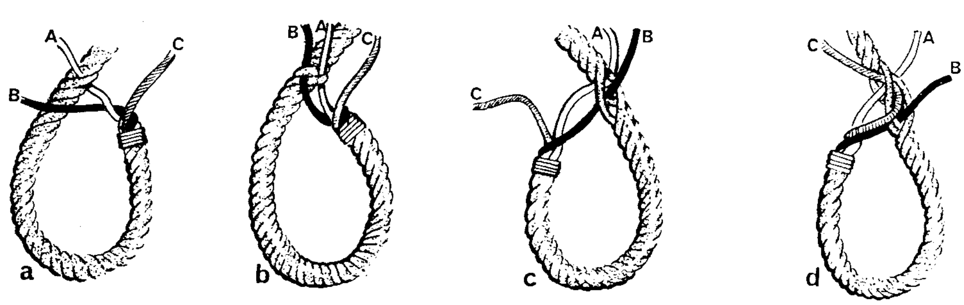


Fig 8.27 Making an Eye Splice

- Starting with strand C, pull each strand taut.
- Complete 4½ tucks.

Short Splice

In this splice the strands of each rope are tucked between the strands of the other rope against the lay, each strand being taken over the strand on its left, then under the next strand and emerging between this and the subsequent strand. In Fig 8.28 the ends of the ropes are marked A and B, and their unlayed strands C, D and E, and F, G, and H respectively.

- Whip each rope at a distance from its end equal to five times the size of the rope (this whipping has been omitted from rope A in the illustration).
- Unlay the strands to the whipping and whip one end of each strand (not shown).
- Marry the ends—that is, lay them together, end to end—so that one strand of each lies between two strands of the other (Fig 8.28a).
- Having ensured a close marry, whip the strands strongly round the join to prevent them slipping, and stop ends C, D and E to rope B with a strong stop (whippings and stop have been omitted in Fig 8.28).

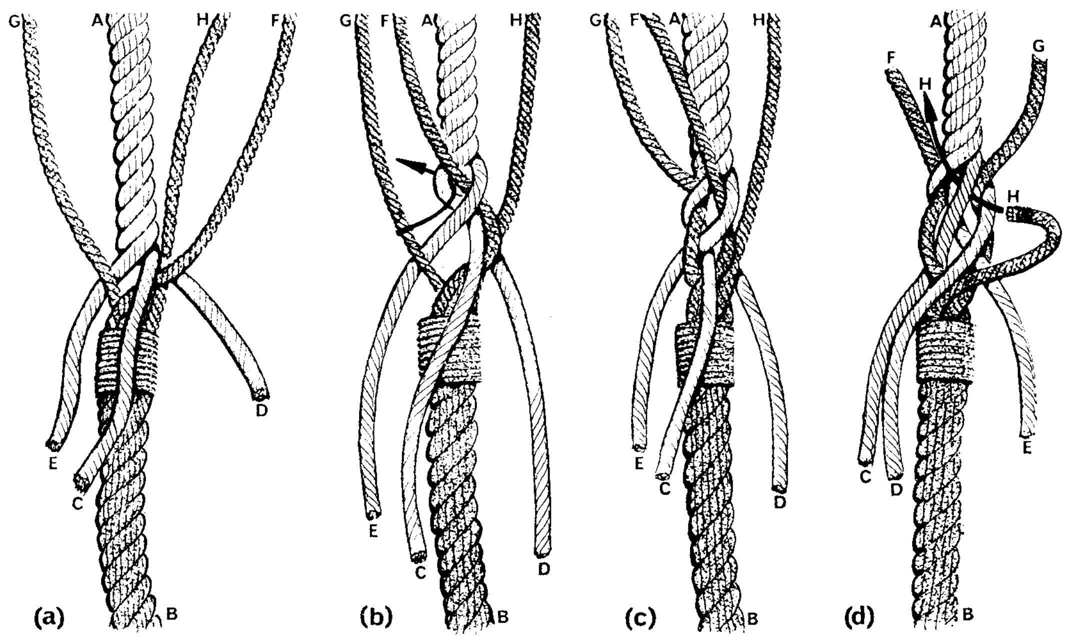


Fig 8.28 Making a Short Splice

- Cut the whipping on A.
- Take F over C, under E, and bring it out between E and D (Fig 8.28b).
- Take G over E, under D, and bring out between D and C (Fig 8.28b and c).
- Take H over D, under C, and bring it out between C and E (Fig 8.28d).
- Stop F, G and H to rope A, cut the stop and whipping on rope B, and tuck C, D and E in a similar manner.
- Pull all six strands taut.
- Again tuck each strand over the strand on its left and under the next one, and then repeat this operation a third time.

Pre-use Checks

Before any rope is used it is important that it is properly checked to ensure that its condition is such that it does not become a hazard to life or equipment. The faults that make a rope unserviceable and their indications are given in Table 3 below.

Table 3 Pre-use Check of Ropes

(a) Natural Fibre Ropes

Fault	Indications
Internal Wear	Extreme flexibility and signs of chafing in lays
External Wear	Reduction in diameter and flattening and fraying of outer strands
Brittleness, friability, shortness of fibre and strands	Small fibres will catch up and stand out from the lays when rope is rubbed through hands
Cuts, bruises and frayed strands	Visual
Insecure splice	Loose or uneven splicing, tucks pulling out or less than 4½ tucks
Life expired	Information on brass tally
Damaged serving	Loose whipping

(b) Synthetic Ropes

Fault	Indications
Abrasions	Rough, hairy
Cuts	Visual
Fraying	Visual
Bulging strands	Strands lifting/bulging
Insecure splice	Loose or uneven splicing, tucks pulling out, or less than 4½ tucks
Damaged serving	Loose whipping
Grease/Chemical Stain	Visual

Care and Maintenance of Ropes

One of the most important aspects of an Aerial Erector's job is *personal safety*. To a large degree, personal safety is a matter for the individual: your pride in yourself, in your job, and of the equipment and tools that you use. Not least of these is the proper care and maintenance of ropes. The following points will help you maintain the ropes you use in a condition that will ensure their maximum efficiency at all times.

Uncoiling Ropes

Fibre ropes should be uncoiled from the centre of a new coil if the coil remains static (Fig 8.29a). Preferably the coil should be placed on a spinner or swivel and uncoiled from the centre (Fig 8.29b).

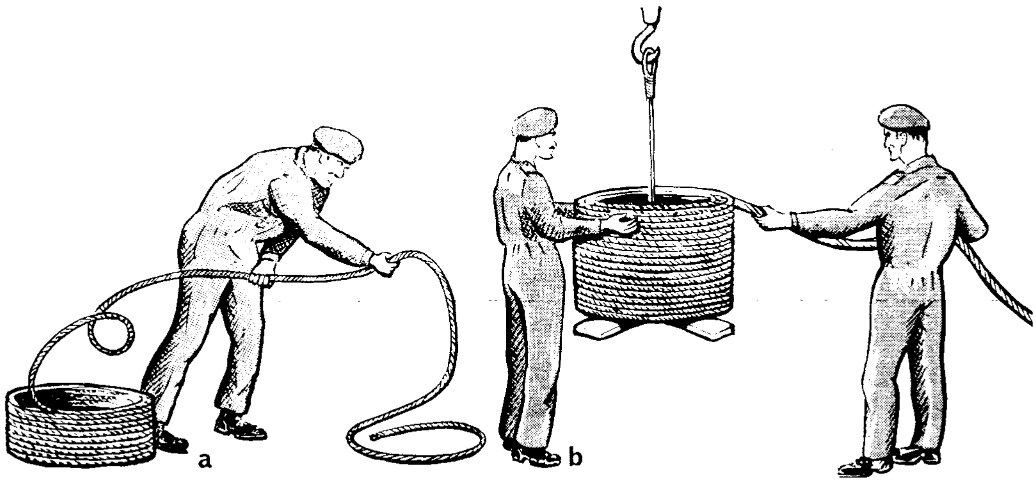


Fig 8.29 Uncoiling Ropes

Coiling Ropes

When coiling fibre ropes they should be coiled down in a direction according to their lay, *ie* right-handed (clockwise) for a right-hand lay rope, and the reverse for a left-hand lay rope.

Faking a Rope

A rope which may have to be paid out quickly should be faked down; that is, layed out in large bights in a zig-zag fashion on the ground in preparation for use (Fig 8.30). When faked, a rope does not have as many turns as when coiled, and it will run out with less chance of becoming snarled. Faking is particularly useful when using *tackles* (tackles are described in Chapter 12).

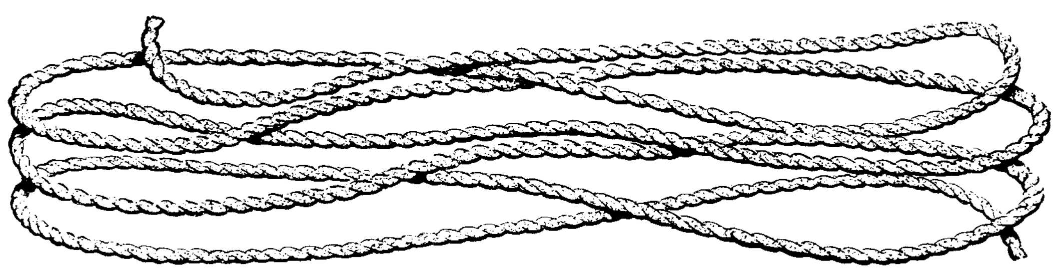


Fig 8.30 Faking a Rope

Care of Ropes

- Store in a dry airy place; do not expose to strong sunlight.
- Dry rope before storing.
- Keep away from paints, oils and chemicals.
- Do not kink.
- Do not overload.
- Slacken off in wet weather if exposed.
- Avoid sharp bends.

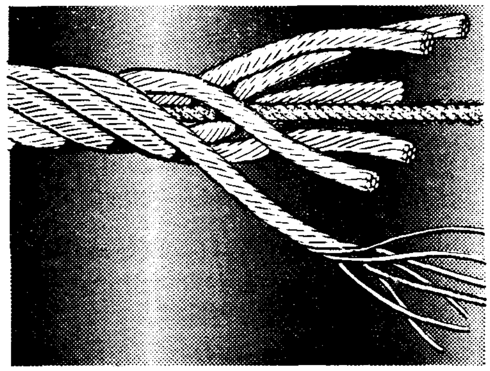
- Use correct size pulleys only (*see* Chapter 11).
- Reverse rope end for end occasionally to equalise wear.
- Avoid abrasions; ensure winch drums and pulley wheels are smooth.
- Use splices whenever possible as opposed to knots.

Summary

It has already been stated that care and maintenance of ropes is important in the matter of personal safety. This statement applies equally to all aspects of rope work; there is no room for a slipshod approach to the making of knots and splices.

CHAPTER 9

WIRE ROPES



Introduction

Masts and antenna systems are often subjected to severe weather conditions and it is important, therefore, that their supports are adequate for such conditions. Sometimes new materials such as terylene can be used but, because terylene is prone to stretching, it is not always a suitable replacement for the well-established wire rope. For this reason there is a continuing requirement for the Aerial Erector to be able to recognize different types of wire rope, to know where to use them, and to be able to use the different methods of joining and terminating them.

Construction of Wire Rope

As shown above, wire rope is manufactured by much the same process as fibre rope. Instead of yarns, a number of thin wires, which extend continuously through the length of the rope, are twisted into strands, and these in turn are laid up to form the rope. The wires forming a strand are twisted left-handed, and the strands forming the rope are laid right-handed about a hemp or jute core. The hemp or jute core has two functions:

- It acts as a cushion into which the strands bed.
- It absorbs the lubricant with which the rope should be periodically treated.

Types of Wire Rope

In your work as Aerial Erectors you will use many different types of wire rope. Most of these will be in the form of pre-manufactured components and only two types are available in bulk issues from service supply sources. These are:

- **Galvanized steel wire rope.** This is a rigid wire rope and has only one single wire per strand made up into a rope (Fig 9.1a).
- **Flexible steel wire rope.** This is a flexible wire rope consisting of a small number of wires wound to form a strand. The strands are then made up round a hemp or jute heart (Fig 9.1b).

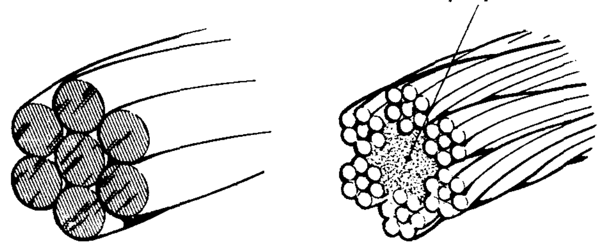


Fig 9.1 Types of Wire Rope

Splicing

Hand splicing of wire ropes is seldom necessary now that more efficient methods such as the *Talurit* process and Preformed line terminations may be used (*see* Chapter 10). However, these alternatives are not always available and the Aerial Erector should be able to hand-splice wire rope. There are several types of wire splice but the only one you will be required to do is the eye splice. The description that follows shows the making of a type of eye splice known as a *hard eye*, *ie* the eye splice is made round a thimble, a common application of the eye splice. If the rope has to be cut prior to splicing, a sharp cold chisel must be used. Fraying of the ends of the rope can be prevented by binding waxed thread tightly around the rope at both sides of the point where the rope is to be cut. Preparation of the rope and the fixing of the thimble in place is carried out as described below.

Preparation of a Hard Eye for Splicing

- Make a west country whipping on the rope 9 inches from its end and bend the rope around the thimble so that the end of the whipping nearest the end of the rope is 1/16 inch from the point of the thimble (Fig 9.2). To hold the thimble in this position, the standing part and the tucking end are held side by side between the jaws of a vice as shown in Fig 9.2.

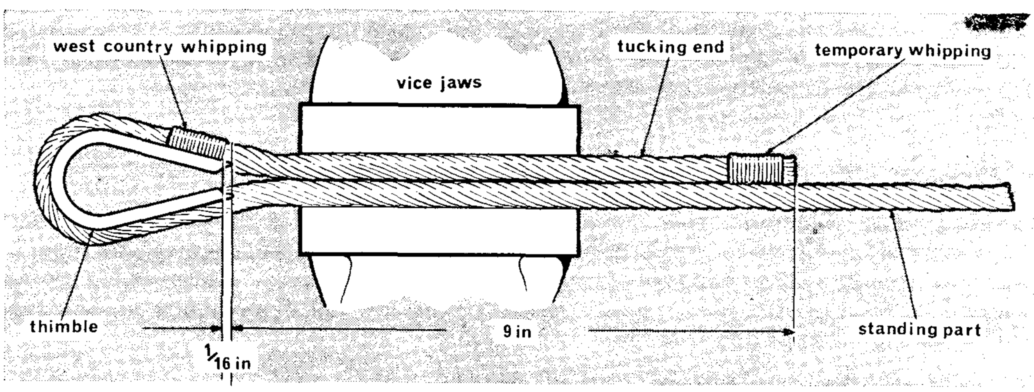


Fig 9.2 Preparation of a Hard Eye (1)

- Double a length of whipping twine to form a 2 foot loop. Pass the two free ends of the loop through the eye of the thimble, around the wire at the centre of the west country whipping and back through the looped end and pull taut (Fig 9.3a).
- Pass the two free ends back through the eye of the thimble, around the wire opposite the whipping and back through the eye of the thimble to form a figure of eight turn (Fig 9.3b).

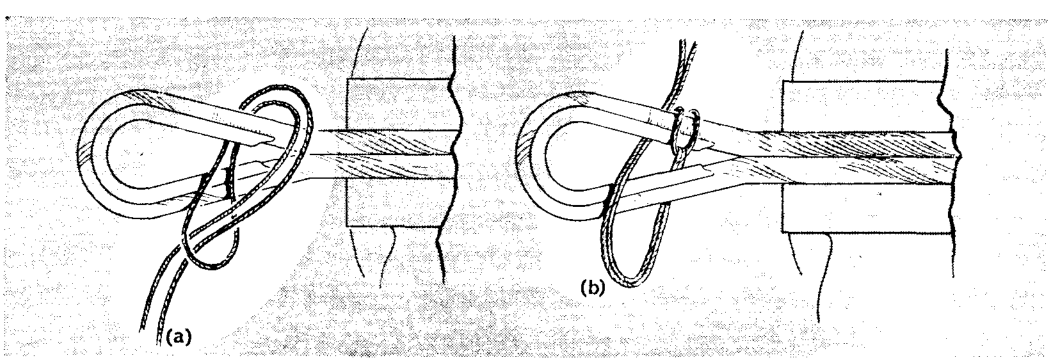


Fig 9.3 Preparation of a Hard Eye (2)

- Continue making figure of eight turns until you have made eight to twelve turns, ensuring that as each turn is made, the whipping is pulled taut. Finish off with a clove hitch (Fig 9.4).

- Make a west country whipping approximately ½ inch long on the end of the thimble as shown in Fig 9.4. The wire is now ready for splicing and can be removed from the vice.

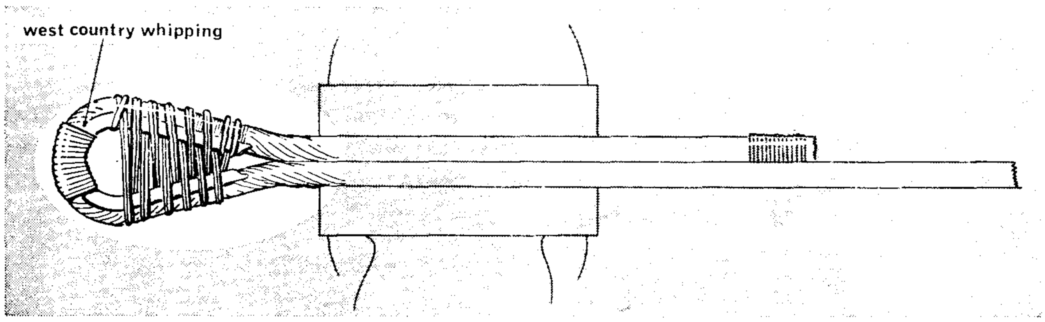


Fig 9.4 Preparation of a Hard Eye (3)

Splicing a Hard Eye

- Remove the temporary whipping from the bare end of the tucking end of the wire and unlay the six strands back to the west country whipping. Cut out the jute heart as close to the west country whipping as possible using the tip of a knife, take care not to damage the whipping.

- Divide the six strands into two sets of three and arrange them so that they lay to either side of the standing part (Fig 9.5). Each strand must be separate and they must not cross one over the other.

- It should be possible to see the standing part close to the thimble between the two sets of strands. Locate a single strand on the standing part which is central between the two sets of strands and as close to the point of the thimble as possible—strand A in Fig 9.5.

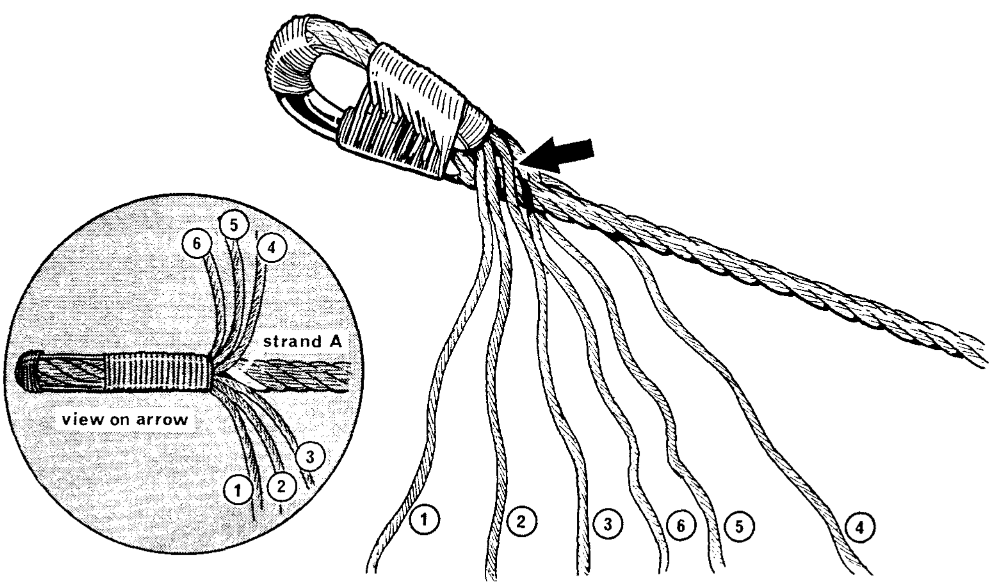


Fig 9.5 Splicing a Hard Eye (1)

- Lever strand A clear of the other standing part strands by inserting the point of an ice pick and pushing it under the strand against the lay (Fig 9.6). Care must be taken not to tear or prize out the jute heart of the standing part.

Note

Since the ice pick can easily slip it is important that the ice pick is always pushed away from you. Also, you must take care to position your hands and body such that they will not be in danger should the ice pick slip.

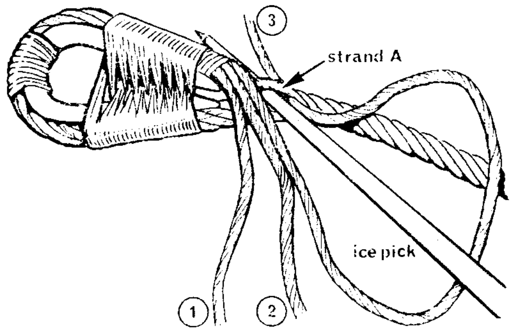


Fig 9.6 Splicing a Hard Eye (2)

- Select the tucking strand *closest* to and *underneath* the ice pick—strand 3 in Fig 9.6—and pass the end of this strand, *against the lay* under strand A. Remove the ice pick and complete the tuck by pulling it taut. This must be done carefully to prevent the strand kinking or unlaying.

- Locate the strand on the standing part nearest to where the first tucking strand enters the lay of the rope—strand B in Fig 9.7—and lever it clear with the ice pick. Take up the tucking strand *nearest to* and *underneath* the ice pick—strand 2 in Fig 9.7. Tuck this strand, against the lay, under strand B and pull taut. Ensure that the strand does not kink or unlay whilst being pulled taut.

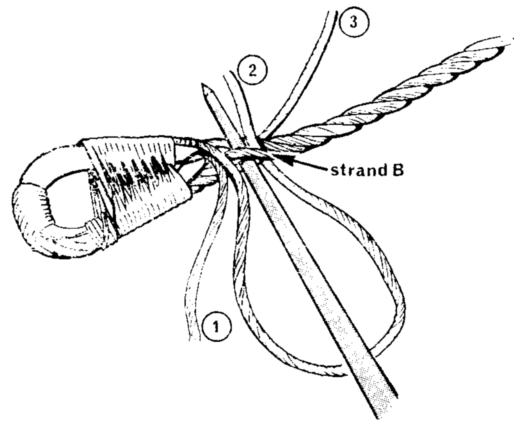


Fig 9.7 Splicing a Hard Eye (3)

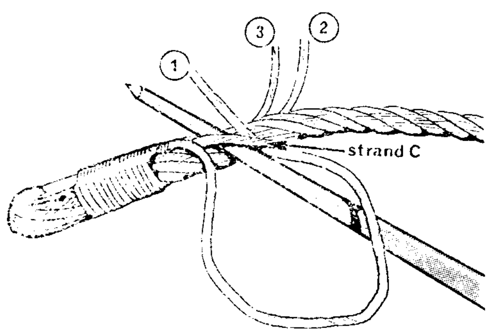


Fig 9.8 Splicing a Hard Eye (4)

- Locate the strand on the standing part nearest to where strand 2 enters the lay of the rope—strand C in Fig 9.8—and lever it clear with the ice pick. Tuck the remaining tucking strand of the first set of three—strand 1 in Fig 9.8.

- Turn the rope over so that the second set of tucking strands—strands 4, 5 and 6—are uppermost.

- Locate the strand on the standing part that is nearest to where the first tucking strand protrudes from the lay of the rope—strand F in Fig 9.9—and lever it clear with the ice pick inserted against the lay.

- Take up the tucking strand *farthest from* and *above* the ice pick—strand 4 in Fig 9.9—and tuck this strand against the lay of the rope.

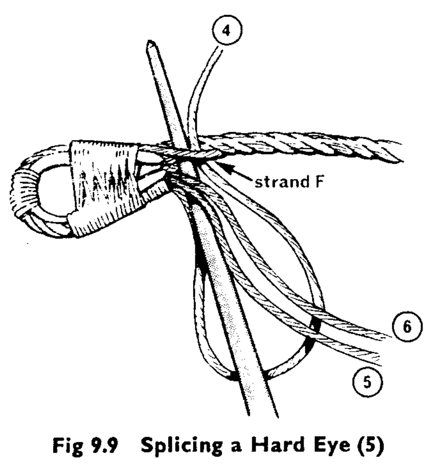


Fig 9.9 Splicing a Hard Eye (5)

- It should now be possible to see two strands on the standing part that have not been levered clear or had strands tucked under them—strands D and E in Fig 9.10. Lever *both* these strands clear with the ice pick.
- Take up the tucking strand *nearest* to and *above* the ice pick—strand 6 in Fig 9.10—and tuck this strand under *both* of the standing strands levered clear (Fig 9.10).

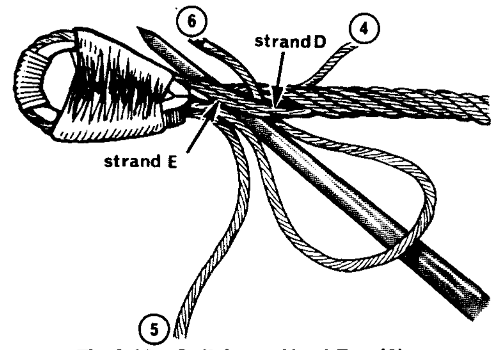


Fig 9.10 Splicing a Hard Eye (6)

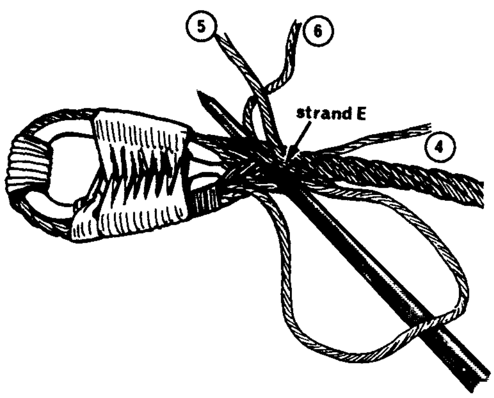


Fig 9.11 Splicing a Hard Eye (7)

- The remaining tucking strand—strand 5 in Fig 9.11—is now tucked under strand E to complete the first round of tucking.
- Use a hide or nylon faced hammer to work in the tucking strands. This is best done by placing the splice over the back of a vice and firmly hammering the tucks whilst the splice is rotated. In doing this, care must be taken not to distort or flatten the strands. Tucks must be worked in to remove all slackness. There should be no large gaps between the strands and the splice should have a rounded appearance. This operation must be carried out after each series of tucks.

The splice is now ready for the second, third and fourth series of tucks. These are made by tucking each strand in turn over one strand on the standing part and under the next. When making the tucks the following points must be observed:

- Ensure that the strands are not kinked or unlayed.
- Tucking strands are not allowed to cross one over the other.
- Tucking strands are not tucked under or passed over two adjacent strands on the standing part.

To complete the splice a series of half tucks are made. To do this fold back each *alternate* tucking strand over the splice (Fig 9.12a) and then tuck each remaining strand *over one*, and *under two*, strands on the standing part (Fig 9.12b). Finish by cutting off the ends of each tucking strand leaving ½ inch protruding from the rope.

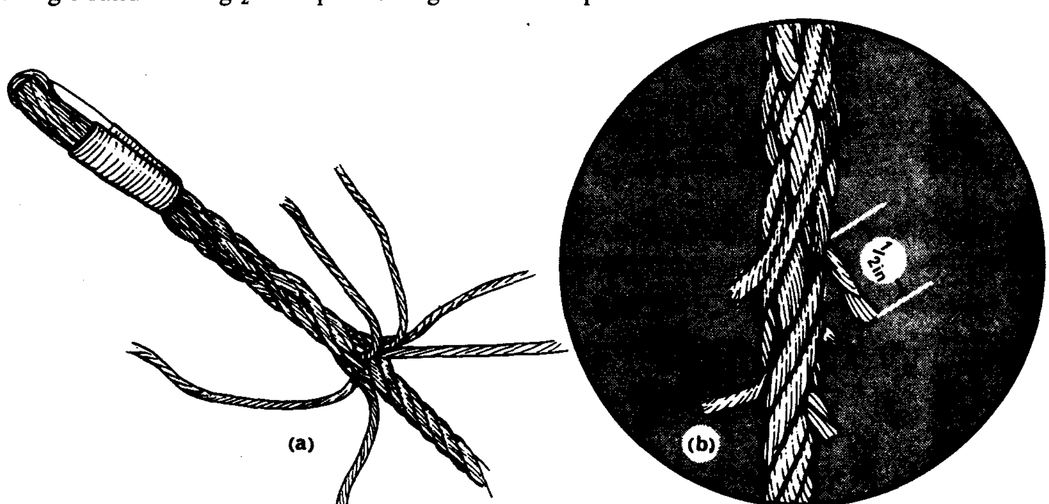


Fig 9.12 Splicing a Hard Eye (8)

Bulldog Grips

Aerial Erectors are often required to terminate wire ropes in situations too difficult for the use of the Talurit press and on lengths of rope too short for the use of Preformed line terminations (see Chapter 10). It may well be a situation which will require some adjustments to the rope, or one needing only a temporary termination for which hand splicing would not be suitable. In these circumstances a suitable method of terminating a wire rope is provided by *bulldog grips* (Fig 9.13). These grips are supplied in various sizes to suit a range of rope sizes. The relevant size is stamped on the bridge and corresponds to the diameter of the rope the grip is intended for.

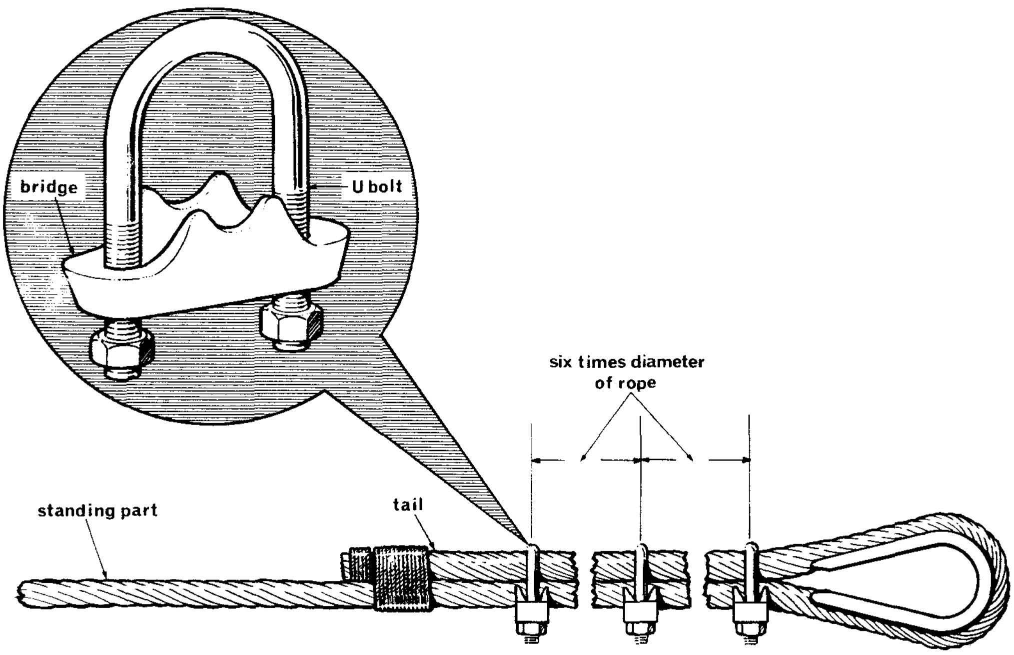


Fig 9.13 Bulldog Grips

Method of Fitting

As shown in Fig 9.13 bulldog grips are fitted to the rope so that the 'U' bolt is around the tail of the rope and the bridge around the standing part. The number of grips to be used and their spacing is determined by the size (diameter) of the rope. The number of grips required are as follows:

- Ropes up to and including 19mm ($^3/_4$ in) in diameter — 3 grips
- Ropes over 19mm ($^3/_4$ in) up to and including 32mm ($1^1/_4$ in) in diameter — 4 grips
- Ropes over 32mm ($1^1/_4$ in) up to and including 38mm ($1^1/_2$ in) in diameter — 5 grips
- Ropes over 38mm ($1^1/_2$ in) up to and including 44mm ($1^3/_4$ in) in diameter — 6 grips
- Ropes over 44mm ($1^3/_4$ in) in diameter — 7 grips

The spacing between each grip should be about six times the diameter of the rope (Fig 9.13). When fitting bulldog grips ensure that the lay of the rope is not damaged by over-tightening.

Pre-use Check of Wire Ropes

Before wire ropes are used they should be inspected for serviceability, observing the following points:

- *Internal wear* — indicated by polished internal strands and reduction of diameter.
- *External wear* — indicated by polished and flattened external strands, broken wires, and reduction in diameter. A reduction of more than 5% in diameter renders the rope unserviceable.

- *Broken wires*—if more than 10% of the total number of wires in a strand are broken over a length equal to eight diameters the rope is unserviceable.

- *Corrosion*—indicated by rust (either externally or internally) or by brittleness.

- *Kinks and knots*—observed visually.

- *Insecure splices*—indicated by loose tucks, broken wires, less than 4½ tucks, open strands and kinks.

- *Insecure swages*—indicated by broken wires, or movement of wire in a ferrule.

- *Damaged serving*—loose or frayed serving yarns, or ends not made off properly.

- *Damaged whipping*—loose or frayed whipping twine, or ends not made off properly.

Unserviceabilities

The points listed above cover not only the selection of a piece of wire rope to make antenna components or rigging for use in the field, but also the pre-use inspection of lifting tackle. Any unserviceabilities should be reported to the NCO IC immediately.

Care and Maintenance of Wire Ropes

The fact that wire ropes are, size for size, stronger and more durable than fibre ropes does not exclude them from proper care and maintenance. They can be dangerous if neglected and weakened if used improperly. Wire rope is much less flexible and is, therefore, much less easily managed than fibre rope. It resists being bent and is much more liable to kink or to spring out of its coil. If handled correctly, however, it may be used for most of the purposes for which fibre rope is used—but bends, hitches and knots cannot be made in it. The following points will help you to use wire rope efficiently and safely.

- *Uncoiling wire ropes.* New coils of wire rope, if small enough, can be rolled along the ground to uncoil them, or placed on a spinner or swivel and uncoiled from the outside. Care should be taken when the rope is uncoiling near to the top of the coil. A man should be stationed at the spinner to prevent several turns springing off, with the danger of subsequent kinking.

- *Coiling wire ropes.* Wire ropes should be stowed on reels or drums where practicable. If it is necessary to coil them down it will be found that they are less able to absorb turns than fibre ropes; they tend to spring and will not lay flat on the coil. They should be coiled down right-handed, but occasionally a left hand turn may have to be inserted to stop the rope from springing out. The nautical term for this is a '*Frenchman*'. Once the wire has been coiled it should be well lashed to prevent the coils from springing out of place.

- *Care of wire ropes.* The following points are important in the case of wire ropes:
  - Do not bend around a pulley or bollard which is too small in diameter to allow free flexure of the rope. The minimum bending radius is *three times* the diameter of the rope.
  - Do not allow excessive friction to be created by seized or incorrectly shaped sheaves and pulleys.
  - Shock loading caused by snatching or the sudden application of a load should be avoided. If the rope is inadvertently shock-loaded it must be thoroughly examined before being used again.
  - Corrosion of the wire strands due to lack of internal lubrication can be avoided by regularly brushing a suitable lubricant or rope dressing into the strands.
  - Do not allow the wire to kink by careless handling.

SUMMARY REVIEW

Construction of Wire Rope

The hemp or jute core of a wire rope has two functions.

Q What are these functions? (p9.1).

Two types of wire rope are available in bulk issue from service supply sources.

Q Name them and describe their construction (p9.1).

Bulldog Grips

The number of grips to be used and their spacing are determined by the size of the rope.

Q How many grips are used on the following rope sizes: up to 3 in, 3 in to 4 in, 4 in to 5 in; how are they spaced? (p9.6).

Pre-use Check of Wire Ropes

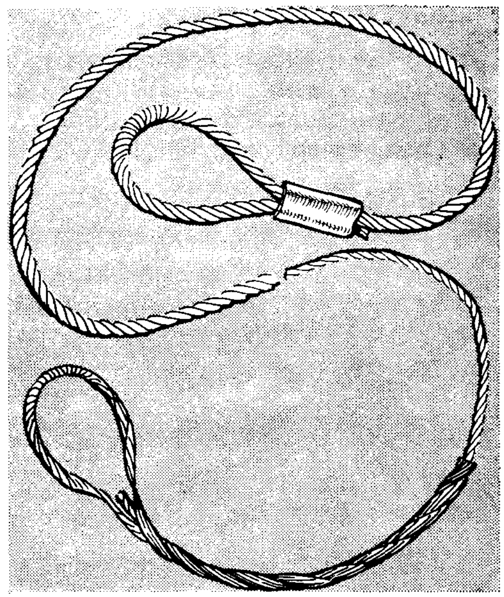
Before wire ropes are used they should be inspected for serviceability.

Q What are the main points to be checked when carrying out a pre-use check? (p9.6 and 9.7).

Care and Maintenance of Wire Ropes

Wire ropes are, size for size, stronger and more durable than fibre ropes. This does not exclude them from proper care and maintenance.

Q List five precautions that will extend the life of a wire rope. (p9.7).



CHAPTER 10

'TALURIT' AND 'PREFORMED' ROPE TERMINATIONS

Introduction

Hand-splicing of fibre and wire rope is both difficult and time-consuming. Fortunately, there are alternative methods of making terminations in synthetic and wire rope; fibre rope still has to be spliced by hand. The two alternatives are provided by the '*Talurit*' clamping process, and by '*Preformed*' *Line Terminations,* both of which will be described in this chapter.

'TALURIT' CLAMPING PROCESS

General

The 'Talurit' clamping process involves the use of an hydraulic hand-operated press which is used in conjunction with aluminium ferrules to provide clamped joints when forming eyes or loops on wire and terylene ropes. Examples of these joints are shown in Fig 10.1.

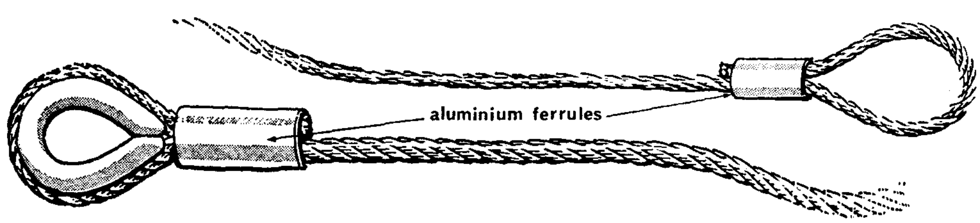


Fig 10.1 Examples of Clamped Joints

Equipment

The equipment provided for the clamping process consists of:

- 'Talurit' 25-ton hand-operated press.
- One set of 'Talurit' swage blocks.
- 'Talurit' wire rope gauge.
- Ferrules.

'Talurit' 25-ton Press

The 25-ton press is a self-contained hydraulically-operated unit mounted on a wooden base (Fig 10.2). The main parts of the press include a pump block and cylinder assembly, a moving swage holder, and a fixed swage holder. Also mounted on the wooden base is a rope twisting and cutting device.

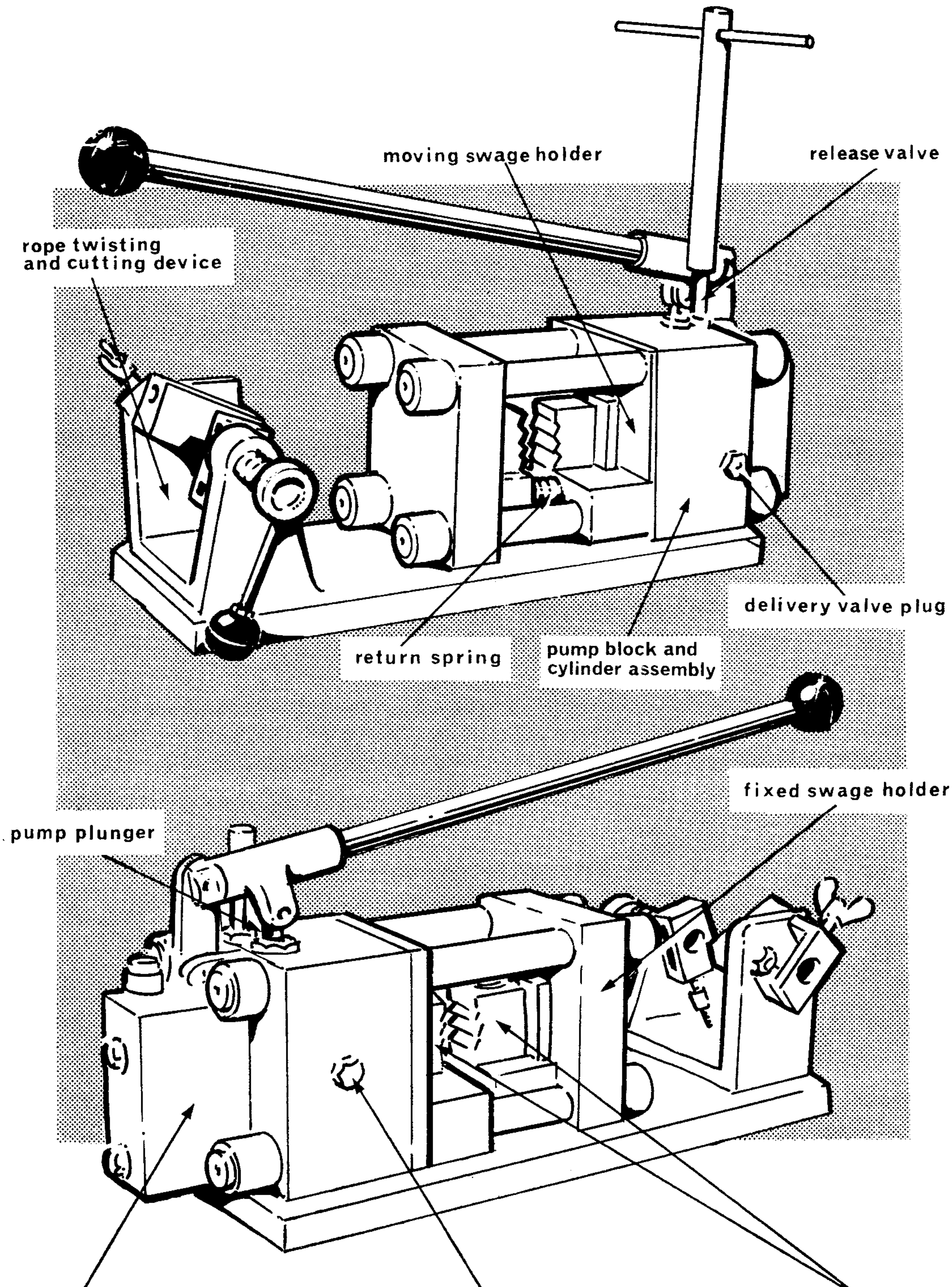


Fig 10.2 'Talurit' 25 ton Hand-operated Press

Swage blocks. The swage blocks (Fig 10.3) are provided in a range of 10 sizes to suit wire ropes of from $\frac{1}{8}$ in to $\frac{3}{4}$ in (3 mm to 19 mm) circumference. Each block is marked with the code number of the ferrule with which it is to be used.

Wire rope gauge. The wire rope gauge (Fig 10.4) is of the 'GO' and 'NO-GO' type and is provided for gauging wire ropes up to $\frac{3}{4}$ in circumference to determine the size of ferrule and swage blocks to be used. The gauge consists of a steel disc which is cut away around its edge to provide the various gauge sizes. The rope sizes are stamped on one side of the gauge, and the ferrule and swage block code numbers on the other side.

Ferrules. The ferrules (Fig 10.5a) are made of aluminium alloy and are supplied in 10 different sizes to suit wire ropes of from $\frac{1}{8}$ in to $\frac{3}{4}$ in (3 mm to 19 mm) circumference. Each ferrule is marked with a code number to indicate the size of the rope in millimeters for which it is to be used.

- For wire ropes with no hemp core, ferrules of the *next size larger*, and their corresponding swage blocks must be used.

The ferrules are shaped so that a double thickness of rope of the appropriate size can be threaded into the hole in the centre. When preparing a rope and ferrule for swaging, the rope is passed through the hole, doubled back on itself, and the end threaded into the ferrule to form a loop, as shown in Fig 10.5b.

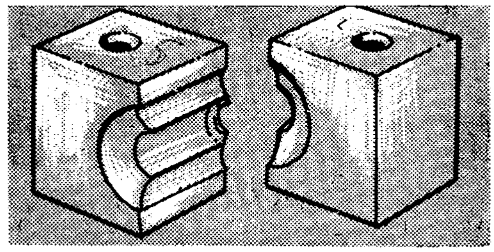


Fig 10.3 Swage Blocks

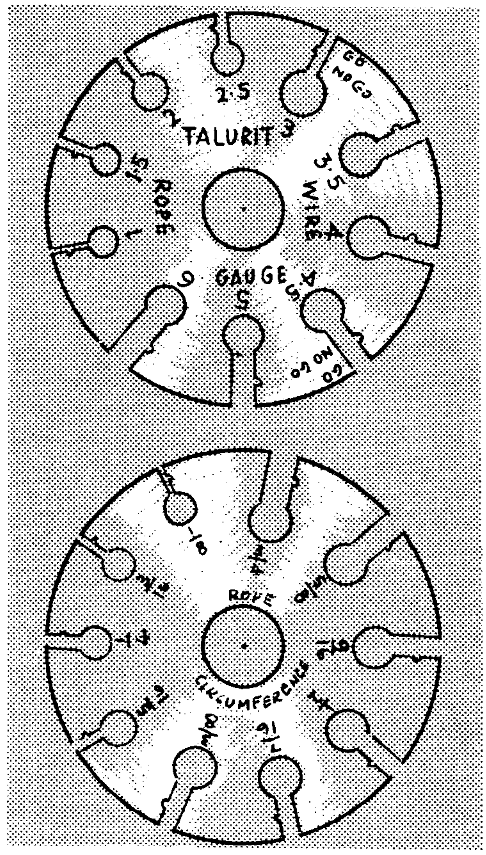


Fig 10.4 Wire Rope Gauge

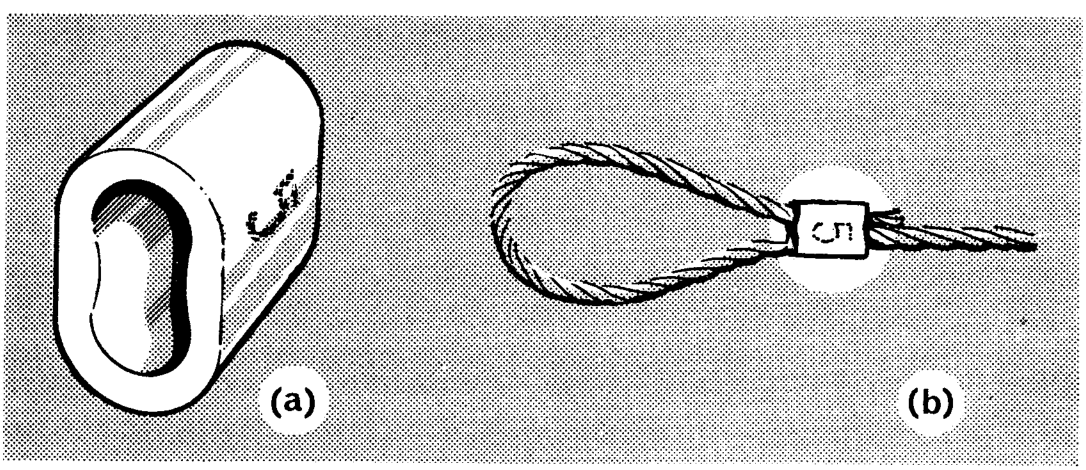


Fig 10.5 Ferrules

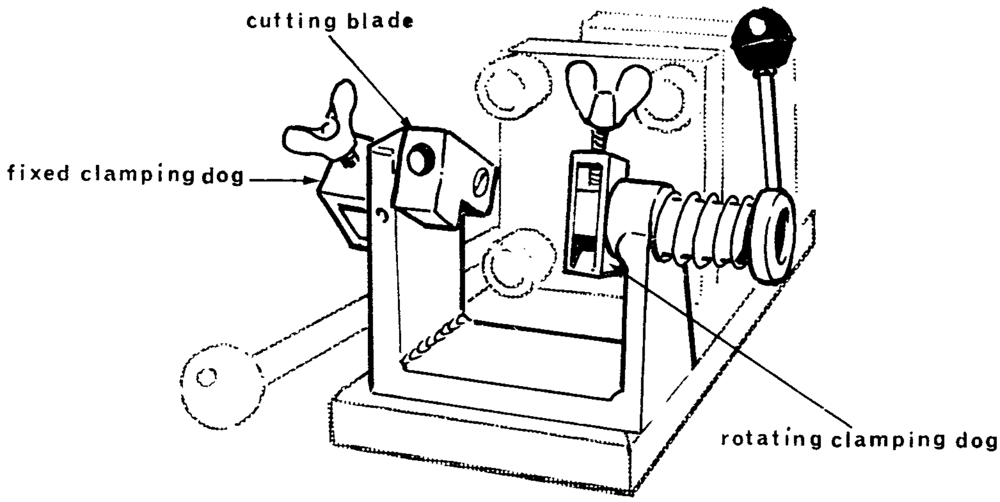


Fig 10.6 Rope Twisting and Cutting Device

Rope Twisting and Cutting Device

This device (Figs 10.2 and 10.6) is used for twisting the wire rope to seal the lay to prevent fraying of the ends when the rope is cut. The device consists of two clamping dogs, each mounted on a vertical plate. The left-hand dog is fixed to its plate and the right-hand dog is fitted with a lever and is free to be rotated. A cutting blade is operated by inserting the end of the press operating lever in a hole in the end of the blade and pressing the lever downwards.

The twisting device is operated by clamping the rope in the dogs, so that the point where it is to be cut is midway between the two dogs, and turning the rotating dog two to three complete turns in the direction of the lay of the rope strands. The rope is finally seized by rotating the dog through 180 degrees in both a clockwise and an anti-clockwise direction. The rope is then released and cut off at the centre of the seized portion by operating the cutting blade.

Operating Procedure

General. The press and the twisting and cutting device should be kept clean and lubricated as a matter of routine. Oil should be applied to all working parts each day before use. The operator should not continue to use the machine if a defect develops.

Precautions. The following precautions should be observed during wire rope clamping operations:

- Ensure that the level of the oil in the reservoir is approximately $\frac{5}{8}$ in below the top of the filler orifice.
- Do not operate the press when there are no swage blocks fitted in the machine.
- Do not use ferrules on rusty, unsound or damaged ropes.
- Do not disturb the lay of the rope when assembling in the ferrule.
- Do not force a rope into the ferrule. Always measure the rope with the 'Talurit' gauge and ensure that the ferrule is of the correct size to suit the rope. If the rope is oversize, use a ferrule of the next size larger.
- Ensure that the number stamped on the swage blocks corresponds to the code number marked on the ferrule.
- Always use a ferrule and its corresponding swage blocks of the next size larger when swaging a joint on wire rope which has no hemp core.

● When setting up the ferrule in the press always ensure that the main axis of the ferrule is in line with the main axis of the swage blocks.

● The maximum stroke of the ram should not exceed that necessary to bring the swage blocks face to face.

● Always ensure that the end of the rope protrudes through the end of the ferrule after swaging (Fig 10.7).

● Always ensure that there is a flash of metal on each side of the ferrule after swaging (Fig 10.7). The joint is incomplete if there is no flash.

● Do not allow the flash slots in the swage blocks to become clogged with surplus metal ejected during the pressing operation.

Cutting the Rope

To cut the rope:

● Pass the rope from left to right through the clamping dogs on the twisting and cutting device until the point where the rope is to be cut is midway between the two dogs. Then tighten the wing nuts on the dogs to clamp the rope in position (Fig 10.8).

● Twist the rope in the direction of the lay by turning the rotating dog. Two or three turns is usually sufficient.

● Turn the rotating dog through 180 degrees in both a clockwise and anti-clockwise direction to finally seize the rope strands.

● Unscrew the wing nuts to release the rope from the dogs, and set the rope so that the point where it is to be cut is in line with the cutting blade.

● Insert the press operating lever in the hole in the end of the cutting blade, and press the lever downwards to cut the rope. After cutting, the rope is ready for insertion in the ferrule.

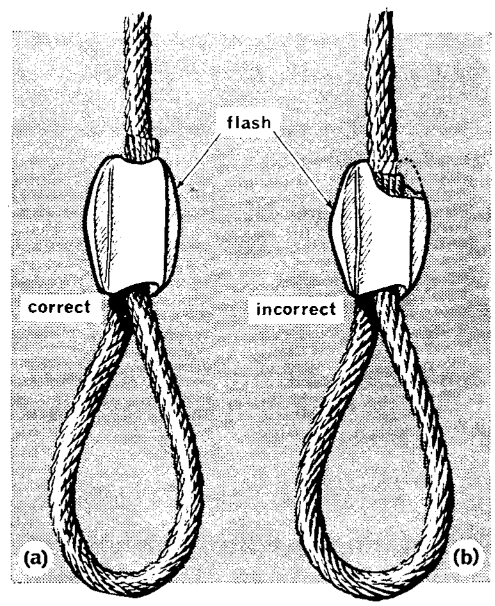


Fig 10.7 Correct and Incorrect Method of Assembly

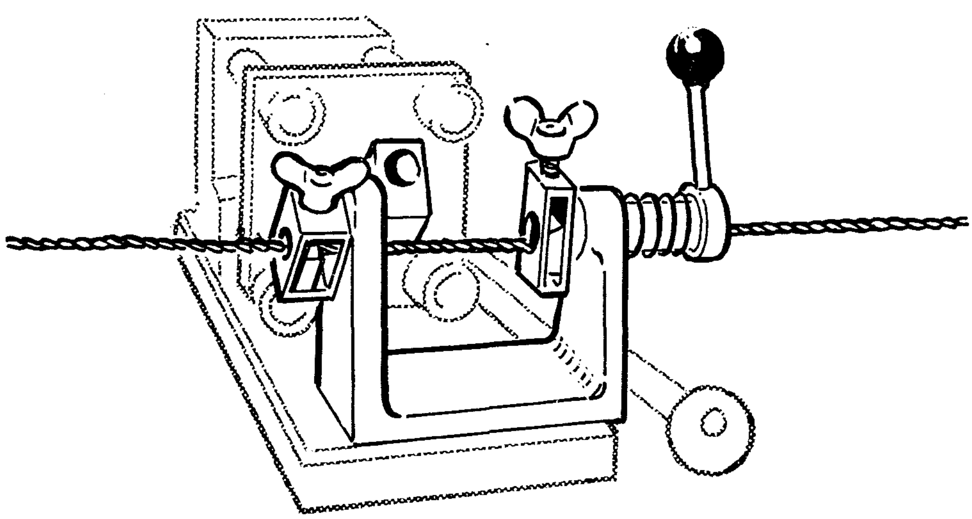


Fig 10.8 Rope Clamped in the Twisting and Cutting Device

Setting the Swage Blocks in the Press

To set the swage blocks in the press:

- Select the swage blocks to suit the wire rope. The code number denoting the diameter of the rope *in millimetres*, is stamped on each block.
- Assemble the swage blocks in the press so that the code number is uppermost, and tighten the bolts finger-tight. If radiused swages are used, for ropes of $\frac{3}{8}''$ to $\frac{3}{4}''$ (9.5 mm to 19 mm) circumference, ensure that the radiused ends are at the right-hand side when viewed from the front of the press.
- Close the release valve (Fig 10.2) and operate the pump to bring the swage blocks lightly face to face; line up the two half blocks and bolt them securely in position, then open release valve. The press is then ready for use.

Swaging the Joint in the Press

To swage the joint on the previously-prepared rope and ferrule, observe the precautions and proceed as follows:

- Place the assembled ferrule between the swage blocks so that the running end of the rope is in the stationary block; ensure that the long axis of the ferrule is truly horizontal.

Notes

1 For ropes of $\frac{3}{8}''$ to $\frac{3}{4}''$ (9.5 mm to 19 mm) circ, set the ferrule firmly against *the radius* in the swage blocks. For ropes of $\frac{1}{8}''$ to $\frac{5}{16}''$ (3 mm to 8 mm) circ, set the ferrule *in the centre* of the swage blocks.

2 To prolong the life of the swage blocks, apply grease frequently to the swaging surfaces.

- Turn the release valve stem in a clockwise direction to close the release valve.
- Move the operating lever in a reciprocating motion to operate the pump, and the swage blocks will start to close.
- Cease pumping as soon as the swage blocks grip the ferrule. The blocks will then remain in that position and act as a vice whilst final adjustment is made to correct the size of loop or the position of the thimble relative to the ferrule.
- Hold the rope in position and continue to close the swage blocks until their faces are in contact.
- When the faces meet, open the release valve and remove the completed pressing.
- Examine the pressing to ensure that the ferrule is free from cracks, that the rope end protrudes through the end of the ferrule and that the flash is present on both sides of the swaged ferrule. Use a rough file to remove the flash.

Note:

If there is no flash on the ferrule, make sure that the swages have been properly closed by repeating the pressing operation. If there is still no flash, use the gauges to re-check the size of the rope and make certain that the correct ferrule and swage blocks have been used.

General Servicing of the Press

The press requires very little routine servicing other than cleaning, lubricating, and maintaining the level of the hydraulic oil and, when necessary, removing air from the hydraulic system.

- **Lubrication.** The following external parts should be lubricated daily with oil OM-21:
  - Press tie-bars.
  - Pump plunger.
  - Operating lever fulcrum pins.
  - Rotating dog on twisting device.
- **Hydraulic oil.** The level of the hydraulic oil is to be checked weekly. Top up as needed with oil OM-13. The correct level is approximately $\frac{3}{8}''$ below the top edge of the filler when the press is fully retracted.
- **Removing an air-lock.** If an air-lock develops in the hydraulic system, remove air as follows:

1. Open release valve and allow ram to retract fully, then close release valve.
2. Lay press on its side with the bleed screw uppermost and slacken the bleed screw.
3. Operate pump until all air is discharged from the system, then tighten bleed screw and stand press on its base.
4. Add oil as necessary to reservoir.
5. Operate press until the swage block faces meet, then open the release valve and allow the ram to return to the fully retracted position.
6. Again check the oil level and top up if necessary.

'PREFORMED' LINE TERMINATIONS

General

In the 'Talurit' process just described the joint produced is a permanent one, and should any adjustment in the length of the rope be required, the old joint must be cut off and a fresh joint made. This unavoidable shortening in the length of the rope is not always acceptable. This problem is most pronounced when using terylene rope which, because it stretches, needs re-adjustment after initial installation to keep it properly tensioned.

In these circumstances 'Preformed' line terminations are used. These provide a simple 'wrap round' method of making an eye in the end of terylene or steel wire rope, and are known as 'dead-ends'.

Description

A typical dead-end is shown in Fig 10.9. In general, they are made of galvanised steel and coated with the same material as the strand to which they are applied. Dead-ends for use on terylene rope are also made of galvanised steel but have a coating of neoprene to protect the soft rope.

Dead-ends are identified by a label attached to the loop; this indicates the size of rope to which the dead-end can be fitted. The dead-end also carries a coloured mark known as a crossover mark which, as shown overleaf, acts as a guide when fitting the dead-end.

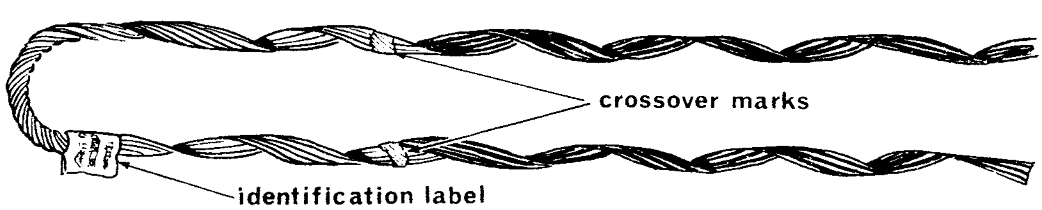


Fig 10.9 Typical Dead-end

Fitting the Dead End

The following description explains how a dead-end is fitted to a terylene rope.

- With the terylene rope under tension, wrap one leg of the dead-end two or three pitches around the rope, starting at the crossover point (Fig 10.10).

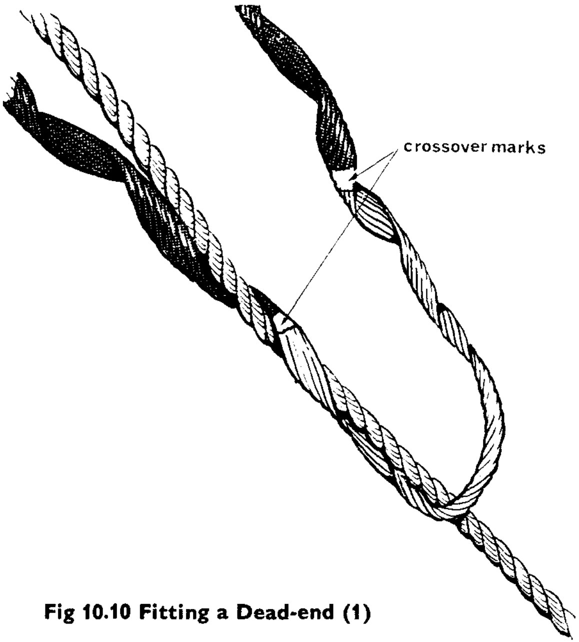


Fig 10.10 Fitting a Dead-end (1)

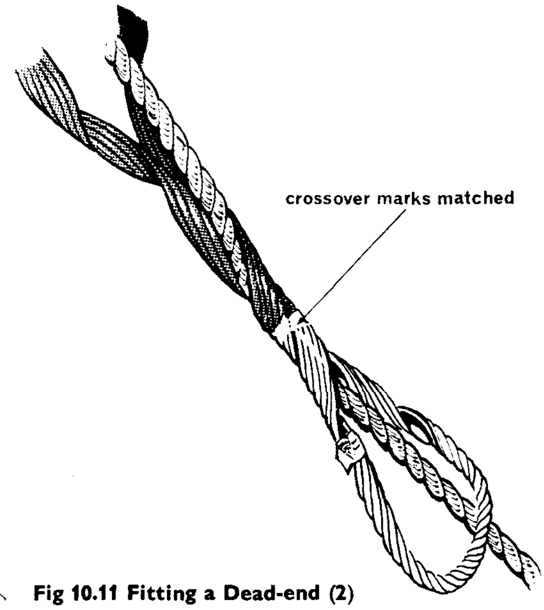


Fig 10.11 Fitting a Dead-end (2)

- Bring the other leg of the dead-end up to the rope, ensuring that the crossover marks match, and wrap two or three pitches of the second leg around the rope (Fig 10.11).
- With a steady rotating movement wrap both legs of the dead-end around the rope, at the same time pulling the legs away from the rope (Fig 10.12).

Fig 10.12 Fitting a Dead-end (3)

- To complete the fitting, cut the rope one inch from the crossover mark (Fig 10.13).
- Procedure for fitting a dead-end to galvanised steel wire rope is identical, except that the wire is not tensioned.

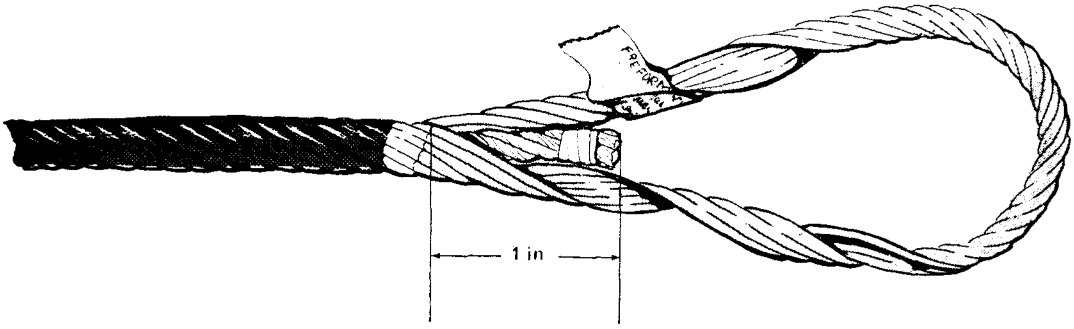


Fig 10.13 Fitting a Dead-end (4)

Precautions

There are certain precautions which, if observed, will ensure the best use of time and materials.

- The direction of lay of dead-ends must always be the same as the rope to which it is fitted. With the terylene rope that you will be using, the lay will always be right-handed. However, some of the galvanised steel wire you will be using has a left-hand lay and you must ensure that the dead-end also has a left-hand lay before fitting.
- Never force a dead-end onto a rope that is too small for it. The use of force will only damage the rope.
- Marlin spikes or pliers should be used only to snap the ends of the dead-end in place.
- The dead-end must be straight after fitting, not bent or spiralled.
- Dead-ends may be removed and replaced up to four times for adjustment purposes on initial fitting; after this they must not be re-used.

SUMMARY REVIEW

'Talurit' Clamping Process

Q What is special about the size of ferrule to be used on wire rope with no hemp core? (p 103).

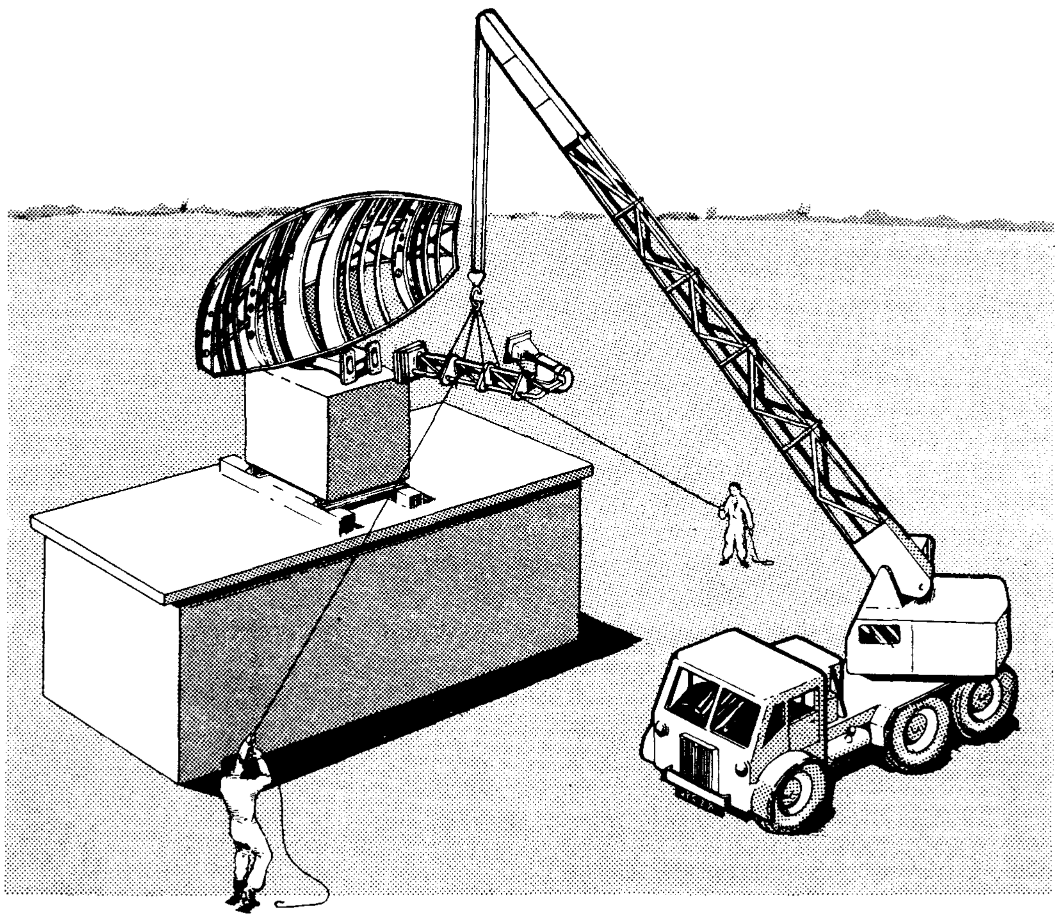
Q What precautions should be observed during wire rope clamping operations? (p 10.4).

'Preformed' Line Terminations (Dead-ends)

Q List the precautions to be observed when fitting dead-ends (p 10.9).

CHAPTER 11

TACKLES AND SLINGS



Introduction

When working on a mast or tower, light or small equipment can be hauled up by simply attaching a rope to the object to be lifted, then hauling it aloft hand over hand. Antenna systems and associated equipment are mostly heavy and bulky, and when such items as these have to be hauled to the top of a mast or tower, a device known as a *tackle* has to be used. A tackle is a device by means of which an applied pull or force can be increased.

Before equipment can be hoisted aloft it must first be attached to the hoisting rope by means of one or more *slings* which may be made of fibre rope, wire rope, or of chain. The different types of slings together with the various types of tackle used by the aerial erector are described in this chapter.

TACKLES

Definition

A tackle consists of a rope rove (threaded) through two or more blocks in such a way that any pull applied to its hauling part is increased by an amount depending upon the number of sheaves (Fig 11.1) in the blocks and the manner in which the rope is rove through them.

Parts of a Tackle

The blocks of a tackle (Fig 11.1) are termed the *standing block* and the *moving block;* the rope rove through them is called the *fall*, which has its standing, running and hauling parts. The size of a tackle is described by the size of its fall; a 3 in tackle, for example, would be rove with a 3 in fall.

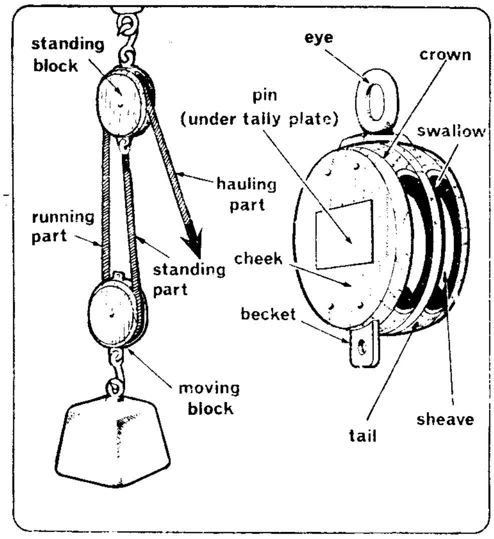


Fig 11.1 Parts of a Tackle

Mechanical Advantage

The amount by which the pull on the hauling part is multiplied by the tackle is called its *mechanical advantage* (MA) and, if friction is disregarded, this is equal to the number of parts of the fall at the moving block. In Fig 11.2, for example, there are two parts, so that the mechanical advantage is 2; in other words, a pull on the hauling part of 100kg would, if friction were disregarded, hold a weight of 200kg.

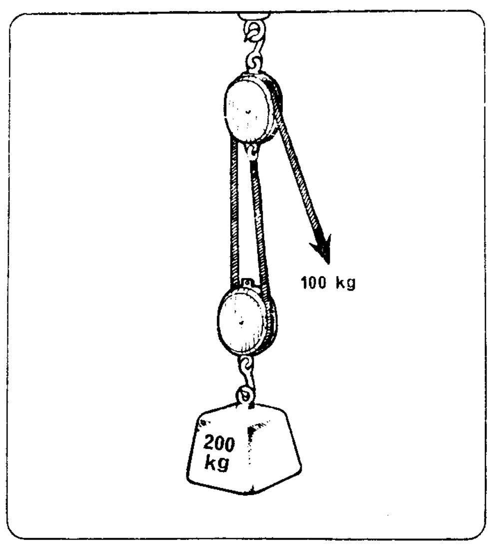


Fig 11.2 Mechanical Advantage

Reeving a Tackle to Advantage and to Disadvantage

The number of parts at the moving block and, therefore, the mechanical advantage, is always greater when the hauling part comes away from the *moving block*, and such a tackle is said to be *rove to advantage* (Fig 11.3a). Conversely, a tackle in which the hauling part comes away from the standing block is said to be *rove to disadvantage* (Fig 11.3b).

The term 'advantage' used in this paragraph should not be confused with 'mechanical advantage'. In this context it is used to describe a tackle rove to give maximum mechanical advantage. The term disadvantage indicates a lower value of mechanical advantage.

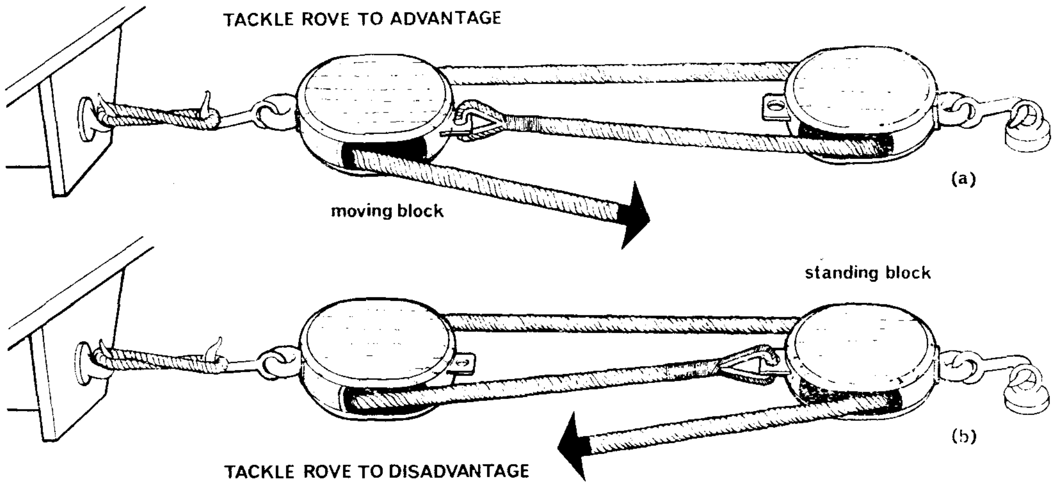


Fig 11.3 Reeving a Tackle to Advantage and Disadvantage

Runner

This consists of a rope rove through a single *moving* block (Fig 11.4). As there are two parts of the fall in the moving block its mechanical advantage, allowing for losses, is 1·82. (This figure, as with all other mechanical advantages in this chapter, allows for the losses due to friction).

Single Whip

This consists of the fall rove through a single *standing* block (Fig 11.5). No mechanical advantage is gained, and it is used for hoisting light loads, and where speed of hoisting is an important factor.

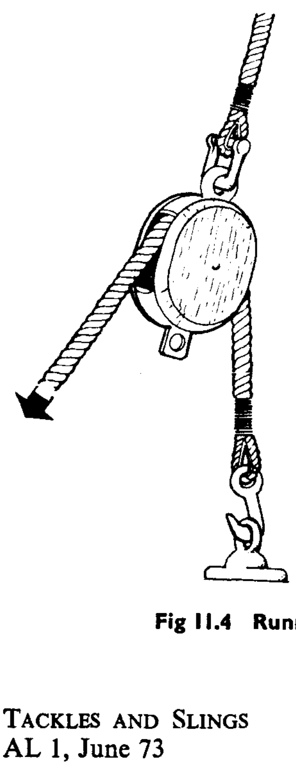


Fig 11.4 Runner

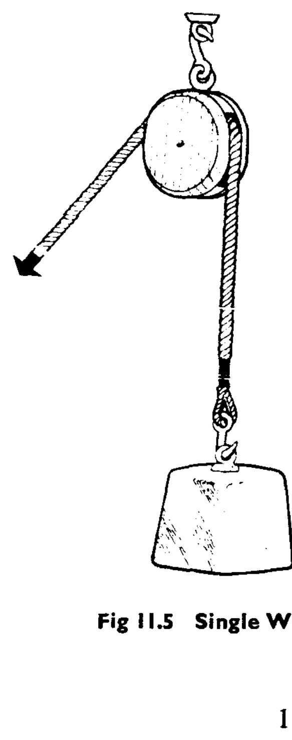


Fig 11.5 Single Whip

Double Whip

This consists of two single blocks. When rove to advantage as shown in Fig 11.6a it has a mechanical advantage of 2·5. When rove to disadvantage as shown in Figs 11.6b and c it has a mechanical advantage of 1·7 (*ie* less than that of single moving block—runner—because of additional friction).

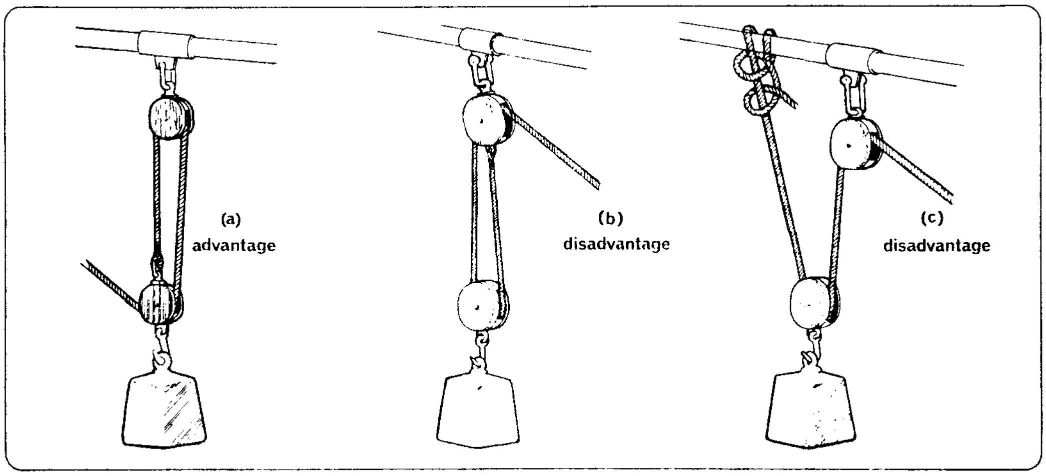


Fig 11.6 Double Whip

Luff

This is a tackle of 3in in size or greater. It consists of a double and a single block, with the standing part of the fall made fast to the single block (Fig 11.7). When rove to advantage its mechanical advantage is 3·08, and 2·3 if rove to disadvantage. When rove with a fall of 2 in or less this tackle is described as a 'handy billy'.

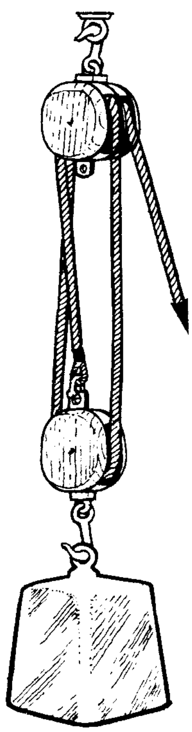


Fig 11.7 Luff

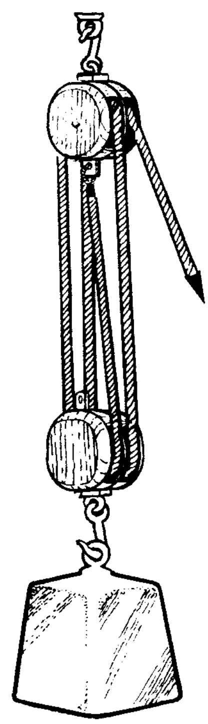


Fig 11.8 Two-fold Purchase

Two-fold Purchase

This consists of two double blocks (Fig 11.8) and is a useful general purpose tackle. When rove to advantage its mechanical advantage is 3·75, and 2·26 when rove to disadvantage.

Three-fold Purchase

This consists of two treble blocks (Fig 11.9) and is used on very heavy equipment. When rove to advantage its mechanical advantage is 4.37, and 3.75 when rove to disadvantage.

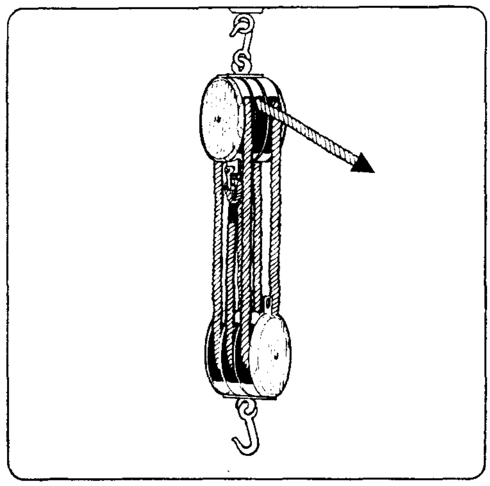


Fig 11.9 Three-fold Purchase

SLINGS

Wire Rope Slings

General. Some slings are single part (Fig 11.10 overleaf), but for heavier loads it may be desirable to use double part slings (Fig 11.11 overleaf). It does not follow that a double part sling will have twice the breaking load of a single part sling made from the same rope; the breaking load depends upon the diameter of the support provided for the bights (loops) in the rope. It is for this reason that wire rope slings must have thimbles fitted in their bights or eye splices.

Thimbles. The range of standard thimbles is based upon the diameters of rope that they may be used on to make up a sling. Each size of rope has its own particular size of thimble and it is important that the thimbles in a sling are not tampered with, *ie* opened out or squeezed in to suit a particular application. Two types of thimble are available—*ordinary* and *reeving;* a reeving thimble is elongated to allow an ordinary thimble to pass through it.

Rope. In Chapter 9 we saw that wire rope is normally laid so that the single wires of the main strand are twisted in the opposite direction to the twist given to the main strand. This type of wire rope should be used only for slings where no rubbing action occurs. Ropes fitted to cranes and winch rope drums, which are constantly rubbing on guide pulleys and against themselves on the drums, are laid in *Lang's lay*, in which the single wires of the main strands and the main strands themselves are twisted in the *same direction.* Under rubbing conditions, this method gives reduced wear compared with ordinary lay.

Strength. The wire rope used in the manufacture of slings has a tensile strength of 100/110 tons per sq in.

Fittings. End fittings such as hooks, rings, *etc* used on wire rope slings are all covered by BS specifications; it is important that the correct fittings are used.

Single Part Slings and Sling Legs

The single part spliced sling (Fig 11.10 overleaf) has an eye splice at each end which encloses a thimble. Each splice is served to protect the user from any ends of wire that may protrude from the splice.

The sling can be fitted with an ordinary thimble at each end, and in this form it may be used as a one-leg sling or as a single leg of a multi-leg sling. It is also obtainable as a one-leg sling with a ring at one end and a hook at the other; when rings or hooks are fitted, ordinary thimbles are used in the eye splices. One-leg slings with reeving thimbles at one or both ends are also widely used.

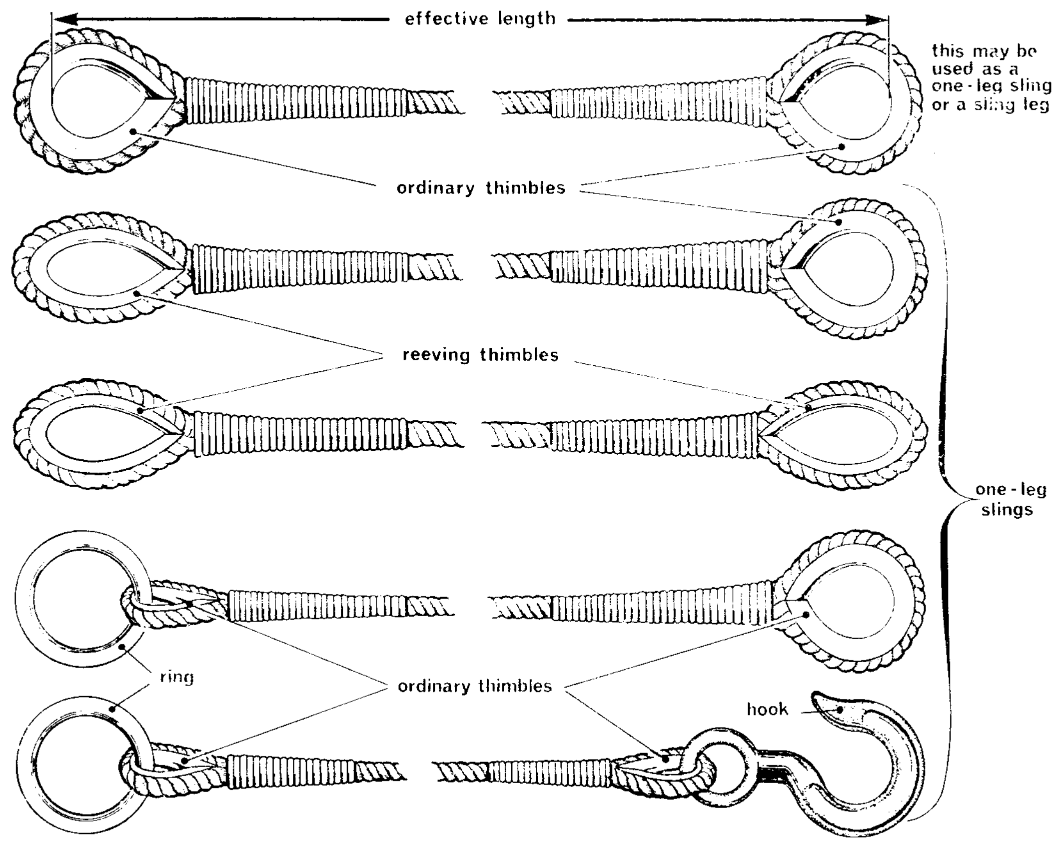


Fig 11.10 Single Part Slings and Sling Legs

Double Part Slings and Sling Legs

An endless sling (Fig 11.11) may be made *spliced* or grommet fashion. A spliced endless sling is constructed by splicing the ends of a rope together so that a loop is formed. An endless grommet sling is made from a single strand of rope which is first looped to the required length. The free end is then spiralled round the loop six times until a six strand rope is formed. The ends of the rope are then tucked into the core of the rope.

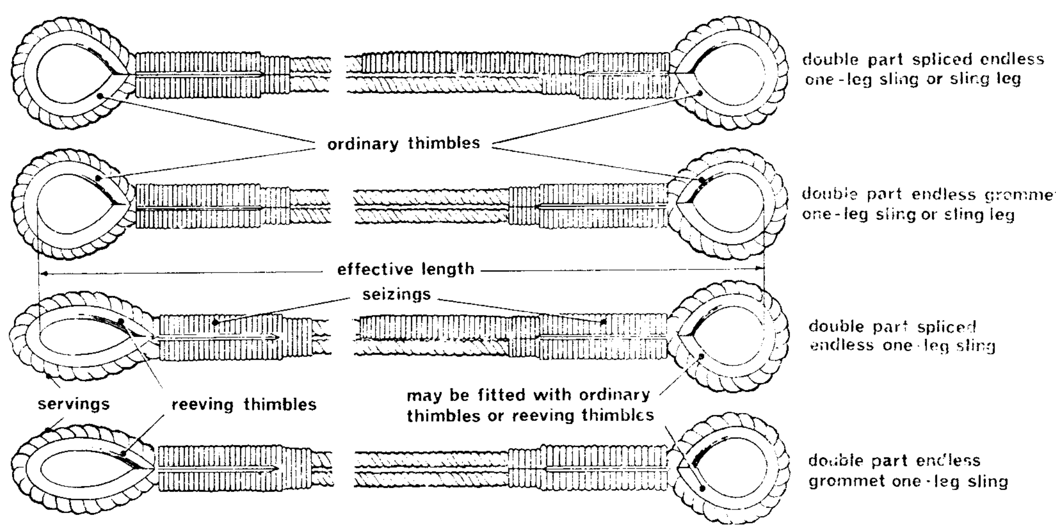


Fig 11.11 Double Part Slings and Sling Legs

The bights at each end of the loop, and the splice if it is a spliced endless sling, are then served and a thimble placed in each bight. The serving has the effect of increasing the diameter of the rope, so it is necessary to fit a thimble that is larger than is normally required for the size of rope. Thus, the thimble is of a size to suit the increased load that a two part sling will safely carry.

The thimbles are secured by throat seizings, *ie* binding around both parts of the rope with galvanized seizing wire so that the thimble is secure in the bight. If the length of the sling exceeds 100 rope diameters it is seized along its length at intervals of not more than 72 rope diameters.

Double part slings may be fitted with ordinary thimbles, reeving thimbles, or one of each. When fitted with ordinary thimbles the slings may be used as sling legs or one-leg slings.

Multi-legged Slings

A multi-legged sling (Fig 11.12) may be constructed from any of the single or double part sling legs shown in Figs 11.10 or 11.11. The two and three-legged slings have the legs mounted on the main ring, but the four legged sling has two intermediate rings, each carrying two sling legs, mounted on the main ring.

The standard two-, three- and four-legged slings are specified to be provided with a terminal hook to each leg, but there are instances when the hook may be omitted thus allowing the thimble ends of the legs to be attached direct to the load by shackles.

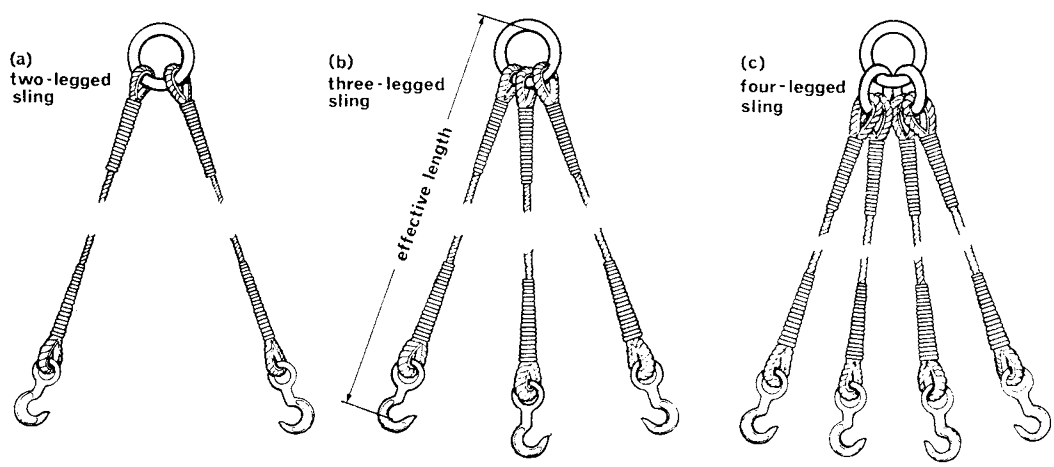


Fig 11.12 Standard Multi-legged Slings

Chain Slings

The length of chain in a single sling has an intermediate link at each end, which is joined to an enlarged egg link or a joining egg link (Fig 11.13 overleaf). These links are used to connect a ring, a link alternative to a ring, or an eye hook to the intermediate link. With collar slings, the reevable or non-reevable egg links are also joined to the intermediate links by joining egg links. The standard rings are of such a design that their safe working load (SWL) which, for any given materials is determined by the internal diameter of the ring and the diameter of the material used, is proportional to the SWL of its sling leg or legs. The links alternative to rings are similarly graded, but weight is saved by using the link in place of a ring where the diameter of the material of the ring exceeds 2 inches.

Standard chain slings. Examples of standard chain slings are shown in Fig 11.13 overleaf. The standard single sling is fitted with a ring at one end and a hook at the other. The two-leg sling consists of two single slings mounted on a main ring, and the four-leg sling consists of two two-leg slings mounted on a ring. A three-leg sling is three single slings mounted on a ring.

The reevable and non-reevable collar chain slings are not fitted with hooks or rings because they may be secured to the load by reeving or by attachment to some types of shackles.

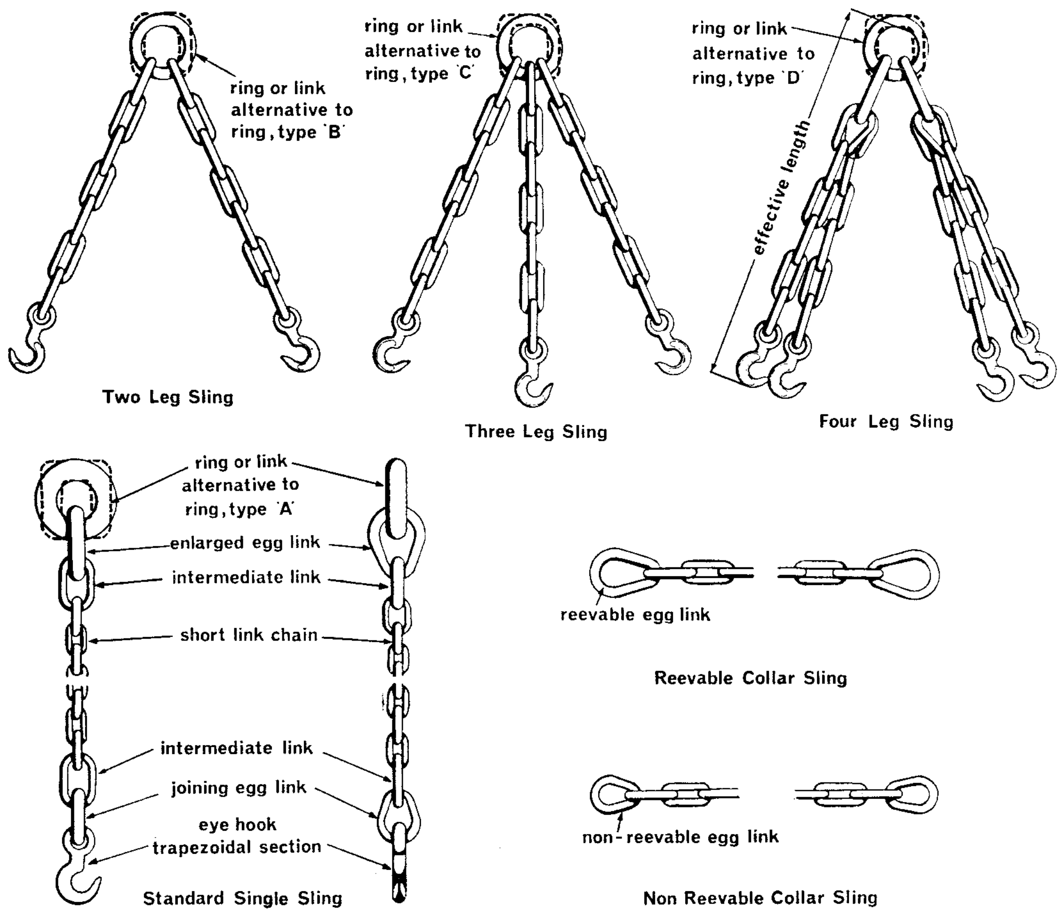


Fig 11.13 Standard Chain Slings

Fibre Rope Slings

The following are the main classes of ropes in general use:

- **Hemp.** A reliable rope used for slinging purposes and for security purposes.
- **Manilla.** Soft and pliable, does not kink, and is used for ropes running over pulleys.

The qualities of the raw materials used in fibre ropes have a varying range of strengths. The normal safe working load of fibre rope is one sixth of the guaranteed breaking load but this is only applicable if the rope is in excellent condition. The safety factor should be modified to suit the condition of the rope.

Condition of the Rope

It is advisable to grade the rope in accordance with its condition and, if necessary, to modify its SWL in accordance with the following:

- **Condition Value 1—Excellent.** This would be a new rope from stores, where the original fibre strength has not been reduced by age or bad storage and shows no signs of having lost the lubricating qualities that should be present in a new rope. The normal SWL may be applied.

- **Condition Value 2 – Good.** Rope which has been used and shows signs of internal and/or external wear or chafe, and where there is a slight apparent loss in the original fibre strength. The normal SWL should be reduced by 20%.
- **Condition Value 3 – Fair.** Rope which has had a fair amount of usage or length of life and shows clear indications of internal and/or external wear and where deterioration of fibre strength is apparent. The normal SWL is to be decreased by 33%.
- **Condition Value 4 – Poor.** Rope badly chafed externally, or worn internally, or where the fibres have deteriorated in strength to a marked degree. *A rope in this condition must not be used for any lifting operation.*

APPLICATIONS OF SLINGS

General

The choice of a sling for a particular job is governed mainly by the following factors:

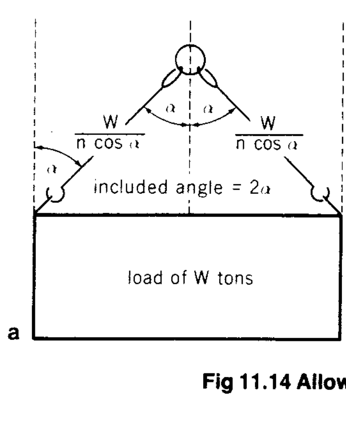
- Weight of the load to be lifted.
- Size and shape of the load.
- Amount of headroom available.
- Provision, or otherwise, of slinging points.

The first factors to consider are the weight and centre of gravity of the load. The most difficult items to lift are those that are awkwardly shaped and badly balanced, and there is always a temptation to wrap the sling around the load without considering the fact that the sling may become permanently deformed or damaged. The overall weight is often marked on a piece of equipment; if the actual weight is not known, a wide margin of safety must be allowed. Many items of equipment have special-to-type slings provided. Where this is so, the special sling must always be used.

Allowance for Angle of Legs

It is vitally important to appreciate how changes in the angles of a multi-legged sling affect the SWL of the sling. The actual tension in each leg can be calculated from the formula shown in Fig 11.14a. This formula assumes ideal conditions – *eg* a symmetrical balanced load.

$$\text{tension in each leg} = \frac{W}{n \cos \alpha} \qquad \text{where } n = \text{number of legs}$$



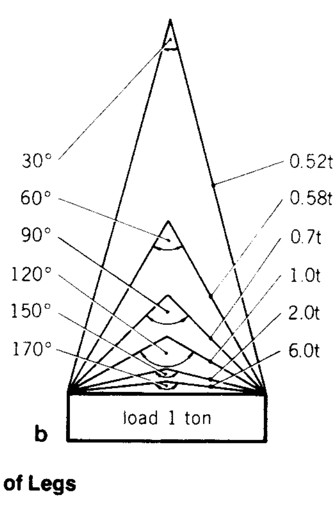


Fig 11.14 Allowance for Angles of Legs

Fig 11.14b shows the increase in the tension in the legs of a two-legged sling carrying a one ton load as the included angle is increased from 30 degrees to 170 degrees. From this it can be seen that at 170 degrees the tension in each leg is just over 6 tons, even with a load of one ton suspended.

All slings are fitted with a brass tally which shows their SWL. The tally fitted to a standard multi-legged sling is marked with the SWL of the sling when the included angle between diagonally opposite legs is 30 degrees, 60 degrees, 90 degrees and 120 degrees (Fig 11.15).

A table showing the SWL of every item of lifting tackle in use should be posted in the room where the lifting tackle is normally stored, and in a prominent position where the tackle is used. For multi-legged slings, the table is to show the SWL of each sling for the same included angles as shown on the brass tally. Normally, the included angle should not exceed 90 degrees.

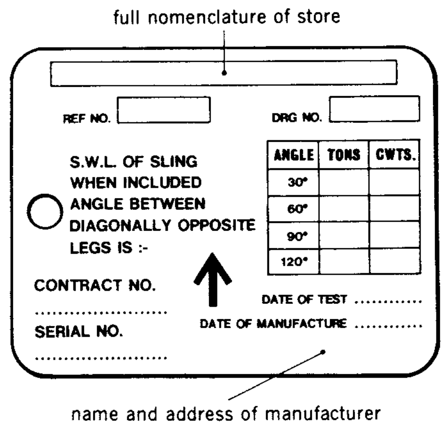


Fig 11.15 Brass Tally for Multi-legged Slings

Attaching the Sling to the Load

Even though precautions are taken to ensure that a particular sling is strong enough for a certain operation, it is still possible to overload the sling by attaching it to the load incorrectly. There are several standard fittings that are designed for use with slings, the most useful of these being eyebolts and shackles.

Eyebolts. There are two types of eyebolts (Fig 11.16). Those without collars are for use where the point of suspension is directly above the eyebolt only; they are not suitable for general purpose slinging. The eyebolt with a collar is designed for use with a shackle only and a hook must not be passed through the eye of the eyebolt. The fit of an eyebolt in its tapped hole, and also the position of the eye, should be checked before proceeding with a lifting operation. When the shackle is fitted to the eyebolt the shackle pin must be at right-angles to the plane of the sling leg; it is usual to use a washer or shim for adjustment purposes.

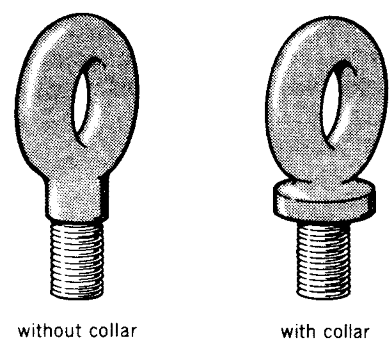


Fig 11.16 Eyebolts

Shackles. There are four standard types of shackles (Fig 11.17), each of which is for use with different terminal attachments. There are also four different types of shackle pins, each of which may be secured to the shackle in a different manner.

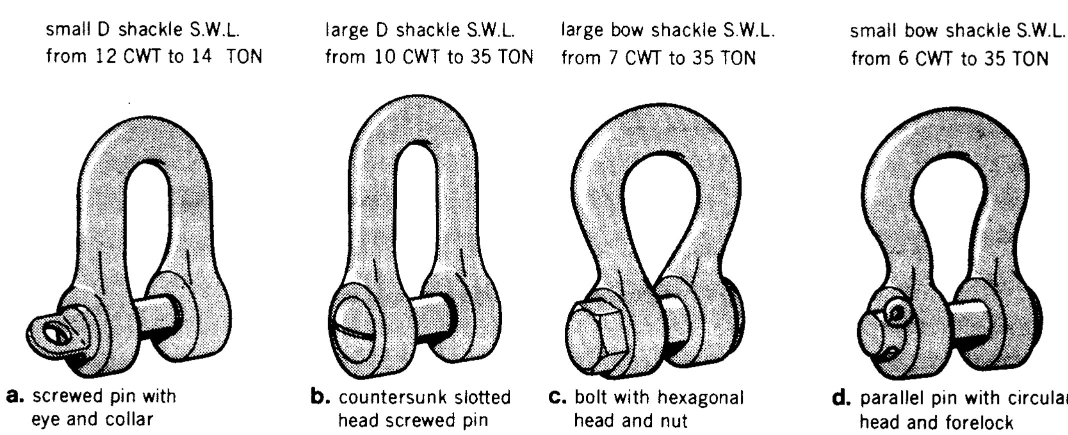


Fig 11.17 Standard Shackles

The nominal size of a shackle is the diameter of the material of the body; each shackle should be marked with its SWL, and markings that will allow identification with its test certificate.

When a tackle is required for a particular application, the one selected must suit the fittings on both the sling and the load. As an example, Fig 11.18a shows a load that is fitted with eyebolts being lifted by a two-legged wire rope sling fitted with eye hooks. It may be assumed that eyebolts permanently attached to a load have a suitable SWL. The type of *shackle* for use with an eyebolt at the pin end and a hook at the bow end is a small bow shackle (Fig 11.17d), and one of this type having a suitable SWL should be selected.

Even when the correct fittings are used it is possible to overload the eyebolts by using the wrong type of sling (Fig 11.18b). In this example, the overloading is caused by the stresses in the horizonatal part of the sling acting upon the eyebolts. In addition to overloading the eyebolts, the method used in Fig 11.18b would produce a very sharp bend in the wire rope, and this would probably result in the sling being damaged or deformed.

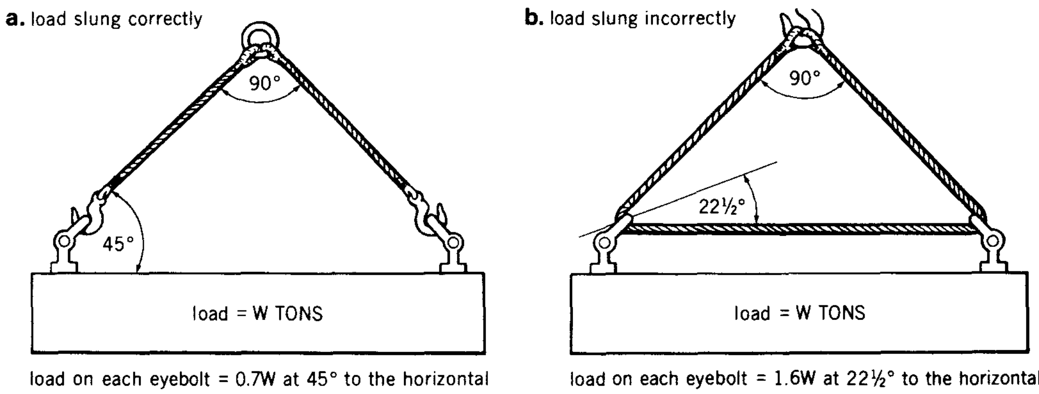


Fig 11.18 Use of Shackles

Precautions

General. Having selected a suitable sling, and decided upon the method of attaching it to the load, there are still certain precautions that have to be observed.

Packing. When a fibre rope, a wire rope, or a chain sling is used, packing must be placed at any point where the sling bends sharply round the load. For a heavy load being lifted with a chain sling, wood is the most suitable packing material. A useful packing piece can be made by removing one quadrant from a short length of circular wood (Fig 11.19); the remaining piece may then be used on any square-edged load.

Position of splice. When using a spliced fibre rope or wire rope sling, ensure that the splice is kept clear of both the lifting hook and the load (Fig 11.20).

Radius of bend. When using wire rope slings, sharp bends in the rope should be avoided whenever possible. The diameter of a bend should not be less than twenty times the diameter of the rope.

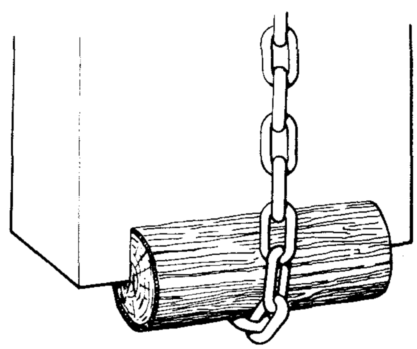


Fig 11.19 Wooden Packing Pieces

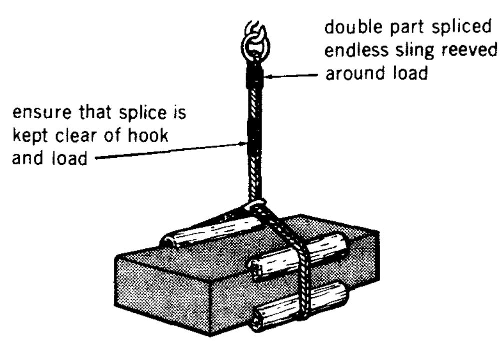


Fig 11.20 Position of Splice

Shortening and joining of slings. Fibre rope, wire rope and chain slings must not be shortened by tying a knot in them or by wrapping them round the lifting hook. Neither should they be jointed by bolts or wire. Always use a sling of the correct length.

Misuse of lifting hook. A lifting hook must only be used on its appropriate ring or shackle. If it is used in any other way the weight of the load may not be borne by the correct part of the hook which would in consequence be overloaded. Fig 11.21 shows a hook with the link of a length of chain passed over its point; the link would probably stay on the hook but any load on the chain would tend to distort the hook. Also, even if the link does bear on the correct part of the hook, there will be a tendency for the link to be deformed by the wedge action of the sides of the hook. The same action may occur with D shackles (*see* Fig 11.17), but not with bow shackles or rings. To avoid failures of this nature, all rings and shackles should be a free fit on the hook with which they are used.

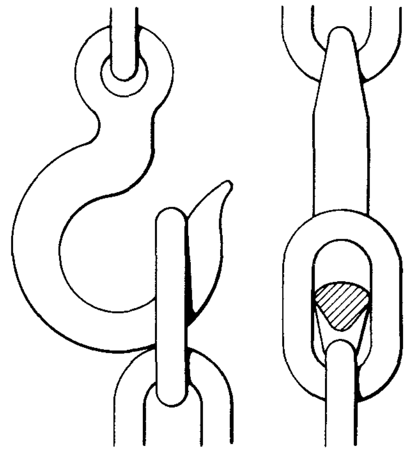


Fig 11.21 Point of Hook Jammed in a Link

Effects of temperature. Extremes of temperature will affect the strength of the material of a sling. Chain slings must be carefully inspected during frosty weather, for if they are notched or nicked, the effects of the very low temperature will tend to weaken the chain at these points. It is safer to use a new chain and, if possible, to warm it slightly before use. All slings should be stored where they will not be exposed to the effects of frost.

Position of lifting hook. When attaching the lifting hook to a sling, ensure that the hook is positioned centrally over the attachment point of the sling. If this is not done, the load will swing as soon as lifting is commenced.

Alignment of slings. Before a multi-legged sling is used it should be laid out on the floor and checked that the fittings such as shackles and hooks are in alignment with the leg of the sling. This is particularly important with wire rope slings, as there is a tendency for them to become kinked.

Lifting

The following rules must be observed by the qualified person in charge of a lifting operation, who is the only person allowed to give signals to the lifting gear operator:

- Ensure that the load is free to be lifted.
- All persons must stand clear of the load and hands must be kept well away from chains and ropes.
- As the load is lifted clear of the floor, watch the sling. If it shows any sign of slipping or moving on the load, lower the load and rectify the fault.
- Never allow the load to be carried over other persons. If necessary, warn them to keep clear of the load.
- Never ride on the load, nor allow any other person to do so.
- Signals to the lifting gear operator must be clear and concise. If the operator is allowed to stop the lifting operation suddenly, or to snatch the load, the sling will be greatly overloaded.
- A load must not be left unattended whilst it is suspended.
- When a load is lowered, do not let it rest upon the sling. If the load is lowered on to supports, a sling that passes under a load can be removed without being damaged. Do not use bricks as supports as they are very liable to crumble when subjected to weight.

SERVICING AND TESTING

General

Owing to the serious consequences which may attend an accident caused either through incorrect use or mechanical defects of lifting tackle, special precautions have to be observed and periodic inspections made by RAF units responsible for the use, servicing and inspection of lifting tackle.

Sources of Supply

All lifting tackle used by the Aerial Erector is supplied through one of two sources:

- Director General of Supply (DGS).
- Property Service Agency (PSA) of the Department of the Environment (DOE).

Responsibilities for Servicing

The responsibility for servicing lifting tackle supplied through DGS belongs to the OC Engineering Wing and the servicing of lifting tackle from DOE is the responsibility of that Department.

Manufacturer's Test Certificate and Serial Number

Lifting tackle supplied by DGS will in all cases be given a manufacturer's test certificate. This certificate must be held by the STO or his appointed deputy and it must accompany the item through the issuing unit to the user unit and on any subsequent transfer. It must not be cancelled or destroyed until the useful safe life of the item is ended. Items of lifting tackle are to be identified by their serial numbers; these numbers must not, therefore, be altered or removed except by modification or STI action. In addition to the foregoing, all items of lifting tackle must bear a brass tally (Fig 11.22) affixed in such a way that it cannot be detached and, when fitted to wire rope slings, it must be spliced in so that it cannot be removed without rendering the sling unserviceable. The tally fixed to multi-legged slings was shown in Fig 11.15 on page 11.9.

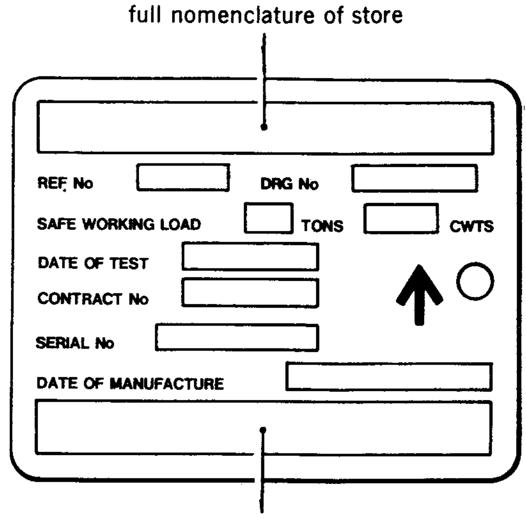


Fig 11.22 Typical tally for lifting tackle

Lifting tackle already in use, but without a manufacturer's test certificate and serial number, must be dealt with as instructed in AP119K-0001-1, Chapter 1, paras 6-9.

Fibre rope sling. In compliance with the Factories act, no proof loading is required on slinging equipment manufactured entirely from fibre rope, but a certificate which guarantees the safe working load is to be issued with the sling by the manufacturer. The SWL will be calculated from the ultimate breaking loads as guaranteed by the manufacturer of the rope.

Lifting Tackle Record Card

The lifting tackle record card (RAF Form 3806A) is a yellow fold-over card that provides a historical record for the inspection and maintenance of lifting appliances and lifting tackle provisioned by the DGS(RAF). The General Engineering Flight (GEF) of the first receiving unit is to raise a F3806A on receipt of each item of equipment.

The F3806A is to be housed in a visible edge pocket and stored in the tray of a Hardex cabinet. The documents are to be kept and maintained by the ground support equipment controller where the lift equipment bay is adjacent to the GEF. When the lifting bay equipment is separate from the central GEF, the documents are to be kept and maintained by the SNCO i/c lifting tackle bay. Continuation cards are to be raised when any field of the preceding card is exhausted. The initial and all continuation cards are to be retained throughout the life of the lifting tackle. On transfer of the equipment, F3806A and test certificate are to be transferred in accordance with AP100B-01 Order 7503. Neither F's 3806A, nor test certificates are to be destroyed, until the lifting tackle to which they refer is struck-off service charge. With the exception of a unit serial number, which is to be entered with soft pencil, all entries on the F3806A are to be either typed or written legibly in waterproof ink.

Safe Working Loads

As stated earlier (page 11.9), a table of the safe working loads of every item of lifting tackle in use is to be posted in the room in which such lifting tackle is normally stored and in prominent positions in all buildings where lifting tackle is used. For multi-legged slings, the table is to show the SWL of the slings when the included angle between diagonally opposite legs are 30°, 60°, 90° and 120°. The table is to be kept up to date by entries corresponding to the entries in the station or unit register of lifting tackle whenever new items of equipment are received, or any items are transferred or returned to store.

Any item of lifting tackle not shown in the table of safe working loads is not to be used. This, however, does not apply to an item of lifting tackle when the SWL (or for multi-legged slings, the SWL at different angles of the legs) is plainly marked on the tackle. No item of lifting tackle is to be used for any load exceeding the SWL as shown on the table or marked on the tackle.

Load Limitations

It is the responsibility of the STO or his deputy to ensure that all persons in charge of lifting operations are aware of the load limitations of the equipment to be used and all other precautions which must be observed during the lifting operations.

Failures of Lifting Tackle

Any item of lifting tackle which fails in use is to be held for investigation in accordance with the instructions contained in AP100B-01 Order 0911.

Precautions in Use

An officer or NCO is to be in charge of all operations involving the use of lifting tackle, with the following exceptions:

- Repetitive operations of a simple nature using specific equipment. In such instances a competent airman may be detailed by the STO.
- At civilian manned RAF units, selected civilians may be nominated by the STO to take charge of such operations.

Lifting tackle is not to be picked up or borrowed in a casual manner for a lifting operation. Every item of tackle must be carefully checked by the person in charge of the operation; he is to ensure that it is the correct equipment for the job in hand and that it is in a serviceable condition immediately before use. If the examination reveals any signs of damage or raises any doubt regarding the serviceability of the item concerned, the item is to be placed unserviceable immediately and is not to be used until it has been properly examined and certified serviceable by a competent person.

The person in charge of a lifting operation will be held entirely responsible that the sling and tackle used are suitable for the work and that the correct method of slinging is employed. He is to ensure that hooks or shackles are in alignment with the lifting chains or cables and that shackles do not foul the attachment lugs internally. Fouling will cause an indirect pull and probable failure of the shackle.

A load must not be left unattended whilst suspended from a crane or lifting tackle, and no member of the lifting party or any other person is to be permitted to stand or pass underneath it.

Slings, chains, hooks or shackles which may become accidently strained through snatching or other causes, are to be considered unserviceable until they have been inspected and certified serviceable. If the person in charge of the lifting operation is not satisfied with the visual inspection, the sling, hook, chain or shackle is to be returned to stores as repairable, marked *'For rectification and proof loading'*.

When using wire rope slings, care must be taken that they do not kink under load. Wire rope slings must NEVER be knotted to shorten them. A brief inspection is to be made of splices, swaging and attachments to wire rope slings immediately before use to ensure that the items are serviceable. Before multiple wire rope slings are fitted to a load, they must be laid out on the floor to ensure that the shackles are correctly attached and that the fittings are not twisted.

To prevent fibre or wire rope slings from being cut by sharp corners of the load, packing is to be inserted as required between the sling and the load.

When a mobile crane is used for a lifting operation, only the person in charge of the operation is to give orders to the crane driver.

SERVICING AND STORAGE

Natural Fibre and Nylon Rope Slings

Fibre and nylon rope slings are to be examined by the user before use and serviced at six-monthly intervals.

Periodic inspections. At six-monthly intervals, all servings and protective coverings are to be removed and the slings examined for the following defects:

- *Internal wear.* This is indicated by extreme flexibility of the rope and signs of chaffing in the lays. The rope is opened up by slightly untwisting the strands, and then inspected carefully for signs of dampness and mildew. Any sling showing signs of dampness is to be hung up under cover and dried out. Slight traces of mildew can be removed by vigorously rapping the sling on a wooden surface. When all traces of mildew have been removed by this operation, the sling can be considered safe for further use provided that no other defects are apparent, but a note should be made on the certificate of inspection to the effect that mildew was traced.
- *External wear of outer strands.* This is indicated by a reduction in the diameter of the rope and by the flattening and fraying of the outer strands.
- *Brittleness,* friability and shortness of fibres in the strands. These can best be detected by rubbing the rope through the hands when small fibres will stand out from the lays.
- *Cuts, bruises and frayed strands.* These may cause internal, as well as external damage, and are indicated by local severing or loosening of the strands. A deep score extending over ten lays or more of the rope can mean that every outer yarn is damaged or cut.
- *Bad splicing, loose or uneven splicing, poor serving, tucks pulling out.* Splices are not to be less than 4½ tucks and they must be examined with particular care at every inspection.

On completion of the inspection the servings and protective coverings are to be replaced.

Subject to a satisfactory inspection as detailed above, natural fibre and nylon rope slings have an indefinite life, but should there be any doubt as to whether or not a rope is fit for use, it should be replaced at once.

Storage. Ropes should be kept in a cool, dry and well-ventilated store, and protected from damp, heat and sunlight. They should be hung on pegs to allow a free circulation of air around them. If coils of rope have to be stored on the floor, they should be placed on timbers or other suitable supports to allow circulation of air.

Man-made Flat Lifting Slings

Man-made flat lifting slings are to be examined by the user before use and serviced at six-monthly intervals.

Periodic inspections. At six-monthly intervals, these slings are to be examined for the following defects:

- *Chafe.* This is the most common cause of weakness. In extreme cases the faces of the webbing become so worn that the outer yarns of the weave are severed. During normal use, some breakage of the surface fibre may occur and is unavoidable. This may be disregarded if not too extensive.
- *Cuts and bruises.* Cuts and bruises, particularly on the edges of the sling, will result in serious loss of strength and slings suffering from these must be taken out of use immediately.
- *Chemical attack.* Chemical attack is indicated by local weakening and softening of the webbing so that surface fibres can be plucked or rubbed off.
- *Seams.* Any damage to the seams renders the sling unserviceable.

Should there be any doubt as to whether or not a flat sling is fit for use, it should be replaced at once.

Storage. Man-made flat lifting slings are to be stored on a well-ventilated rack in an even temperature away from moisture. It is important for the slings to be dry before storage.

Wire Rope Slings

Wire rope slings are to be examined by the user before use and serviced at six-monthly intervals. Slings found unserviceable are to be returned to stores as repairable, marked *'For Rectification and Proof Load Testing'.*

Periodic inspection. At six-monthly intervals wire rope slings are to have any protective covering or splice servings removed and are then to be thoroughly washed in white spirit. They are then to be examined for the following defects:

- *Broken single wires.*
- *Excessive internal wear.* This is indicated by polished internal strands and reduced diameter.
- *Excessive external wear.* This is indicated by polished and flattened outer strands, and eventually by broken strands.
- *Internal corrosion.* To detect this, lightly bend and partially untwist the lay, taking care not to damage the rope. Any sign of internal corrosion indicates that the sling is dangerous to use.
- *Loose splices, broken wires in the splice, insufficient tucks (minimum of 4½ tucks) and slack loop over the thimble.* A certain amount of slackness between the loop and the thimble will be present in all slings that have been subjected to proof loading. A comparison with a new sling will indicate the amount of slackness that can be tolerated. Excessive slackness is a sign that the adjacent splice is in a dangerous condition and the sling is to be considered unserviceable.
- *Damage to wire caused by rough handling.*
- *Swaged ferrules.* Check for security of any swaging, for broken wires around the swage, and for signs of movement of wire in the ferrule. The free end of the wire rope is to be level with, or protrude from, the end of the ferrule. This position is to be checked against that which was recorded on the F3806A during the initial acceptance check.
- *Open strands and kinks.* An open strand adjacent to a splice indicates that the splice is about to fail and that one of the tucks is loose.
- *Pins and shackles.* Pins and shackles are to be removed and individually inspected for signs of wear.
- *Multi-legged slings.* Particular attention should be paid to the main rings which bear the whole load suspended on the slings.
- *Composite slings.* All load-bearing components, such as intermediate rings, pins, shackles and spreader bars should be examined for bowing, excessive wear and shearing.

Slings found serviceable at the six-monthly inspection – *with the exception of slings used with compressed gas cylinders* – are to be lubricated by immersing in oil OMD 110, NATO Code No 0-180, or OMD 75 for at least one hour. When the sling is removed, wipe off any surplus oil and replace the splice servings and any protective coverings.

Note: *Slings for use with compressed gas cylinders, are not to be lubricated or treated with PX9.*

Storage. Wire rope slings are to be stored by suspending them by their ring or hook.

Chains, Chain Slings, Grabs and Allied Equipment

Chains, chain slings, grabs and allied equipment are to be examined by the user before use and serviced at six-monthly intervals.

Periodic inspection. At six-monthly intervals, chains, chain slings, grabs and allied equipment are to be examined for cracks, flaws, distortion, excessive wear and socketing. A quick check for the serviceability of a chain is to ascertain its flexibility. When a chain has been overstretched, the sides of each link tend to pinch the ends of adjacent links with the result that the chain becomes stiff. In extreme cases, with wrought iron elliptical links, the chain will become rigid. Any lack of flexibility in a load chain is, therefore, to be taken as a definite sign of its unserviceability. *Socketing* is the name given to the grooves produced in the ends of the links when the links chafe against each other. If cracks, flaws, distortion, excessive wear or other defects are observed, the defective parts are to be marked and the equipment returned to the appropriate unit for reconditioning. All pins or shackles are to be removed and individually inspected for signs of wear. When multi-legged slings are inspected, particular attention should be paid to the main rings which bear the whole load suspended on the sling. Composite slings are to have all load bearing components such as intermediate rings, pins, shackles and spreaders examined for bowing, excessive wear and signs of shearing.

Storage. Chains and chain slings are to be stored by suspending them from their ring or hook.

Chain Pulley Blocks

Chain pulley blocks are to be inspected before use and at six-monthly intervals.

Periodic inspection. At six-monthly intervals the pulley blocks are to be dismantled, cleaned, and all working parts examined for wear. After cleaning, the load chains are to be examined link by link for cracks, flaws, distortion, excessive wear and socketing. Sheave pins, worn gears and other moving parts should be checked for wear. Pitched chains are to be run over their wheels to ensure that the pitch of the chain is coincident with the pitch of the sprockets in which they fit. Components which are worn beyond safe limits are to be renewed and any chain showing signs of stretching is to be rejected. If, on close visual examination, no signs of defects in the load chain or excessive wear of the moving parts of the pulley block can be detected, the equipment is to be reassembled and lubricated throughout with oil OMD 110 or OMD 75.

The maximum permissible amount of wear of a load chain is 10 per cent reduction on the original diameter of the material from which the links were formed.

Storage. Chain pulleys blocks are to be stored on shelves in a clean, dry place.

Wire Rope Pulley Blocks

Wire rope pulley blocks are to be inspected before use and at six-monthly intervals.

Periodic inspection. At six-monthly intervals, wire rope pulley blocks are to be dismantled, cleaned, and all working parts examined for cracks, distortion, damage, and excessive wear. Renew parts as necessary, and then lubricate and assemble ensuring that all moving parts operate freely.

Storage. Wire rope pulley blocks are to be stored on shelves in a clean dry place.

Shackles, Swivels and Eye Bolts

Shackles, swivels and eye bolts are to be inspected before use and at six-monthly intervals.

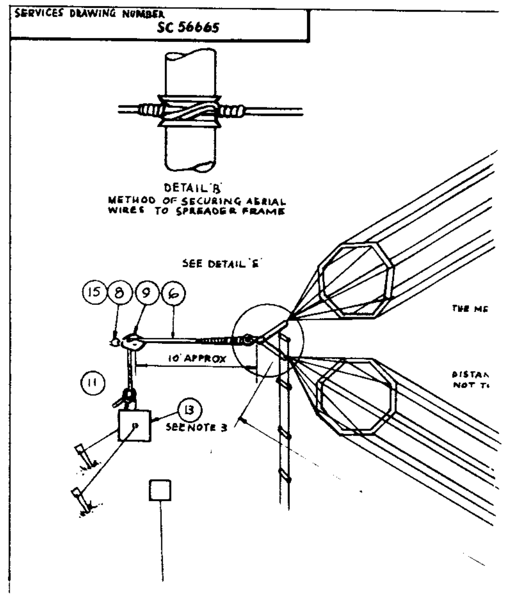
Periodic servicing. At six-monthly intervals, these items are to be examined for cracks, flaws, distortion and excessive wear. Threaded portions are to be examined for cross-threading.

Winches and Hoists

Winches and hoists are to be serviced in accordance with the relevant Air Publications.

Crane Wire Ropes

Crane wire ropes are to be serviced in accordance with their relevant Air Publication. In addition, if the rope can be fitted without splicing, it should be renewed by the unit concerned. However, if the rope requires splicing, the crane should be returned to an approved depot to have a new rope fitted.



CHAPTER 12

ANTENNA INSTALLATION DRAWINGS

Acknowledgement. *The extracts from BS* 308 *Engineering Drawing Practice, Parts* 1, 2, *and* 3 1972, *are reproduced with the permission of the British Standards Institution, Park Street, London.*

Introduction

Before any important engineering part can be made, modified, repaired or assembled, a drawing is needed. The purpose of the drawing is to show craftsmen, in a clear and unambiguous way, precisely what the designer of the equipment requires him to do. The drawing will indicate the materials to be used, every feature, dimension, type of finish, and any other special instructions that may be needed in order to complete the work. All this information is presented in a standard easy-to-read style laid down by the British Standards Institution (BSI) in their publication BS 308 Engineering Drawing Practice (1972).

In BS 308, the standard methods of drawing presentation, to be adopted by all British engineering concerns, are set out. Also included are the units, symbols, and abbreviations recommended by the International Organization for Standardization (ISO), which is an authority largely concerned with European standards and the introduction of the metric system into British engineering.

Lines and Conventions

To show every feature of an engineering drawing distinctly and without ambiguity, a contrast is needed between the large number of lines used in its construction. For instance, since the shape of the object is of major importance, the outline is always drawn in a thicker, much bolder line than those used for pure construction. From the basic continuous thick and thin line, a variety of lines have been developed and accepted by British Standards for use in engineering drawings. These lines and their specific uses are shown in Fig 12.1.

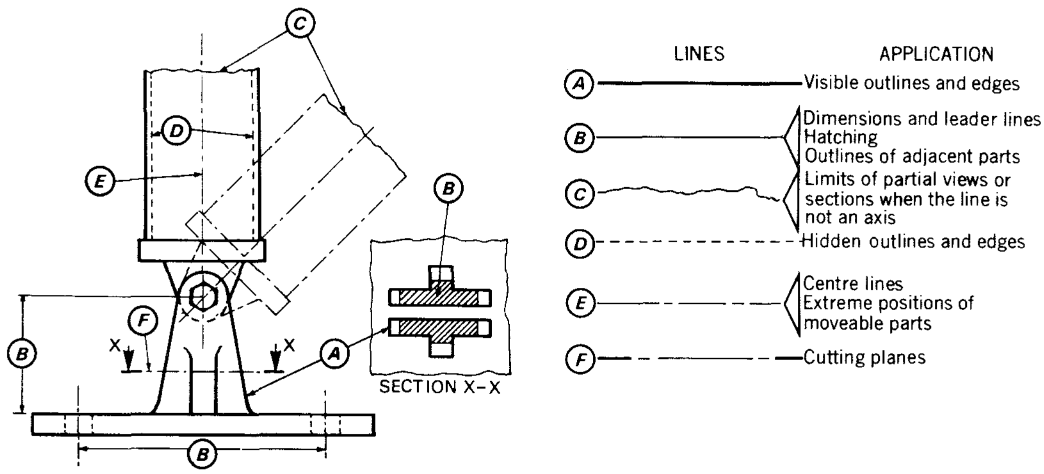


Fig 12.1 Lines and Conventions

Sectional View

A sectional view is used to show the important features of an object which cannot normally be seen. The hidden parts are exposed on the drawing by assuming that the part of the object obscuring the feature has been either cut or broken away. Just where the imaginary cut or break has been made is indicated by long chain lines, thickened at the ends and at any change of direction. The direction of view is shown by arrows resting on the cutting lines and designated by capital letters (Fig 12.2).

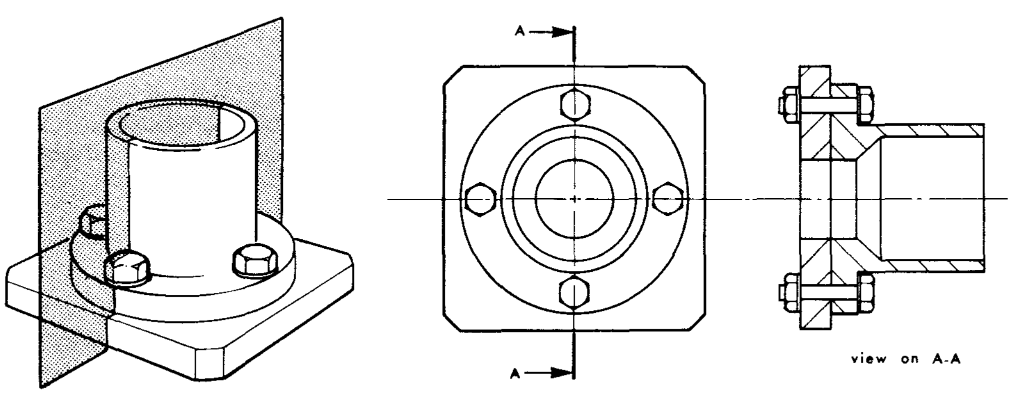


Fig 12.2 Sectional View

Interrupted Views

Certain short-cuts in engineering drawing are permitted to show clearly those parts and features that would otherwise prove a waste of time and space to draw in every detail. Such a short-cut is the interrupted view used to shorten views of long uniform parts. Four examples of interrupted views are shown in Fig 12.3.

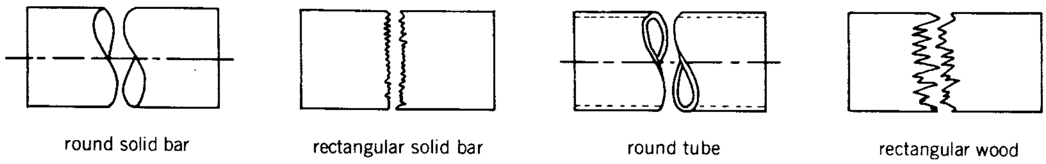
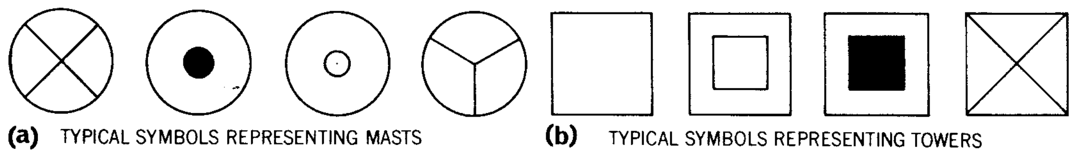


Fig 12.3 Interrupted Views

Symbols

Symbols are used whenever possible and a key to their identity usually appears somewhere on the drawing. Some of the more common symbols used in antenna installation drawings are shown in Fig 12.4.



The basic symbol for a mast is a circle and the symbol for a tower is a square
These may be modified and related to a legend to show different heights, types, guy positions and whether or not the mast or tower is erected

Fig 12.4 Symbols

Abbreviations

Abbreviations play an important part in enabling the technical information, which is needed to support an engineering drawing, to be presented clearly and without clutter. The full stop which normally follows an abbreviation is not used except where the abbreviation makes a word which may be confusing — for example, when 'No' is used as the abbreviation of 'Number'. A list of approved abbreviations extracted from BS 308 is given below.

Term	Abbreviation or Symbol
Across flats	A/F
Assembly	ASSY
Centres	CRS
Centre Line	℄ or CL
Chamfered	CHAM
Cheese head	CH HD
Countersunk	CSK
Countersunk head	CSK HD
Counterbore	C'BORE
Cylinder or cylindrical	CYL
Diameter (in a note)	DIA
Diameter (preceding a dimension)	Ø
Drawing	DRG
External	EXT
Figure	FIG.
Hexagon	HEX
Hexagon head	HEX HD
Hydraulic	HYD
Insulated or insulation	INSUL
Internal	INT
Left hand	LH
Long	LG
Material	MATL
Maximum	MAX
Minimum	MIN
Number	NO.

Term	Abbreviation or Symbol
Pattern number	PATT NO
Pitch circle diameter	PCD
Pneumatic	PNEU
Radius (preceding a dimension, capital letter only)	R
Required	REQD
Right hand	RH
Round head	RD HD
Screwed	SCR
Sheet	SH
Sketch	SK
Specification	Spec
Spherical diameter (preceding a Dimension)	SPERE Ø
Spherical radius (preceding a dimension)	SPHERE R
Spotface	S'FACE
Square (in a note)	SQ
Square (preceding a dimension	□
Standard	STD
Undercut	U'CUT
Volume	VOL
Weight	WT
Full indicated movement	FIM
Taper, on diameter or width	⊳

Title Block

Information relating to the drawing and the part, or parts, to be made is also contained in the title block (Fig 12.5), which is usually located at the bottom of the drawing sheet but may be extended up the sides of the drawing. The block provides space for all the essential information required for the identification, administration, and the interpretation of the drawing. This includes the number of the drawing, its title, source of authorization, and the signatures of the persons who produced and approved the drawing. It also includes an indication of the *scale* of the drawing. This normally appears in the block as a ratio — for example, 1:1 for full size, 1:2 for half size, 2:1 for twice full size, and so on. On drawings showing complete antennae installations, normal map scales are used *eg* 1/2500 or 80cm to 1 km (50 in to 1 mile).

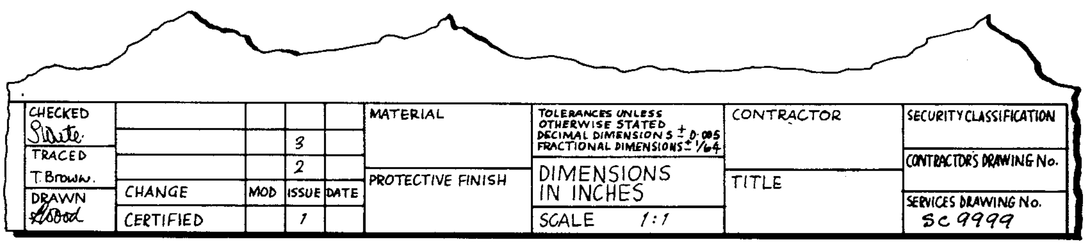


Fig 12.5 Title Block

Issue number. Each drawing is given an issue number, starting with the original drawing as Issue 1. Every time a change is made to the drawing it is given a new issue number — Issue 2, 3, 4 *etc.* The issue number appears in the title block together with brief details of the change and the date of change.

Using Antenna Installation Drawings

When an antenna erecting team are tasked with erecting antennae at a particular installation, it will be issued with a full set of drawings relevant to the task. These drawings must be checked against the main drawing list included in the issued set of drawings (Fig 12.6) to ensure that all the relevant drawings are present and that they are the latest issue.

Items list. Every drawing has an associated items list, an example of which, together with part of the drawing to which it applies, is shown in Fig 12.7 at the end of the Chapter. As shown, each component on the drawing is given a number; reference to this number in the appropriate column of the items list will identify the component and also provide other information such as the material used and the quantity required. Not every drawing has a separate items list; in some instances this list is included on the drawing.

Secondary drawings list. The main drawings list contains references to secondary drawings lists for individual antennae (items 6-9 in Fig 12.6). The drawings and, where applicable, associated items lists itemized in these secondary drawings list should be located and pinned together.

Care of Drawings

Certain precautions are necessary if the maximum useful life of drawings is to be achieved. These precautions are as follows:

- Lay drawing flat to read.
- Keep clean and dry.
- Do not make alterations without prior authorization.
- Do not take into the field unless absolutely necessary.
- Refold using original folds and ensure that the drawing number is outermost.

[redacted] CLASSIFICATION

DATE	I	ITEM	SIZE	DRAWING No	TITLE	ISSUE
26-1-73		1	A4	90G 109634	THIS DRAWING LIST	LATEST
		2	A1	90G109634	Æ INSTALLATION	1
		3	A4	90G 109634	ITEMS LIST SHT: 1	1
		4	A4	90G 109634	ITEMS LIST SHT: 2	1
		5				
		6	A	SC 54258	D/L RHOMBIC Æ	5
		7	A	SC 56665	D/L QUADRANT Æ	6
		8	A	SC 56662	D/L DIPOLE Æ (8 WIRE)	3
		9	A	SC 62485	D/L DIPOLE Æ (3 WIRE)	2
		10	C	90G 4241	SLOPING 'V' Æ (RX)	4
		11	D	S.C. 48726	GANTRY FEEDER LINE TERMN	1
		12	B	S.C. B64190	USE OF 'CABLOCK' FITTINGS	2
USED ON						

CHECKED Yjw.	CONTRACTOR	CERTIFIED [illegible] DATE 29-1-73
	CODE M6	SECURITY CLASSIFICATION UNCLASS
TRACED /	H Q 90 (SIGNALS) GROUP RAF	CONTRACTORS DRG. LIST FOR
	TITLE CODE	
DRAWN RaR.	Æ INSTALLATION EEI-8931	DRAWINGS LIST FOR 90G-109634 — SHT No — A4

Fig 12.6 Main Drawings List

CHANGES	ISSUE	SECURITY CLASSIFICATION				
DATE 5/4/63	1	ITEM	DRAWING No	DESCRIPTION	QTY	REMARKS
ITEM 5 WAS T375 ITEM 16 ADDED ITEMS 3 4 5 & 14 QTYS REDUCED 27-7-65	2	1	90G 1991	SPREADER ANTENNA	*	10B/9560411
		2		WIRE COPPER HD DRN 100LB/MILE	*	5E/1775
		3	S.C. 54342	INSULATOR STRAIN	6	10B/9331433
ITEM 1 REF No AMENDED 4·9·69		4	S.C. 54343	THIMBLE	6	10B/9331433 SSU MANUFACTURE -
RETRACED 5·9·70		5	SC 54382	INSULATOR SPACER	8	10B/9444563
ITEMS 8, 12, 14, 15 REF Nos UPDATED 6.2.73	5	6		TERYLENE ROPE HEAT SET PRE-STRETCHED 1 1/8" CIRC.	*	52A/9331562 MARLOW ROPES LTD
		7		TERYLENE ROPE HEAT SET PRE-STRETCHED 3/4" CIRC.	*	32A/9331559 MARLOW ROPES LTD
		8		SHACKLE 3/8" DEE SHAPE	14	28Y/9563602
ITEMS 4 & 5 SSU MANUFACTE ADDED ITEM 12 WAS PICKET TYPE 11 DM 1373	6	9	SC 55061	BLOCK TACKLE	3	10B/9331574
		10	90G 3797	LINK AERIAL CONNECTING	1	
		11		GUY GRIP DEAD ENDS CAT No 35 NADE 1/8" (0·350)	6	10B/9331567 OBTAINABLE FROM PRE-FORMED LINE PRODS. (GB) LTD ANDOVER HANTS
ITEMS 8 & 15 WERE QTY 12 ITEM 17 ADDED MS 10·1·74	7	12		STAKE GUY	2	10B/9560406
		13	WT 54223/9	HALYARD WEIGHING ASSY	1 SET	
		14		TALURIT FERRULE No.6.	2	29H/1250133
		15		SHACKLE PIN 3/8"	14	28Y/9563601
		16		GUY GRIP DEAD ENDS 24 NADE 3/4" (0.217)	2	10B/9331564
		17		THIMBLE GALV. HEART FOR	2	DAVY & CO LTD.
				1 1/4" CIRC. ROPE No. 1201		88 WEST INDIA DOCK RD LONDON E 14.

* FOR QUANTITIES OF ITEMS 6 & 7 SEE APPROPRIATE STATION

USED ON: AERIAL RIGGING CHART

* FOR QUANTITES OF ITEMS 1 & 2 SEE APPROPRIATE STATION AERIAL INSTALLATION DRAWING

CHECKED	CONTRACTOR	CERTIFIED DATE 5/4/63
TRACED B. Coleman	HQ 90 (SIGNALS) GROUP RAF — CODE M6	SECURITY CLASSIFATION UNCLASS
DRAWN R. Wood	TITLE: AERIAL QUADRANT 8 WIRE CAGE DETAILS & RIGGING WHEN RIGGED BETWEEN 3 MASTS OR TOWERS — CODE	CONTRACTORS ITEM LIST FOR
		ITEM LIST FOR SC 56665 — SHT No 4 — A

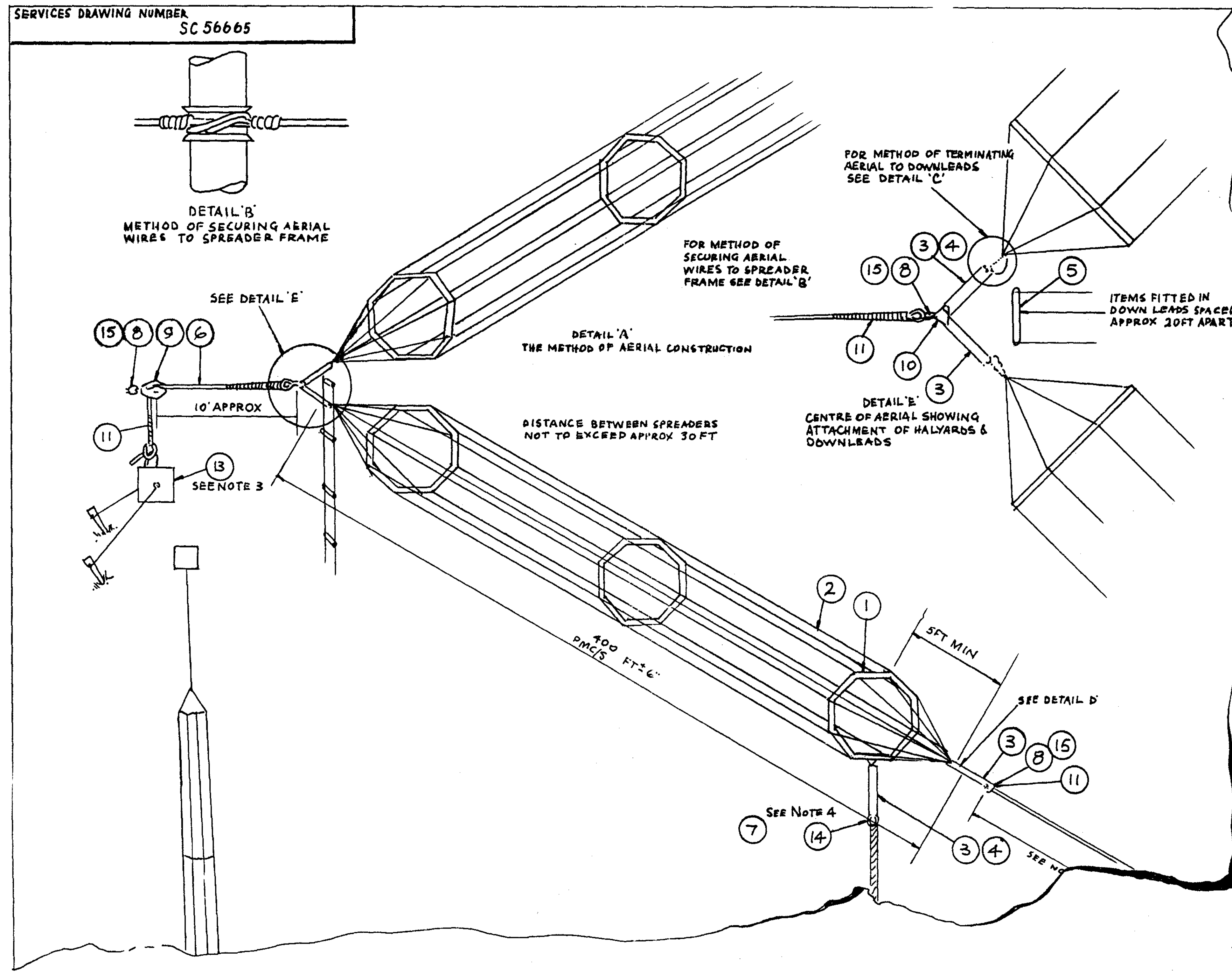
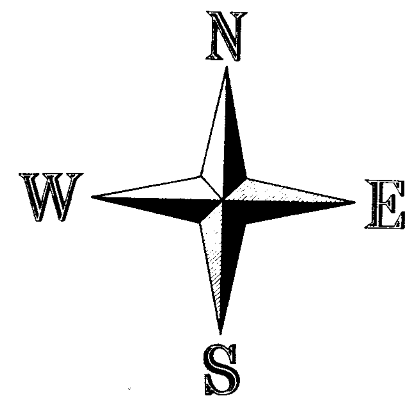


Fig 12.7 Secondary Drawings List



CHAPTER 13

THE MAGNETIC COMPASS

Introduction

Before any mast or tower can be erected, its exact location must be known. If several such masts or towers are to be erected as part of an antenna system, then the *direction* in which the system is to operate must also be known. It is apparent, therefore, that some reliable means of determining direction must be provided if an antenna system is to be accurately set up. The simplest, and most commonly-used, device for determining direction on the surface of the earth is the *magnetic compass.*

The Simple Magnetic Compass

In its simplest form, the magnetic compass consists essentially of a small magnet which is allowed to swing freely on a pivot. No matter where the compass may be on the surface of the earth, the magnet will always align itself in the north/south direction (Fig 13.1).

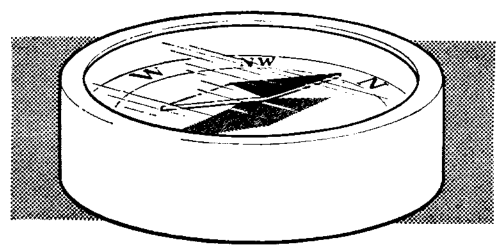


Fig 13.1 A Simple Magnetic Compass

The compass magnet does this because the earth itself behaves like a huge magnet whose axis is almost in line with the axis upon which the earth rotates (Fig 13.2). Since *unlike* magnetic poles attract each other (north pole attracted to south pole) and like poles repel each other, the pivoted compass magnet will position itself so that its north and south poles will face in the direction of the earth's south and north poles respectively. The fact that the compass magnet always indicates the direction of north and south enables all other directions to be determined.

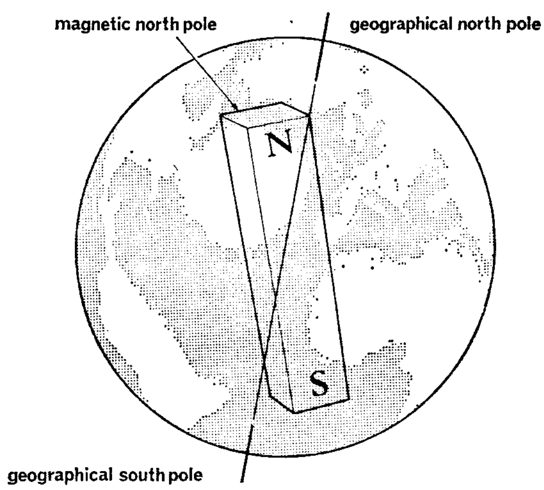


Fig 13.2 The Earth as a Magnet

Methods of Defining Direction

Direction may be defined in one of two ways:

- **The point system.** The point system is one in which the circle of direction about a given point is divided, with North as its datum, into a number of equally spaced 'points' (Fig 13.3a). These are named with reference to the cardinal points—North, South, East, and West, and the intercardinal or half-cardinal points—North-East, South-East, South-West, and North-West.
- **The 'three-figure' system.** The 'three-figure' system is the system in which the circle of direction is divided clockwise from North into 360 equal divisions or degrees, starting with the North datum as 000° or 360° (Fig 13.3b). When using this system, direction is always written as a three-figure group, *ie* 025°, 125°.

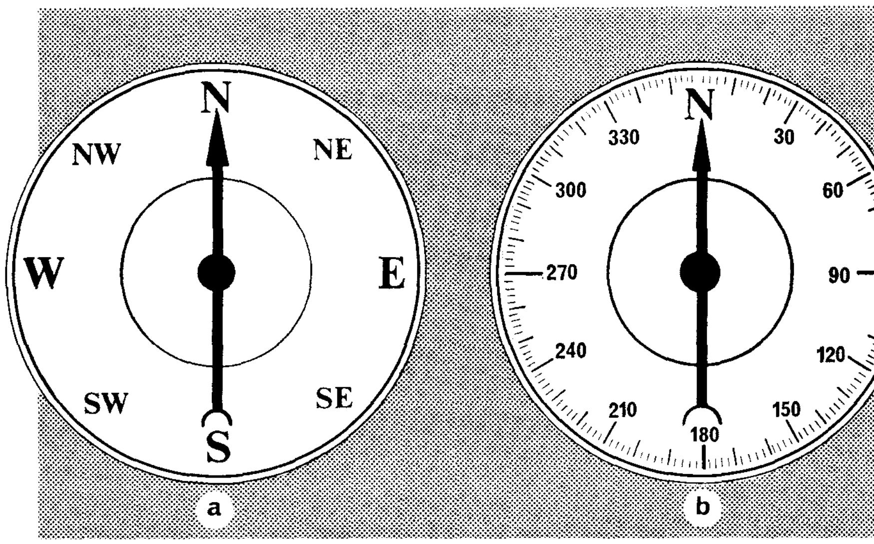


Fig 13.3 Methods of Defining Direction

Variation

The main drawback with the magnetic compass arises from the fact that north and south magnetic poles do not coincide with the north and south geographical poles, *ie* the poles at the ends of the axis upon which the earth spins (*see* Fig 13.2). These two poles are known as True North and True South. The magnetic compass does not, therefore, indicate the direction of True North. This difference between Magnetic North and True North is called *variation.*

Variation is measured in degrees and is termed East or West according to whether the north-seeking end of the compass lies to the East or West of True North at any given point. When converting magnetic direction (°M) to true direction (°T), the value of variation is added to the magnetic direction when variation is East and subtracted when it is West. Conversely, when converting true direction to magnetic direction, the value of variation is subtracted from true direction when the variation is East and added when it is West, *ie*:

Magnetic Direction	Variation	True Direction
278° M	4° East	282° T
142° M	8° West	134° T

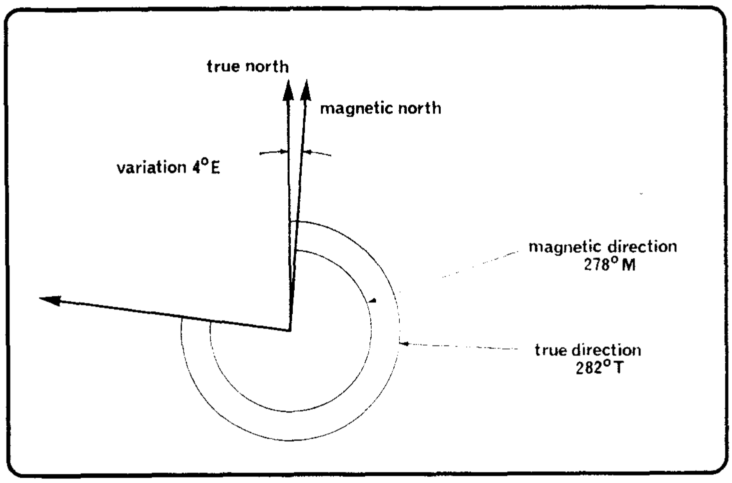
These examples are illustrated in Fig 13.4.

A helpful memory aid is as follows:

Variation East—magnetic least (lowest).

Variation West—magnetic best (largest).

Variation not only changes from place to place on the surface of the earth, it is also subject to gradual change with the passage of time at any given point on the surface of the earth. This change, which is indicated in the margin of a map, is not large but in certain places may amount to as much as one degree in five years. On Ordnance Survey maps the value of variation is given



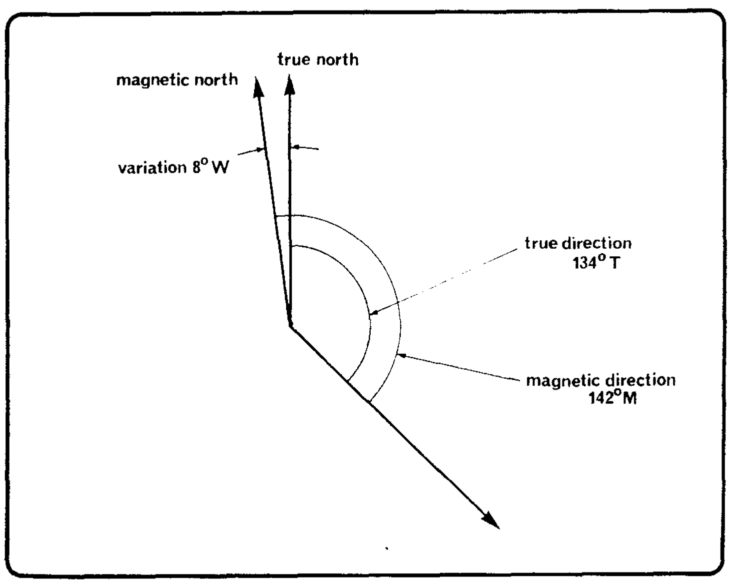


Fig 13.4 Application of Variation

in one of the margins together with the date at which the value applies. The annual change is also given so that the value of variation may be updated. The exact value of the magnetic variation for any particular location will be known by the local Department of the Environment representative or the nearest flying unit.

The Prismatic Compass

The type of compass that you will be using is known as a *prismatic compass* and is shown in Fig 13.5.

The magnet system of this compass, which consists of a float carrying two parallel bar magnets and a compass card, is supported on a pivot in the compass bowl.

A foresight, consisting of a nylon sighting line fitted in a folding sighting frame, and a prism (hence the name prismatic compass) and slot backsight are fitted to the verge ring. A circular spirit level, which enables the compass to be set level in all directions, is also fitted to the verge ring (Fig 13.5).

The compass fits on a tripod which has a ball and socket head for quick levelling. The compass is secured to the ball and socket head by a clamping ring. The compass is then free to rotate on the ball and socket head although secured by the compass clamping screw. A plumb line and bob is supplied for centralizing the compass over any selected spot, and this is attached to a hook at the centre of the tripod.

Method of Using the Compass

The method of using the compass is as follows:

- Set the tripod central over the selected spot using the plumb line and bob suspended from the hook on the tripod.

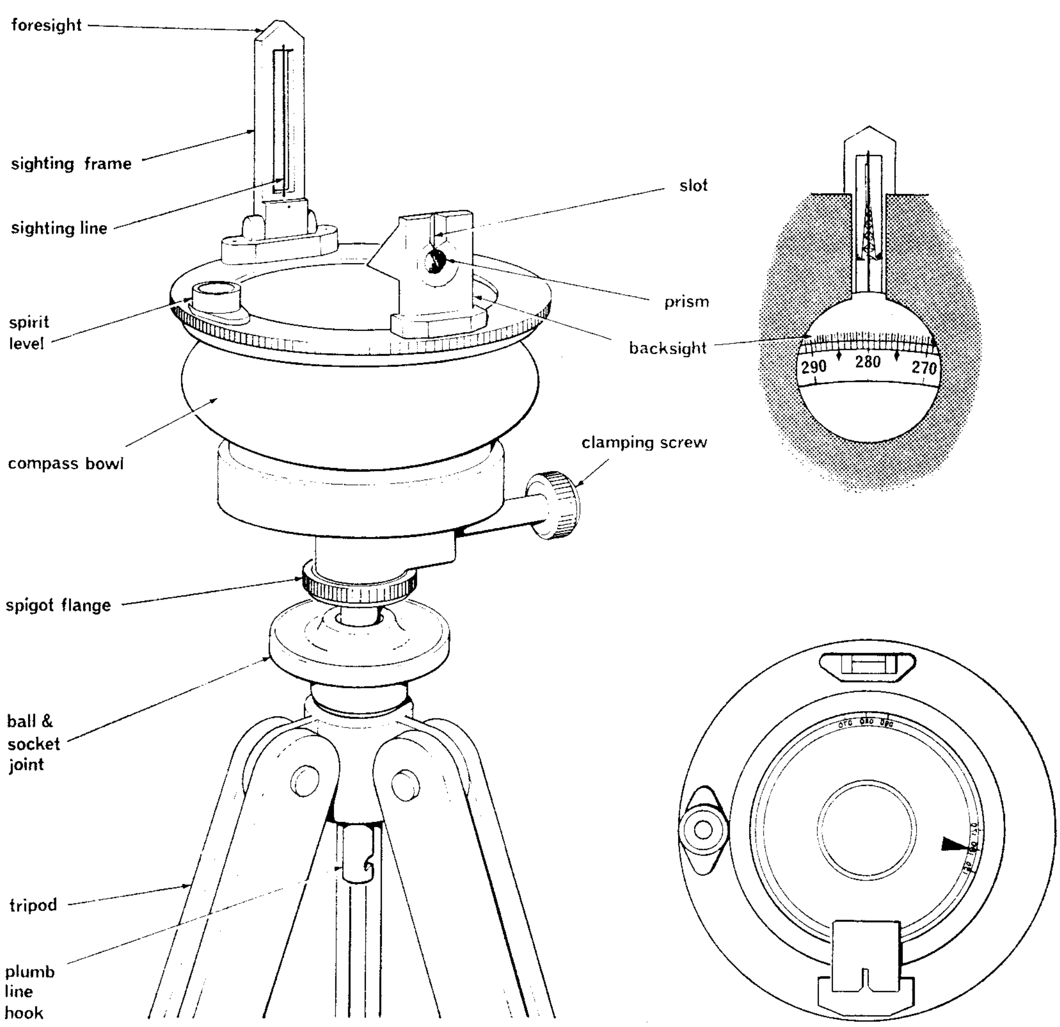


Fig 13.5 The Prismatic Compass

- Ensure that the mating faces of the compass base plate and the tripod spigot flange are free from burrs so that the compass will seat truly on the flange.
- Secure the compass to the tripod by the clamping screw and check that the compass rotates freely on the spigot.

- Level the compass by adjusting the ball and socket head, referring to the circular spirit level.
- Raise the sighting frame vertically and 'sight' through the slot in the prism mounting, rotating the compass until the object whose direction is it required to know is in line with the sighting line.
- Read the direction through the prism at the point where the sighting line appears to cut the scale. The graduations on the compass card are upside down to enable them to be read directly through the prism.

SUMMARY REVIEW

The Simple Magnetic Compass

The magnet of a compass will always align itself in the north/south direction.

Q What causes the compass magnet to align itself in this way? (p 13.1).

Direction may be defined in one of two ways:

Q Name and describe the two methods (p 13.2).

The difference between Magnetic North and True North is called variation.

Q How is variation measured and how is it applied? (p 13.2).

The Prismatic Compass

Q What is the procedure for setting up and using the prismatic compass? (p 13.4).

CHAPTER 14

MASTS

Introduction

In Chapter 1 we saw that the higher the point from which 'signals' are transmitted and received, the greater is the distance over which the message can be relayed, and the less is the interference from obstacles on the ground. In order to achieve a greater transmitting range, antennae are mounted on masts. In this chapter three such masts will be described; they are:

- Antenna Mast Type 23.
- Antenna Mast Type 34.
- Antenna Mast Type S11/1.

ANTENNA MASTS TYPE 23 AND 34

Introduction

The antenna masts Type 23 and 34 (Fig 14.1) are similar in construction except that the Type 23 is 23·8 metres (78ft) high, and the Type 34 is 15·9 metres (52ft) high. Both masts are transportable and can be quickly erected or dismantled.

Construction

The masts are constructed of tubular steel sections that fit into each other to form cigar-shaped assemblies. Three of these 'cigars' are coupled together to form the Type 23 mast and two 'cigars' to form the Type 34 mast.

The tubular sections that make up a 'cigar' are tapered to fit tightly into each other and when hammered together they make a very rigid unit. Each 'cigar' is composed of the following sections (Fig 14.1):

- Two No 2 Sections, 2·03 metres (80ins) long.
- One spigot, 660mm (26ins) long.
- Two No 3 Sections, 1·98 metres (78ins) long.

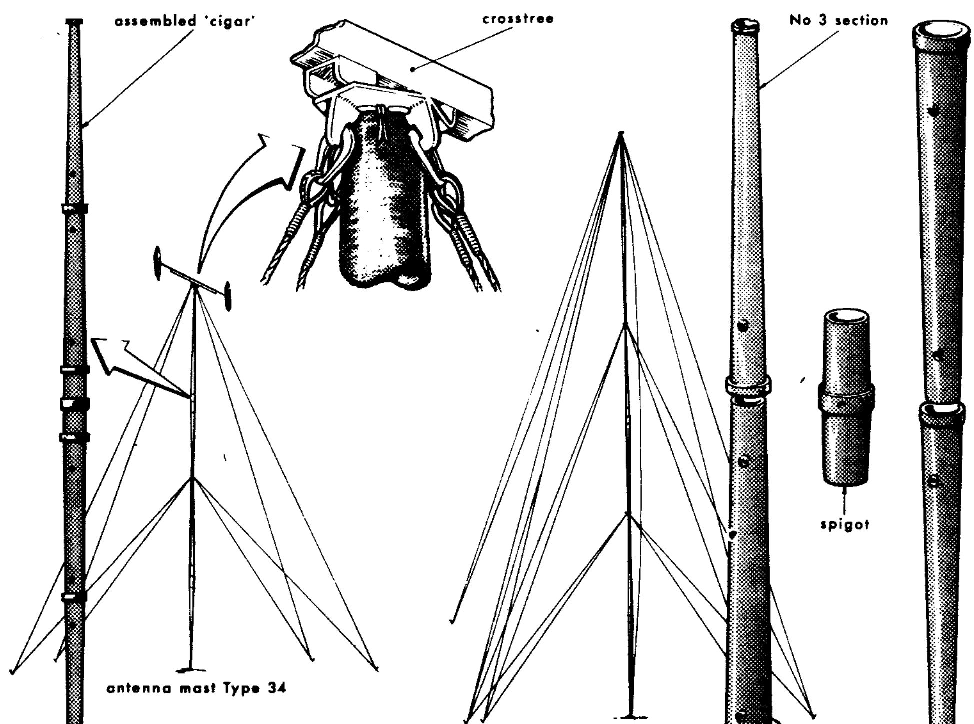


Fig 14.1 Antenna masts Types 23 and 34

The spigot forms the centre of the 'cigar', onto each end of which is fitted a No 3 Section. The No 2 Sections are then fitted to the ends of the No 3 Sections.

The assembled mast is mounted on a base plate (Fig 14.5) and is held in the vertical position by four guy ropes attached to the top of the mast, and four guy ropes attached to each of the couplings joining the 'cigar' sections. The guy ropes are secured to four pickets spaced 90 degrees apart and arranged in a circle round the base at a radius of 8·38 metres (27½ft). When two masts are used to support an antenna slung between them, there is a force applied to the masts tending to pull them together. Under these circumstances, an extra guy rope is attached to the top of each mast and secured behind the mast in line with the antenna. This guy is known as a back stay (Fig 14.2).

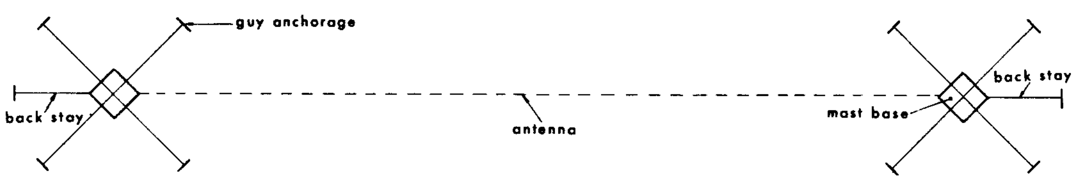


Fig 14.2 Ground layout for a pair of masts

Selection of Mast Site

If at all possible, a level site should be chosen for erecting Type 23 and 34 masts. This will reduce the number of adjustments that will have to be made to the guy ropes when raising the mast. When two or more masts are required to support an antenna, level ground will ensure that the tops of the masts will be at the same height. The minimum clear ground required for the erection of one Type 23 mast is 36·6 metres by 18·3 metres (120ft by 60ft), and for the Type 34 mast, 27·4 metres by 18·3 metres (90ft by 60ft).

The nature of the ground should be checked to ensure that it is firm enough to support the mast and prevent the base plate from sinking into the soil. The soil where the pickets are driven in should also be firm, to ensure that the pickets do not work loose. Should one picket work loose, the mast would tend to sway in the wind and gradually loosen the remaining pickets.

Six men are required to assemble and erect these masts. Fewer men will be required if a Tirfor winch is used.

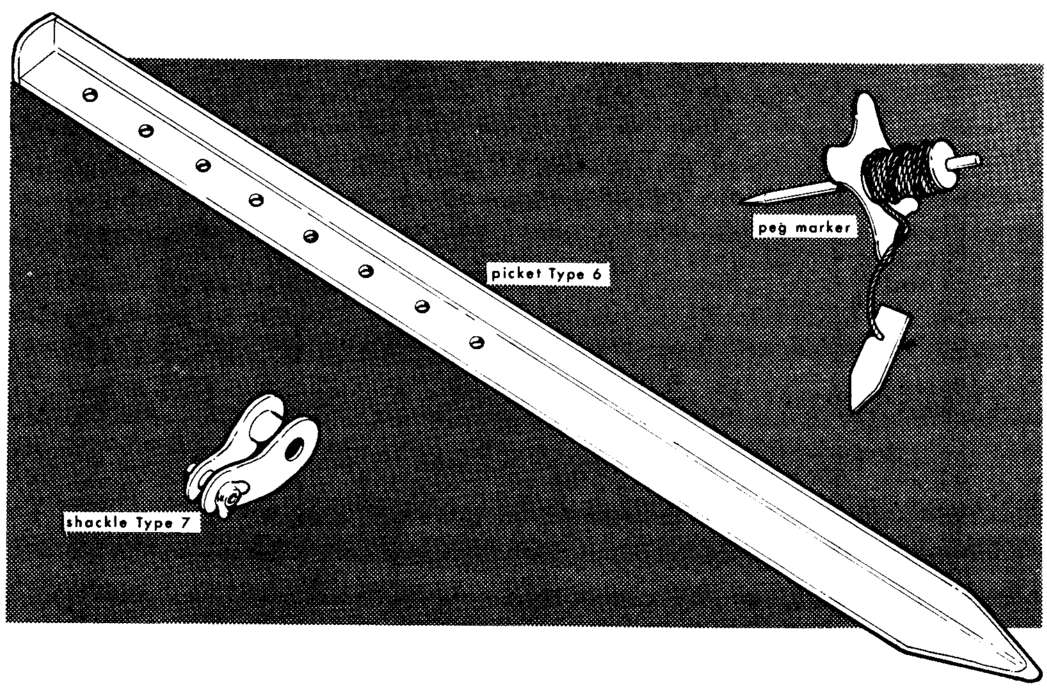


Fig 14.3 Peg marker, picket and shackle

Marking Out the Site

The site is marked out as shown in Fig 14.4. Included in the kit of tools supplied with the mast, is a peg marker consisting of a plate fitted with a spool on which is wound a length of cord with a peg at its end (Fig 14.3). The length of this cord—8·38 metres (27½ft)—is the distance that the pickets must be placed from the mast base. To mark out the site, one man stands at the spot where the mast base plate is to be sited, holding the spike of the peg marker. A second man walks away from him drawing the cord off the peg marker spool until it is all unwound. The spike of the peg marker is then pushed into the ground where the mast base plate is to be placed.

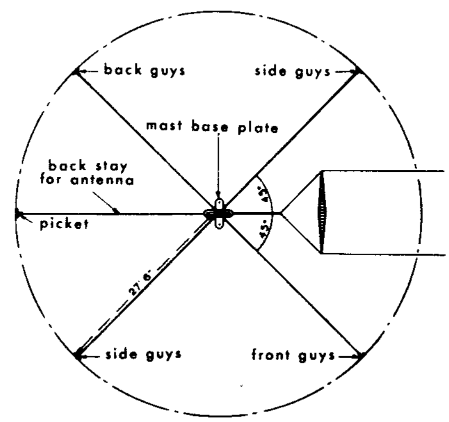


Fig 14.4 Site marked out for one mast

The direction of the guys is then decided. With a single mast, the guys can be arranged, 90 degrees apart, around the mast in any position. However, where two masts are supporting a horizontal antenna, an additional back stay for the antenna must be positioned as shown in Fig 14.2. The position of the first picket from the mast base is located as explained in the preceding paragraph. The picket is driven into the ground at this point at an angle of 30 degrees to the vertical and leaning away from the mast and with the web facing the mast. Only the top three holes of the web should remain above the ground.

With the cord still stretched out to the picket, the man at the base now rotates the peg marker plate until one of the holes in the plate is under the cord. The man at the picket then walks round, holding the cord taut until the cord is over the next hole in the peg marker plate. As before, a picket is driven into the ground and this procedure is then repeated for the remaining pickets.

Where an antenna back stay is required, its position should be determined as in Fig 14.2 and the additional picket driven into the ground.

A shackle, Type 7 (Fig 14.3) to which the guys will be attached, should then be fitted to each picket (in the hole nearest the ground).

Remove the peg marker and replace it with the mast base plate. The cord can now be rewound on to the peg marker spool which can then be stored away.

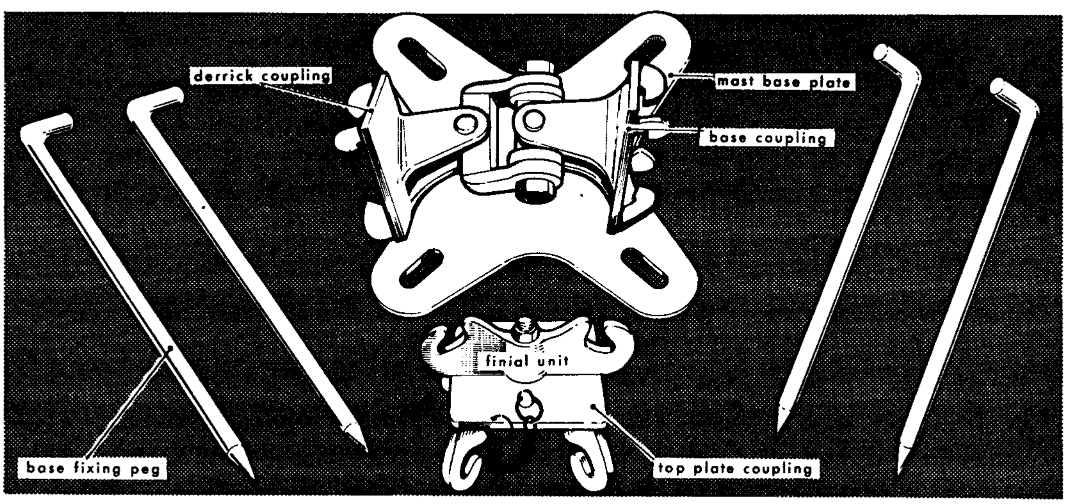


Fig 14.5 Mast base plate, pegs and top plate coupling

The mast base plate must now be positioned so that the mast base coupling (Fig 14.5) faces towards one of the pickets. It is then secured to the ground by driving a base fixing peg (Fig 14.5) through each of the slots in the base plate. The horizontal top portion of the pegs should fall *outwards* from the centre of the base plate.

ERECTING

Assembly of Mast and Derrick

The sections that comprise the mast and derrick must be assembled on the ground. To avoid carrying the assembled 'cigars', the sections can be fitted together working outwards from the base plate. There are three points that must be kept in mind during the assembly:

- When inserting one section into another, the reinforced holes must be kept in line (Fig 14.6). This ensures that the guy ropes will be attached to the mast correctly, in order to take the load in the correct direction. It also facilitates the dismantling procedure.
- The longitudinal welded seams of adjacent sections should be on alternate sides to give extra strength to the mast.
- A liberal coating of grease should be applied around each tapered end of a section that fits into an adjacent section to prevent them jamming.

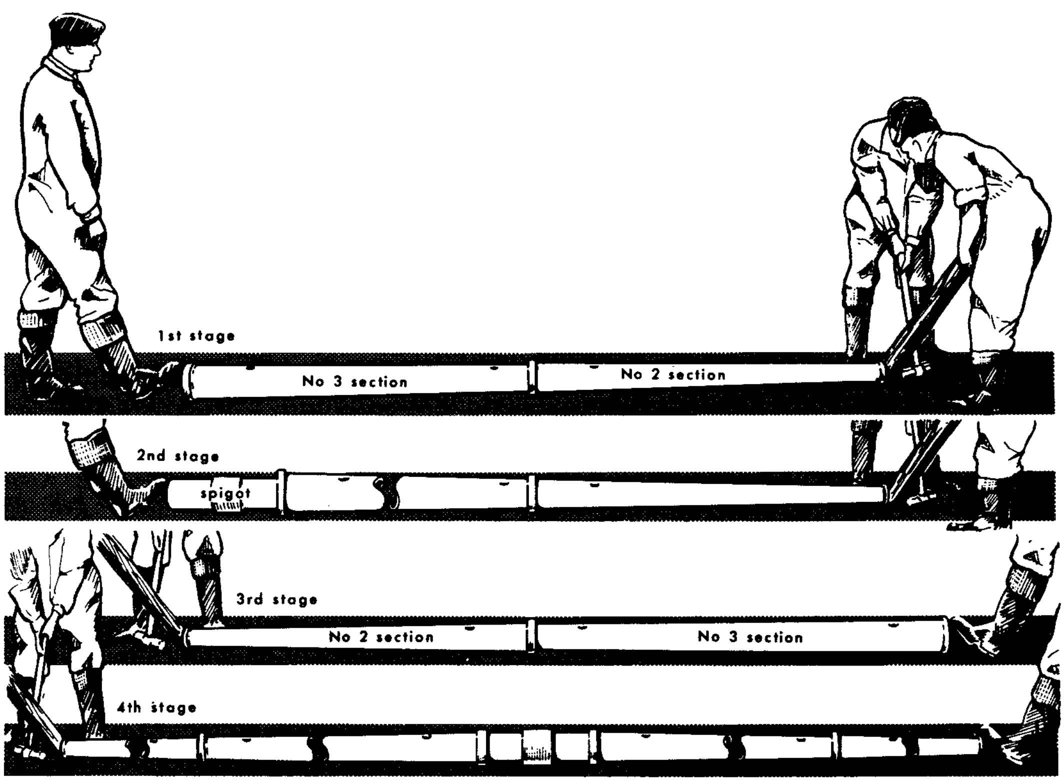


Fig 14.6 Four stages in the assembly of a 'Cigar'

To assemble a 'cigar' for use as a derrick or part of a mast, proceed as follows:

- Grease the tapered end of a No 3 section and insert it into a No 2 section with the holes aligned.
- While one man places his foot against the open end of the No 3 section (Fig 14.6) a second man holds a piece of wood against the closed end of the No 2 Section and a third man gives the wood several light blows with a sledge hammer. Heavy blows are not necessary and should be avoided.
- Insert the spigot into the No 3 Section and again tap the end of the No 2 section (Fig 14.6).
- Now assemble another No 2 and No 3 section as before and then fit the No 3 section over the open end of the spigot.
- Tap the whole assembly or 'cigar' to ensure the five parts are secure.

One man should now make a rigidity test on the 'cigar'. To do this he should lift one end of the 'cigar' about 2 or 3 feet from the ground and shake it up and down. Any slackness in the joints will be readily felt and can be rectified by a few more taps with the hammer.

If any of the joints fail to tighten up, that joint should be dismantled and the ends of the sections checked to ensure that no dirt has lodged in the tube or that the ends of the sections are not distorted. The remaining 'cigars' are now assembled in a similar manner.

The mast is laid out from the base in the direction of the back picket. The derrick will then lie nearly at right angles to the mast, on whichever side of it that is convenient. The top of the derrick will then be close to the mast side guy pickets.

Should there be a slope on the site it is desirable that the mast sections be laid out and assembled so that the mast can be raised from the ground lying directly uphill or downhill. This will considerably reduce the number of adjustments that will-be required to the side guys as the mast is raised to the vertical position.

One 'cigar' is now attached to the mast base coupling by placing the slotted end of the 'cigar' between the vertical parts of the mast base coupling plate. The 'cigar' is then twisted one-eighth of a turn until the hole in the coupling and the notch in the 'cigar' end plate are aligned. The two parts are then secured in position by means of the split pin attached to the coupling plate.

To make up a Type 34 mast the remaining 'cigar' is then joined to the bottom 'cigar' in a similar manner, using a centre coupling (Fig 14.7). An additional 'cigar' is required to make up a Type 23 mast and should be joined to the second 'cigar' by another centre coupling.

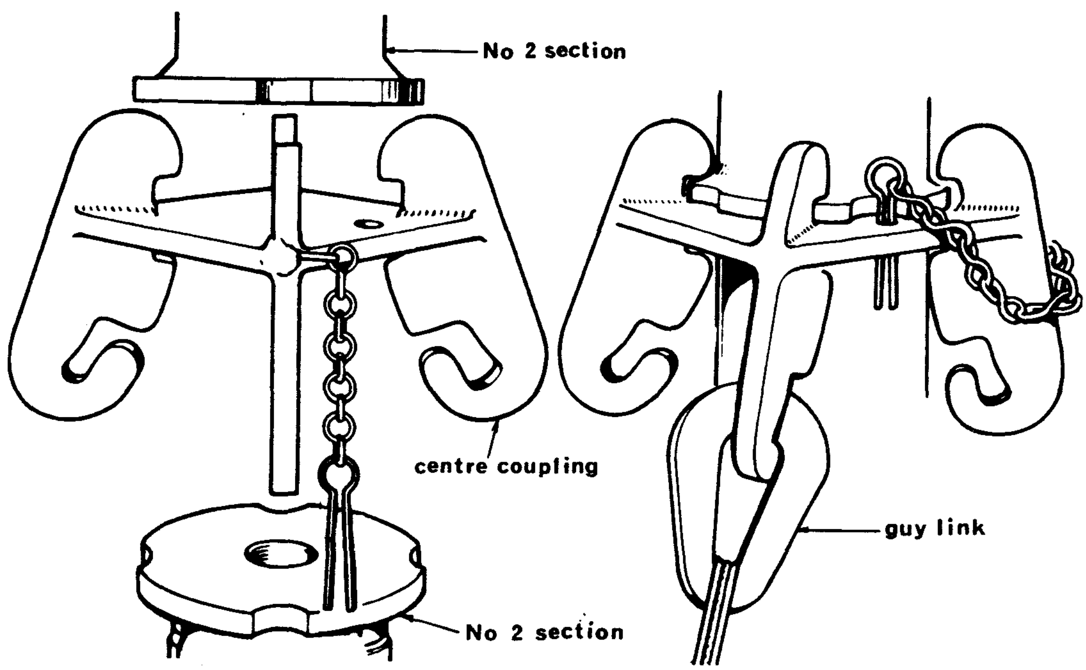


Fig 14.7 Method of coupling mast cigars

A top plate coupling and finial unit (Fig 14.5) is then attached to the end of the top 'cigar', of the Type 23 mast. A top coupling complete with a crosstree is attached to the end 'cigar' of the Type 34 mast (see Fig 14.1).

The derrick 'cigar' is now attached to the derrick base coupling plate in the same manner as the mast was attached to its base coupling plate. The derrick should be positioned so that it is at an angle of slightly less than 90 degrees to the mast (the top of the derrick should be 1 metre (3 feet) away from the right angles position). This allows for the space taken up by the blocks and tackle when the mast is in the upright position. The base bridge plate (Fig 14.5) must be in the vertical position so that when the derrick has been raised to the vertical position, the derrick can be hauled down to the horizontal position thus raising the mast.

Finally, attach the derrick coupling when the mast and derrick will be ready for the attachment of the fibre rope guys.

Attachment of the Guys

Three sets of guys are fitted to the Type 23 mast, one set at the mast head and one set at each of the centre couplings at the junctions of the 'cigars'. On the Type 34 mast only two sets of guys will be required, one at the mast head and one at the centre coupling. The following description of the assembly and attachment of the guys relates to the Type 23 mast but is applicable, except in the number of sets of guys, to both types of mast. The back guys are those lying under the mast before it is erected and the front guys are those which are attached to the derrick to raise the mast.

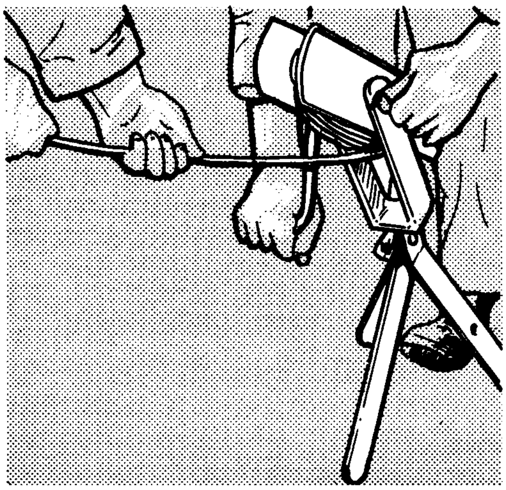


Fig 14.8 Spool winding frame

The guys are wound on spools and can be readily identified by the colour painted on the spools. For the Type 23 mast, the upper guy set is coloured red, the middle set blue, and the bottom set yellow.

The spool winding frame (Fig 14.8) is used to facilitate the rapid winding and unwinding of the guys. The frame is placed in position near to the coupling on the mast to which the guy is to be attached, and pointing in the direction in which the guy must run. While one man steadies the frame, by placing one foot on it and holding the handle, a second man takes the end of the guy and walks slowly away in the required direction.

The back guys should be run out first as they have to be fixed to the underside of the mast when it is lying on the ground and they must be underneath all the other guys before the mast is erected. The upper guy should be laid out first followed by the middle and lower guys.

When one of the back stays is unwound the link is detached from the inside of the spool and connected to the mast coupling plate. Fig 14.7 shows one of the links attached and Fig 14.9 indicates the method of attachment.

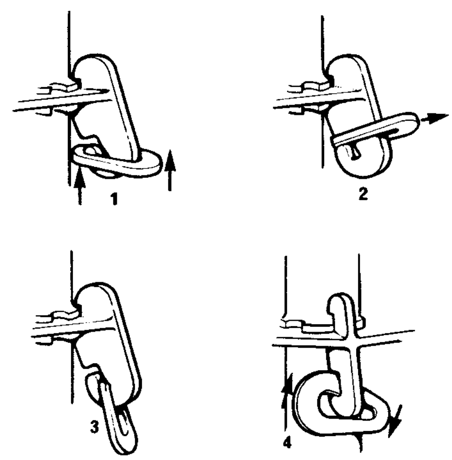


Fig 14.9 Attachment of guy link

The other end of the guy has clamps on it and it is now adjusted to have a loop of about 1·5 metres (5ft) in length at the picket at which it is to be attached. The remaining two back stays are now dealt with in a similar manner. The Type 7 shackle is removed from the picket and the three loops are passed through it and the shackle reconnected to the picket. As these three guys remain slack until the mast is vertical, care should be taken when laying them out on the ground that no kinks develop in them as the mast is raised.

The side guys are dealt with in the same manner but, on being shackled to the side pickets, they must be adjusted to take up the slack with the mast straight on the ground and passing close to the back picket.

Derrick Tails

The derrick tails consist of an assembly of three (or two for the Type 34 mast) short lengths of wire rope terminating in a common ring and link. The free ends are spliced to an adjuster clamp screw. They are temporarily attached by the clamps to the front guys during the erection of the mast, and until such times as the guys can be secured to a picket and suitably adjusted after the mast has been raised to the vertical position. The tails are connected by the link to the derrick coupling and laid out in the direction of the mast.

The front guys are then attached to the mast, but instead of the bottom ends being looped and attached to the picket, they are clamped to the derrick tails. The guy is also secured to the tail by its loose clamps to give added grip and to facilitate adjustment of the length of the guy.

Note: *It is most important that all clamps on the tails are screwed up very tightly. The ends of the guys attached to the derrick tails must* **NOT** *be looped and secured by the loose clamp; this would seriously reduce the grip of the clamp.*

The derrick tails should be clamped to the guys with the bottom guy to the bottom tail, the middle guy to the middle tail and the top guy to the top tail, to prevent twisting of the guys during erection. Fig 14.10 shows the derrick tails attached to the top of a derrick.

Each tail should be adjusted for the same tension to ensure that, when the mast is being raised, each front guy is carrying the same load.

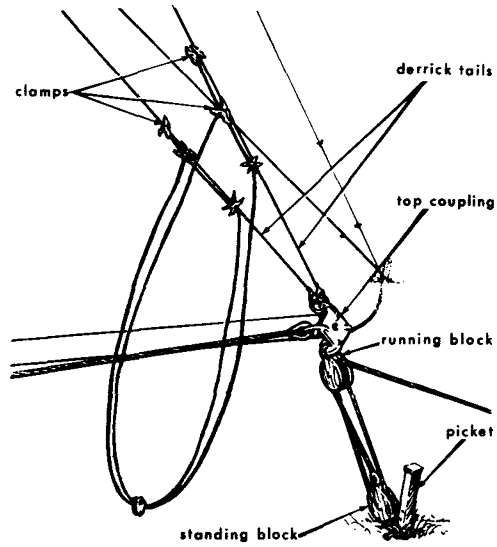


Fig 14.10 Derrick tails

The derrick side guys (manilla rope) are now attached to the side hooks of the derrick coupling (Fig 14.10). The top of the derrick is close to one of the mast side guys pickets and the appropriate side guy of the derrick should be attached to this picket in a hole above that in which the mast side guys are shackled. The remaining derrick side guy is laid out in the direction of the other mast side picket.

Attach a two-sheave pulley block, by means of a shackle to a hook of the derrick finial (Fig 14.10), and attach a single sheave block to the picket intended for the mast front guys and which, until this time, has had nothing attached to it.

If a halyard is required on the mast, the halyard pulley block should be fitted to one of the swivel hooks on the mast finial and the halyard rove through the block. The halyard should be arranged on the required side of the mast, usually the top side, and its lower end should be secured to the lower end of the bottom 'cigar'. Join the free ends of the halyard together to prevent it from unreeving from the block as the mast is erected.

Attach the antenna back guy on the finial swivel (if required) and lay it on the ground where it will not foul the other guys during the erection of the mast. No antenna back guy is required on the Type 34 mast because it has a different finial to which is bolted an antenna arm or crosstree.

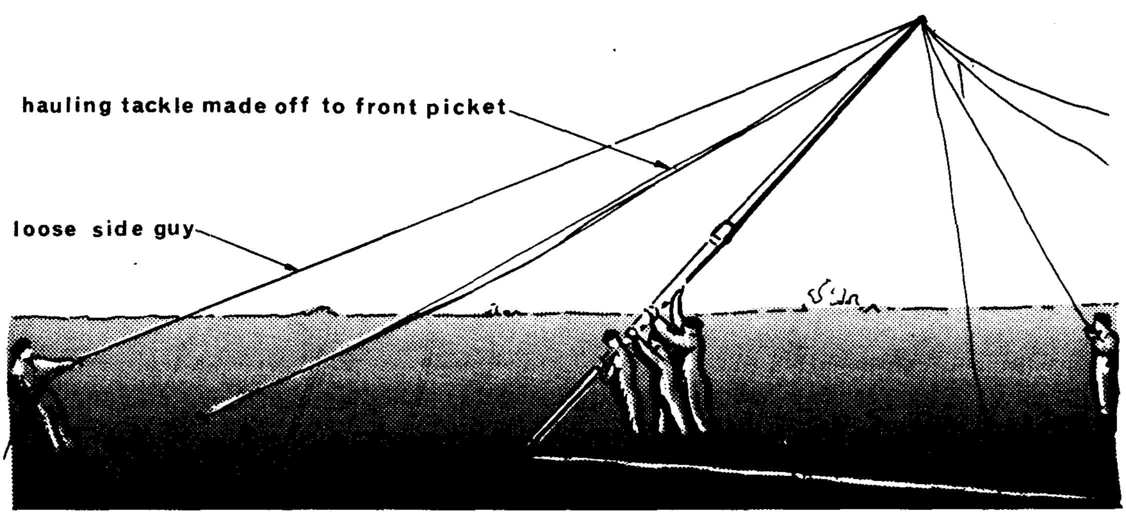


Fig 14.11 Erection of Derrick

Erection of Derrick

Before attempting to raise the derrick, check over all the clamps, pickets and connections to ensure that they are secure. Verify that the bridge base plate (Fig 14.5) to which the derrick base plate coupling is affixed, is in the vertical position.

One man holds the rope of the hauling tackle, takes up the slack, and secures the rope to the front picket. Three men then lift the derrick at its upper end and walk slowly forward towards the base pushing upwards as they move forwards, so that the derrick swings on its base pivot towards the vertical position. At the same time one man (left hand man in Fig 14.11) takes the loose side guy rope and hauls on it walking backwards towards the picket to which it will be attached while another man holds the opposite side guy rope taut to steady the derrick (right hand man in Fig 14.11).

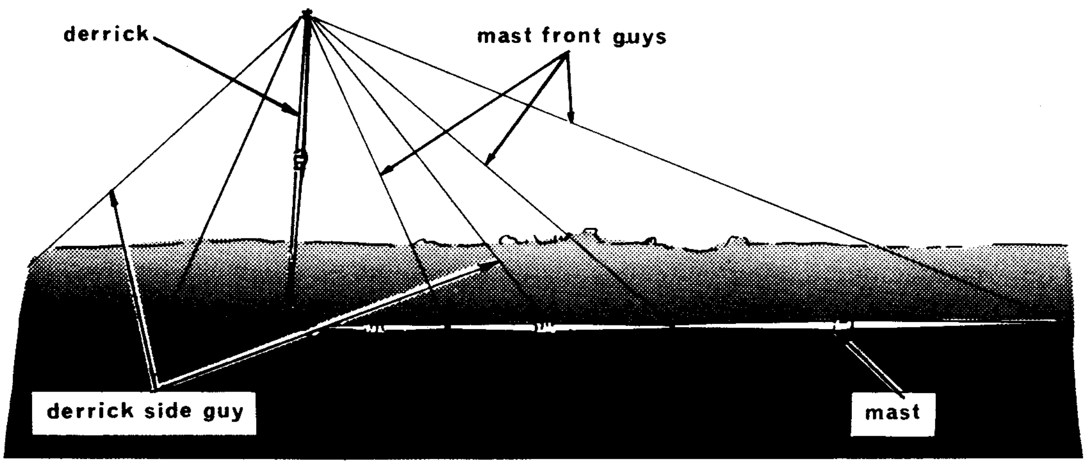


Fig 14.12 Derrick raised

When the derrick is vertical, the rope guys must be attached to their pickets and then adjusted to keep the derrick vertical (as viewed from the picket to which the pulley block is attached). When viewed from the side, the derrick should be inclined slightly towards the mast. Fig 14.12 shows the derrick and mast prior to raising the mast.

Erection of the Mast

Six men are required to haul on the rope of the hauling tackle (Fig 14.13) at the initial stage, with one man in charge (positioned by one of the side pickets). The mast should be elevated until its finial is two feet from the ground when the side mast guys must then be checked and adjusted as necessary. The front guys must be checked to ensure that the load is evenly shared between them. When all these conditions have been met, hauling can be resumed and continued until the mast is at an angle of about 45 degrees to the ground.

Note: *The derrick must be lowered to enable the tension of the front guys to be adjusted.*

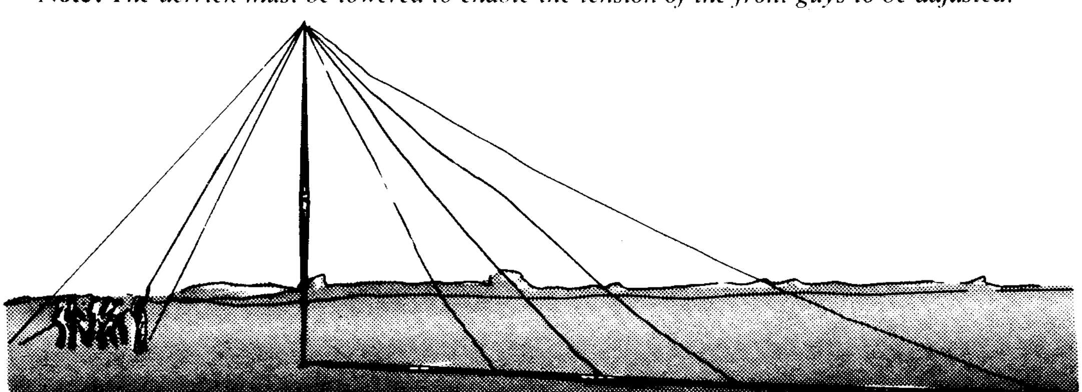


Fig 14.13 Initial stage of raising the mast

Three of the men on the hauling tackle must now move round and each take one of the back guys which are hanging loose. While they hold their guys taut, hauling of the derrick is resumed. The mast should be elevated very slowly, with a series of long steady pulls and, as it nears the vertical position, the men holding the back guys must keep them taut enough to prevent the mast from overswinging the vertical position (Fig 14.14).

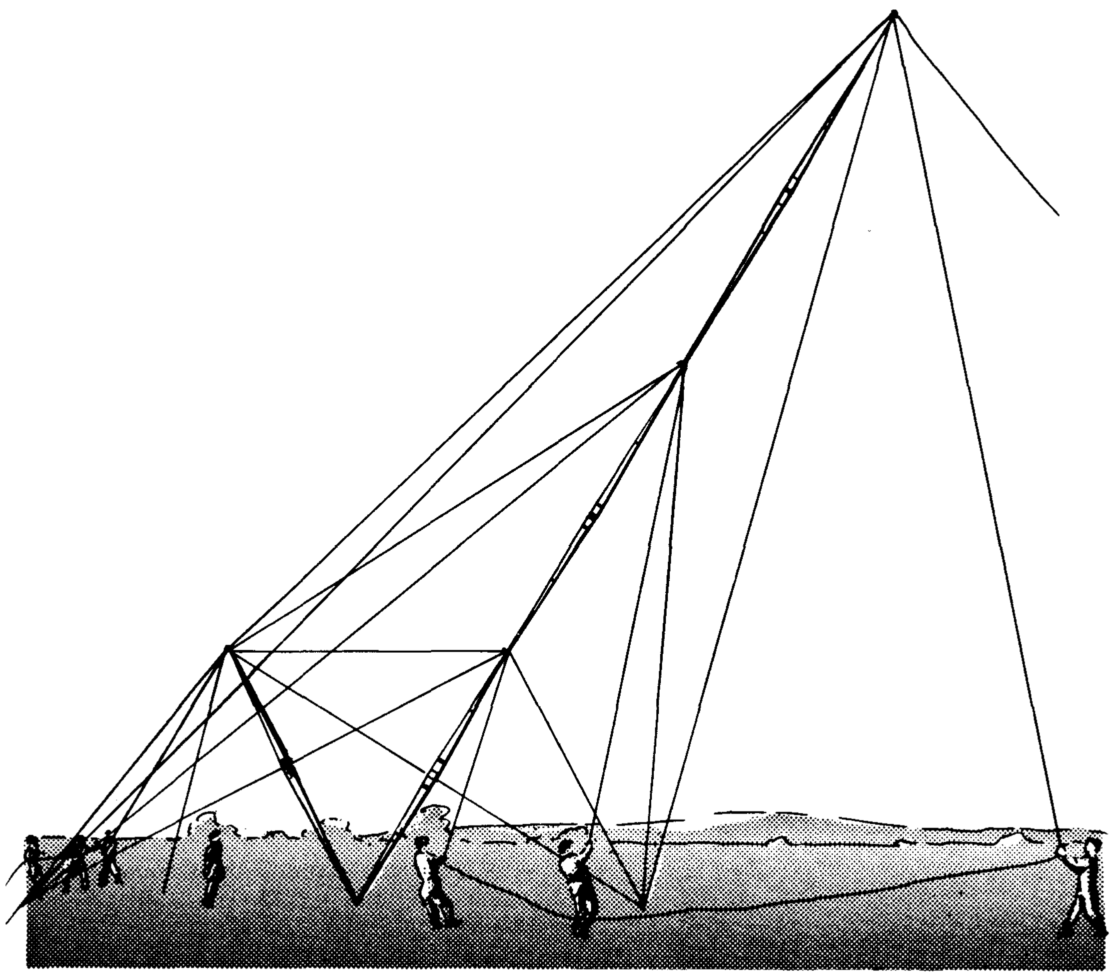


Fig 14.14 Mast partly raised

The man in charge must at all times keep a careful watch on the side guys to ensure that they do not become either too slack or too taut. This is most important when the mast site is not level. If he notices anything incorrect he should immediately stop the hauling operation and rectify the fault.

Note: *It is important to ensure that, once the mast is off the ground, adjustments are made by loosening only one clamp at a time. On no account may both clamps of a guy be loosened at the same time.*

If the mast has to be erected on boggy or sandy ground and the base shows signs of moving during the course of erection, steps must be immediately taken to check the movement. This may be done by driving in a picket in front of the base plate or by burying a baulk of timber. If a picket tends to become loose in the ground, a second picket must be driven into the ground about 600mm (2ft) behind the loose picket and the top of the loose picket lashed to the second picket at ground level. In very bad cases a third picket can be added in a similar manner.

As soon as the derrick reaches near horizontal, the ends of the guys hanging from the derrick tails should be looped and shackled to the front picket and properly secured. After this is done the tails should be unclamped from the guys so that the derrick can be lowered to the ground.

Note: *The three guys must be attached to the front picket before removing the tails because, under certain conditions, two men cannot hold a guy against the tension on it and it will be pulled from their grasp with serious consequences.*

The derrick side guys and hauling tackle should now be removed from the derrick and from the pickets. The derrick is then uncoupled from the derrick coupling on the mast base plate. If other masts are to be erected in the vicinity, the derrick should be removed complete to the next mast site. If, on the other hand, the derrick is no longer required, it should be dismantled as described on page 14.11.

Adjustment of the Guys

The mast should now be adjusted to the true vertical position by means of the guys. First, the bottom 'cigar' is made vertical by adjusting the bottom set of guys. Next, the middle 'cigar' is adjusted, and finally the top 'cigar'. An inspection of the guys should be made before commencing these adjustments, as it may be found that the top guys will have to be slightly altered before the bottom 'cigar' can be made vertical. The final adjustments, however, must be made from the bottom 'cigar' upwards.

The antenna back guy must now be positioned. The picket can be driven into the ground as far from the mast as possible, provided a loop of about 762mm (29·6in) is left in the guy to allow for future adjustment.

Finally, check that all the pickets are secure in the ground and that all guy adjusting clamps and picket shackles are screwed up tightly.

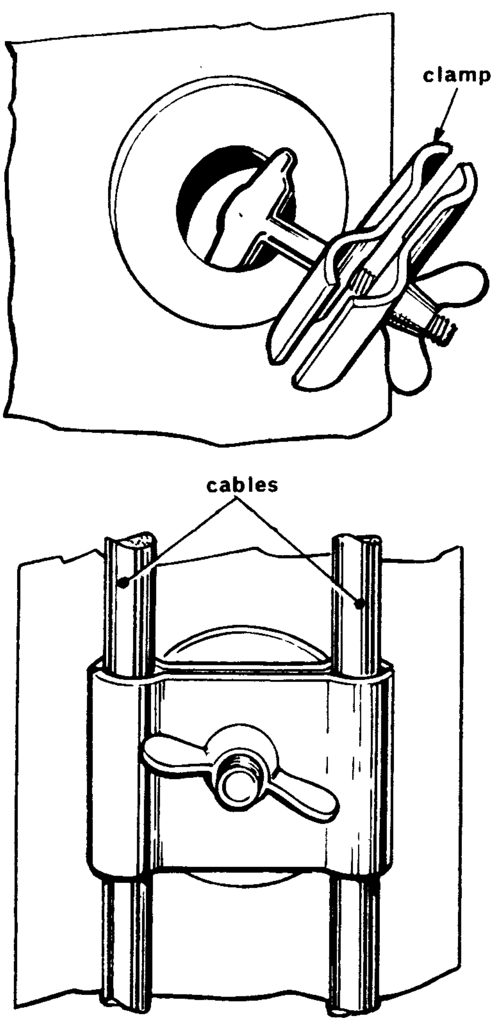


Fig 14.15 Cable clamps

Type 34 Mast

The preceding instructions apply to both the Type 23 and 34 masts. There are, however, some slight variations in the Type 34 mast, apart from the fewer number of guys required. An antenna arm is bolted to the finial of the Type 34 mast (Fig 14.1), and this must be fixed in position when the mast is on the ground. The co-axial cables from the antenna are led down the mast and secured in six special clamps (Fig 14.15). Each clamp is fitted into one of the reinforced holes in the mast section and the wing-nuts tightened to secure the whole assembly to the mast.

Routine Checks

During the first few weeks after the mast has been erected, the guys must be checked at frequent intervals, particularly after strong winds, and any slackness due to stretching of the guys, settling down of the mast sections or slight movement of the mast base plate or pickets must be taken up. The screws of the clamps should be well greased. Metal parts (mast and mast components, including stays and guys) are to be treated with anti-corrosive paint.

DISMANTLING

Lowering the Mast and Derrick

To lower the mast, the derrick must first be re-assembled as described on page 14.7, fitted to its coupling on the mast base plate, and laid on the ground with its top coupling close to one of the front guy pickets. The rope guys are then fitted and adjusted. The hauling tackle is then fitted and the derrick tails attached to the front guys. The front guys can now be disconnected from the picket.

When all the clamps are secure, three men must hold the rope of the hauling tackle while three men pull on the back guys to start the mast moving downwards. When the mast is at an angle of about 60 degrees to the horizontal, the three men on the back guys must be transferred to the hauling tackle rope.

The man in charge must keep a careful watch on the side guys to ensure that they do not become too tight or too loose. The lowering of the mast should be immediately halted if any adjustments become necessary. The side guys should be just sufficiently tight to check any tendency of the mast to move sideways.

When the mast is on the ground, the derrick should be lowered in the reverse order to that in which it was erected. The halyard and guys should be detached and carefully wound on to their correct spools using the spool winding frame. The link plate of the guy can be fitted inside either of the spacer pieces on the spool, by inserting it diagonally and twisting it to the opposite diagonal to lock it in position.

Separation of the Sections

The dismantling unit (Fig 14.16) is used to separate the 'cigar' sections. The pins of the unit are inserted into the reinforced holes of the sections. One pin is adjustable so that the lever of the unit can lie in the vertical position to commence the separating action (Fig 14.17). The pin should be tightened with a tommy bar so that its shoulder is hard against the slide box.

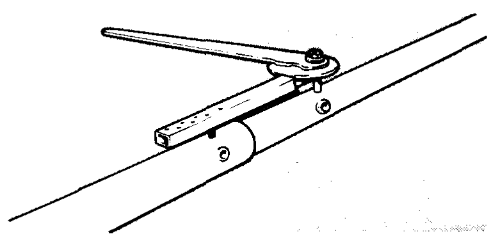


Fig 14.16 Dismantling unit

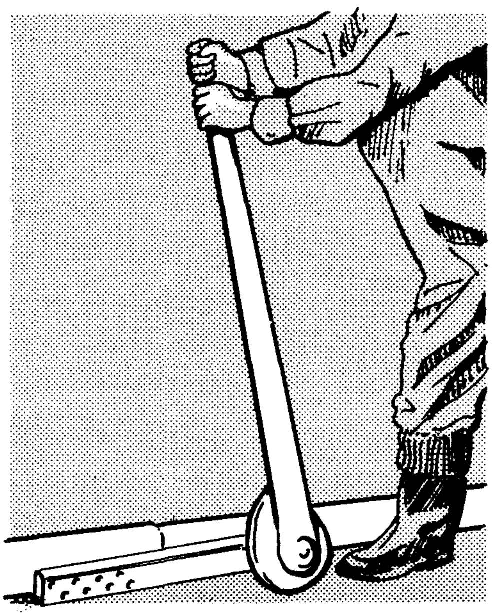


Fig 14.17 Separation of sections

Should the sections have jammed together, excessive force should not be applied to the dismantling unit, as this might bend the lever. The jammed sections should be tapped at their junction with a solid block of wood and a further attempt made to separate them. The dismantling unit can also be removed and inserted in the holes on the other side of the sections and a further attempt made to separate the sections. If two dismantling units are available, they should be inserted in the holes on opposite sides of the sections and operated in unison. It is essential that adequate grease is applied to the sections during assembly (page 14.4) to reduce the possibility of the sections jamming in this manner.

When all the sections are separated they can be nested inside each other. The pickets are loosened in the ground by tapping sideways with a sledge hammer and pulling out by hand; in difficult cases, they can be dug out. The base plate pickets are also removed by tapping them loose in the ground.

Summary of Procedures

Assembly

- Mark out the site using the peg marker.
- Fix the mast base plate in position.
- Position the pickets.
- Lay out the mast and derrick sections.
- Grease tapered ends and join sections together.
- Couple the 'cigars' together and to the base plate coupling.
- Fit finials.
- Attach back guy and side guys to mast and pickets.
- Attach front guys to derrick tails.
- Attach derrick side guys to derrick and one of them to a picket.
- Attach hauling tackle.
- Fix halyard pulley block with pulley and back stay (if required).

Erection

- Check all connections and clamps and make certain that all are secure.
- Swing derrick to vertical position.
- Attach second derrick side guy to picket and adjust both guys.
- Haul mast to vertical position.
- Attach guys on derrick tails to picket before releasing tails from guys.
- Remove derrick side guys, hauling tackle and derrick.
- Adjust mast guys until mast is vertical.
- Drive in picket for back guy if needed and attach and adjust.

Dismantling

- Reverse the procedure for erection.
- Attach tails to front guys and place men on the hauling tackle rope before removing guys from pickets.
- Keep tension on back guys when lowering during the first 30 degrees of mast movement.
- Slacken or tighten side guys as necessary.
- Use dismantling unit to separate the sections.
- Nest the sections and spigots and store away.

ANTENNA MAST TYPE S11/1

Introduction

The antenna mast Type S11/1 (Fig 14.18), is a lightweight tubular antenna mast with an erected height of 24·4 metres (80ft). It is supported in its vertical position by guys made of plastic impregnated steel wire rope secured to four ground anchors equally spaced on a radius of 12·2 metres (40ft) from the mast base.

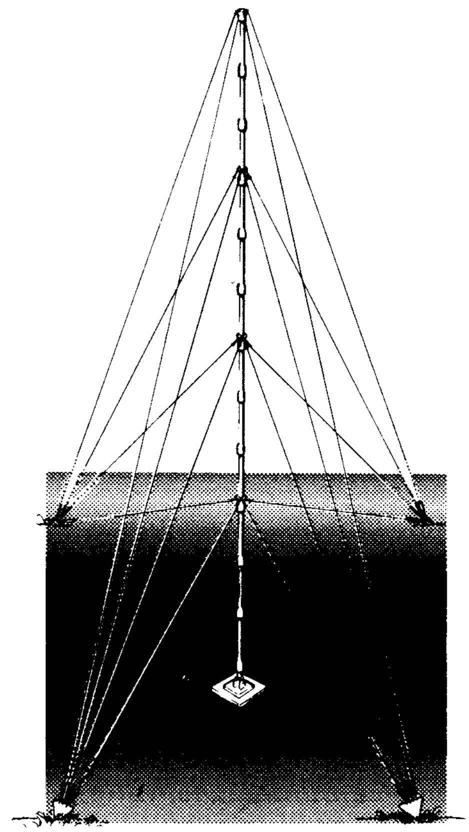


Fig 14.18 Antenna mast Type S11/1

Description

The mast is assembled from twelve identical mast sections, each section consisting of a length of aluminium alloy tubing of 114·3mm ($4\frac{1}{2}$ inches) outside diameter and 2·2 metres (7ft $6\frac{1}{2}$in) long. The tube is swaged (enlarged) at one end to form a socket 220mm (9in) deep, allowing sections to be assembled to produce a mast of the required height.

The other components used with the Type S11/1 mast are as follows:

- **Mast head cap.** The cap is a light alloy casting designed to fit over the unswaged end of the top mast section. The casting embodies the necessary lugs for the attachment of the upper mast guys (Fig 14.23).
- **Mast guy attachments.** The attachments are cast in the form of an alloy circular sleeve with projecting lugs for the attachment of the intermediate and lower guys. They are designed to slide on the appropriate mast section and rest on the swaged portion of the tube. For the S11/1 mast, the mast attachments rest on the swaged portions of the fourth, seventh and tenth sections from the mast base (Fig 14.23).
- **Heel plug assembly.** This assembly (Fig 14.22) plugs into the swaged end of the lowest mast section and is the means by which it is assembled to the mast base assembly.
- **Shoulder bolt.** This bolt (Fig 14.20) is an 8mm ($\frac{5}{16}$in) diameter shouldered bolt used in conjunction with a $\frac{5}{16}$inch BSW nut to secure the mast heel plug to the mast base assembly. The bolt acts as a pivot for the bottom of the mast during erection operations.
- **Mast base assembly.** This is a light alloy square plate with integrally cast twin lugs drilled to accept the shoulder bolt when the heel plug is attached. The plate is drilled at each corner to facilitate bolting to a prepared ground anchorage or securing to the ground by the use of tent pins (Fig 14.22).
- **Mast guys.** The guys are made from 6mm ($\frac{1}{4}$in) plastic impregnated steel wire rope, the rear and side guys being formed in one complete length, whilst the front guys have a steel ring inserted at varying distances from the lower end of the guy. These specially constructed guys are those used for attachment to the derrick head cap, during erection and lowering operations.

- **Spreader plates.** These spreader plates (Fig 14.19) are triangular in shape with one hole at the apex for securing the plate to the anchorage points. Four holes at the base of the plate provide securing points for the rigging screws and chains.
- **Rigging screws and chains.** The rigging screws and chains (Fig 14.19) are used between the ends of the mast guys and the spreader plates. The galvanized long-link 9·5mm ($\frac{3}{8}$in) dia chains are each 1·8 metres (6ft) long with one end shackled to the lower end of the guy by 9·5mm ($\frac{3}{8}$in) 'dee' shackles (*see* Chap 11) and shackle pins. After the mast has been erected, adjustment is made to the guys by selecting alternative links on the chain and tightening the rigging screws
- **Retaining strap.** The strap is made from light alloy strip, semi-circular in form, two straps being bolted together to encircle the appropriate mast section (Fig 14.23). The pair of straps are secured by two hexagon head $\frac{3}{8}$ inch BSW bolts, nuts and washers.
- **Guy anchors 1·07 metres (42in).** These ground anchors are of the helical plate type (Molex), which are driven into the ground by a screwing action. The anchors are used for guy anchorages on *temporary* installations, normally one anchor for each anchorage point (Fig 14.19).

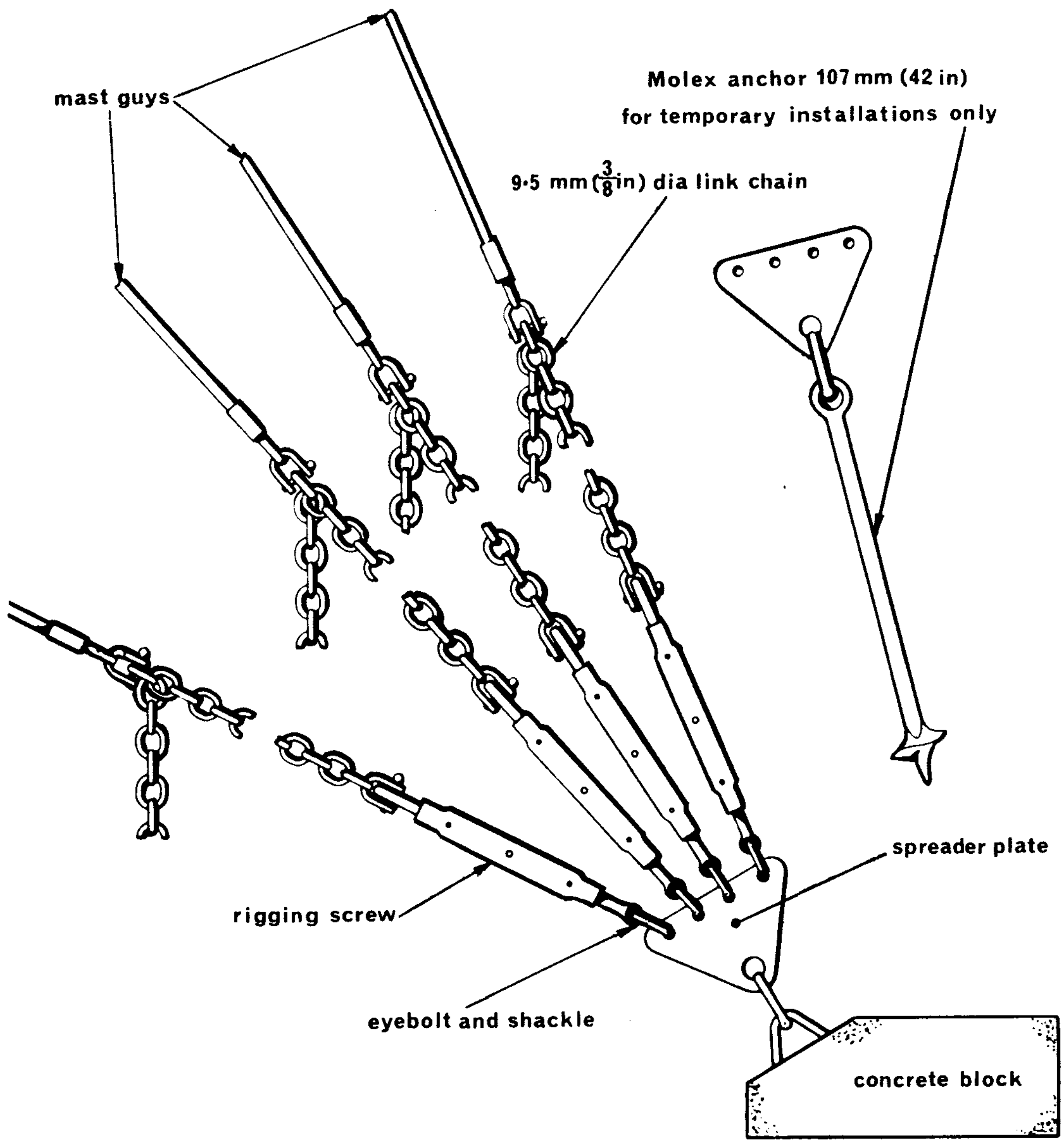


Fig 14.19 Anchoring mast guys

Antenna Mast Erector Type S7/1

The antenna mast erector consists of a derrick, assembled from three mast sections, a derrick head cap, heel plug assembly and derrick retaining straps. The derrick head cap is designed with the necessary lugs for securing the shackles for attaching the derrick side guys, the mast guys and the moving block of the erector tackle. The assembled derrick is attached to the main mast by means of retaining straps, to which the derrick heel plug is secured by the derrick shoulder bolt. The retaining straps are bolted together round the swaged portion of the bottom mast section, just above the mast heel plug (Fig 14.20).

Other equipment supplied with the antenna mast erector are two Type 36 pickets, 762mm (30in) Molex anchors, shackles and shackle pins, side guys and fall rope of 38mm (1½in) circumference polyester rope and two 102mm (4in) treble sheave blocks.

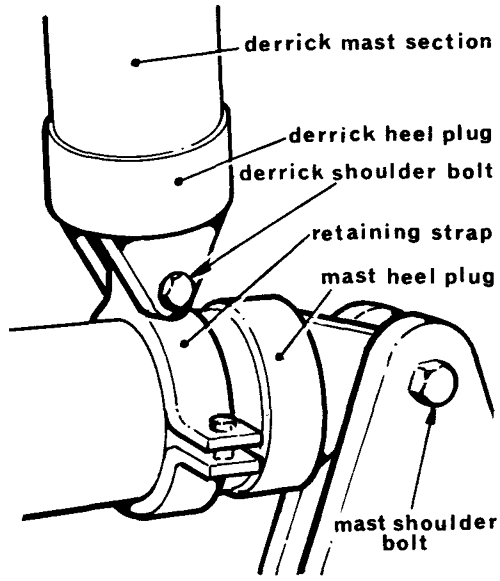


Fig 14.20 Derrick heel attachment

The Type 36 pickets are used to secure the free ends of the derrick side guys and are positioned 9·1 metres (30ft) either side of the mast base assembly on a line at right angles to the assembled mast (Fig 14.21). The Molex anchor (762mm long) is inserted 9·1 metres (30ft) forward of the mast base assembly and is used to secure the standing block of the tackle, the moving block being shackled to the derrick head cap. The hauling end of the fall rope is laid out from the standing block in a direction opposite to that of the mast base and made off to the main mast front guy anchor.

Mast Erection

Where the Type S11/1 mast is to be erected for a permanent installation, the site will have been prepared and concrete blocks provided for the mast base and guy anchorage positions. For temporary installations, the site must be cleared as necessary, the mast base and guy anchor locations marked (Fig 14.21), guy anchors 1067mm (42in) inserted at the four mast anchor positions and the Type 36 pickets used with the erector equipment, located and inserted.

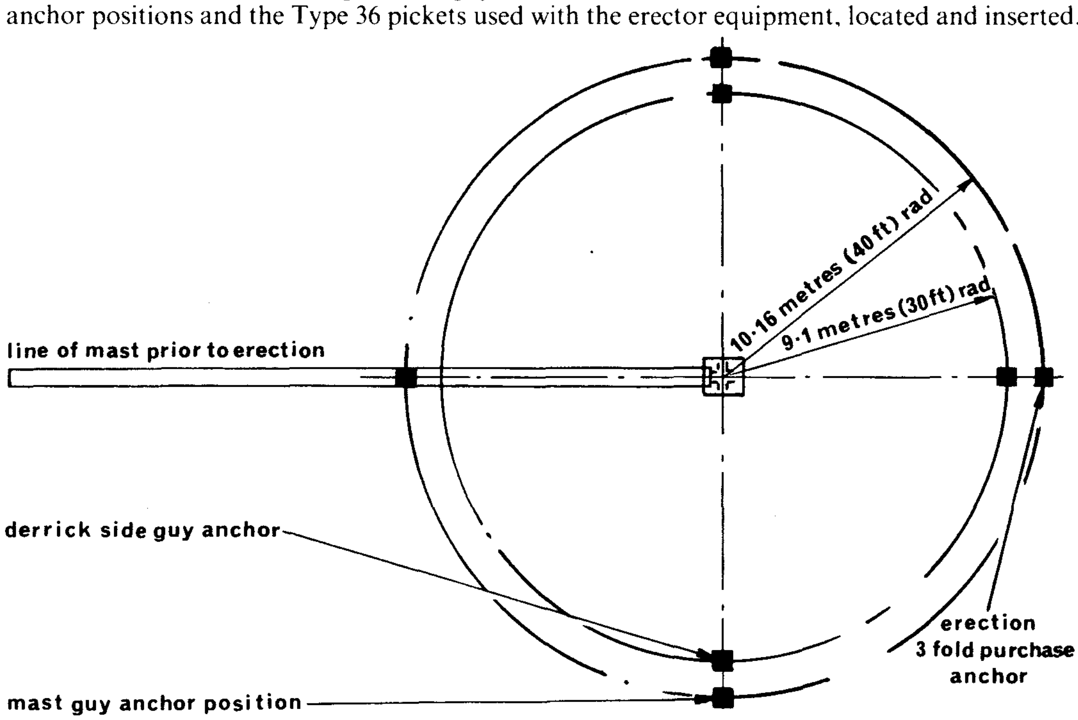


Fig 14.21 Guy anchor location

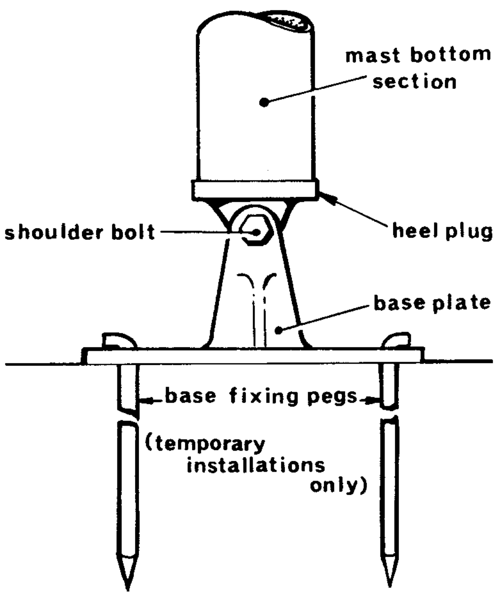


Fig 14.22 Base plate and heel plug assembly

Secure one spreader plate to each of the four anchorage points using 16mm ($\frac{5}{8}$in) harp shaped shackles and shackle pins. Loosely assemble four 'dee' shaped shackles together with $\frac{3}{8}$in BSF shackle pins to each of the four spreader plate holes at the side and rear anchorage points, and similarly assemble four shackles to the derrick head cap.

Bolt the mast base assembly to the concrete base, after coating the contact face with 'Detel' EP paint or an approved equivalent. For temporary installations, secure the mast base assembly with four tent pins (Fig 14.22). The subsequent erection procedure is given in the following sub-paragraphs and applies to both temporary and permanent installations. An erecting party of a supervisor and six men is required.

- The mast and derrick are assembled on the ground and, in the following operations, the upper side of the mast will be referred to as the front and the underside as the rear.
- Secure the mast heel plug assembly to the mast base using the shoulder bolt and $\frac{5}{8}$ inch BSW nut with the heel plug resting on the mast base in the direction of the rear guy anchor.
- Assemble four mast sections with the swaged end of the first section fitting over the heel plug and the remaining sections added in the direction of the rear guy anchor. Slide a mast guy attachment on the fourth section to rest against the swaged end.
- Add a further three mast sections and slide a guy attachment on the seventh section. Assemble three more mast sections, sliding a guy attachment to the tenth section and finally add the two remaining sections and fit the mast head cap. Bolt the mast retaining straps to the top mast section just below the mast head cap. During assembly support the mast approximately 150mm (6in) off the ground on blocks at the guy attachment positions (Fig 14.23).
- Loosely assemble the derrick retaining straps to the swaged portion of the first mast section using the two stainless steel $\frac{1}{2}$ inch BSW 50mm (2in) long bolts, nuts and washers provided with the erector.
- Using the derrick shoulder bolt and $\frac{5}{8}$ inch BSW nut, secure the derrick heel plug assembly to the derrick retaining straps (Fig 14.20), with the heel plug resting in the required direction for the assembly of the derrick mast sections. Assemble three mast sections with the first section fitted over the derrick heel plug and the derrick head cap fitted to the third section with the shackles in the upper or mast side of the derrick. On completion of the assembly, the angle between the derrick and the mast should be slightly less than a right-angle.
- Secure the moving and standing blocks of the erector tackle to the underside lug of the derrick head cap and downhaul anchor respectively, using 9·5mm ($\frac{3}{8}$in) 'dee' shaped shackles and shackle pins, laying out the fall rope as necessary. Secure the eye ends of the side guys to the side lugs of the derrick head cap with 9·5mm ($\frac{3}{8}$in) harp shaped shackles and shackle pins and lay out the side guys to their respective Type 36 pickets (Fig 14.23).
- The mast guys are colour coded with plastic tubing according to their mast attachment positions as follows:

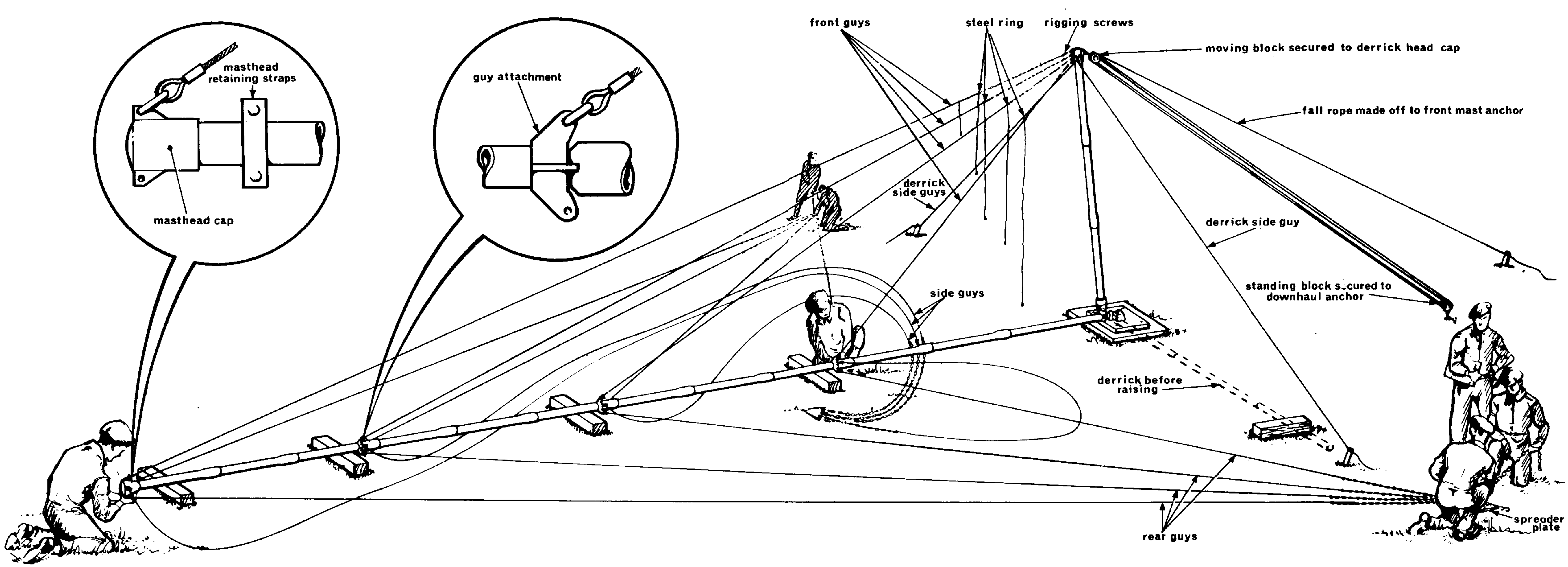


Fig. 14.23 Mast raising—Initial stages

Top mast guy	red
Upper intermediate mast guy	blue
Lower intermediate mast guy	yellow
Bottom mast guy	green

The ends of the guys are connected to their respective guy attachments and mast head cap using 'dee' shackles and 9·5mm (⅜in) shackle pins (Fig 14.23).

Note: *If a back guy is to be used with the mast for any particular antenna installation, it should be attached to the mast head retaining straps at this stage.*

- Secure the rear guys to their respective spreader plate at the rear anchorage by means of the chains, rigging screws and shackles provided, laying them out to avoid entanglement and allowing about 2·1 metres (7ft) of slack in the standing part of the guys. Attach both sets of side guys to their respective spreader plates again using chains, rigging screws and shackles and adjust each guy to a light tension.

- Using the chains and rigging screws with 'dee' shackles and ⅜ inch BSF shackle pins, secure the front guys to the derrick head cap. Shackle one end of the chain to the steel ring on the front guy allowing the short strap to hang loose and secure the rigging screw between the other end of the chain and the derrick head cap (Fig 14.23). Ensure that the guy chains are correctly located on the derrick head cap. Tension the guys sufficiently to maintain an angle of about 80 degrees between the mast and the derrick with the intermediate and bottom guys under tension to induce a sag into the mast during erection. Take up any slack in the rope between the tackle blocks and secure the hauling end to the mast front anchor.

- Three men are required to raise the derrick to its perpendicular position and one man is situated at each derrick side guy to haul or steady according to the direction of the lift. The three men lift the derrick head and continue to lift whilst walking slowly towards the mast base and the man on the appropriate side guy hauls to assist the lift. When the derrick has been raised and the side guys made off to their respective pickets, ensure that the derrick is inclined towards the mast at about 10 degrees from the vertical (viewed from the side) and vertical when viewed from the standing block anchor.

- Raising the mast is achieved by four men hauling on the hoisting rope whilst the remaining two men make the necessary adjustments to the side guys during lifting (Fig 14.24). Raise the mast clear of the supporting blocks and check that the front guys have been adjusted to allow the mast to sag at the centre. After any adjustments, tighten the derrick retaining straps at the base of the mast.
- The supervisor must control the mast-raising operation, ensuring that the operation is stopped and the hauling rope tied off in order to release more men when adjustments become necessary. The hauling party should pull steadily and be ready to stop pulling and tie off the hauling rope when instructed by the supervisor. As the mast rises, the hauling effort required will reduce and, when the mast is about 30 degrees from the vertical, one man may be released from the hauling party to carry out adjustments at the rear guys during the final stages of erection.
- When the mast is vertical and the derrick has completed its full travel, one man should bear down on the derrick head while the rear guys are adjusted and secured. Transfer the front guys from the derrick head cap to the front anchor spreader plate, one at a time, starting with the top guy and working downwards. Release each guy in turn, removing the chain rigging screw and shackles from the derrick head cap and guy steel rings. Transfer the free end of the chain to the lower end of the guy short strap and the rigging screw end of the chain to the appropriate hole in the spreader plate, selecting a link that will fully extend the guy. Make final adjustments with the rigging screw.
- After the transfer of the front guys, adjust the guys to straighten the mast and equalize guy tensions with a suitable tensiometer used with the wire part of the guy. On completion of all adjustments the mast must be vertical, straight and rigidly supported. Finally, check the security of all guy and chain attachments, shackles and shackle pins including spreader plate anchorage securing shackles.
- Dismantle the erector equipment and detach derrick retaining straps from the mast. If required, transfer the equipment to another site for the erection of a similar mast.

Routine Checks

After erection, frequent checks must be made of the anchors and guys, particularly the anchors used for temporary installations, which should be checked for security of guy attachment and movement of anchors. The guys should be regularly checked for slackness, preferably by tensiometer. Greasing should be limited to the threaded mast components, *ie* shackles and pins, rigging screw threads, shoulder bolts. Damaged protective surfaces should also be greased. Grease should be used sparingly.

Dismantling

When dismantling the mast, the erection procedure is reversed and the Type S7 1 antenna erector used for lowering the mast. The derrick should be clamped to the mast as described on page 14.16, the Type 36 pickets and molex anchor located and inserted, and the side guys and hauling tackle attached as described on page 14.16. The hauling end of the fall rope should be made off to the front guy anchor after taking up the slack between the tackle blocks. The derrick retaining strap bolts should be tight.

Ease the tension in all guys and with one man bearing down on the derrick head, transfer the front guys singly from the spreader plate to the derrick head cap, starting at the bottom guy and working upwards. The supervisor should control the lowering operation in the same manner as for the erection and be ready to stop the procedure at any time. The men should initially be stationed with two men on the hauling end of the tackle rope and one man stationed at the rear guys with this man pressing on one of rear guys to start the lowering operation until the weight of the mast begins to act. He should then join the men on the fall rope. The men stationed at the side guys for adjustment purposes should position the supporting blocks as the mast nears the ground.

If the mast is to be re-erected within a short space of time it is convenient to leave the smaller components, *ie* spreader plates, shackle and pins together with their securing hardware, in their assembled condition. Similarly, the retaining straps could remain attached to their appropriate mast section. After the dismantling of the mast the shoulder bolt should be reassembled to the mast heel plug. The mast guys should be disconnected from the mast guy attachments and from the shackles at the anchor end and neatly coiled. The mast sections should be detached and carefully stowed to avoid damage and distortion. If the mast sections tend to stick together they can be separated by a few light taps with a wooden block. The mast guy attachments, head cap and heel plug should be detached from their mast sections and strung together for transit.

If the anchorage points are permanent, the spreader plates should be detached and the shackles and shackle pins re-assembled to the spreader plates. The same procedure will apply to temporary installations except that, after detachment of the spreader plates, the molex anchors are withdrawn and cleaned.

If the mast is not to be re-erected, it should be completely dismantled.

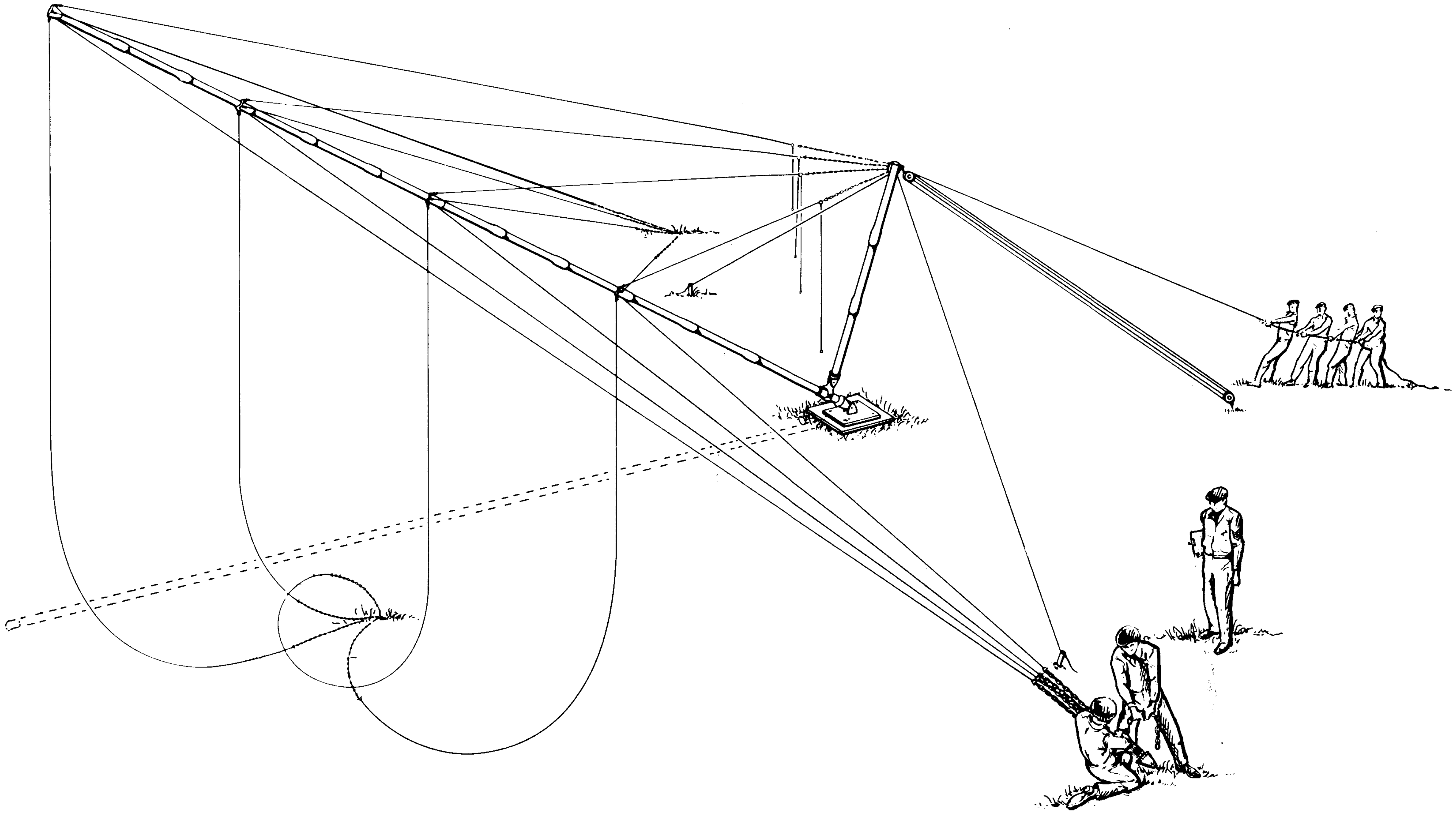
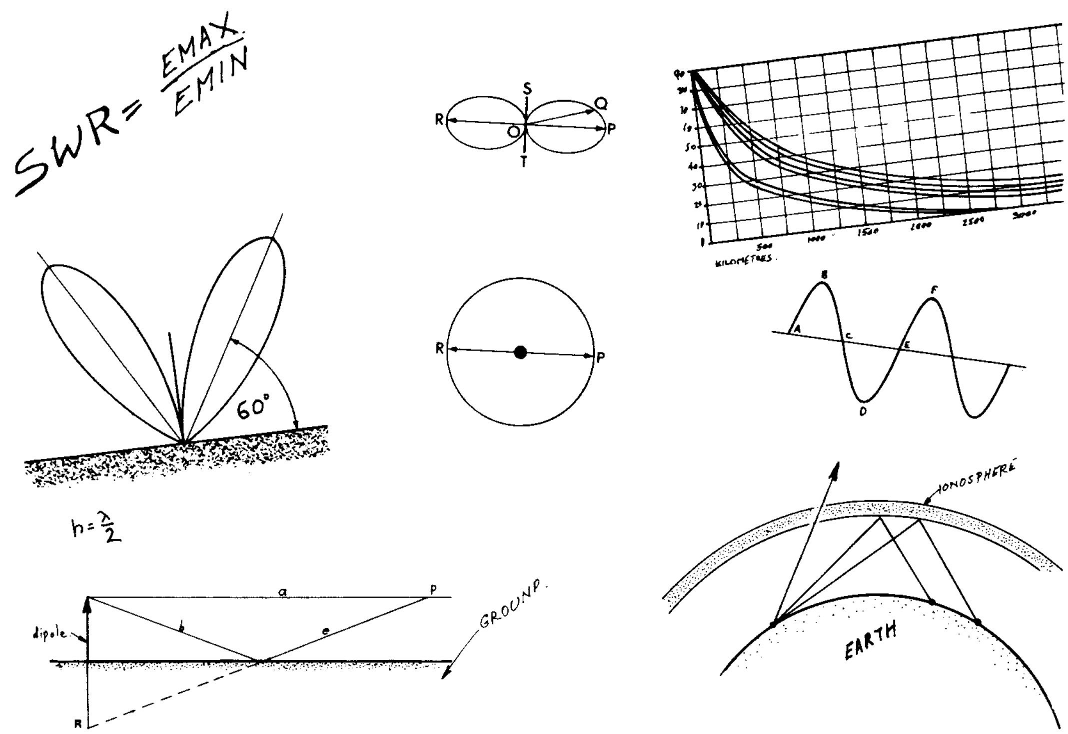


Fig 14.24 Mast raising—Interim stages

CHAPTER 15

ANTENNA THEORY



Introduction

An antenna is one of the essential components of a communication system which uses radio waves to transmit and receive information. In the simple system outlined in Fig 15.1 you will see that the antenna forms the link between the transmitter and the receiver.

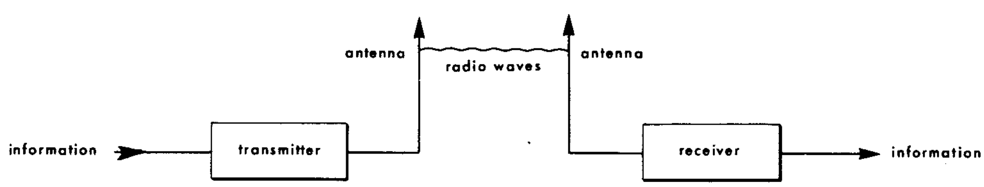


Fig 15.1 Basic communications system using radio waves

In the same way that a microphone converts sound waves into electrical signals and a loudspeaker converts these electrical signals back into sound signals, so an antenna is required to convert electrical signals into radio waves and *vice-versa*.

Radio Waves

Radio waves are a form of *energy*. There are many forms of energy, *eg* electrical energy (electric fire), chemical energy (battery), mechanical energy (car engine), and so on. Radio waves belong to another energy group—that of *electromagnetic energy*. All forms of 'radiation' belong to the electromagnetic energy group. It contains not only radio waves, but light, ultraviolet rays, infra-red rays, gamma rays (from atomic radiation) and cosmic rays (from outer space).

Although radio waves, light, X-rays and so on are all examples of electromagnetic radiation, it is clear that radio waves, for example, are different from X-rays. In what way do they differ? The answer to this question is simply that their *wavelength* is different. This prompts the question, 'What is meant by the term wavelength?'

Wavelength

We have probably used the term 'wavelength' without really appreciating the meaning of the term. When we tune into Radio 2 on our transistor radio we turn the tuning control to a wavelength of 1500 metres. A radio signal, like all forms of electromagnetic energy, is radiated as a wave. If we draw a graph of this waveform against distance for one fixed interval of time we get the result shown in Fig 15.2.

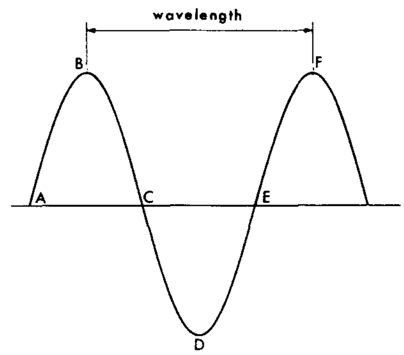


Fig 15.2 Wavelength

We can see from Fig 15.2 that the waveform passes through a definite sequence. It rises from zero to maximum in one direction and then returns to zero; it then reverses and rises to a maximum in the other direction and falls again to zero. This complete sequence of events from A through B, C and D to E is called a *cycle* and the distance from the beginning to the end of the cycle is the *wavelength* (measured in metres), and is usually measured from crest to crest of the waveform (B to F).

Frequency

A cycle can take a long time or a very short time, and the number of cycles occurring in one second is called the *frequency* of the waveform, measured in *hertz*.

If, in Fig 15.3, A to B represents a time of one second, then (a) represents a waveform with a frequency of 2 hertz, and (b) a frequency of 10 hertz. In radio communication the frequencies range up to many millions of hertz. Hertz is usually abbreviated to Hz; kilohertz (kHz) denotes so many 'thousand hertz'; megahertz (MHz), is so many 'million hertz'.

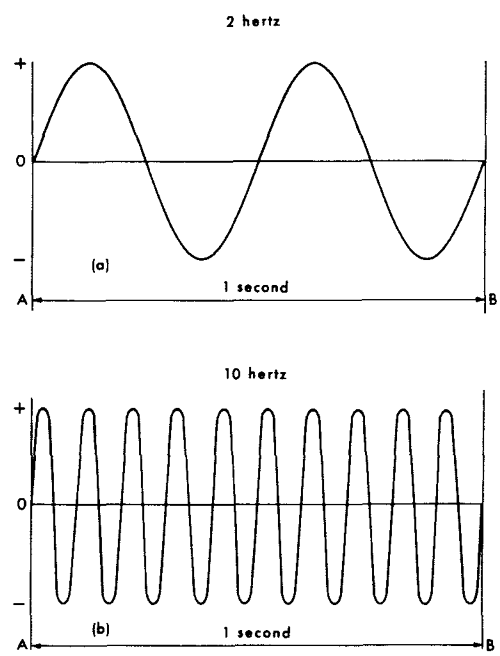


Fig 15.3 Frequency

Relationship between Frequency and Wavelength

Radio waves travel forward at the speed of light, which is 300 000 000 (3×10^8) metres per second; therefore, the distance travelled by a radio wave in one second is 300 000 000 metres. If we know the frequency of the radio wave it is easy to work out its wavelength. Let us take an example. The BBC Radio 2 programme broadcasts on a frequency of 200 000 hertz—written as 200 kilohertz or 200kHz. This means that the radio wave goes through 200 000 cycles over a distance of 300 000 000 metres; each cycle, and therefore the wavelength, is $\frac{300\,000\,000}{200\,000} = \frac{3000}{2} = 1500$ metres long. In general terms.

$$\text{Wavelength } (\lambda) = \frac{\text{speed of light (metres/sec)}}{\text{Frequency (Hz)}} \text{ metres.}$$

Radio communication takes place over a wide frequency range—from about 30kHz (λ = 10 000 metres) to about 30 000MHz (λ = 10 millimetres). For convenience, this range is sub-divided into various sub-ranges, the main ones of interest to us being:

- High frequency (hf): 3–30MHz (λ = 100–10 metres).
- Very high frequency (vhf): 30–300MHz (λ = 10–1 metre).
- Ultra high frequency (uhf): 300–3000MHz (λ = 1 metre–100 millimetres).

The hf band is used for long distance communications, and the vhf and uhf bands are for short distance communications.

Conversion of Electrical Signals into Radio Waves

Any conductor will radiate energy when fed with an alternating electrical signal and in many instances this radiation, unless it is suppressed, will interfere with the efficient operation of electronic equipment. In radio communications we are concerned with a device specially designed to give *as much radiation as possible*. When this device is supplied with electrical energy at the correct frequency, as much of this energy as possible must be converted into electromagnetic energy (radio waves). This device is known as an *antenna*.

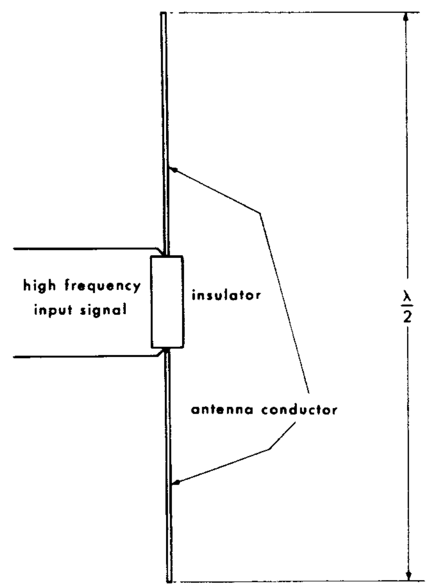


Fig 15.4 Half-wave dipole

The Dipole

The simplest form of antenna is a half-wave dipole (Fig 15.4). This antenna consists of a straight conductor half a wavelength ($\frac{\lambda}{2}$) long at the frequency of the current being carried by the antenna. For example, if the frequency is 30MHz (10 metres wavelength) a half-wave dipole for use at this frequency will be 5 metres long. As illustrated in Fig 15.4, the usual way of energizing a dipole is to break the dipole at the centre and feed in the high frequency electrical signal at this point.

Polar Diagrams

The radio wave does not spread out equally in all directions from the dipole. As shown in Fig 15.5, most of the radiation comes from the centre of the dipole and no radiation comes off the end of the dipole. The diagrams shown in Fig 15.5 are known as *polar diagrams*. The polar diagrams of the dipole show that it radiates energy in all directions (omnidirectional) in the plane perpendicular to the dipole.

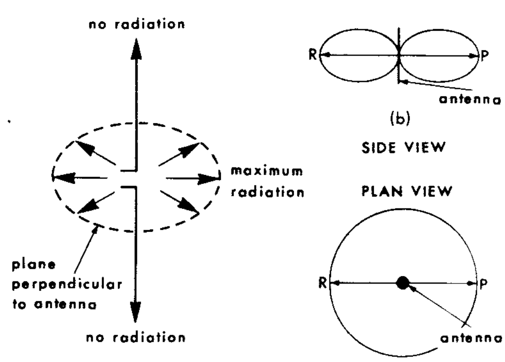


Fig 15.5 Polar diagram

Polarization. An electromagnetic radiation consists of electric fields and magnetic fields. Since these fields have direction as well as magnitude and can, consequently, only induce a voltage in a conductor if that conductor is placed in the appropriate direction to the fields, then we say that the radiation is *plane polarized*. For a dipole the plane of polarization lies along the *axis* of the antenna; a vertical dipole is vertically polarized and a horizontal dipole is horizontally polarized. Thus, if a transmitter antenna is a vertical dipole, a distant antenna would also have to be vertical in order to pick up the transmission.

Disadvantages of a Simple Dipole

The dipole is essentially omnidirectional and will, therefore, pick up all transmissions on the same frequency from every direction. However, we may wish to pick up transmissions which are sent from *one direction only*. Transmissions on the same frequency from other directions would merely confuse the issue and cause interference with the wanted transmissions. Unfortunately, the simple dipole cannot distinguish between wanted and unwanted directions of transmissions.

Also, we often require to receive transmissions on several frequencies. However, since a dipole is sensitive to one frequency only it cannot be used for this purpose.

Further Considerations

Radio waves travel in straight lines and, therefore, to ensure communications beyond the horizon, the waves have to be *reflected* in some way.

Reflections. Good conductors tend to reflect radio waves in certain situations and, since the earth and the ionized layers of the earth's atmosphere (ionosphere) are good conductors, they may prove useful to us.

- **Earth reflections.** When a dipole is supported above the earth, the earth acts as a reflector and reflects some of the radiation back into the atmosphere (Fig 15.6). The reflected radiation is in such a direction that it appears to radiate from a point vertically below the dipole and at a depth beneath the earth equal to the height of the dipole (point R in Fig 15.6). When the primary radiation meets the secondary radiation from the earth's surface (point P in Fig 15.6) they combine.

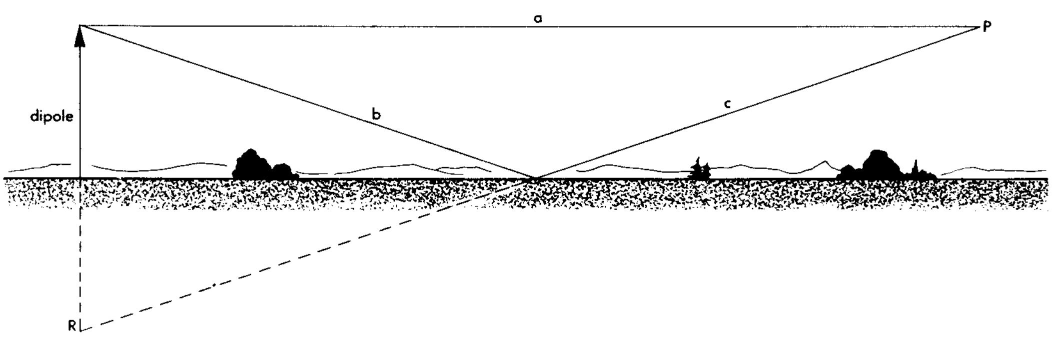


Fig 15.6 Earth reflections

If the distances a and (b + c) in Fig 15.6. differ by half a wavelength then at point P the radio waves will be *in anti-phase* and will cancel each other. If they are *in phase* at point P they will add and provide a strong signal. By plotting points P for a certain height (h) of the dipole above the ground—where the waves add, where they cancel, and at intermediate stages—we arrive at a polar diagram for the antenna at that height. The height of the dipole can be chosen so that the radiation is 'thrown' into space at any required angle, this angle being known as the *angle of propagation* (*see* Fig 15.7).

- **Ionospheric reflections.** The earth is spherical in shape and has conducting layers of gas in the upper atmosphere. These layers of gas (the ionosphere) reflect radio waves. If we know the distance between the transmitter and receiver, we can work out the angle at which we have to direct the radiation in order to reflect the radiation off the ionosphere into the receiver antenna (Fig 15.8).

As discussed earlier, the angle at which the radiation is directed is known as the 'angle of propagation' and can be controlled by varying the height of the dipole above the earth (*see* Fig 15.7). When the ionosphere is used for radio communication, the signal effectively 'hops' from the transmitter to the receiver via the ionosphere. The smaller the angle of propagation the greater is the distance of the hop (sometimes referred to as 'skip distance').

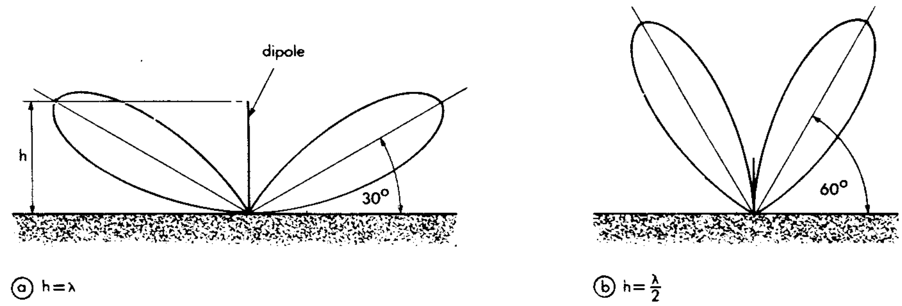


Fig 15.7 Angle of propagation

Multi-element Antennae

Several dipoles can be arranged to form an array such that when a signal is fed to all the dipoles, the total sum of all the radiations gives a resultant radiation *in one direction only*. The direction of the resultant radiation depends upon the separation of the dipoles in relation to the wavelength.

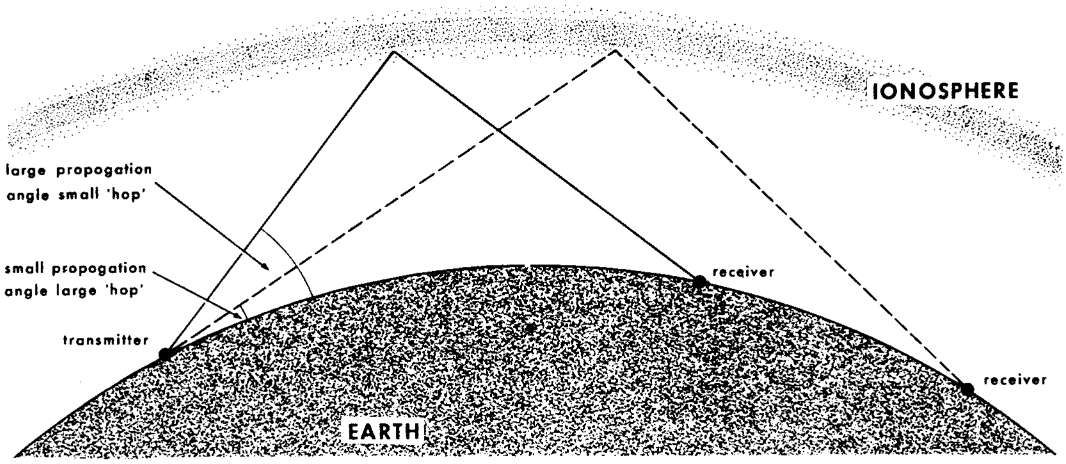


Fig 15.8 Ionospheric reflections

VERTICAL PROPAGATION ANGLE

General

As we have seen, the vertical propagation angle of an antenna (sometimes referred to as the wave angle) governs the distance per hop and thus the range of a radio space wave, for a given effective reflecting layer height.

The actual distance per hop will depend upon the seasonal and day or night variations in the height of the effective reflecting layer for the frequency and wave angle of the radio wave. Average values for day and night heights of these layers are, respectively:

Bottom (E) layer—90 and 100km (56 and 62 miles).

Top (F2) layer —250 and 350km (155 and 217 miles).

Critical Angle

As the vertical propagation angle is increased, a critical angle is reached at which the radio wave is just sufficiently reflected to return it to earth (Fig 15.9). At angles higher than this, the wave is not reflected back to earth but passes through the ionized layer into the space beyond. It will be evident that radiation at such angles represents a waste of energy since it is of no use for communication.

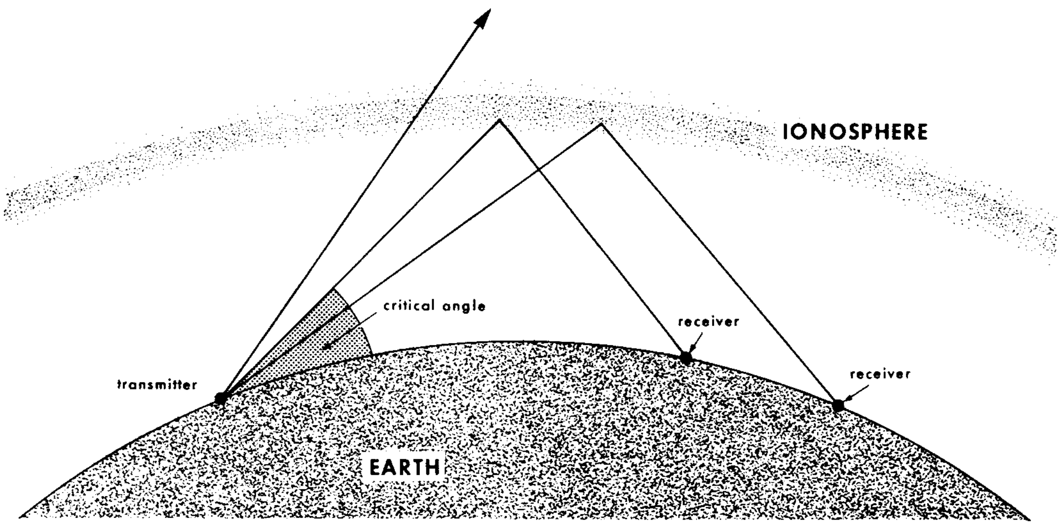


Fig 15.9 Critical angle

Determination of Vertical Propagation Angle

Single-hop communication. The curves of the graph shown in Fig 15.10 enable the required vertical propagation angle to be determined for various distances per hop and for the reflecting layer heights given earlier.

It will be seen by reference to Fig 15.10 that, if the vertical propagation angle is zero, the maximum single-hop distance is approximately 2250km (1250 miles) when the E layer is effective, or approximately 4000km (2500 miles) when the F2 layer is effective. This is not really a practical example, however, because if the vertical propagation angle were zero, there would be considerable weakening of the signal by obstructions in the vicinity of the transmitting antenna. An angle of 5 degrees is a more practical value and, as shown in Fig 15.10, this will give a single-hop distance of approximately 1350km (800 miles) for E layer reflection in daytime or approximately 3200km (2000 miles) for F2 layer reflection at night. These may be considered maximum practical single-hop distances.

The curves shown in Fig 15.10 refer to single-hop transmission. If more than one hop is required, the distance to be covered should be divided by the number of hops and the appropriate vertical propagation angle for this shorter distance obtained from the curves. This vertical propagation angle must, of course, be less than the critical angle. For example, if the distance to be covered is 4800km (3000 miles) and it is required to use two hops, the appropriate vertical propagation angle is about 10 degrees since this corresponds to a single-hop distance of 4800 ÷ 2, *ie* 2400km (1500 miles) for F2 layer propagation.

General

Whenever possible, single-hop communications will be used in the interests of providing maximum signal at the receiving antenna. Inevitably, multi-hop communication involves additional attenuation (weakening) of the signal at every 'reflection'. Consequently, for covering long distances, the lowest possible vertical propagation angle will normally be used, *ie* an angle in the order of 5 degrees.

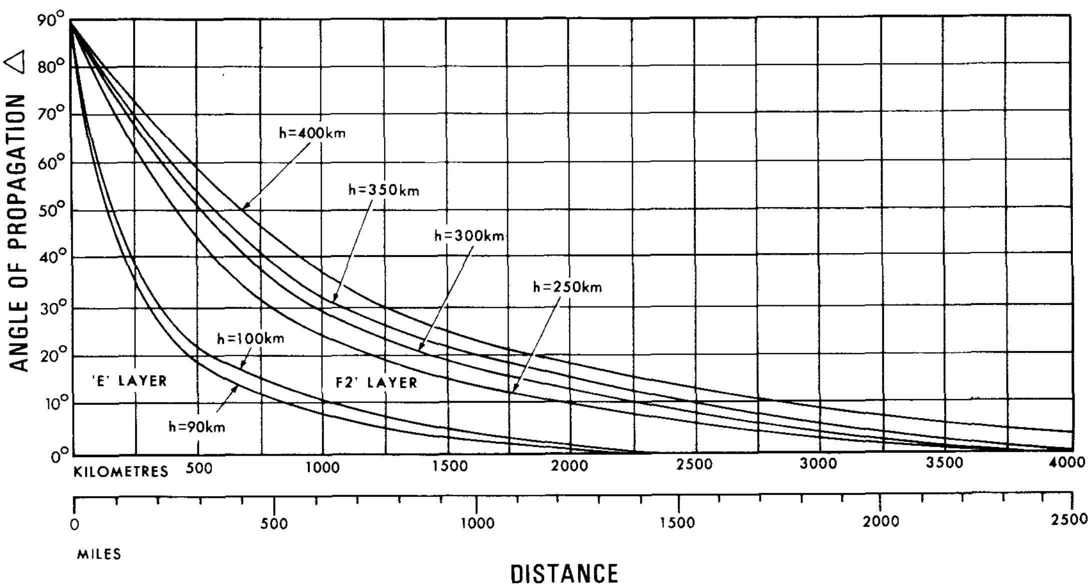


Fig 15.10 Determination of vertical propagation angle

In this chapter, the various values of angles have intentionally been given as approximations. It must be emphasised that the optimum vertical propagation angle depends upon the state of the ionosphere, which is variable. Thus the optimum vertical propagation angle is itself variable. It follows that it is advisable to use a transmitting antenna which has a reasonably broad angular coverage in the vertical plane. In general, the sector between 5 and 15 degrees from the horizontal should be covered.

SUMMARY-REVIEW

Q What is meant by the wavelength of a radio wave? (p15.2).

Q Given the speed of light in metres/sec and the frequency of a radio wave in hertz, how can the wavelength of the radio wave be determined? (p15.2).

Q What are the frequency ranges for:

a. High frequency radio transmissions? (p15.3).

b. Very high frequency radio transmissions? (p15.3).

c. Ultra high frequency radio transmissions? (p15.3).

Q What is the usual way of energizing a dipole antenna? (p15.3).

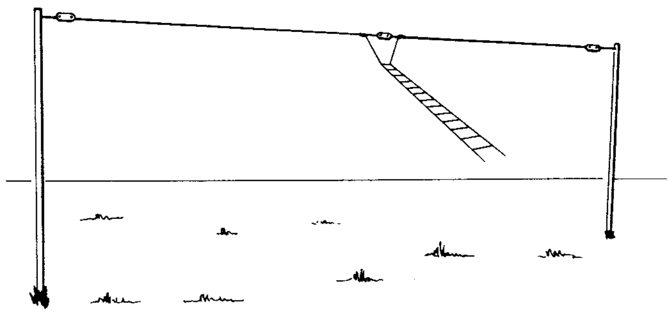
Q What is the main disadvantage of a dipole? (p15.4).

Q What is the 'angle of propagation'? (p15.4).

Q What is the 'critical angle of propagation'? (p15.6).

CHAPTER 16

BASIC ANTENNAE AND FEEDERS



Introduction

The most serious defect in long distance communications by sky wave transmission is that the signal is subject to fading (*ie* the signal strength varies in a random manner—strong at one instant, weak the next).

There are a number of reasons why a signal fades:

- Random variations in the ionosphere produce similar random variations in the strength of the sky wave signal arriving at the receiver antenna.
- If the signal arrives at the receiver antenna by more than one path (multi-path effect) the two signals will be in phase (add together) at one instant and out of phase (cancel each other) the next instant.
- In most long distance communications systems using the sky wave, there is also a shorter range ground wave and, where the two waves interact, fading can occur as described above.

There are several ways of reducing the effects of fading. Among them are the following:

- For sky wave communication, use the highest working frequency possible for the conditions. This reduces the multi-path effect and, in certain circumstances, may shorten the ground wave range.
- Use a large vertical angle of propagation to suppress the ground wave, or use the polarization characteristics of the antenna to suppress the ground wave or sky wave as appropriate.
- Use diversity antennae systems (space, frequency or polar); these systems use more than one receiving antenna so arranged as to reduce fading of the signal at the receiver.

Ideally, transmitting and receiving stations should be sited where the ground is moist and of high conductivity, because reflection losses are then minimised.

Antennae should be designed to have good horizontal directivity and radiate energy at the correct vertical propagation angle.

The vertical propagation angle depends upon:

- The type of antenna, and its length and height above the ground.
- The conductivity of the earth.

Horizontal directivity depends upon:

- The type of antenna.
- Antenna length and orientation.

The antennae described in this chapter may be divided into two broad categories: those which radiate well in all directions perpendicular to the line of the wire, *eg* dipoles; and those which radiate in one direction only, *eg* rhombic.

Dipoles

Horizontal dipole. The horizontal dipole consists basically of a single horizontal wire a half wave long ($\frac{\lambda}{2}$) or multiples of a half wavelength long, *eg* λ, $\frac{3\lambda}{2}$ (Fig 16.1). In practice it takes various forms, *eg* folded cage. There are different methods of feeding these antennae depending on the input impedance and availability of matching units. However, the horizontal and vertical polar diagrams remain the same as those for the basic dipole.

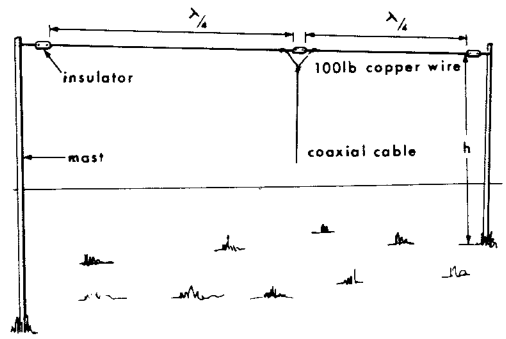


Fig 16.1 Basic horizontal dipole

The design characteristics of the dipole are as follows:

- Length of horizontal half-wave dipole is given by the formula:

$$\text{Length} = \frac{468}{\text{f (MHz)}} \text{ feet.}$$

- The height (in wavelengths) of the dipole depends on the vertical propagation angle.
- Input impedance for half wave dipole is as follows:

73 ohms at height of $\frac{\lambda}{4}$ or $\frac{\lambda}{2}$.

95 ohms at height of $\frac{3}{8}\lambda$.

58 ohms at height of $\frac{5}{8}\lambda$.

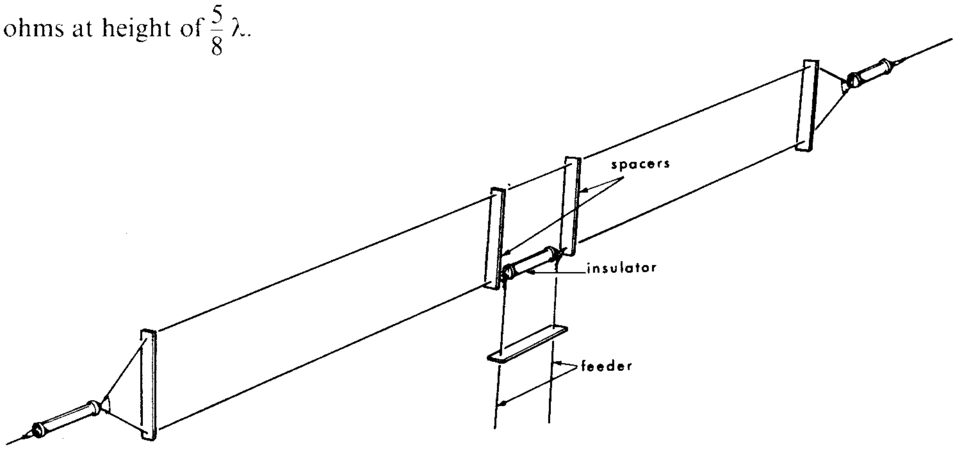


Fig 16.2 Two-wire folded dipole

Two-wire folded dipole. This antenna (Fig 16.2) may be regarded as a normal dipole with an increased bandwidth by virtue of the folded form of construction, *ie* greater cross-sectional area. The input impedance for this antenna is 300 ohms.

Three-wire folded dipole. The characteristics of this antenna (Fig 16.3) are similar to the single wire dipole, but the three-wire folded dipole has a greater bandwidth. It has an input impedance of 600 ohms.

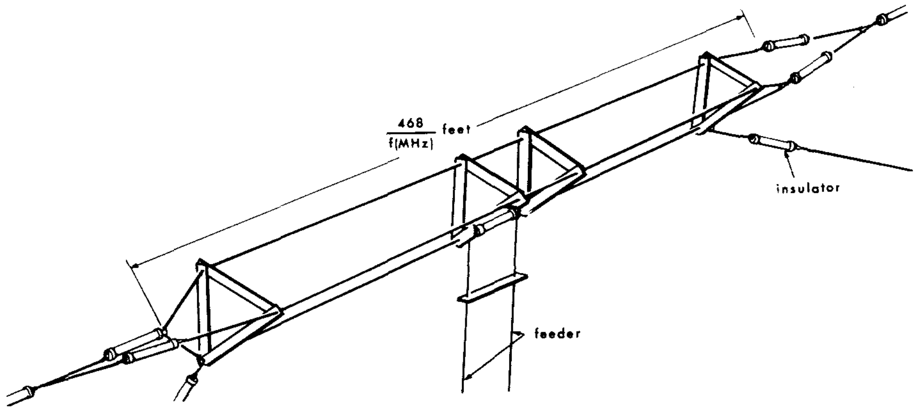


Fig 16.3 Three-wire folded dipole

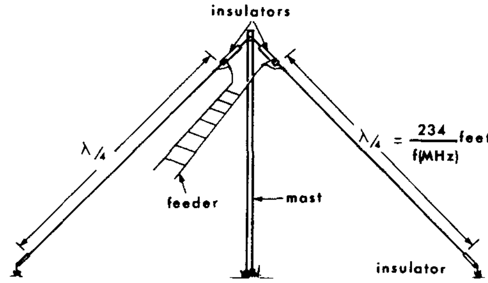


Fig 16.4 Droopy dipole

Droopy dipole. This antenna (Fig 16.4) has an advantage over the three previous dipoles in that it requires only one mast to support it. Also, if made in sections for wideband operation, its resonant length can most probably be adjusted from the ground. It is said to give best results on frequencies below 7MHz. The input impedance of this antenna is 50 ohms.

Eight-wire cage quadrant. This is simply an eight-wire cage dipole which has been bent at the centre until the two halves are approximately at right-angles (Fig 16.5). As a result, the normal horizontal directional pattern is destroyed and is replaced by an omni-directional pattern. The vertical polar diagram remains the same as that for a dipole. The characteristics of this antenna are as follows:

- Leg length $L = \frac{430}{f\,(MHz)} \simeq \frac{\lambda}{2}$ ft.
- Input impedance = 600 ohms.
- Frequency range 1.5 to 1 for transmitter (*eg* 5 to 7.5MHz)

  2 to 1 for receiver (*eg* 5 to 10MHz).

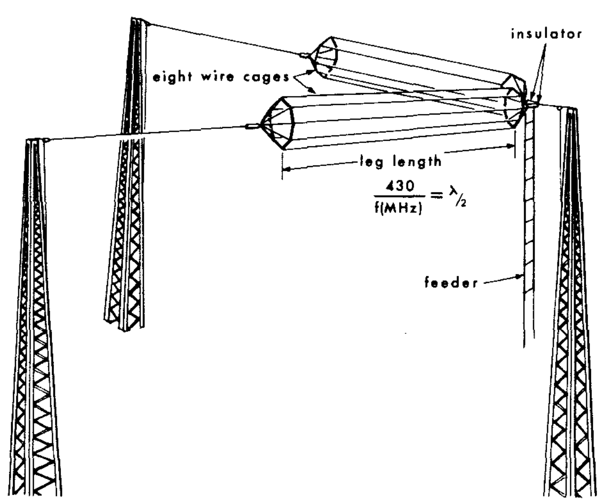


Fig 16.5 Eight-wire cage quadrant

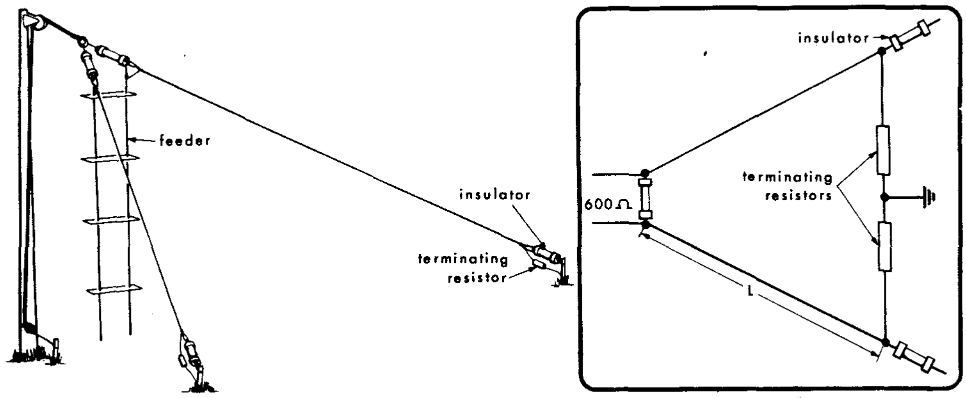


Fig 16.6 Terminated Vee

Terminated Vee. This is a wideband antenna capable of being used over a frequency range of 3 to 1. As with the droopy dipole, this antenna has the advantage of requiring only one supporting mast (Fig 16.6). Its gain is approximately 16 times that of a dipole—usually written as +12db with respect to a dipole. The characteristics of this antenna are as follows:

- Leg length. This should be at least two wavelengths at the lowest operating frequency. If the desired frequency range of the antenna is 3:1, then:

  Leg length (feet) $= \dfrac{2 \times 960}{f(MHz)}$ where f is the *lowest* frequency.

Example. Required frequency range is 5 to 15MHz (*ie* 3:1 range).

$$\text{Leg length} = \frac{2 \times 960}{5} = 384 \text{ ft.}$$

If the desired frequency range is less than 3:1, then:

Leg length (feet) $= \dfrac{6 \times 960}{f(MHz)}$, where f is the *highest* frequency.

Example. Required frequency range is 10 to 20MHz (*ie* 2:1).

$$\text{Leg length} = \frac{6 \times 960}{20} = 288 \text{ ft.}$$

- **Apex angle.** An optimum value of this angle can be chosen for one frequency only, the frequency to be used being the *mean* of the frequency band to be covered. The value of the apex angle depends upon the leg length.

- **Apex height.** The height of the antenna apex is dependent upon the required angle above the horizontal of optimum reception and the leg length measured in wavelengths.

The terminating resistors, one in each leg, should have a value of between 350 and 400 ohms. The input impedance of the antenna is 600 ohms.

Rhombic. An antenna which is designed to give radiation in one given direction only, produces a main beam (or 'lobe') of energy in that direction, as shown in Fig 16.7. Unfortunately, no matter how carefully the antenna is designed, it also produces smaller amounts of radiation in unwanted directions, giving rise to '*side lobes*' in the radiation pattern (Fig 16.7). The primary purpose of a rhombic antenna (Fig 16.8) is to provide a high gain of 15db (*ie* about 30 times that of a dipole)—or more at low vertical propagation angles (wave angles)

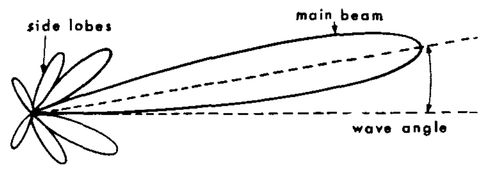
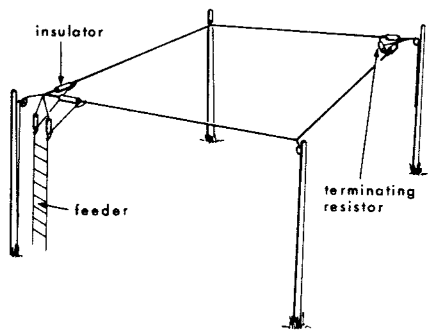


Fig 16.7 Side lobes

—and to suppress unwanted side lobes of radiation. The rhombic antenna has a greater gain than a Vee antenna, but more height, space and masts are required.



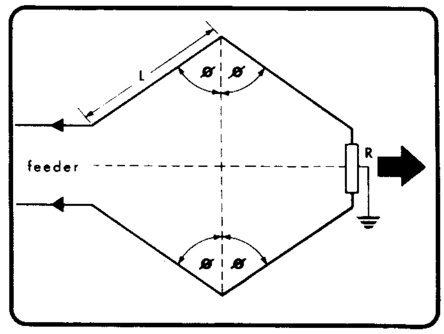


Fig 16.8 Rhombic antenna

Design. The single wire construction shown in Fig 16.8 is adequate for reception. However, a multi-wire construction (*see* Chapter 17) assists in keeping the input impedance constant and is mainly used for transmission employing high power levels.

The leg length should be a minimum of two wavelengths; gain increases with leg length. The ideal dimensions of a rhombic antenna for maximum output at given wave angles are given in Table 1.

TABLE 1

Wave Angle (degrees)	Half Angle (Ø degrees)	Side Length (L wavelengths)	Height (H wavelengths)
10	80	17.0	1.45
14	76	8.5	1.04
18	72	5.3	0.81
22	68	3.7	0.67
26	64	2.7	0.57
30	60	2.0	0.50

The dimensions of a rhombic using a side length restricted to 2 wavelengths are given in Table 2.

TABLE 2

Wave Angle (degrees)	Half Angle (Ø degrees)	Height (H wavelength)
5	52.0	3.00
10	52.5	1.45
15	54.0	1.00
20	55.0	0.75
25	57.5	0.60

The input impedance of a single wire rhombic varies from about 800 to 600 ohms when the applied frequency is varied from about 5MHz to 22MHz. The multi-wire rhombic has a constant input impedance of 600 ohms.

The terminating resistance for a receiving rhombic usually takes the form of a 600 ohm carbon resistor. Transmitting rhombics require a termination more suited to the high power involved. The termination usually takes the form of an open wire line made of stainless steel or nickel chrome resistance wire 122 metres (400ft) in length and 150mm (6 in) spacing between the wires, and suitably terminated. Both single and multi-wire rhombics are fed from a standard 600 ohm open wire feeder.

HF Broadband Antennae

General. The range of frequencies designated hf extends from 3MHz to 30MHz. Transmitters and receivers now in use can be automatically tuned to any frequency (channel) in this range. Therefore, an antenna which can accommodate the whole, or even half, of this frequency range, would have definite advantages in point-to-point working over distances where several channel changes may be required in a twenty-four hour period. There would also be a great saving in the initial capital cost of a new unit where only one antenna (or perhaps two) need to be used for a given service. Antennae suitable for use over such a wide range of frequencies are known as *broadband antennae*. Three currently used broadband antennae are:

- The hf biconical.
- The hf discone.
- The hf log periodic.

Of these, the latter is the most recently developed and is frequency-independent. The discone and variations of the biconical will accommodate the hf band for ground-to-air communications in much the same way as they do for the uhf band.

Biconical antenna. The biconical antenna (Fig 16.9) is constructed from two cones connected base to base; the lower cone has the shorter slant height and larger semi-angle and is used as a form of termination for the main radiating element (upper cone). Multi-wire cage construction is used. The radiation pattern of such antennae should be omni-directional and predominent in the horizontal plane with the main vertical pattern intensity from between approximately 10° to 60° for sky wave propagation.

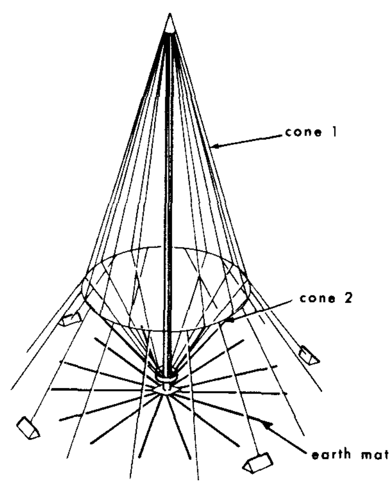


Fig 16.9 Biconical antenna

The frequency range of this antenna is in the order of 2:1 for transmission, which means that four antenna are needed to cover the hf band (*ie*. 3 to 6MHz, 6 to 12MHz, 12 to 24MHz, and 24 to 30MHz). It is claimed that the frequency range is 3:1 for reception. The method of construction reduces the overall weight and windage problems and the radiating elements are supported by a single guyed mast mounted on an insulated base. An earth system, comprising 32 radial elements is laid out to form a circular earth mat of 10 metres (33ft) radius. The radial elements are terminated at an earth plate secured under the mast base and are also bonded by concentric wire rings.

The double conical shape of the antenna is maintained by two spreader rings to which 16 radiator elements are secured. The radiator elements are pre-covered and metallic contact with the mast structure is made only at the mast top cap and the insulated base.

Discone. The discone antenna (Fig 16.10) is a multi-wire high frequency antenna with a buried ground plane earth system: its broadband characteristics cover a frequency range of 3 to 18MHz. The multi-wire radiators are supported by three catenaries slung between vertical wooden poles at a height of approximately 24 metres (80ft). The radiators converge to a terminal box mounted on a wooden ground frame mounted approximately 2 metres (6 ft) above ground level and located at the centre of the triangular catenary formation.

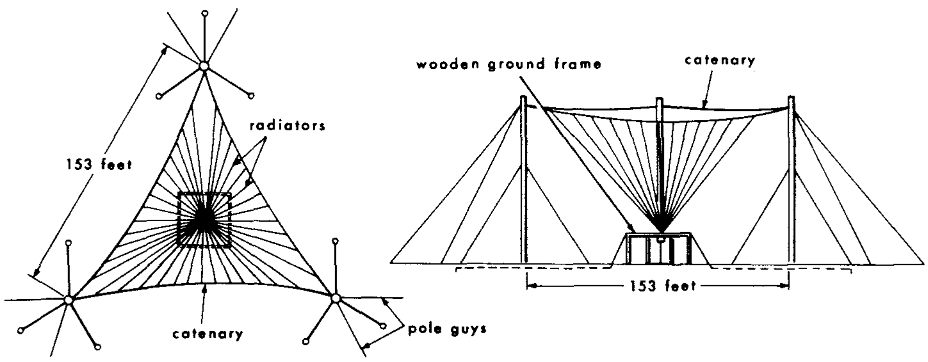


Fig 16.10 Discone antenna

The ground system consists of radial earth wires of hard drawn 100lb/mile copper wire secured to earth rods inserted at angular intervals of 10 degrees on radii of 6 metres (21ft) and 33.2 metres (110ft) from the centre of the elevated ground frame.

Only two antenna of this type are required to cover the hf band. In some instances it is possible to arrange that the band covered by the equipment and antenna for a specific purpose coincide, so that only one antenna will suffice.

The construction of the hf discone antenna normally follows that of the biconical antenna except that the cone will probably be upside down, the wires being hung from poles, the apex near the ground and the ground plane earth system actually on the ground. The ground earth system is similar to that of the biconical antenna. The approximate dimensions in terms of wavelength (λ) is shown in Fig 16.11. The spacing between the apex of the cone and the ground plane earth system is of importance in the matching of the system (matching is described at the end of this chapter).

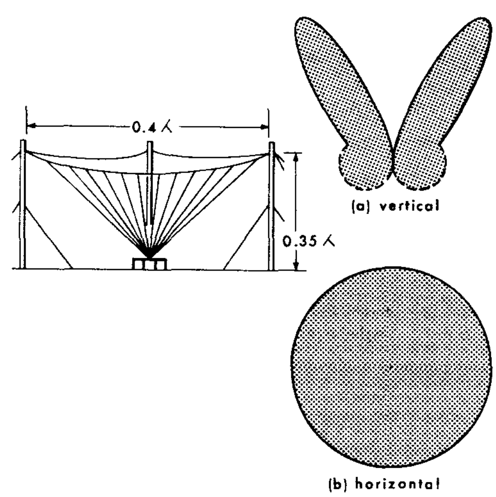


Fig 16.11 Discone dimensions and radiation patterns

Log periodic antenna. The log periodic antenna is a directional antenna that can be used to transmit moderately high power over almost the whole of the hf range of frequencies. There are two main types, horizontal and vertical, the designation referring in each case to the plane of polarization and the main plane in which the radiating elements lie.

Horizontal log periodic antennae (Fig 16.12) are arranged to slope toward the ground at the narrow end or apex, maintaining each element at the same electrical height (height above earth in wavelengths at the resonant frequency). This arrangement increases the directive gain. The wide end of the array is usually supported by two masts or towers.

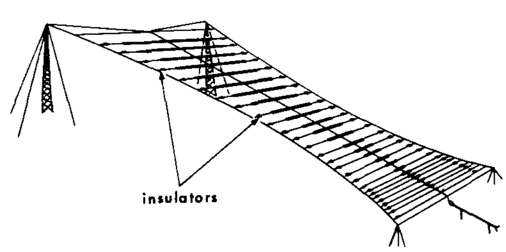


Fig 16.12 Horizontal log periodic antenna

Vertical log periodic antennae (Fig 16.13) are constructed in a similar manner to the horizontal versions, but are suspended in the vertical plane between a high mast or tower and a much lower one. The height of the taller mast must be more than $\frac{3}{4}\lambda$ at the lowest frequency of operation.

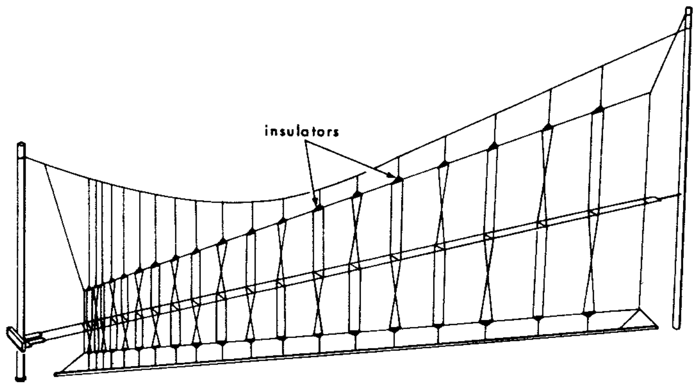


Fig 16.13 Vertical logarithmic periodic antènna

FEEDERS

When an antenna is erected at a distance from the transmitter or receiver it is necessary to connect the two by means of a suitable feeder. The feeder must be as loss-free as possible and also non-radiating. There are two types of feeder—open-wire and coaxial (Fig 16.14).

- **Open-wire feeders.** The impedance that a transmission line presents to a source of power is known as its *characteristic impedance (Zo)*. The characteristic impedance for a pair of parallel wires separated by air is given by:

$$Zo = 276 \log \left(\frac{2S}{d}\right)$$

where S = centre-to-centre spacing

d = diameter of the wire.

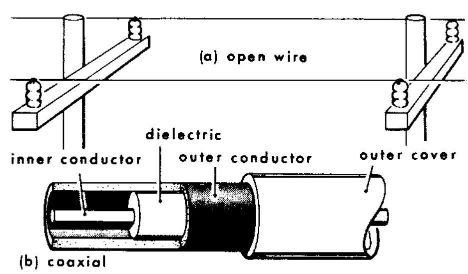


Fig 16.14 Feeders

A graph giving values of characteristic impedance for various spacings of different sizes of hard drawn copper wire is shown in Fig 16.15a.

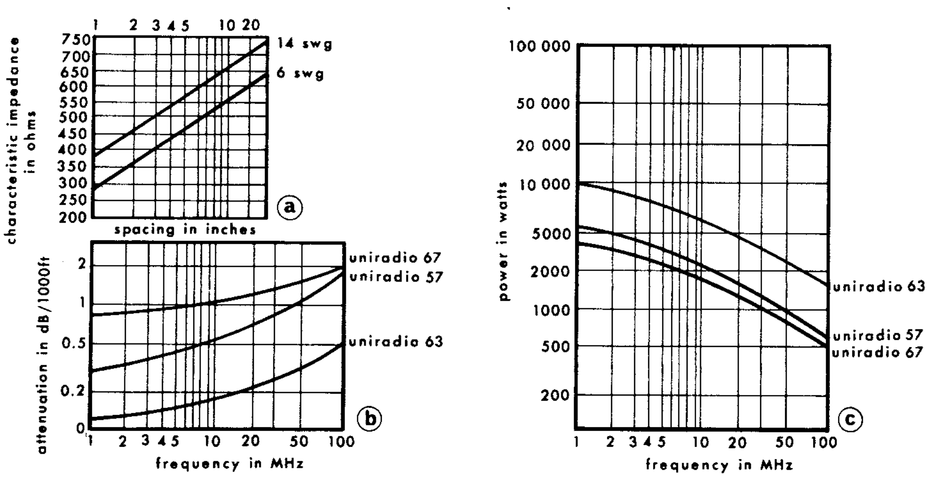


Fig 16.15 Feeder characteristics

- **Coaxial feeders.** The coaxial feeder behaves in a similar manner to the open wire feeder. Its characteristic impedance depends on the diameters of the inner and outer conductors and the dielectric constant of the insulation (dielectric) between the two conductors. Another characteristic of the coaxial feeder is that it attenuates (*ie* reduces the amplitude of a signal as it passes along the cable). The attenuation at various frequencies for the coaxial cables in common use is given in the graph of Fig 16.15b. The power handling capacity of various coaxial cables is shown in Fig 16.15c. The characteristic impedance of some of the coaxial cables in common use as feeders is given below:

  Uniradio 57—75 ohms.

  Uniradio 67—50 ohms.

  Uniradio 63—75 ohms (for use up to 3000MHz).

MATCHING

Every feeder has a characteristic impedance and every antenna has a definite impedance at the point where the feeder is connected (its input impedance). When a feeder is connected to an antenna whose input impedance is equal to the characteristic impedance of the feeder, all the power travelling along the feeder from the transmitter is completely absorbed by the antenna and none is reflected back to the transmitter. In this condition the feeder and the antenna are said to be correctly *matched* and maximum power is transferred from the feeder to the antenna.

If the feeder and the antenna are *not* correctly matched, some of the power is reflected back to the transmitter producing what is known as a *standing wave* of voltage (or current). The result of this is that something less than maximum power is transferred from the feeder to the antenna: exactly how much less depends upon the degree of mismatch.

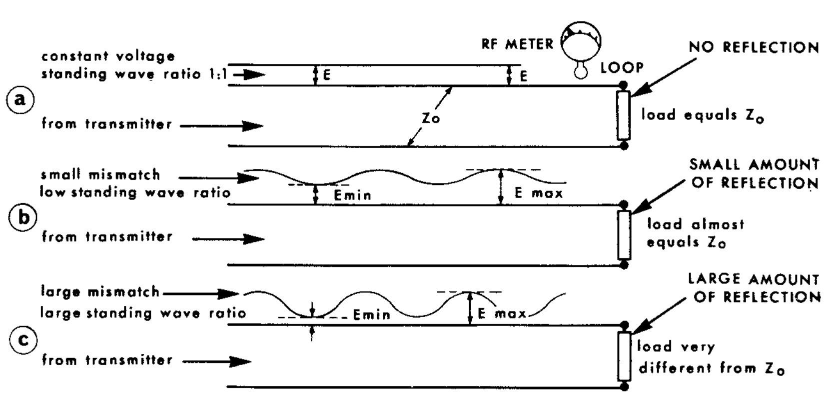


Fig 16.16 Standing wave ratio

Standing Wave Ratio

The value of voltage (or current) at any point along an unscreened feeder can be measured by connecting a suitable radio frequency (rf) meter to a loop of wire and placing the loop close to one of the wires in the feeder (Fig 16.16).

When the feeder and antenna are correctly matched the meter will give the same reading at all points along the line (Fig 16.16a). This is the ideal condition for maximum power transfer.

The result of a mismatch is that the value of the voltage (or current) will vary from point to point, rising and falling between a maximum and minimum value as the meter is moved along the line.

The range of variation gives an indication of the degree of mismatch and is usually expressed in terms of the '*standing wave*' *ratio (swr)*.

The standing wave ratio may be defined as the ratio $\frac{\text{maximum voltage}}{\text{minimum voltage}}$ or as the ratio $\frac{\text{maximum current}}{\text{minimum current}}$. These two ratios are the same and both will be greater than unity (except for a matched line). Thus:

$$SWR = \frac{E\ max}{E\ min} = \frac{I\ max}{I\ min}.$$

When a line is perfectly matched there is no standing wave; Emax = Emin and the swr = 1:1 (Fig 16.16a). With a slight mismatch Emax is only slightly greater than Emin and the swr is slightly greater than 1:1 (Fig 16.16b). As the degree of mismatch increases, the swr increases (Fig 16.16c).

In practice a swr of 1:1 is difficult to obtain. A swr of 2:1 is usually good enough for communication transmitters. The maximum permissible swr for an installation is given in the appropriate Air Publication for the equipment, and the line must be examined and adjusted where necessary to give the required conditions. The adjustment usually includes the use of matching devices.

Special transformers are available for matching 75 ohm coaxial cables to 600 ohm rhombic and Vee antennae, and for matching 600 ohm open wire feeders to 75 ohm dipole antenna.

Delta match. The characteristic impedance of a half-wave dipole varies from about 73 ohms at the centre to about 2500 ohms at the ends. On either side of the centre there are points where the impedance is 600 ohms and suitable for connecting to a 600 ohm open-wire feeder. The distance between these two points at the connection points would be about one eighth-wavelength which is too great for the radiation from the feeder wires to cancel completely and the feeder would act as an antenna. In practice, therefore, an ordinary feeder is used and opened out at the antenna (Fig 16.17). A dipole fed in this way is said to be a delta-matched dipole. The correct dimensions for this arrangement are given in Fig 16.17.

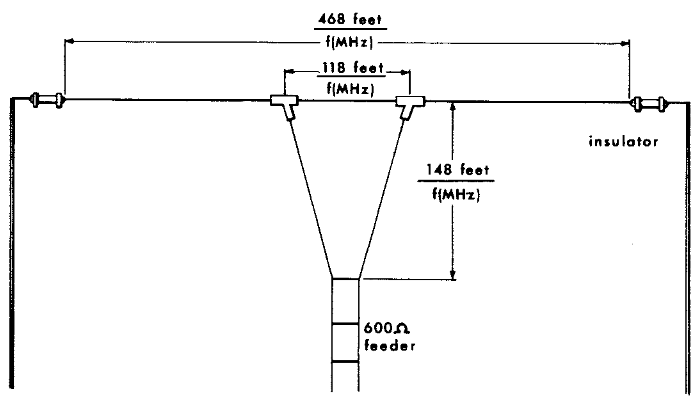


Fig 16.17 Delta matching

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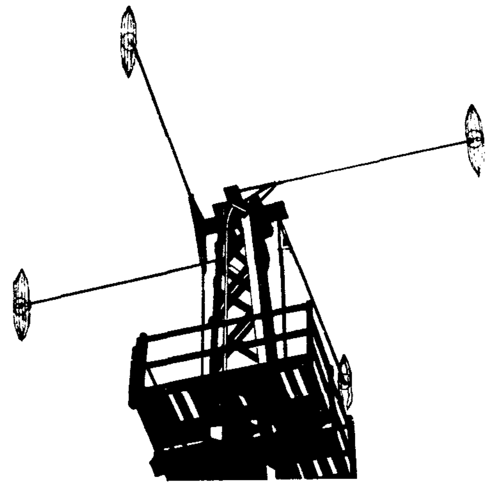


CHAPTER 17

PRACTICAL ANTENNAE

Introduction

In Chapter 15 the theory of antennae was discussed and we saw that antennae can be considered in three main groups according to the frequency of the radio waves they transmit or receive. The three groups are:

- Medium and high frequency (MF and HF) antennae.
- Very high frequency (VHF) antennae.
- Ultra high frequency (UHF) antennae.

In this chapter one example from each of the three groups will be described in some detail and are as follows:

- Rhombic — HF antenna
- Antenna system type 298 — VHF antenna.
- Antenna unit design 41 — UHF antenna.

RHOMBIC ANTENNA

Introduction

In radio communication it is normal to select a type of antenna best suited to the particular service required. For long distance communication the preference is for the high gain directional array of comparatively narrow beam-width and broad-band frequency coverage. In both the Services and commercial fields, particularly for long distance point-to-point communication in the hf-band (3Mhz — 30Mhz), the more popular design is the rhombic or rhombic type, travelling-wave antenna which posesses, to a large extent, the required gain, directivity and broad-band characteristics.

Travelling Wave Radiators

In radio systems employing reflections from the ionosphere for long-distance transmission it is often necessary to change the working frequency to compensate for ionospheric variations over the distances involved and, as these frequencies will be different for day and night working, there is thus a need for an antenna element of much greater band-width than that supplied by resonant, standing-wave radiators or arrays of such elements. This need is met by the travelling wave or non-resonant type of radiator in which reflections and standing waves are prevented by terminating the radiator with an absorbing resistance.

A single wire, long in terms of wavelength, when excited at one end and terminated at the other end by a resistance equal to the characteristic impedance of the line, will produce a hollow

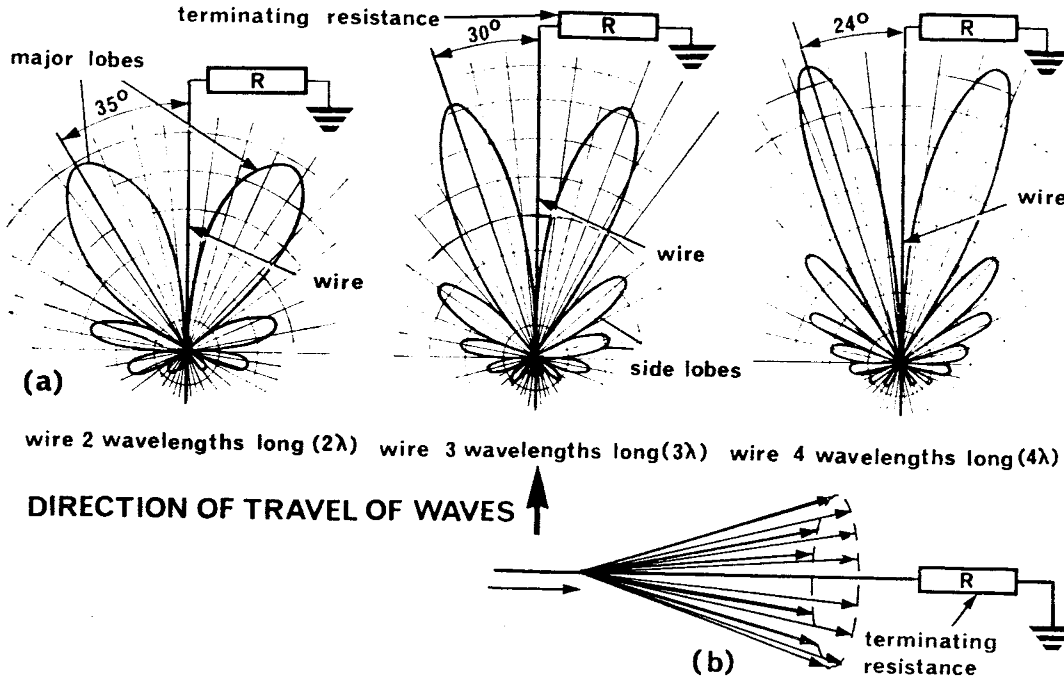


Fig 17.1 Single Wire Carrying a Travelling Wave

conical radiation pattern around the wire inclined in the direction of the terminating resistor, the pattern varying according to the wire length (Fig 17.1). As the length of the wire increases in terms of wavelength, the number of side lobes increase and the major lobes move in towards the wire and also increase in amplitude.

The characteristic impedance of such a wire is practically independent of frequency and the radiating properties of the travelling-wave antenna are affected only slightly by changes in its operating frequency. In contrast, a dipole radiates effectively *only at one particular frequency* and, if the transmittei frequency is different, the conditions necessary to produce standing waves are upset and the antenna ceases to be an efficient radiator.

Description

A rhombic antenna may be considered as two inverted-V antennae (*see* Chap 16) joined together to form an equilateral parallelogram or rhombus with a common resistor (R) terminating the ends remote from the input (Fig 17.2a). The arrangement, provided the lengths of the sides (L) and the tilt angle (Ø) are correctly selected, will combine the individual radiation patterns of the four sides, as illustrated by the shaded lobes, to produce a very concentrated forward lobe (Fig 17.2b) in the direction of the terminating resistor. The rhombic antenna, typical of all travelling wave (non-resonant) antennae, is thus highly directional, radiating strongly in the direction of the terminating resistor, the best reception being from the same direction.

Advantages and Disadvantages of Rhombic

For long distance point-to-point communications in the hf band, the rhombic antenna is probably the most effective in general use and, therefore, a statement of its advantages and disadvantages is of value in assessing the overall performance.

Advantages

- The antenna operates over a frequency range of at least 2:1 (*eg* from 4MHz to 8MHz) which can be improved by using multi-wire (two, three or four wire) construction techniques to increase bandwidth. Vertical and horizontal polar diagrams of a rhombic operated over a

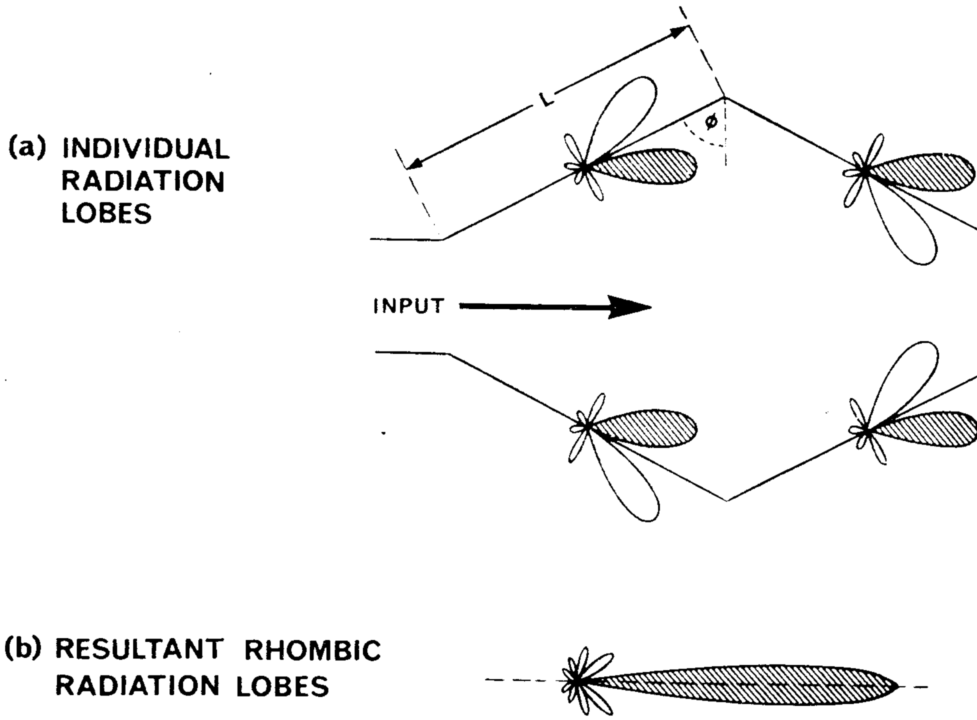


Fig 17.2 Formation of Rhombic Radiation Pattern

frequency range of 2:1 are given in Fig 17.3. From this it can be seen that changes in operating frequency from 2f to f cause the effective length of the side of the rhombic to change from 4λ to 2λ, and this affects both gain and directivity. Such variations can be reduced to acceptable limits by good design.

- The rhombic is not critical in operation or adjustment and is easy to match. By careful positioning of the masts, it is possible to make adjustments to the tilt angle in the field.
- In comparison with other types of antenna comparable gain and directivity, the rhombic is less complex to erect and maintain.

Disadvantages

- The rhombic requires a large area for its installation as each side must be at least two wavelengths long at its lowest operating frequency. It also requires four supporting masts and associated rigging which presents transportation problems for mobile installations.
- Approximately half the power fed into the antenna is lost in the terminating resistance; this represents roughly the power that would be radiated backwards if the termination were fully reflecting.

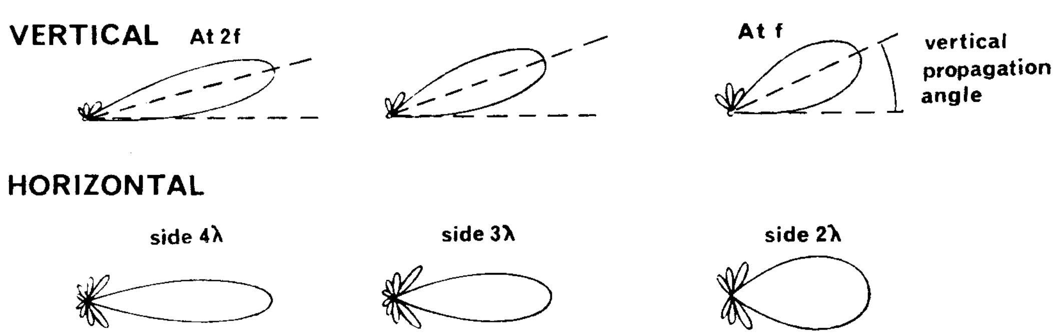


Fig 17.3 Polar Diagrams over Frequency Range of 2:1

- The portions of the radiation cones which do not combine to form the main beam cause considerable side lobes having both horizontal and vertical polarization.
- The interdependence of the rhombic's vertical and horizontal radiation patterns can be considered a disadvantage, as with the higher vertical propagation angles the horizontal pattern broadens and gain reduces (Fig 17.3). This assumes less importance when it is considered that the rhombic is used essentially for long distance transmissions at low vertical propagation angles.

Design Considerations

As mentioned in the preceding paragraphs an effective rhombic antenna must have a minimum side length of at least two wavelengths and, for the hf band, the dimensions involved dictate that for practical reasons the antenna must be mounted horizontally. Although erected in the horizontal plane, the maximum radiation pattern in the vertical plane is inclined at some angle above the horizontal — termed the vertical propagation angle or *wave angle* (Fig 17.3). The value of this vertical propagation angle, the determination of which is essential for ionospheric working, depends on the height of the antenna above the ground, the side length L and the tilt angle Ø. These three factors all have a best (optimum) value, any deviation from which will have some detrimental effect on the maximum power radiated at the desired vertical propagation angle.

The rhombic dimensions, therefore, must be selected to ensure a satisfactory value of vertical propagation angle for the service the antenna is required to provide. In this respect, it is usual to design a rhombic to give the lowest vertical propagation angle at the highest frequency at which the antenna is to be used. The reason for this is that the design of the antenna is most critical at the highest frequencies where a few degrees change in tilt angle has a large effect on the vertical propagation angle.

We have just seen that the three factors that influence the maximum power output for a given vertical propagation angle are:

- Height of antenna above the ground (H).
- Side length (L).
- Tilt angle (Ø).

Table 1 lists correct values of these three factors for maximum output of the rhombic antenna at given vertical propagation angles.

TABLE 1

Optimum rhombic dimensions for maximum output

Vertical propagation angle (degrees)	Tilt angle ø degrees	Side lengths L (wavelengths)	Mean height H above ground (wavelengths)
10	80	17·0	1·45
14	76	8·5	1·05
18	72	5·3	0·81
22	68	3·7	0·67
26	64	2·7	0·57
30	60	2·0	0·50

The use of a rhombic antenna of optimum design may often be limited, particularly at the lower frequencies, by the space available and, therefore, values of tilt angle and mean height corresponding to given vertical propagation angles for sides of limited lengths (two, three or four wavelengths) are given in Table 2. These are compromise designs which represent the best that can be expected within the limitations of restricted side lengths.

TABLE 2

Optimum dimensions for compromise designs

Vertical propagation angle (degrees)	Mean height H (wavelength)	Tilt angle ø (degrees)		
		Side length 2λ	Side length 3λ	Side length 4λ
5	3·00	52·0	59·0	63·0
10	1·45	52·5	60·0	64·5
15	1·00	54·0	62·0	66·5
20	0·75	55·0	63·5	68·5
25	0·60	57·5	65·0	—

Effect of Ground Reflections

The radiation pattern of a horizontal rhombic is affected by ground reflections in exactly the same manner as the pattern of any other horizontal antenna. There is an optimum height for an antenna above ground at which radiated energy reflected from the ground combines with the main pattern to produce maximum radiation at a given vertical propagation angle. This optimum height is that quoted in Tables 1 and 2. In common with other types of antenna, as the height above ground of a rhombic is increased, so the vertical propagation angle at which maximum radiation occurs is reduced.

If the maximum gain is to be achieved from the ground reflection ahead of the antenna, the reflecting zone should be reasonably flat and level with uniform conductivity. Any local roughness should not exceed about one-eighth of a wavelength in height. If the circumstances are such that a rhombic has to be installed over sloping ground with a reasonably uniform slope, the antenna dimensions should be chosen to produce a vertical propagation angle that will include both the desired wave angle (above horizontal) and the angle of the slope. As an example, a rhombic has to be erected over ground with a downward slope of 5 degrees in the direction of radiation whilst the desired vertical propagation angle would be 10 degrees on level ground. The antenna dimensions should be chosen to give a vertical propagation angle of 15 degrees with the antenna mounted parallel to the downward slope (Fig 17.4).

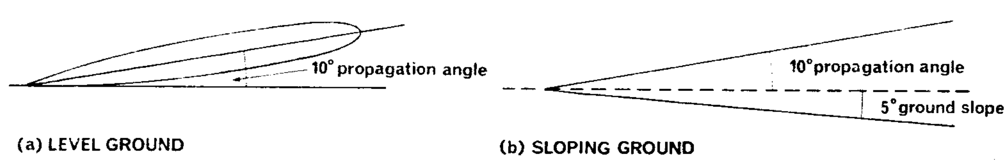


Fig 17.4 Compensation for Ground Slope

Terminating Resistor

The rhombic antenna under discussion is the non-resonant, travelling-wave type of antenna and is always terminated by a resistor (R in Fig 17.2). As a result, a large proportion of the available power — up to 50 per cent in some instances — is dissipated in the resistor, although with a multi-wire rhombic the figure is somewhat lower (up to about 30 per cent). However, the uni-directional quality of maximum radiation and the considerable gain of the antenna more than compensate for the loss due to the terminating resistor.

For correct operation, the proper value of resistance must be used to terminate the rhombic, a suitable value for the multi-wire type in general service use being approximately 600 ohms. The resistance used must function as a pure resistance at all frequencies at which the antenna is required to operate since any inductance in the terminating resistor would cause some reflection of energy and the formation of standing waves. These conditions would result in variations of the antenna characteristics and radiation pattern with changes of the applied frequency.

A terminating resistor for a receiving rhombic usually takes the form of a non-inductive carbon resistor. Transmitting rhombics require a form of termination more suited to the dissipation of the power involved and, for these, a high attentuation transmission line is used, the termination end of the antenna being connected directly to an open-wire balanced line of the required characteristic impedance, The line is constructed from high resistance conductors to increase attenuation, with an electrical length sufficient to give an input terminal impedance substantially independent of the far end termination, which is usually a short circuit to earth. A practical line is made of stainless steel or nickel chrome resistance wire 122 metres (400 feet) in length and with 178 mm (6-inch) spacing between the wires. The end of the line remote from the antenna is short-circuited to earth.

Method of Feeding

The rhombic input and termination impedances are roughly equal and of the order of 600 to 800 ohms resistive, the input impedance of a conventional single-wire rhombic varying from about 800-600 ohms as the applied frequency is varied from about 5MHz to 22MHz. The problem of maintaining a constant input impedance with respect to the terminating impedance, over a wide frequency range, can be solved by the use of the multi-wire rhombic.

The multi-wire rhombic has a feed impedance of approximately 600 ohms and, therefore, provides a close match for a standard 600 ohms open-wire transmission line which connects the rhombic antenna to the transmitter or receiver. At the station end, the 600 ohm line is usually terminated by a matching unit (receiver) or matching transformer (transmitter) from which a coaxial feeder connects to the transmitter or receiver.

Multi-wire Rhombic Antennae

The use of multi-wire rhombic antennae ensures a reasonably constant input impedance with respect to terminating impedance over a wide frequency range. It also reduces the power dissipation in the terminating resistance. Of the three high frequency multi-wire rhombic antennae in general use in the Service (*ie* two, three and four-wire arrays) the three-wire rhombic constructed to Headquarters No 90 (Signals) Group Drawing List SC54258 is the most popular for long distance hf communications. This antenna is, therefore, used as the example of a practical rhombic discussed in this chapter.

Note: Headquarters No 90 (Signals) Group is now Support Command Signals Headquarters (SCSHQ).

Three-wire Rhombic Antenna

This antenna which may be used for both transmission and reception is constructed from the equipment listed in Table 3. It should be appreciated that the quantities of certain items will vary according to antenna side lengths, as limited by site locations and intended frequency coverage. Therefore the particular station antenna rigging data chart must be consulted for precise quantities of such items.

Preliminary Rigging Instructions

The distances between masts on both the major and minor axes of the proposed three-wire rhombic antenna (Fig 17.5) must be physically checked to ensure that the mast centres agree with the dimensions given in the mast layout drawing. It is important that any discrepancy noted should be halved and either added to or sutracted from the appropriate LI dimension annotated on the antenna rigging chart. If during handling of the antenna wire a kink develops in the wire the kinked portion must be cut off and discarded. Jointing of antenna elements is not permitted. When repair to an existing rhombic is necessary due to a broken element the complete wire of the antenna affected must be rebuilt. Replacement of individual wires is not permitted.

The following special equipment is required for rigging a rhombic antenna:

- Recalibrated access equipment tensiometer to Drawing No SC55028.
- Antenna wire spinner to Drg No SC55029.

TABLE 3

Three-wire Rhombic Antenna Equipment

Key to Fig 17.8	Drg No	Description	Quantity Transmitter	Receiver
1	SC54342	Insulator strain	8	6
2		Insulator Type 375	16	12
3	SC54383	Spreader Assembly	2	2
4		Shackle harp shape ⅜″	8	7
5		Wire copper HD 100lb/mile	*	*
6		Rope, terylene heat set pre-stretched ¾″ circ.	30 ft	30 ft
7		Rope, terylene, heat set pre-stretched 1⅛″ circ.	*	*
8	SC55061	Block tackle	4	4
9		Thimble NCS ¾″	16	12
10	WT54223	Halyard weight assembly (weight specified on antenna rigging chart)	2	2
11		Guy grip, dead ends, No 35 NADE 1⅛″ (0·35)	8	8
12		Ferrule, Talurit, code 6 ¾″ circ.	16	12
13	SC54382	Thimble	8	8
14	SC54624	Resistor (Terminating Rx only)	1	1
15		Shackle ⅜″ Dee shape	4	4
16		Shackle pin ⅜″ dia	4	4
17	SC58198A	Insulator rhombic aerial	4	4
18	SC58198B	Insulator rhombic aerial	4	4

* For details and quantities see respective station antenna rigging chart.

Note: Terminating resistance assembly for transmitting rhombic is drawn on Drg No SC53494 Iss 4.

Rigging Procedure

In the following description of the rigging procedure it is assumed that there is free access across the antenna site sufficient to lay out and tension a length of antenna wire whose length is equal to two side lengths plus 2 metres (6ft). Reference to the rigging chart will give the appropriate side length dimensions. If there is no such free access across the site the nearest suitable clear space available should be used.

Mark out the length of one complete element of the rhombic using two pegs positioned two side lengths apart placing one peg close to a major axis mast. A third peg is used to mark the mid-point between the first two pegs (Fig 17.5).

Set up the antenna wire spinner about 2 metres (5 to 6ft) from the first peg and approximately in line with all three marker pegs (Fig 17.5). Reel out a length of wire from the spinner equal to two side lengths plus 2 metres (6ft). Secure the free end of the antenna wire by pushing it into the ground; cut off the length of wire at the spinner and secure this in the same manner. Repeat this procedure twice more to give three lengths of antenna wire laid out as shown in Fig 17.5.

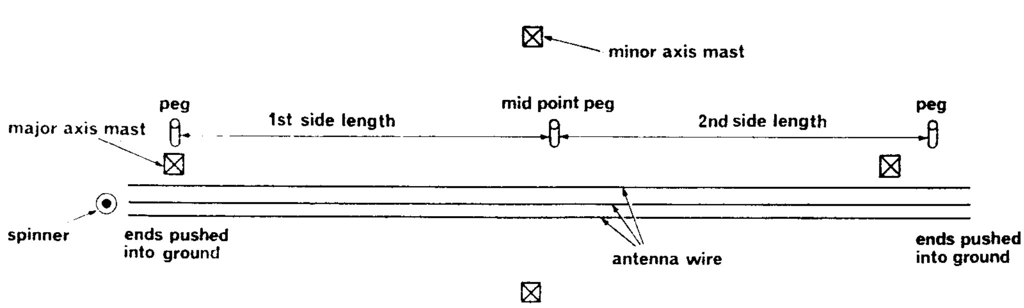


Fig 17.5 Cutting Antenna Element Wires

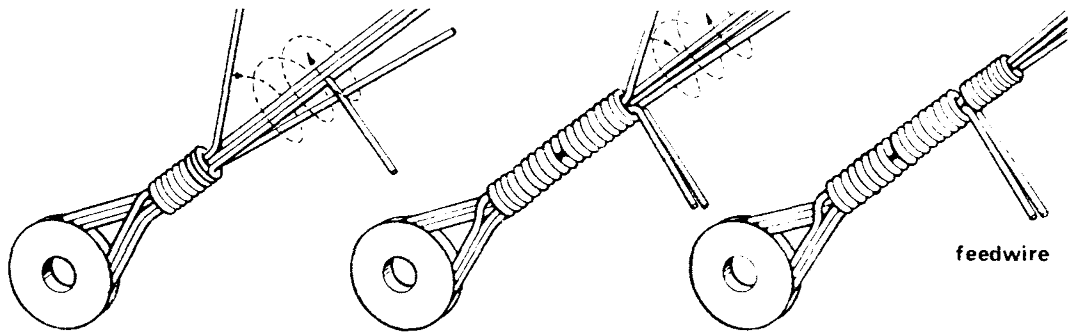


Fig 17.6 Method of Constructing an Eye around Insulator Thimble

Gather together one set of the three ends of the antenna wire lengths and construct an eye around a thimble using the method shown in Fig 17.6 and assemble the thimble in its insulator. Secure the other end of the insulator to a picket or some other suitable anchorage so that the centre of the thimble is in line with the peg marking one end of the antenna element (Fig 17.7).

Attach a tensioning device such as a drawvice or wire tensioner (*see* Chapter 6), to each of the free ends of the antenna wire and secure them to a suitable anchorage. Tension the wires to 100lb/wire (using the re-calibrated access equipment tensiometer) and allow a period of approximately one hour for the wires to stretch and settle (Fig 17.7). After one hour re-check and adjust the tension.

With the antenna wires still under tension, mark each wire with a tape at the mid point marker peg position and attach an insulator thimble in accordance with the appropriate installation drawing. When this is completed, mark the wires at the peg locating the extremity of the antenna element at the tension end (Fig 17.7).

Release the tension on the wires. Gather up the three free ends of the antenna wire lengths and construct an eye around an insulator thimble close behind the marker tapes and assemble the thimble in its insulator (Fig 17.7).

Lay the completed element aside and repeat the operation for the second element.

Note. When constructing a rhombic element you must ensure that the wires remain parallel to each other at all times. If the completed element has to be moved any considerable distance, it is advisable to tape the wires together at about 9 metre (30ft) intervals to reduce snagging risks during handling.

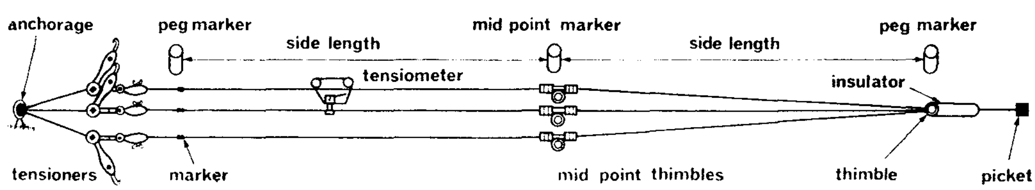


Fig 17.7 Making up One Element of a Rhombic Antenna

Erection Procedure

In preparation for erection, the minor axis attachment points should be carried in the direction of the minor axis masts until the mid points are in position adjacent to the minor axis spreaders when rigged. The other preparations necessary are illustrated in Fig 17.8, for which the key to item numbering is given in Table 3. The following notes should be read in conjunction with Fig 17.8 (at the end of the chapter).

- The side length, half-angle, mean height, rigging heights, minor axis weight blocks and rigging dimensions L1 and L2 are specified on the respective station antenna rigging data chart.

- The total quantity of wire required (*see* Table 3) may be calculated from the following: Quantity = (side length × 12) + (rigging height × 4) for a transmitter; or (side length × 12) + (rigging height × 2) for a receiver.
- It is important to note that the antenna construction and rigging conforms to Drg No SC54632 (3 sheets) which gives details of additional equipment required to facilitate correct rigging.
- For details of the terminating resistance for transmitting antenna see Drg No SC53694. It should be noted that on some sites an alternative method may be specified on the relevant station installation drawing.
- Where Talurit ferrules are used in conjunction with terylene rope, all sharp edges must be removed from the ferrules before swaging.
- The connections between antenna elements and downleads are made by securely binding antenna elements and downleads together in accordance with Drg No SC51250, Sheet 85, Part A.
- The spacing insulators (2) shown in Fig 17.8B and C are secured in position as follows:
  - Securely whipped to the terylene straps (6) (9) (12) using lacing cord.
  - Securely whipped in the position shown on the downlead (5) (13) and at 6 metres (20 ft) intervals down the length of the downlead using short lengths of wire as whipping.
- The terminating resistance end illustrated in Fig 17.8C illustrates both the receiving and transmitting rhombic methods of termination. The resistor (14) is used only for the receiving rhombic, and is installed by securely binding the tails of the resistor to the two antenna elements. The downlead arrangement shown is used only for the transmitting rhombic and is similar to that illustrated in Fig 17.8B for the major axis feeder end which is common to both types.

With both axis ends prepared as shown in Fig 17.8, insert the spacing insulators (17 and 18 in Fig 17.8) at each end of both sides of the antenna to the dimensions shown in Fig 17.8B. Each insulator is connected to the centre antenna element and secured in position by crimping the copper end troughs to the upper and lower elements. Any cross-over of elements must be carefully eased out by hand.

Construct and attach the downleads (Fig 17.8B and C) in accordance with the station installation drawing.

Rig both minor axis assemblies (3), and couple the antenna elements to their respective spreader insulator (Fig 17.8D) ensuring that no element cross-over occurs.

Haul down on the major axis halyards (7) until the flagged points, positioned in accordance with the respective station antenna rigging data, just pass the pulley blocks on the mast and then make off the halyard to the mast base hairpin. Ensure that the antenna and downleads do not foul the feeder poles and crossarms, during erection.

Haul down the minor halyards (7) until the flagged points L2 are approximately 2 metres (6ft 6 in) from the ground, and temporarily make off the spare fall length to the mast base. Attach Preform dead-ends (11) to the halyards at the flagged points and shackle the specified weight block (10) to the Preform. Cast off the temporary make-off, allowing the weight to float.

Check that the upper flags at position L1 on the major axis halyards are still located approximately at the pulley blocks, adjusting the halyard make-off points as necessary. After adjustments, ensure that the weight block heights are still correct and stay the blocks as shown (Fig 17.8D).

Alternative Rigging Method

Under certain circumstances the rhombic antenna may be supplied to a site in the ready-made condition, having been constructed at some central source under controlled conditions which embrace pre-tensioning, measuring and all fabrications. The pre-constructed antenna will be supplied loosely coiled on formers drilled to engage the spinner locating pins to facilitate the running out of the antenna. This class of antenna is installed using the procedure described in the preceding paragraphs.

TYPE 298 ANTENNA SYSTEM

Introduction

The Type 298 antenna system (Fig 17.9) is designed for use at ground transmitter and receiver stations operating in the VHF band (100–156 MHz) and consists of a wide-band, vertically polarized Type 24 dipole antenna and a tubular steel gibbet.

Type 24 Dipole Antenna

The Type 24 dipole antenna consists of the following components, as shown in the exploded view in Fig 17.10.

- Two wide-band radiating elements.
- Three synthetic resin paper rod elements.
- A two-piece synthetic resin rod spacer.
- A quarter-wave sleeve containing a 340 mm (2ft 9 in) UR57 coaxial cable. The coaxial cable is terminated at one end with a coaxial plug and fitted with a circular synthetic resin paper washer. The other end of the quarter-wave sleeve is terminated by a Diakon insulator to connect with the radiating elements.

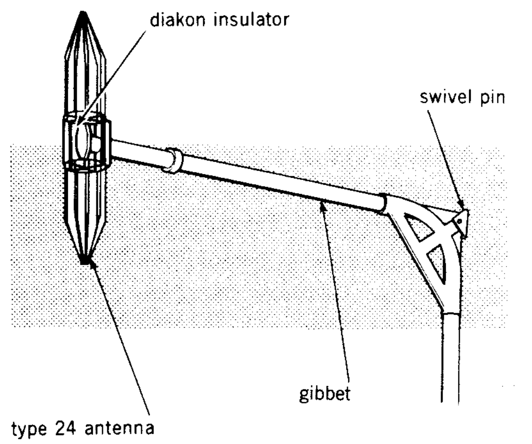


Fig 17.9 Type 298 Antenna System

The radiating elements are secured in position by threaded brass inserts fitted at both ends of each spacer. The two-piece spacer is clamped around the quarter-wave sleeve by bolting it to a flange which forms part of the sleeve.

To prevent the ingress of moisture, a rubber gasket, packing plate and 'O' ring are clamped between the Diakon insulator and the quarter-wave sleeve. The coaxial connector is soldered to the inner ends of the terminals in the Diakon insulator, the cavity of which is filled with silicone grease and sealed with a rubber gasket and perspex cover plate.

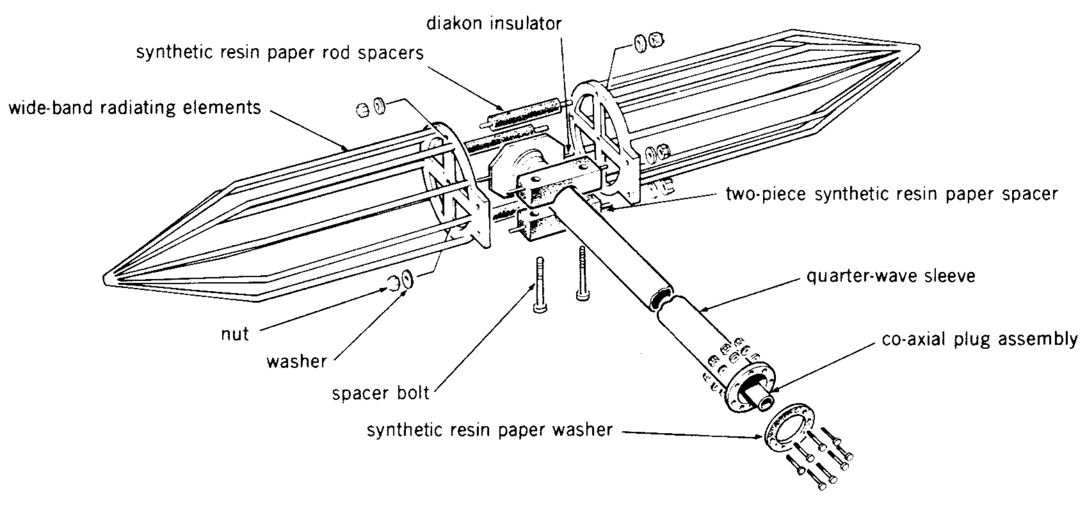


Fig 17.10 Exploded View of Type 24 Dipole Antenna

Antenna Gibbet

The gibbet consists of two straight tubular steel sections held at right-angles by clamps in the curved section of the reinforced hinged bracket (Fig 17.9). A connector consisting of approximately 5.2 m (17 ft) of UR57 coaxial cable terminated at the antenna end by a socket and at the transmitter/receiver end by a plug, is fitted inside the gibbet.

The gibbet arm, to which the antenna is fitted, is provided with a flange which has eight holes. The antenna is attached to this flange by eight 2BA nuts and bolts.

Assembling the Antenna System

The method of assembling the antenna and mounting it on a tower is as follows:

- Remove end plate from gibbet.
- Fix end plate to the flange of the 5.2 m coaxial connector, thread the connector through the gibbet and refit the end plate.
- Connect the gibbet coaxial cable to the coaxial cable in the quarter-wave sleeve and attach the antenna to the gibbet.
- Attach the gibbet to the tower at the two points shown in Fig 17.11 below. The bracket of the gibbet has a square plate connected to it with a swivel pin. This plate is attached to a U-section metal crosspiece on top of the tower by means of four ½ in nuts and bolts. This supports the weight of the gibbet, the lower end of which is clamped to the tower.

The coaxial linking the antenna to the transmitter/receiver building is cleated to the mast at 0.6 m (2 ft) intervals and terminates at a Type 483 bracket inside the building.

In Fig 17.11, the length of coaxial cable between the base of the mast and the building is shown buried in a trench. In some installations, this length of connector is carried above ground on a catenary.

ANTENNA UNIT DESIGN 41

Introduction

The antenna unit design 41 (Fig 17.12 overleaf) is a UHF antenna suitable for ship or shore installations. It covers the complete UHF band 225 MHz to 400 MHz and may be used with either one receiver, one transmitter, one transmitter-receiver, or a number of transmitters or receivers grouped for a common antenna working system.

The main design features of the antenna are: operation over a wide frequency band; radiation in all directions in the horizontal plane; good impedance match into a coaxial line without the need for any matching or balun arrangement; and lightweight. The unit weighs only 3.8 kg (8¼ lb).

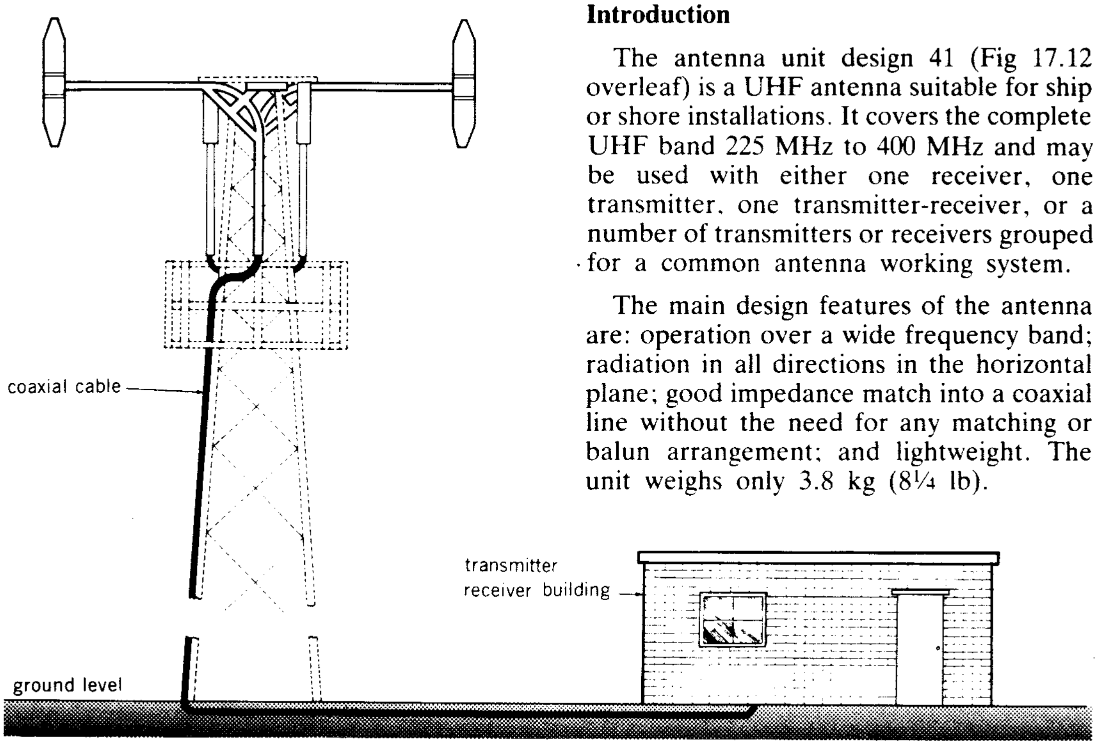


Fig 17.11 Type 298 Antenna System Mounted on a Lattice Mast

The antenna may be mounted upright or it may be completely inverted (Fig 17.13). In either of these positions it will radiate or receive radio waves which are essentially vertically polarized. It will have a free space radiation pattern in the vertical plane, consisting of a single lobe with its maximum at right-angles to the axis of the antenna.

The antenna may be mounted on the top of a pole or mast. Alternatively, it may be mounted on a gibbet or spur projecting from a mast. In exceptional circumstances, two antenna, one upright and the other inverted beneath it may be mounted on a single gibbet as shown in Fig 17.13. Since lattice masts are usually sited at RAF transmitting and receiving stations, the antenna units will normally be mounted on a Type 110 support projecting from the mast.

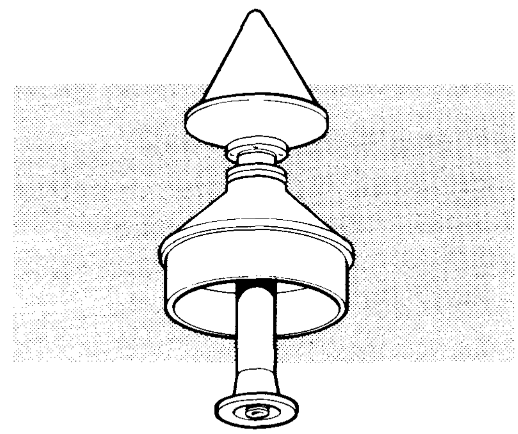


Fig 17.12 Antenna Unit Design 41

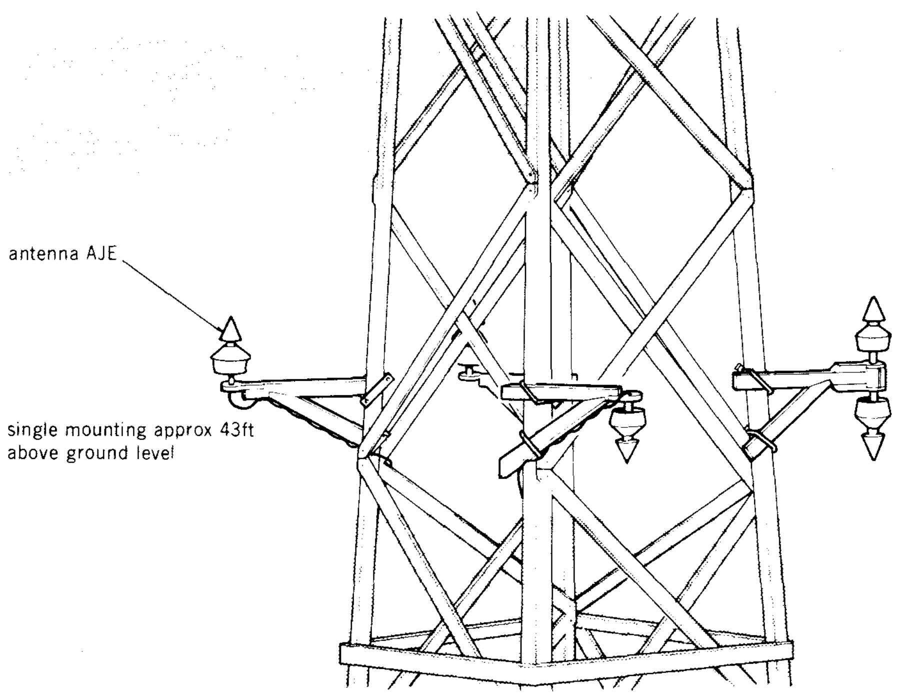


Fig 17.13 Method of Mounting Antenna on a Mast

Antenna Plug Board

The antenna plug board (Fig 17.14) is recommended for use with the UHF ground equipment and should be mounted near the equipment. The plug board consists of a type 606 bracket into which the plugs at the end of the antenna cable may be clamped. The main body of the board is made from hardboard and should be screwed to the wall or other suitable support. The plugs fit into the recessed holes in the bracket and are clamped in place by a clamping strip. The clamping strip consists of a piece of mild steel backed by a leather cushion. The clamping strip is held in place by five coach bolts.

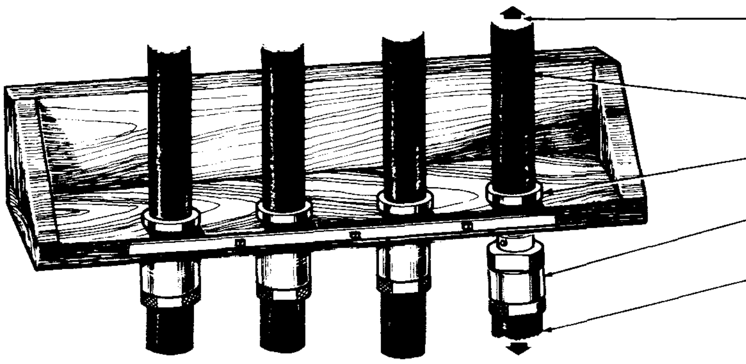


Fig 17.14 Antenna Plug Board

Antenna Feeders

Uniradio 74 cable should be used between the antenna and the antenna plug board. A socket is fitted to the antenna end of the cable to mate with the plug at the base of the antenna. A type C socket is fitted to the cable at the plug board end.

Uniradio 67 cable should be used between the antenna plug board and the receiver, the length of this cable being kept to a minimum. This cable is terminated by a Type C socket at the plug board end, and by an SRG socket at the receiver end.

Fitting XCA 345 to Uniradio 74 Coaxial Cable

The components of the socket design fitted on the Uniradio 74 cable to mate with the plug at the base of the antenna unit are shown in Fig 17.15. All threads of the socket should be greased with C-P grease CS881 before assembly. The method of assembling the socket on the cable is as follows:

- Prepare the end of the Uniradio 74 cable to the dimensions shown in Fig 17.15b.
- Loosen the 4BA screws of the clamp unit and pass the clamp nut, metal washer, rubber sealing washer and taper washer over the cable in that order and solder the socket to the inner conductor (Fig 17.15c).
- Ensure that the 'O' ring seal is fitted to the socket body, then fit the socket body with the taper portion under the metal braiding (Fig 17.15d).

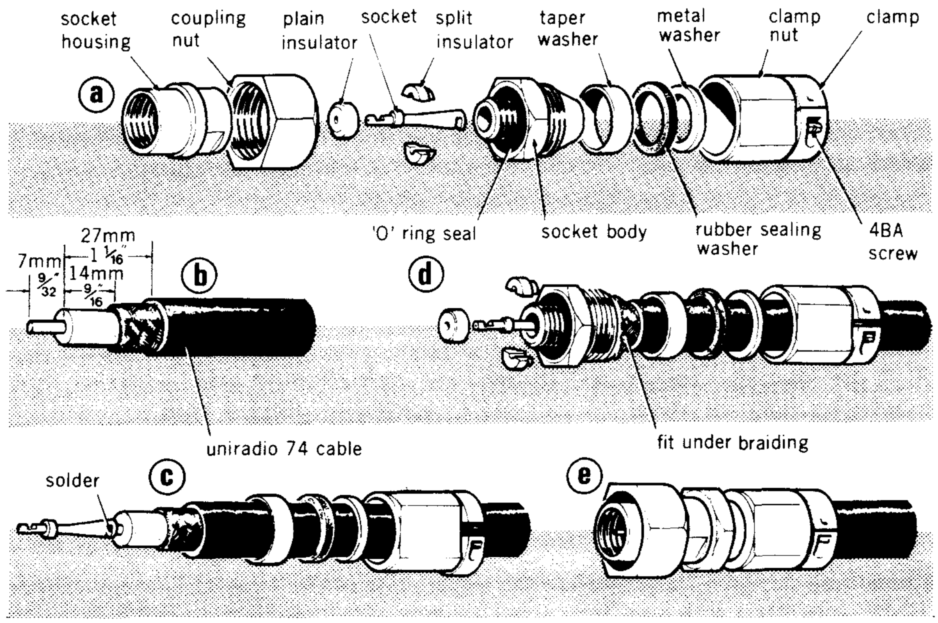


Fig 17.15 Method of Fitting Socket to Antenna End of UR74 Cable

- Fit the split insulators over the socket, close to the ridge on the socket, and move the socket body up to clamp the insulators in place (Fig 17.15d).
- Fit the taper washer over the metal braiding and the tapered portion of the socket body, then tighten the clamp nut on to the socket body making sure that the split insulator stays in place.
- Fit the plain insulator to the socket, then pass the socket through the coupling nut and screw the housing securely on to the socket body (Fig 17.15e).
- Ensure that the clamp nut is tight, and then tighten the two 4BA screws to clamp the cable.

Type C Plugs and Sockets

The Type C plugs and sockets used at the antenna plug board have bayonet type couplings. These connections have been chosen since the noise generator CT207 makes connections at the plug board and quick action, together with mechanical durability, is essential. A type C plug (CC15A) fits on the Uniradio 74 cable on the end remote from the antenna and a Type C socket (UG572/U) fits on the Uniradio 67 cable at the end remote from the receiver — both connections being made at the antenna plug board.

Method of Fitting Type C Plugs and Sockets to Coaxial Cable

The component parts of the Type C plug and socket, and the method of assembly are shown in Fig 17.16.

- Prepare the end of the cable as shown in Fig 17.16b and comb out the braid (Fig 17.16c).
- Place the nut and gasket over the cable (Fig 17.16c) and fit the clamp portion of the plug or socket over the braid on to the covering of the cable (Fig 17.16d).
- With the clamp in place, fan out the wires of the braid, trim to length and fold them back smoothly on to the clamp (Fig 17.16d).
- Trim the exposed portions of the inner conductor and polythene insulator to the dimensions, shown in Fig 17.16d.
- Solder the contact to the inner conductor.
- Move up the gasket towards the end of the cable and ensure that the sharp edge of the clamp enters the groove in the gasket.
- Fit the body of the plug (or socket) and tighten the nut. If assembled correctly, the end of the contact in the plug will be flush with the end of the body, while the end of the contact in the socket will be recessed about 0.010 in. The nut should be tightened sufficiently to split the gasket and ensure a good contact between the nut and the clamp.

Mounting the Antenna

For ground station installations where a lattice mast is in position, the antenna unit design 41 can be mounted on a Type 110 antenna support which may be clamped to the mast as shown in Fig 17.13. If the mast also carries AS505 antennae, the antennae unit design 41 should be mounted between them at about 13 metres (43 ft) above ground level.

One lattice tower can thus accommodate four upright mounted antenna units design 41. In circumstances where more than four antenna are required, then two can be mounted on a single gibbet, one inverted between the other (Fig 17.17 overleaf). It is important, however, that the drain holes in the inverted antenna are enlarged as shown in Fig 17.17.

The antenna unit design 41 is secured to the metal plate of the Type 110 antenna support by six ⅜ in BSW bolts fitted with nuts and spring washers. The complete assembly is clamped to the upright of the tower by two U-bolt and clamp angles which are supplied with the antenna

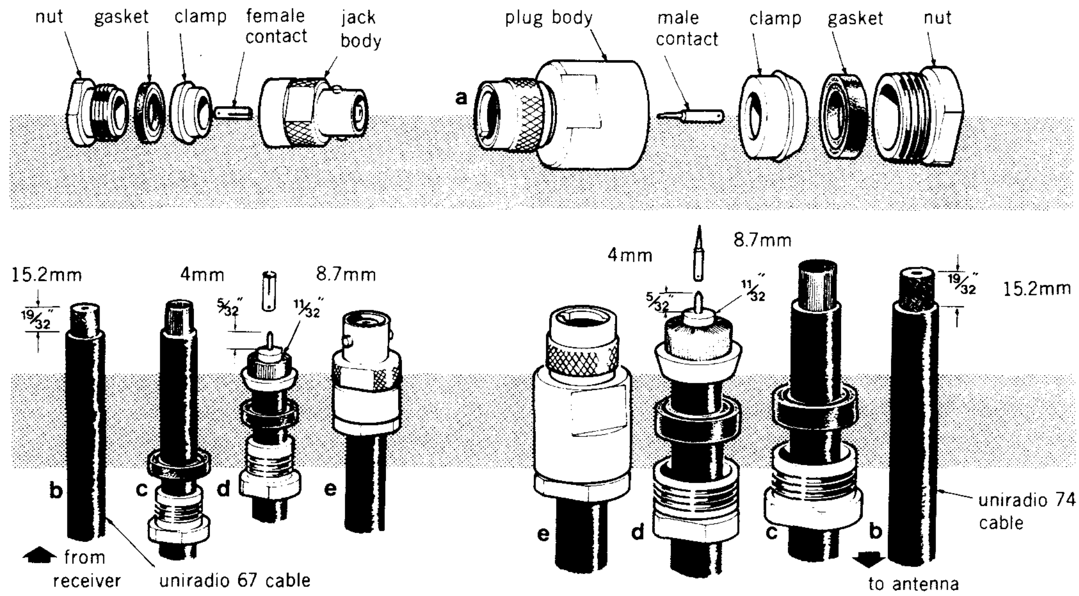


Fig 17.16 Method of Fitting Type C Plugs and Sockets to Coaxial Cable

support (Fig 17.13). The two U-bolts and clamp angles are not identical, their widths being slightly different. The reason for this is that the arm and brace do not meet the upright of the tower at the same angle; the wider of the two should be used at the top.

After assembly, the Uniradio 74 cable should be fastened to the tower using rubber-covered 'P' clips and No 10 × ⅜ in wood screws. These clips should be spaced at about 600 mm (2 ft) intervals.

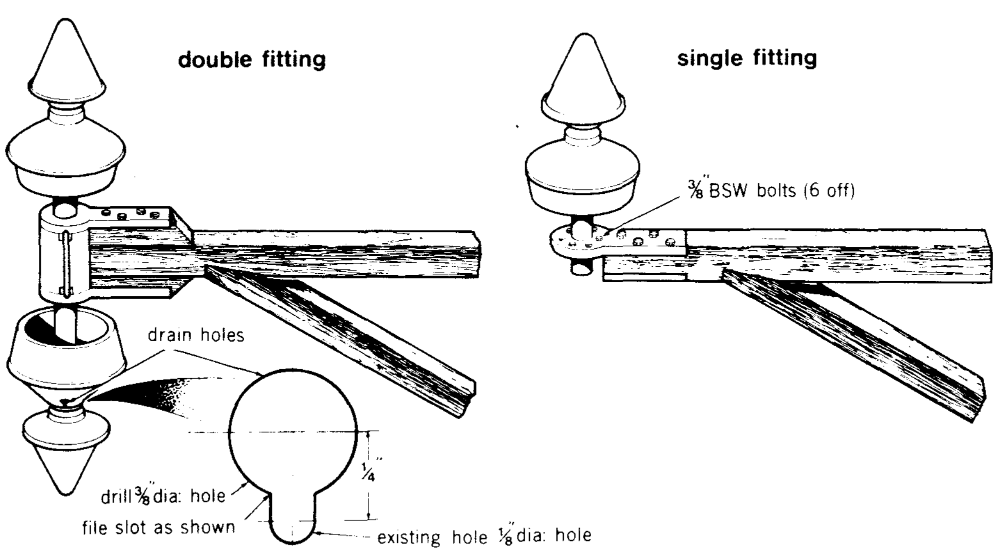
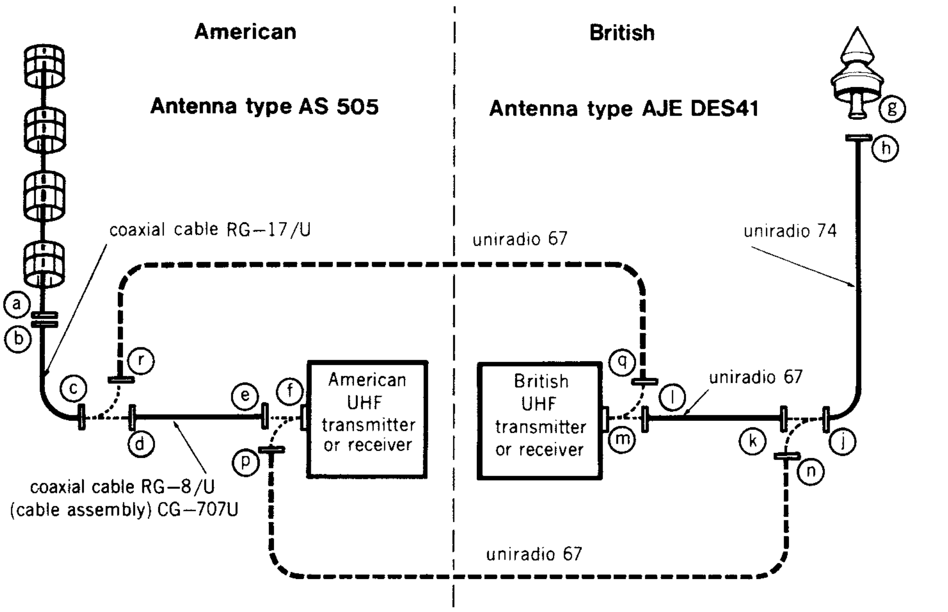


Fig 17.17 Single and Double Antenna Mounting



(a) CONNECTOR REF. UG496/U SOCKET FEMALE FIXED

(b) CONNECTOR REF. UG495/U PLUG MALE FREE

(c) CONNECTOR REF. UG495/U PLUG MALE FREE

(d) CONNECTOR REF. UG60A/U SOCKET FEMALE FREE

(e) CONNECTOR REF. UG59A/U PLUG MALE FREE (STRAIGHT)

(f) CONNECTOR REF. UG496/U SOCKET FEMALE FIXED

(p) CONNECTOR REF. UG59A/U PLUG MALE FREE (STRAIGHT)

(r) CONNECTOR REF. UG60A/U SOCKET FEMALE FREE

(g) RF PLUG 'SPECIAL' (SUPPLIED WITH AERIAL)

(h) SOCKET ELECTRICAL
(REF No 5935 5935-99-9116893)

(j) RF PLUG ELECTRICAL CC15a
(REF No 5935-99-6540902)

(k) RF SOCKET ELECTRICAL UG572/U
(REF No 5935-99-9116861)

(l) RF SOCKET MALE FREE STYLE SR4G (Z560044)

(m) RF PLUG FEMALE FIXED STYLE PR4E (Z560046)

(n) RF SOCKET ELECTRICAL CC15a
(REF No5935-99-6540902)

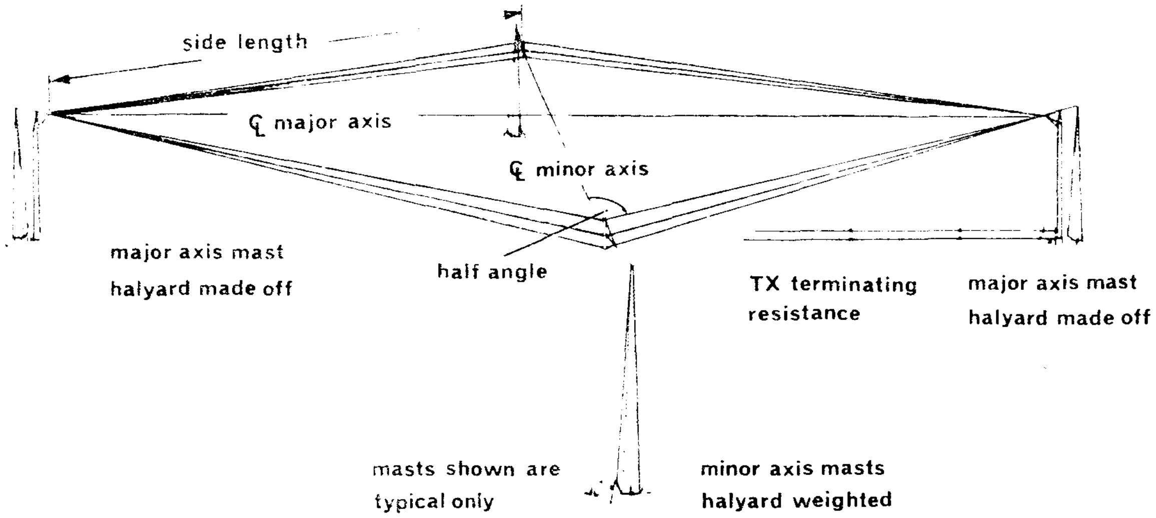
(q) RF SOCKET MALE FREE STYLE SR4G (Z560044)

Fig 17.18 British/American Interconnections

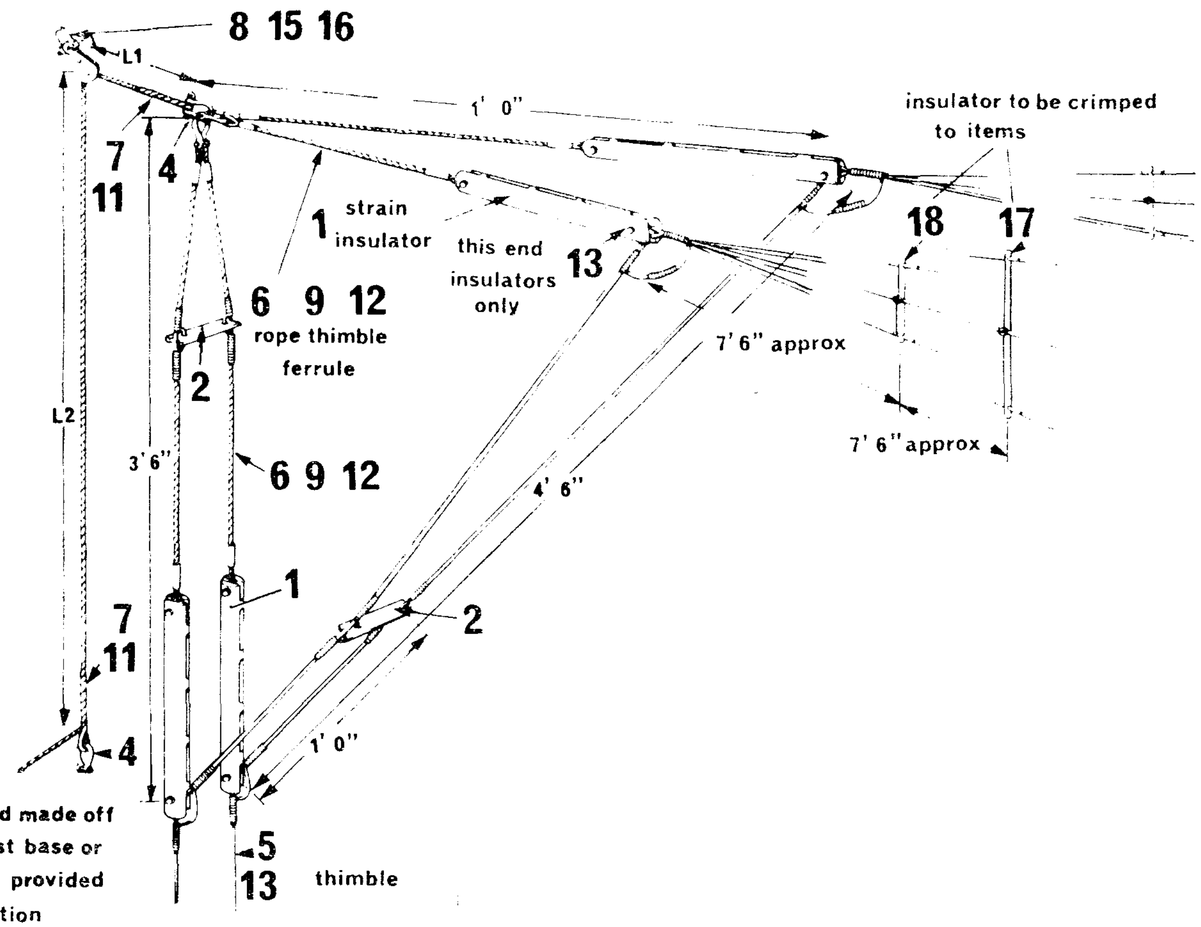
British/American Interconnections

Where it is required to operate British uhf equipment using American antenna, or *vice versa,* it will be necessary to make an adapter. The items required are shown in Fig 17.18.

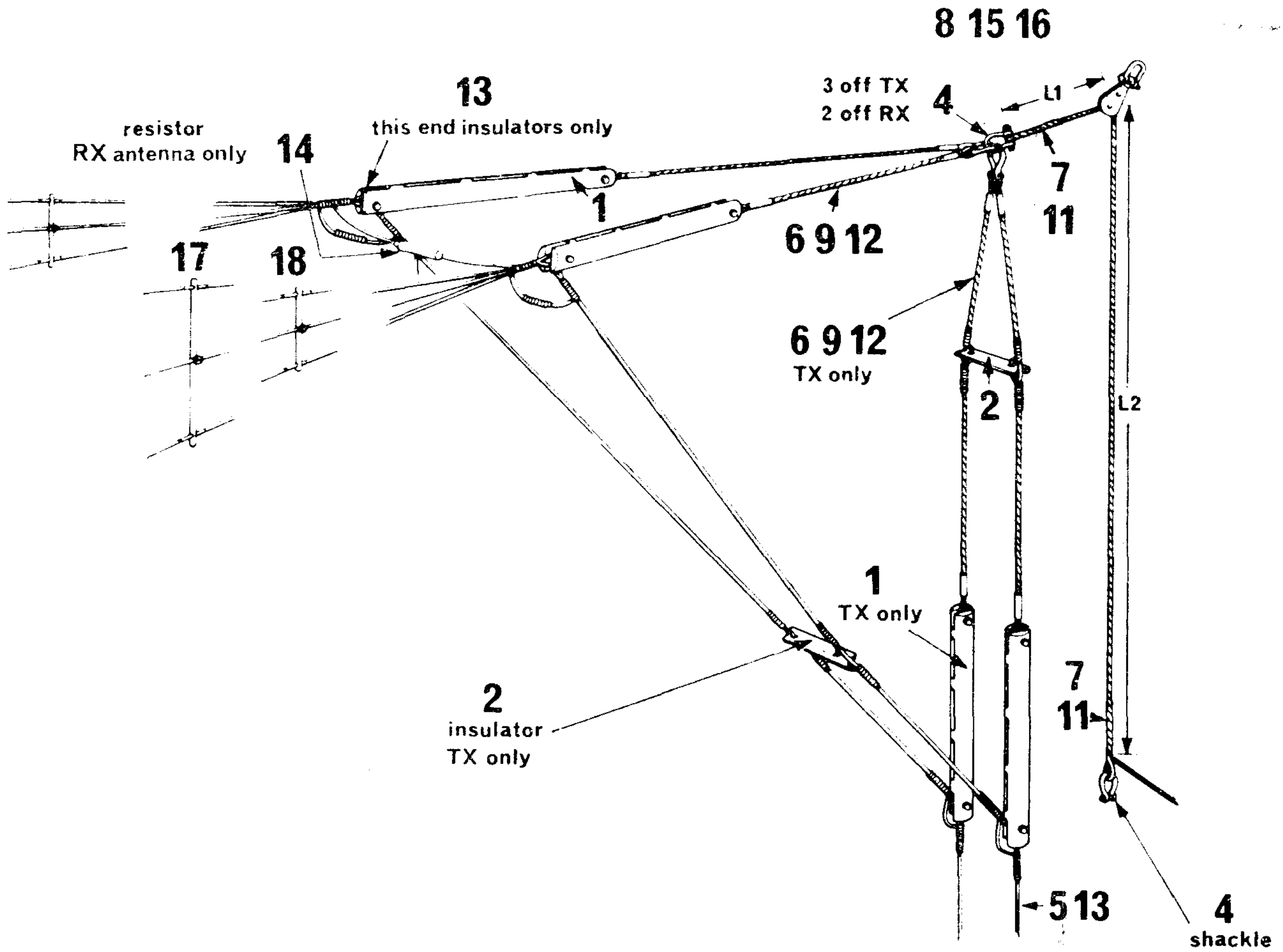
Printed in England for Her Majesty's Stationery Office, by Nelson Brothers of Chorley
(22.1.82) 14217 1114307 8229947 3347



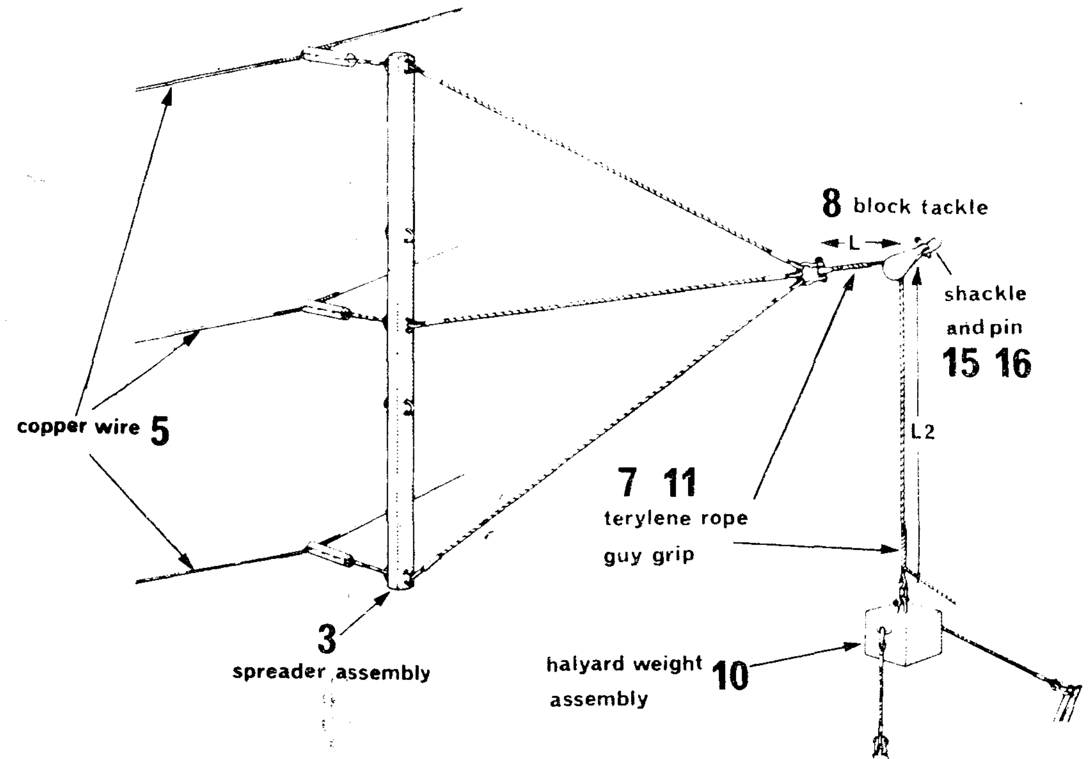
(A) GENERAL ARRANGEMENT OF ANTENNA



(B) RIGGING OF MAJOR AXIS FEEDER END



(C) RIGGING OF MAJOR AXIS



(D) RIGGING OF MINOR AXIS ENDS

Fig 17.8 Three-wire Rhombic — Rigging Details

CHAPTER 18

OPEN-WIRE FEEDERS

Introduction

The source of radio-frequency currents fed to the various types of antennae described in Chapter 17 is the output stage of a radio transmitter. Although in some circumstances it is possible to connect antennae directly to the transmitter (usually in portable or mobile transmitters using vertical antennae) more frequently the antennae are necessarily separated from the transmitter for the following reasons:

- Some antennae are erected at heights well above ground level.
- The building housing the transmitter, if situated close to the antenna, may act as an obstruction and affect the polar diagram.
- In communication centres where it is necessary to change the direction of transmission, and also the frequency, in order to maintain constant communications, different types of antennae may be required for use at various times of day and night by the same transmitter. These antennae must be adequately spaced and, therefore, must be located at some distance from the transmitter.

The connecting link between the transmitter or receiver and the distanct antennae is the radio frequency *transmission or feeder line* the sole purpose of which is to transfer radio frequency power from one point to another as efficiently as possible thus ensuring that the output from the transmitter is fed to the antenna terminals with minimum loss.

In reception the function of the feeder is to transfer minute currents (produced in the receiving antenna by the radio waves propagated by a distant transmitter) to the receiver input terminals, again with minimum loss. The same considerations apply for both transmitter and receiver feeder lines — apart from the greater *power* carried by transmitter feeder lines.

Losses in low frequency (50-60Hz) power lines may be minimized by adequate insulation and reduction of line resistance by the selection of conductors of sufficient size for the load. At radio frequencies, since each conductor has considerable length in relation to the wavelength in use, the conductors acts as antennae and radiate power. Unless special care is taken to minimize this radiation, the power loss may considerably exceed the resistance losses.

Power loss by radiation is generally avoidable by using two conductors so arranged that radiations produced by one conductor are completely balanced by the radiations produced by the other conductor. This is achieved in practice by placing two parallel conductors a fraction of a wavelength apart (for the frequency involved) and insulating one from the other. There are several ways in which this is done and the method to be described in this chapter is that known as the *open-wire feeder system*.

An open-wire feeder system consists of two identical wires, insulated from each other and spaced a fraction of a wavelength apart. These wires are supported above the ground on poles and cross-arms (Fig 18.1). Two systems are used in the United Kingdom, one using wooden poles and cross arms, and the other aluminium poles and cross arms. Concrete poles and cross arms may be used overseas, but these are not described in this chapter.

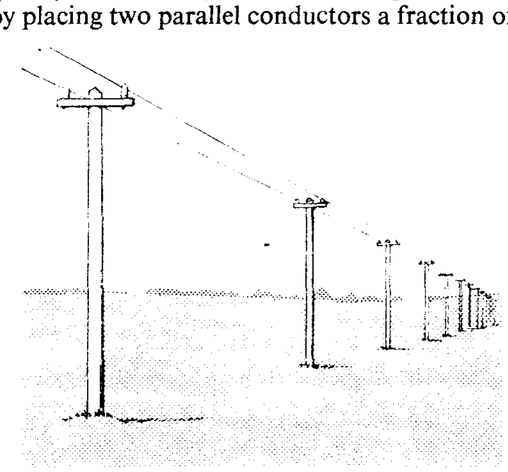


Fig 18.1 Open-wire Feeders

Definition of Terms

In antenna 'farms', where there are large numbers of antennae to be connected to distant transmitters and receivers, there will be a correspondingly large number of feeder lines. To differentiate between the various feeder lines, terms such as 'route', 'branch', 'spur' are used; their meanings are defined as follows (*see also* Fig 18.2).

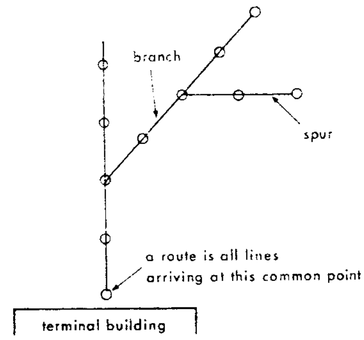


Fig 18.2 Definition of Terms

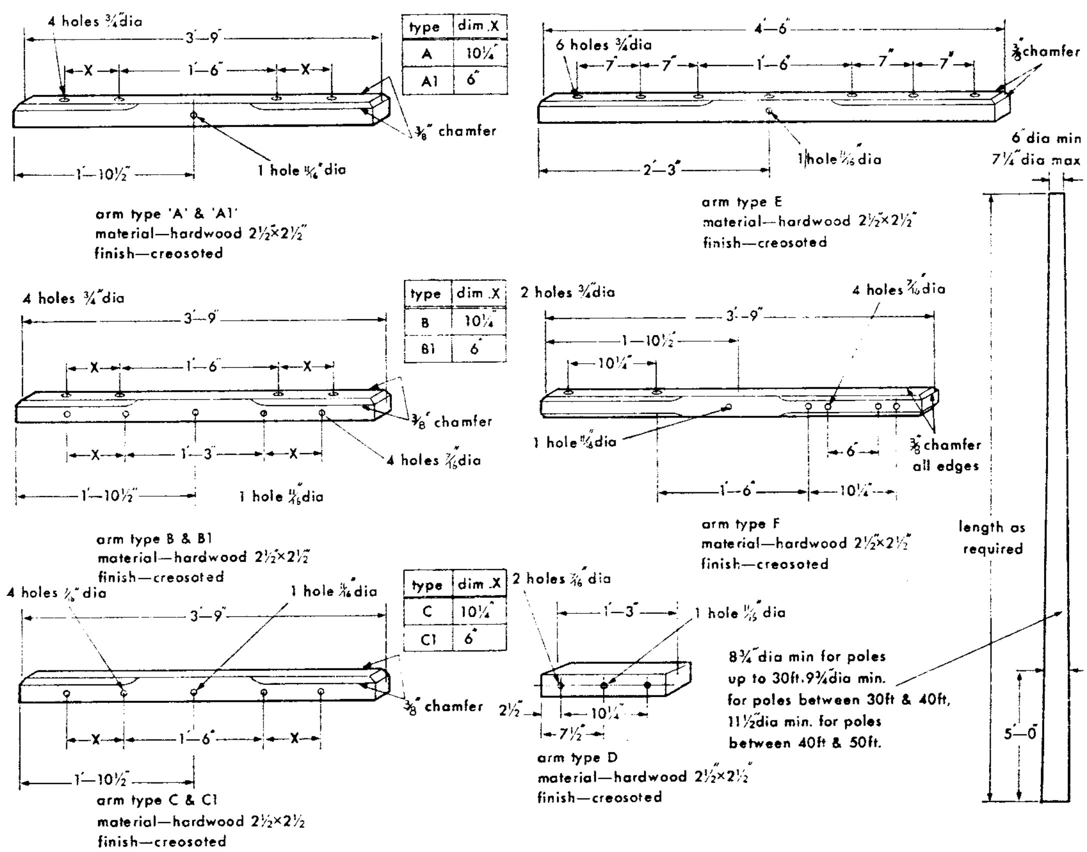
Route. A route is taken to be all lines, poles *etc* between the various antenna positions and a common point, adjacent to the transmitter/receiver building.

Branch. A branch is taken to be that portion of a route consisting of two or more pairs of wires leading into the main route.

Spur. A spur is taken to be that portion of a route consisting of a single pair of wires leading into a branch or the main route. Normally a spur leads directly to an antenna position.

Poles and Cross Arms

Wooden feeder poles are made of good quality fir, or equivalent, creosoted under pressure so that they are impregnated right to the centre. The dimensions for the various lengths of pole are given in Fig 18.3. The cross arms used with wooden poles are made from 63.5 mm ($2\frac{1}{2}$ in) square hardwood protected with creosote. Constructional details of the various standard cross arms are given in Fig 18.3.



type	dim X
A	10¼"
A1	6"

type	dim X
B	10¼
B1	6"

type	dim X
C	10¼"
C1	6"

Fig 18.3 Wooden Feeder Poles and Cross Arms

Fitting Cross Arms to Poles

The method of fitting the cross arms to the wooden poles is illustrated in Fig 18.4. The arms must be fitted with their ends in alignment and square with the pole. The upper arm must be located 50 mm (2 in) from the top of the pole and a vertical spacing of 457 mm (18 in) must be maintained between each arm (Fig 18.4a). Thus, if only two arms are fitted, they should occupy positions 1 and 2 in Fig 18.4a.

Fig 18.4b shows in detail the method of attaching the arms to the poles. A black Whitworth bolt, 203 mm, 229 mm or 254 mm (8 in, 9 in or 10 in) in length must be used according to the diameter of the post. The two rectangular washers required may be made up to the dimensions shown in the detail given in Fig 18.4c.

Alternatively, the required bolt, nut and washers, may be selected from the following list of items from the GPO Rate Book, Sect 1, PLS:

Arm bolt No 7 — $\frac{5}{8}$ in Whitworth bolt, 190 mm ($7\frac{1}{2}$ in) long.

Arm bolt No 8 — $\frac{5}{8}$ in Whitworth bolt, 216 mm ($8\frac{1}{2}$ in) long.

Arm bolt No 10 — $\frac{5}{8}$ in Whitworth bolt. 241 mm ($10\frac{1}{2}$ in) long.

Washer, galvanized No 4 — 76 mm x 50 mm x 6.4 mm (3 in x 2 in x $\frac{1}{4}$ in) MS galvanized.

Notes:

a. All arm bolts are supplied complete with one nut and one No 4 washer. One additional washer must be demanded for each bolt.

b. The bolt threads should be well greased before fitting.

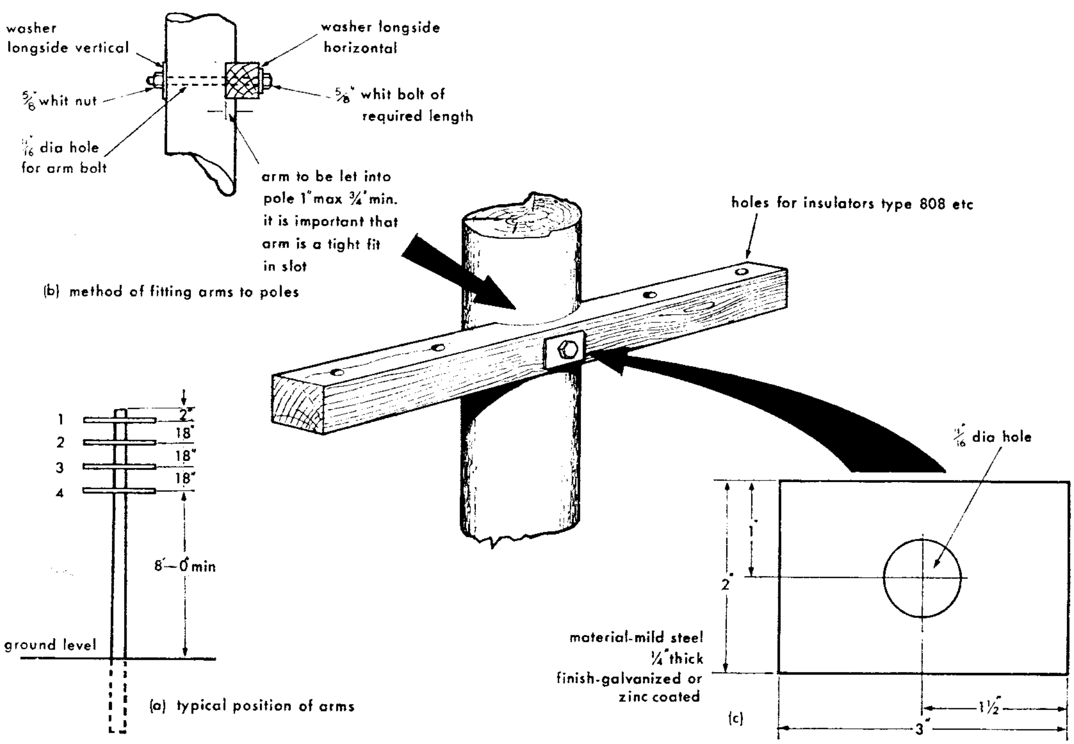


Fig 18.4 Method of Fitting Cross Arms to Feeder Poles

Excavation of Hole

The hole for the feeder pole should be excavated in steps as shown in Fig 18.5a overleaf. The depth of the hole may be decreased by 305 mm (1 ft) in soft rock and increased by 305 mm (1 ft) in loose soil, *but not without the permission of the engineer in charge.* Loose earth must be pounded down. Poles must not be concreted in.

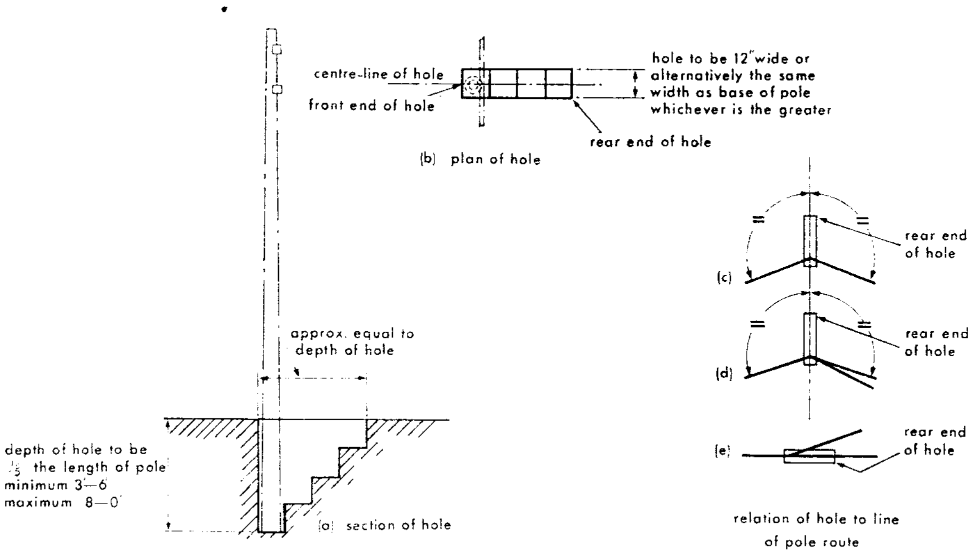


Fig 18.5 Relationship of Foundation Hole and Cross Arms to Line of Feeder Route

Relationship of Hole to Line of Feeder Route

When excavating a hole for a feeder pole the following rules must be observed:

a. Except at building terminal pole positions, all excavation holes on straight portions of the route are to be located with their centre lines along the line of the route, with the front end of the holes nearest the building. The dimensions of the holes are given in Fig 18.5a and b.

b. At building terminal pole positions, the centre-line of the hole is to be located along the line of the route with the rear end of the hole nearest the building.

c. At positions where the route bends (whether main branch or spur) the centre-line of the hole is to bisect the outer angle of the bend as shown in Fig 18.5c.

d. Should a branch or spur intersect at the positions referred to in (c), the same rule applies. This is illustrated in Fig 18.5d.

e. At positions where a branch or spur intersects the main route or branch, rule (b) applies (Fig 18.5e).

Relationship of Cross Arm to Line of Pole Route

On straight portions of a main route, branch or spur, the pole should be positioned so that the cross arms are square to the route as shown in Fig 18.6a.

Where the entire route bends (whether main route, branch or spur) the pole should be positioned so that the cross arms bisect the angle of bend, as illustrated in Fig 18.6b.

Where a branch or spur intersects a main route or branch, the pole should be positioned so that the cross arms are square with the original route (Fig 18.6c).

Where a main route or branch bends at the intersection of a branch or spur, the pole should be positioned so that the cross arms bisect the angle of the route carrying the greater number of wires (Fig 18.6d).

If a main route splits into two branches or spurs each carrying an equal number of wires, the pole should be positioned so that the cross arms are square with the original main route or branch (Fig 18.6e).

Except at building terminal post positions, the cross arms are to be located on the side

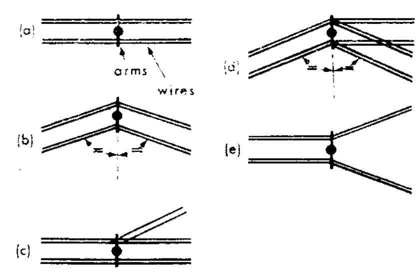


Fig 18.6 Relationship of Cross Arms to Line of Pole Route

of the pole facing *away* from the building. At building terminal pole positions, the cross arms are to be on the side of the pole *facing* the building.

Method of Staying Poles

To make sure that the feeder poles remain vertical, they are supported by stay wires as shown in Fig 18.7. Referring to the typical installation shown in Fig 18.7a, the hole for the stay block should be excavated to a depth of 1 metre (3 ft) in heavy soil, 1.2 metres (4 ft) in medium soil or 1.5 metres (5 ft) in light soil. A slot must be cut, as narrow as possible, for the stay rod, care being taken not to disturb the surrounding soil. The hole is then undercut for the stay block as shown. In very light soils, a concrete stay block may be used, as shown in Fig 18.7b.

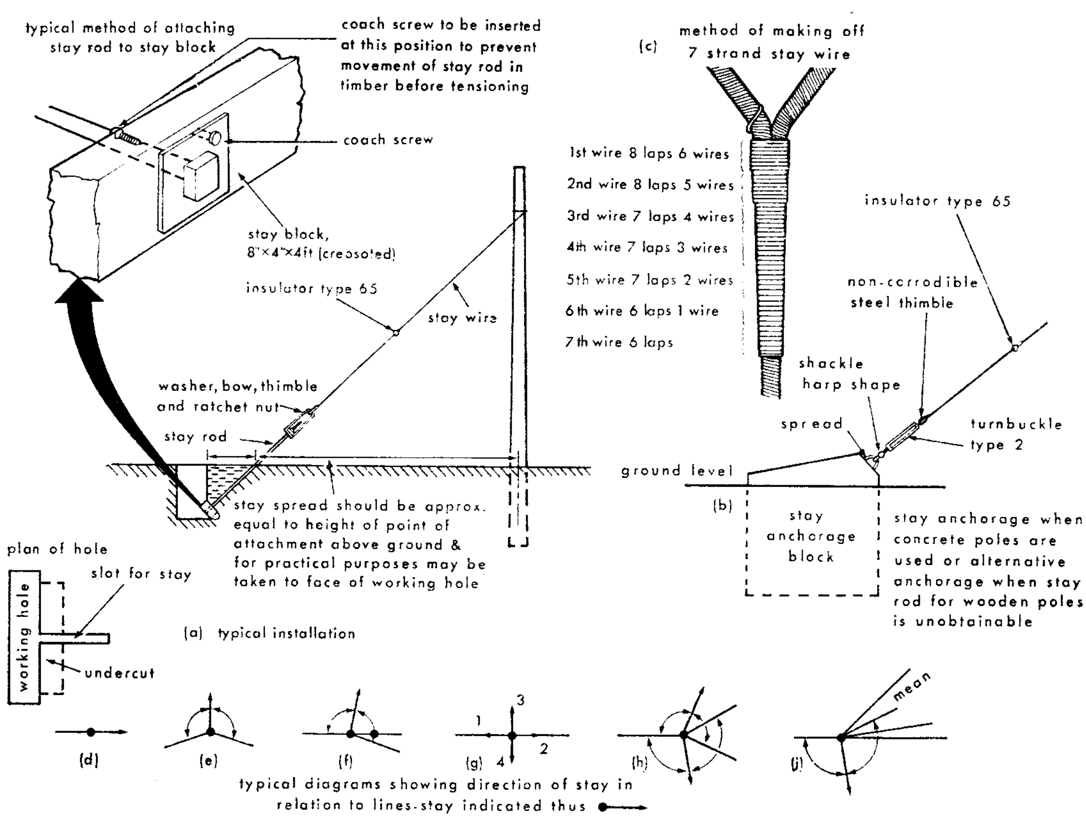


Fig 18.7 Method of Staying Feeder Poles

Attachment of stay wire. The stay wire is lapped twice around the pole and secured with a staple on the side remote from the stay rod. The first lap should be parallel to the ground and the second lap in the direction of the stay. The loose end of stay is unstranded for 381 mm (15 in) and the wires placed symmetrically around the stay wire to which it is to be spliced. As shown in Fig 18.7c, each wire is then bound round the stay wire and the remaining strands.

Direction of stay in relation to lines. Figs 18.5d to j give typical diagrams showing the direction a stay should take in relation to the lines.

Erection of Poles

The erection of light wooden poles should present no difficulties, However, the erection of heavy wooden poles requires the use of a derrick with block and tackle as shown in Fig 18.8 overleaf.

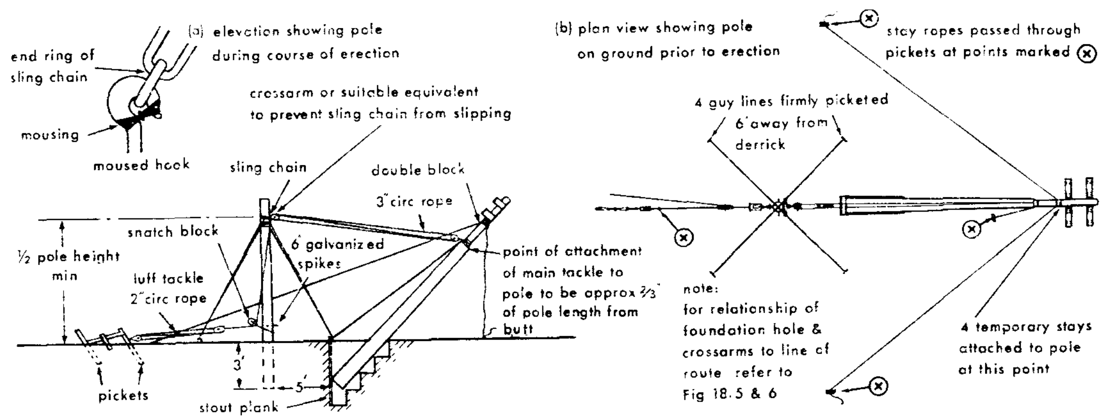


Fig 18.8 Method of Erecting Heavy Wooden Poles

ERECTING OPEN-WIRE FEEDERS (WOODEN POLES)

Introduction

The following paragraphs describe the routeing of open wire feeders and the various precautions to be taken when covering long routes, making deviations from straight runs and crossing roadways *etc*. The methods of erecting, tensioning and terminating the wires are also described. A typical layout is shown in Fig 18.9 at the end of the chapter.

Limitation on Number of Cross Arms

The approved method of positioning and fitting cross arms to feeder poles is shown in Fig 18.4. The number of 4-way (2-pairs) cross arms that may be fitted to the poles used at receiving stations is limited by the wind conditions as indicated in Table 1.

TABLE 1

Limitation on number of cross arms (receiving)

Wind Velocity	Maximum number of 4-way (2-pair) cross arms
Where not normally expected to exceed 80 mph.	4
Where more than 80 mph is experienced	3

Note: For transmitting stations, only one 4-way (2-pair) cross arm per pole is permitted. This is to make servicing easier.

Height of Feeders

In general, where no future development is envisaged on a main branch or spur, the lowest arm, irrespective of the number of arms fitted, need not be more than 2.5 metres (8 ft) above the ground. However, in instances where the feeders are carried over roadways *etc.* a sufficient clearance must be left below the wires to allow for the passage of traffic (Fig 18.10).

When increasing the height of feeder lines over roadways *etc* and where the ground is uneven it is important to ensure that the feeder lines do not exert a vertical pull on the poles, thus tending to draw them out of the ground. The correct procedure is shown in Fig 18.10.

Note: Where feeders have to cross railways, main roads or overhead power or telephone lines, special arrangements have to be made. In such circumstances, the engineer-in-charge must be consulted before erecting the feeders.

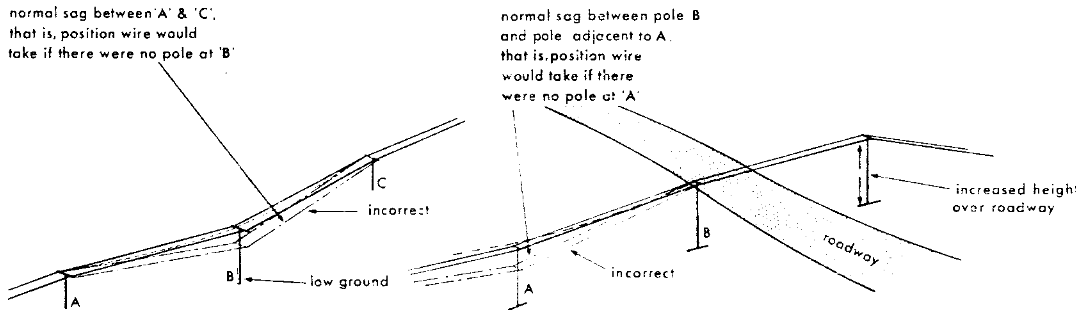


Fig 18.10 Erecting Feeder Lines of Varying Heights

Method of Erecting Feeder Wires

Feeder wires are supported by Type 808 insulators. These insulators are illustrated in Fig 18.11 and, on a typical cross arm, four such insulators are mounted as shown. The insulator bolt is inserted in the hole in the cross arm and secured with a washer and nut, care being taken to ensure that the slot in the insulator is parallel to the line of the feeder run. Once the insulator has been fitted, proceed as follows:

- Run the wires of one route loosely through the insulator slots.
- Terminate the antenna end of the wire using one of the methods shown in Fig 18.12 overleaf — the method selected depending upon the type of cross arm and the spacing of the feeder lines in use.
- Tension the line.
- Slacken the nut securing the insulator to the cross arm and rotate the insulator through 45° so that it retains the wire.

Note:

- Work from the antenna end of the run towards the building in each case.
- Terminate and tension the wires two or four at a time using the procedure described in the following paragraphs.

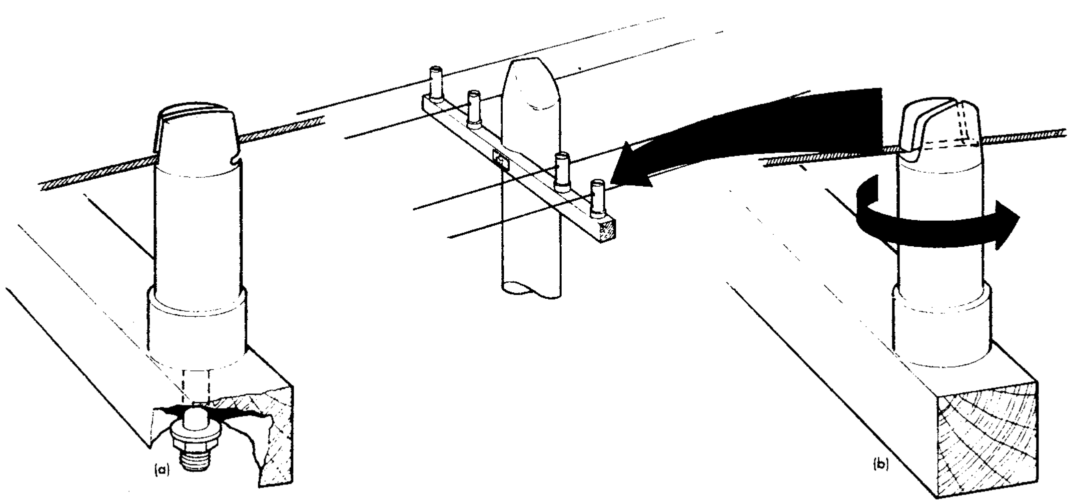


Fig 18.11 Positioning of Type 808 Insulators

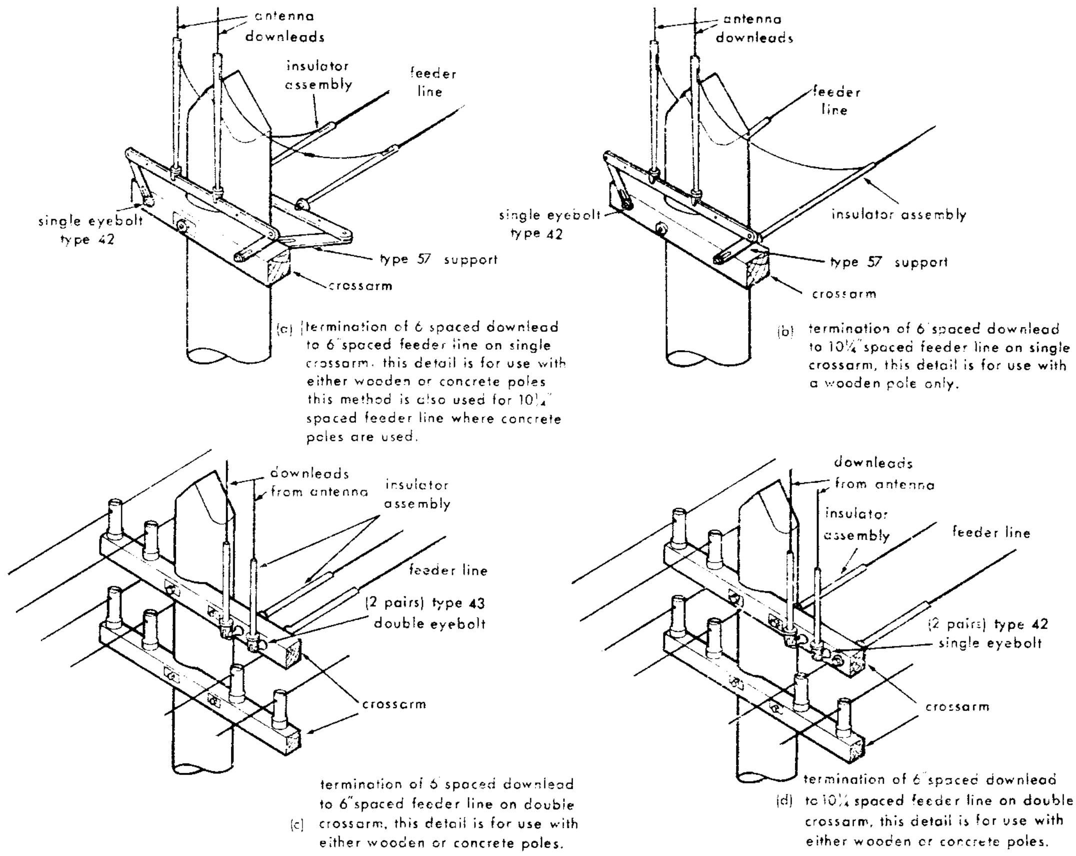


Fig 18.12 Terminating Feeders at Antenna

Method of Tensioning and Terminating Wires

Equipment required. The following items are required to tension the feeder wires:

- *Collets.* The size of collet used will vary according to the hard drawn copper wire used, *ie* 100 lb/mile, 200 lb/mile *etc.*
- *Clamping tool. See* Chapter 6, page 6.8.
- *Lead washer.* For use on porcelain strain insulators only.
- *Roller tool.* This tool is to be locally manufactured. The construction and function of this item will be apparent from Fig 18.13.
- *Wire Tensioner* (Rachet Strainer and Tongs). *See* Chapter 6, page 6.8.

Procedure. The procedure for tensioning and terminating the feeder wires is illustrated in Fig 18.13. The sequence of operations is as follows:

- Fit a single eyebolt and place the roller tool over the cross arm as shown in Fig 18.13a and fit the strain insulator.
- Thread a Type 45 lead washer (porcelain strain insulator), the assembled collet and collet tool over the wire (Fig 18.13b). Tension the wire over the cross arm as shown in Fig 18.13c. For the correct tension at the tongs refer to Fig 18.14. It is important that the picket is positioned in line with the strain insulator.
- Fit the collet to the wire at the position shown in Fig 18.13d using the collet tool. Remove the collet tool.
- Fix the insulator on the line by adjusting the eyebolt so that the collet is bedded in the strain insulator recess as shown in Fig 18.13e.

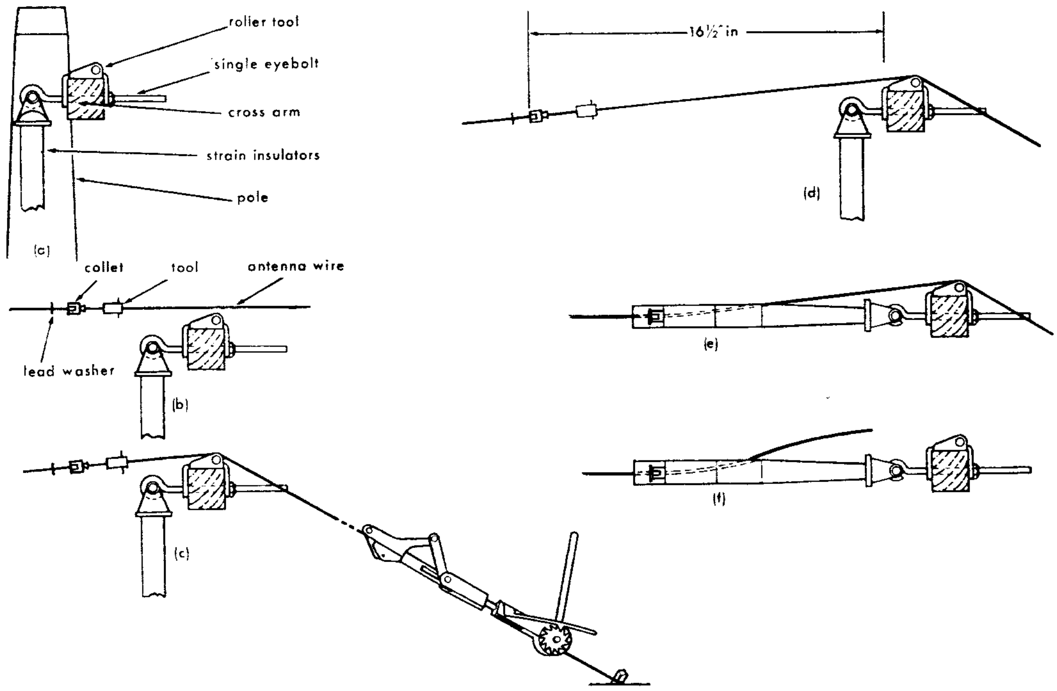


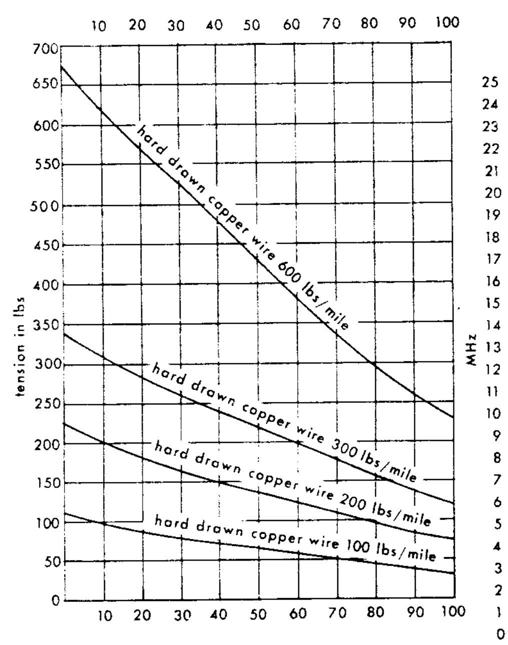
Fig 18.13 Terminating and Tensioning Feeder Wires

- Make a further adjustment to the eyebolt so that the indicator on the wire tensioner just begins to move back towards zero.
- Remove the tensioner and cut the wire at a suitable point for jointing (Fig 18.13f). Remove the roller tool before jointing.

Erecting a Feeder Line Over an Existing Line

The procedure to be adopted to prevent shorting of the line during the erection of one feeder line over another is illustrated in Fig 18.15 overleaf. The procedure is as follows:

- Throw a length of dry cordage over the existing line and secure it in the form of a tight endless loop around the cross arms which are to carry the new line.
- Secure one end of the new line to the cordage as indicated at point A in Fig 18.15.
- Feed the new line over the existing line by pulling on the cordage and attaching small supporting loops, as indicated at point B in Fig 18.15 at approximately 3 metre (10 ft) intervals. Care should be taken to avoid excessive sagging of the wire between the loops.
- When the new wire has been carried across the span between the poles, unfasten the end at point A and attach both ends temporarily to the cross arms. Remove the small loops by pulling the cordage back in the opposite direction.



temperature above the expected minimum at time of erection

these curves are based on a wind pressure of 25 lbs/sq ft with no ice formation and a minimum factor of safety of 2·5- tensions to be within ± 5 lbs

Fig 18.14 Temperature/Line Tension Graph

- Terminate both ends at their correct positions as shown in Fig 18.12.

Note:

The foregoing procedure may also be found useful in erecting feeder lines across streams and over hedges.

Division of Long Routes

Routes of excessive length shall be divided into sections not exceeding 402 metres (440 yards) in length. A route 914 metres (1000 yards) in length should, for example, be divided into three mechanically isolated sections. At the end of each section, all feeder lines on this portion of the route should be terminated as shown in Fig 18.16.

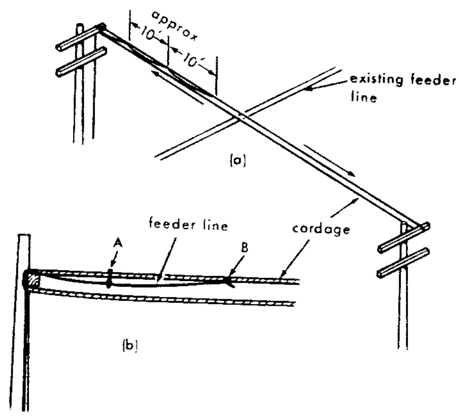


Fig 18.15 Erecting a Feeder Line over an Existing Line

Bends

The feeder routes should always be as straight as possible. Where a deviation from the straight involving a turn of more than 10 degrees is necessary, the pairs of wires must be 'turned vertically' using the method described in the following paragraphs.

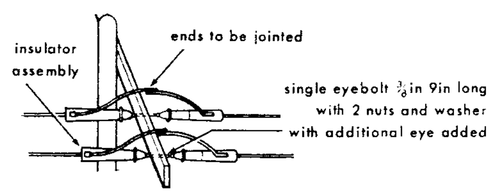


Fig 18.16 Terminating Ends of Sections

Vertical turning. The method to be adopted when the feeder line run has to be turned through an angle greater than 10 degrees is illustrated in Fig 18.17. As shown in this illustration, the pole at the point where the feeder line is to be turned, carries two cross arms. The insulators carrying the pair of lines are mounted one on each cross arm and positioned one vertically above the other.

When positioning the feeder wires in the insulators proceed as follows:

- The wire carried by the inner insulator on the pole before the bend is taken to the insulator on the *upper* arm on the pole at the bend and then to the *outer* insulator on the next pole.

- The wire carried by the outer insulator on the pole before the bend is taken to the insulator on the *lower* arm on the pole at the bend and then to the *inner* insulator on the next pole.

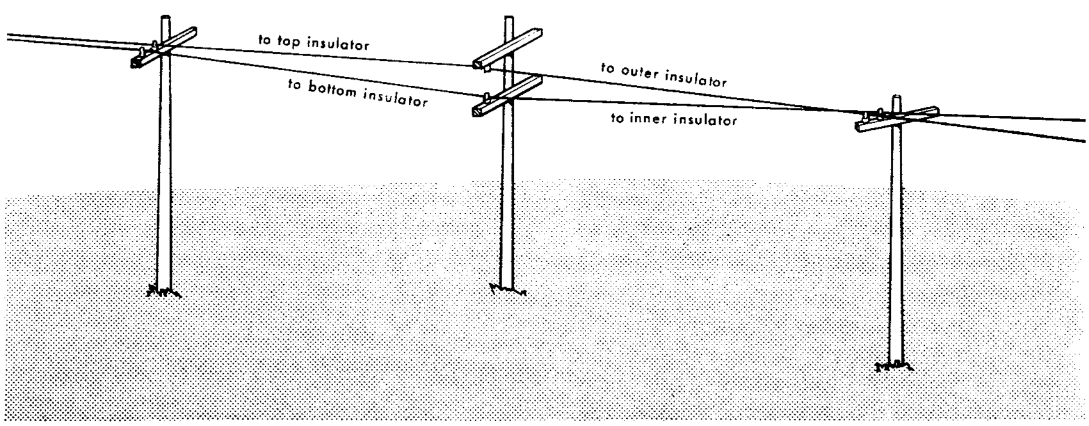


Fig 18.17 Vertical Turning

Typical Arrangements of Cross Arms and Insulators

The positioning of cross arms and insulators for nine typical arrangements is shown in Fig 18.18.

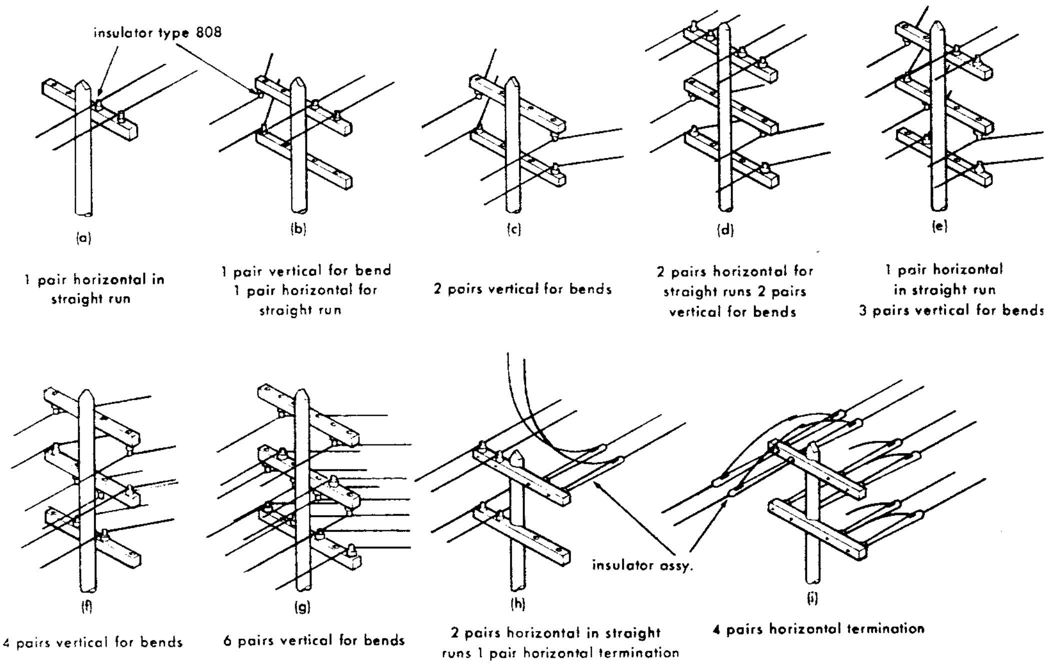


Fig 18.18 Typical Arrangements of Cross Arms and Insulators

Pole Spacing

Feeder poles should be spaced approximately 30 metres (100 ft) apart, with a maximum of 38 metres (125 ft).

Staying

The method of staying feeder poles was discussed on p18.5 and is illustrated in Fig 18.7. Poles should be stayed at all bends as indicated in this illustration, and all terminal poles must be fitted with back stays as shown in Fig 18.7d.

Poles between sections should be stayed as shown in Fig 18.9 at the end of the chapter (poles C10, D11 and D29 are examples). On straight portions of a route where no branches or spurs intersect, poles should be stayed as shown in Fig 18.9 (pole D14 is an example). Open-Wire Feeders (Aluminium Poles)

Introduction

The remainder of this chapter will be devoted to a description of open-wire feeders carried on aluminium poles and cross arms. This system differs from the wooden pole system mainly in the components used; the methods of erecting, tensioning *etc* are similar.

Poles

There are three standard poles used, Types A, B and C, and these are illustrated in Fig 18.19 overleaf. The different lengths of the poles enable the feeder wires to be kept horizontal when passing over undulating ground and to raise the height of the feeders when they pass over roadways *etc*.

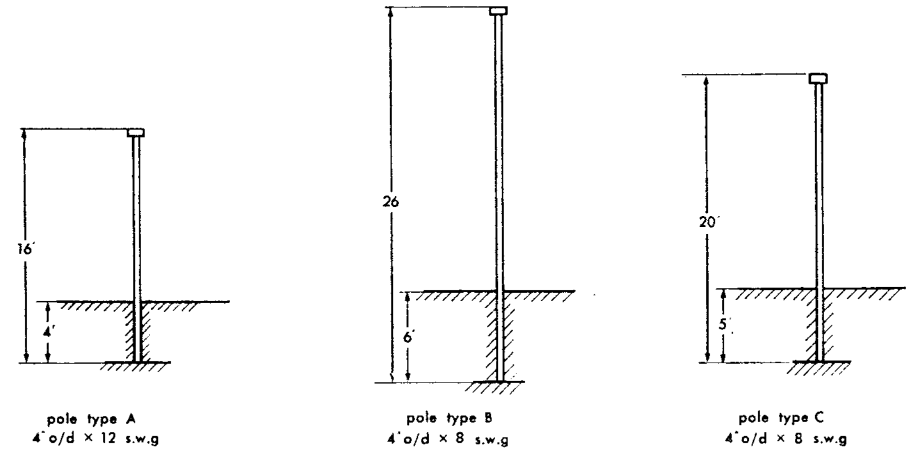


Fig 18.19 Standard Aluminium Poles

Arm Assemblies

There are four standard arm assemblies as illustrated in Fig 18.20. They are as follows:

- Type A — used to terminate 10 in feeders to 6 in downleads from antenna.
- Type B — used to carry one pair of feeders forming part of a straight run. The pole carrying this arm is not stayed.
- Type C — used in conjunction with a Type B arm for turning one pair vertically (*see* Fig 18.21). The arm has provision for the attachment of a stay.
- Type D — this is a double arm used to carry two pairs of feeders forming part of a straight run.

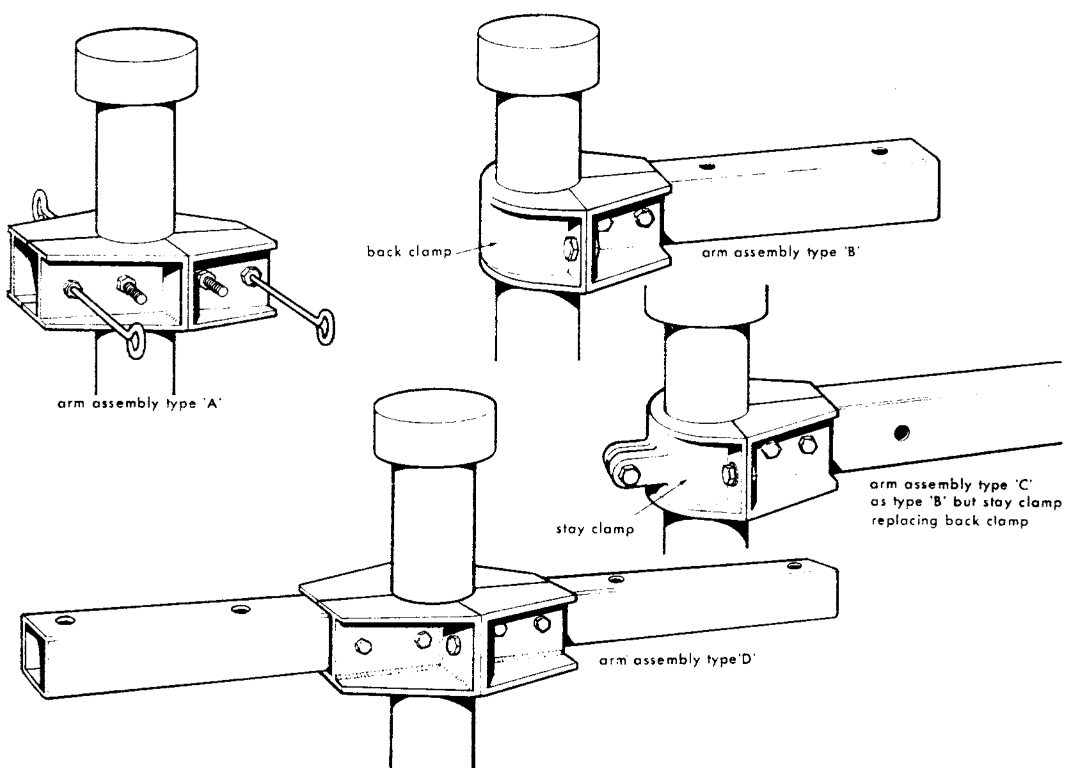


Fig 18.20 Standard Arm Assemblies

Pole Arrangements

The arm assemblies illustrated in Fig 18.20 may be used in a number of different combinations to suit the requirements of a particular feeder run. The various combinations are shown in Fig 18.21, in which all poles are shown as viewed from the building to the antenna.

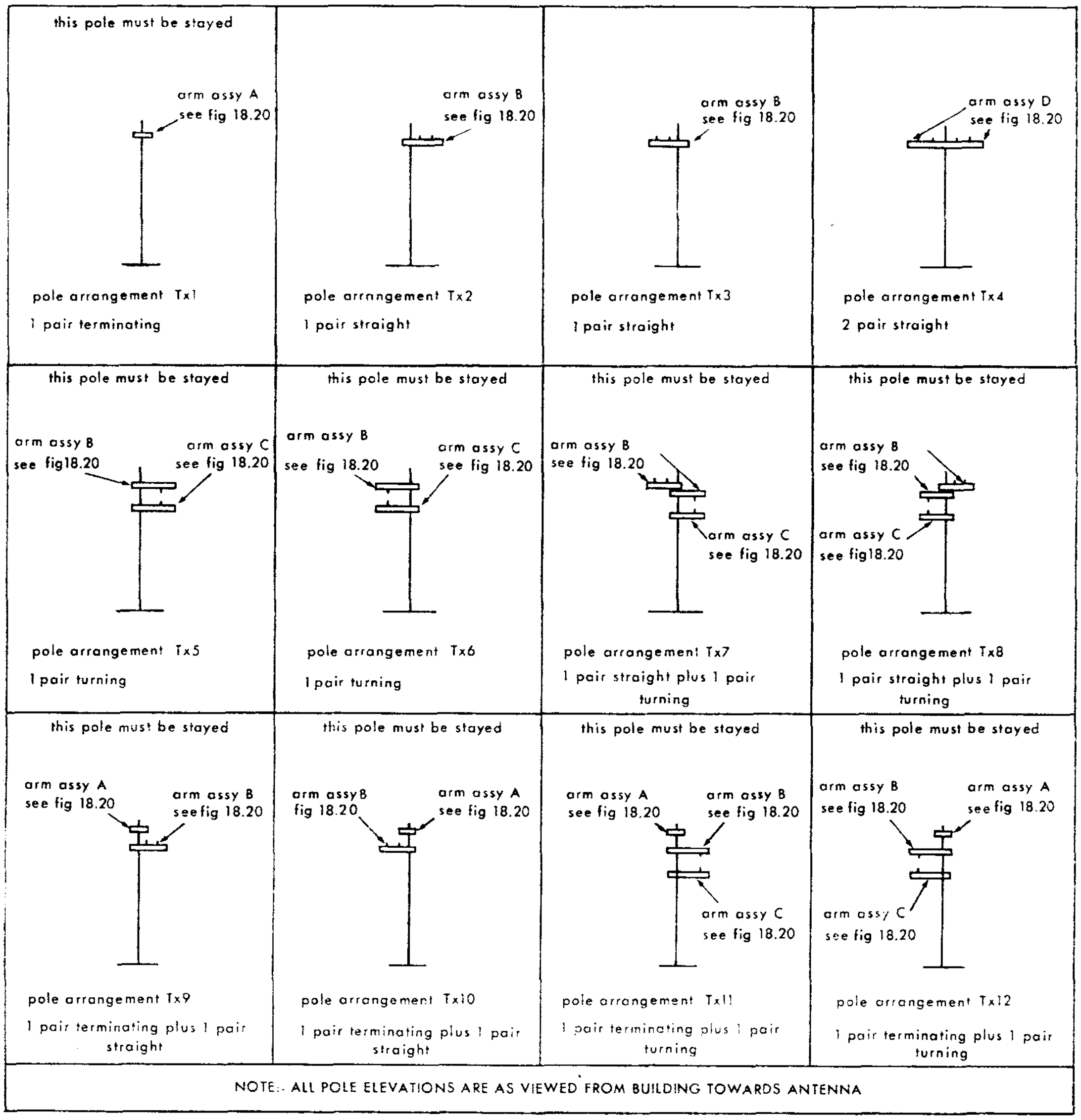


Fig 18.21 Pole Arrangements

Beam Assemblies

The four standard beam assemblies are illustrated in Fig 18.22 overleaf. They are as follows:

- Type E — used in pairs for turning 2 pairs vertically. The stay clamp, to which the stay is attached, may be fitted to either end of the beam depending on the direction in which the feeders are turned. The beam is supported on two poles.
- Type F — an extension beam used to extend a Type E beam assembly by the addition of one pole. The use of this beam allows an extra 2 pair of feeders to be turned vertically.
- Type G — used to terminate 2 pair of feeders.
- Type H — an extension beam used in conjunction with a Type G beam by the addition of one pole. This allows a further 2 pair of feeders to be terminated.

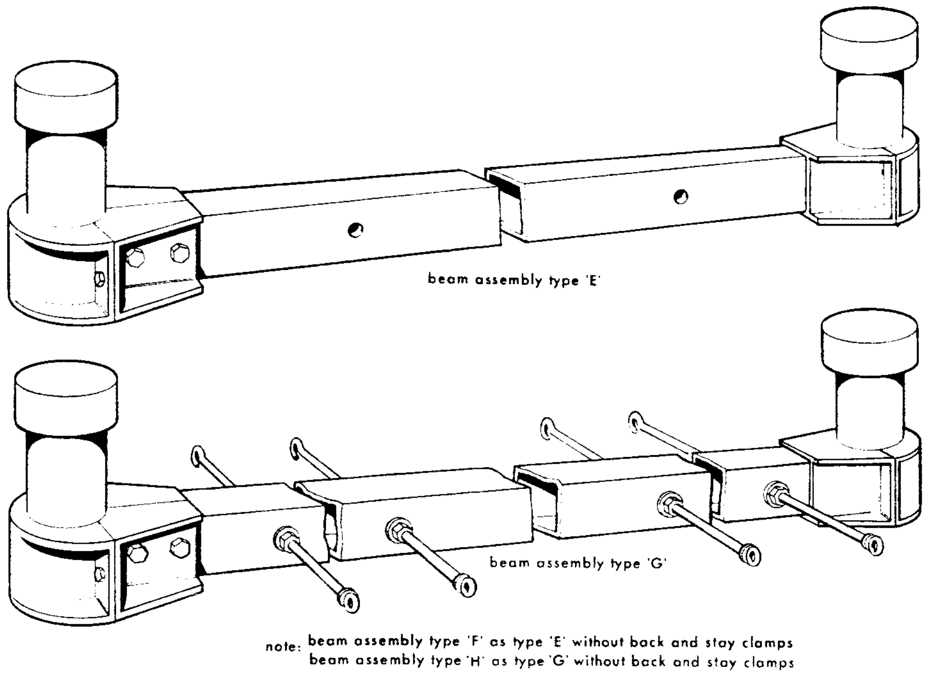


Fig 18.22 Standard Beam Assemblies

Gantries

A structure made up of one or more beam assemblies supported by two or more poles is called a gantry. Two types of gantry are used to support feeder lines: one is the vertical turning gantry and the other the terminating in-line gantry.

Vertical turning gantry. The basic vertical turning gantry consists of two Type E beam assemblies supported on two poles (Fig 18.23). The stay arrangements may be fitted at either end of the gantry depending on the direction of the turn. This basic gantry can be extended by the use of pairs of Type F beam assemblies, one additional pole being required for each additional pair of extension beams (Fig 18.23).

Gantry designation. A 2-pole gantry turning a maximum of two pairs of feeders is termed a gantry arrangement GT2. Similarly, a 5-pole gantry turning a maximum of eight pairs of feeders is termed a gantry arrangement GT5. The maximum number of poles per gantry is seven.

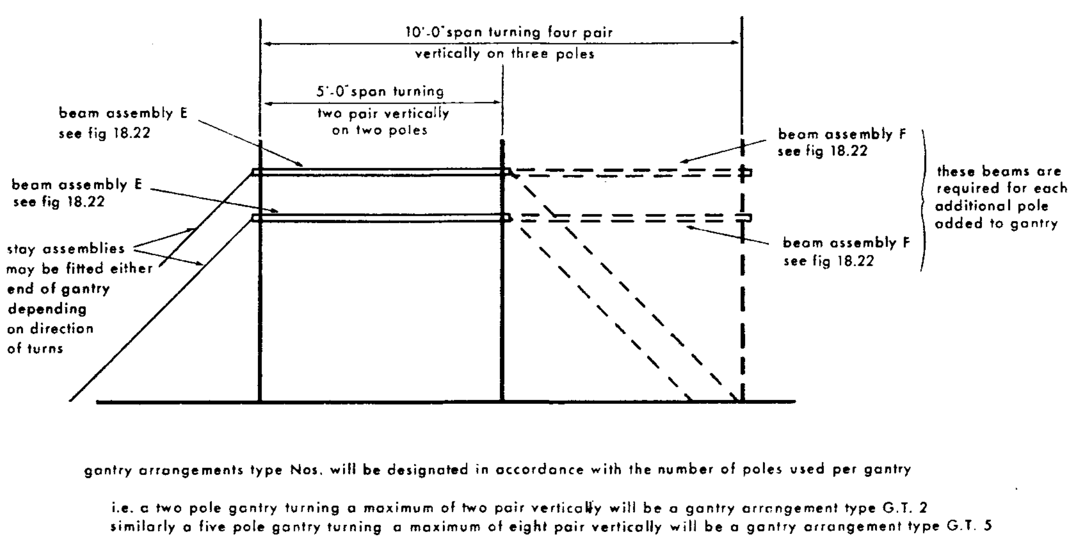
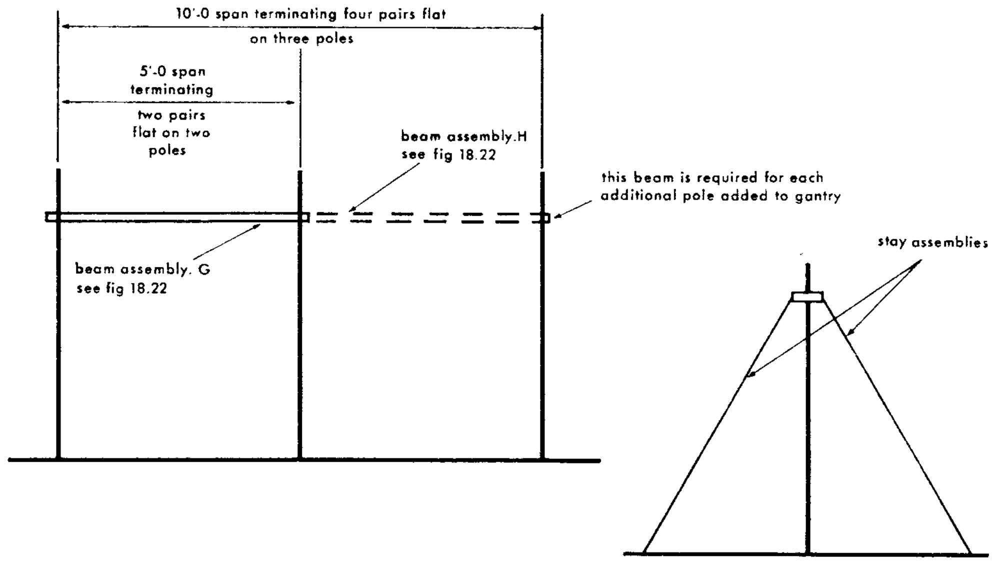


Fig 18.23 Vertical Turning Gantry

Terminating in-line gantry. The basic terminating in-line gantry consists of one Type G beam assembly supported on two poles (Fig 18.24). This basic gantry can be extended by the addition of Type H beam assemblies as shown in Fig 18.24.



gantry arrangement type Nos. will be designated in accordance with the number of poles used per gantry

ie a two pole gantry terminating two pairs of feeders will be a gantry arrangement G.S. 2
similarly a five pole gantry terminating 8 pairs of feeders will be a gantry arrangement G.S 5

Fig 18.24 Terminating In-Line Gantry

Gantry designation. A 2-pole gantry terminating two pairs of feeders is termed a gantry arrangement GS2. Similarly a 5-pole gantry terminating eight pairs of feeders is termed a gantry arrangement GS5. The maximum number of poles per gantry is seven.

Pole Stays

Four types of stays are available and these are graded according to the maximum tension to which they can be subjected. Each type has three variants, one for use in temporary installations and the other two for permanent installations. The instructions and details of the various stays are given in Fig 18.25 (a pull-out page at the end of the chapter).

Stay Arrangments

There are three types of stay arrangements. These, together with their applications, are shown in Figs 18.26, 18.27 and 18.28.

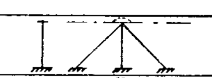
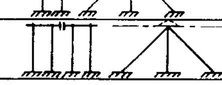
feeder pole arrangement	stay assembly	remarks
pole supporting 1 pair	type 'B' (medium duty)	qty 2 stays/pole 
gantry supporting 1 or 2 pairs	type 'B' (medium duty)	qty 2 stays/pole 
gantry supporting more than 2 pairs	type 'C' (heavy duty)	qty 2 stays/pole 

Fig 18.26 Stay Arrangements Type 'R' — In-Line Poles and Gantries

feeder run arrangements	maximum angle of turn	STAY TYPE: type 'A' from	type 'A' to	type 'B' from	type 'B' to	type 'C' from	type 'C' to	type 'D' from	type 'D' to	
pole turning 1 pair vertical	90°	0	30°	30°	75°	75°	90°	—	--	qty 1 stay
gantry turning 2 pair vertical	90°	0	15°	15°	45°	45°	90°	—	—	qty 1 stay; gt 2 gantry
gantry turning 3 or 4 pairs vertical	85°	0	15°	15°	45°	45°	70°	70°	85°	qty 2 stays; gt 3 gantry
gantry turning 5 or 6 pairs vertical	55°	—	—	0	25°	25°	45°	45°	55°	qty 2 stays; gt 4 gantry
gantry turning 7 or 8 pairs vertical	40°	—	—	0	20°	20°	30°	30°	40°	qty 2 stays; gt 5 gantry
gantry turning 9 or 10 pairs vertical	30°	—	—	0	15°	15°	25°	25°	30°	qty 2 stays; gt 6 gantry
gantry turning 11 or 12 pairs vertical	25°	—	—	0	10°	10°	20°	20°	25°	qty 2 stays; gt 7 gantry

Fig 18.27 Stay Arrangements Type 'S' — Turning Poles and Gantries

feeder run arrangement	stay assembly	remarks
pole terminating 1 pair	type 'A' (medium duty)	qty 1 stay/pole
gantry terminating 2 pairs GS2 gantry	type 'B' (medium duty)	qty 1 stay/pole GS2 gantry
gantry terminating more than 2 pairs GS2,GS3 etc gantries	type 'C' (heavy duty)	qty 1 stay/pole GS2, GS3 etc gantries

Fig 18.28 Stay Arrangements Type 'T' — Terminating Poles and Gantries

ERECTING OPEN WIRE FEEDERS (ALUMINIUM POLES)

Standard Symbols

The standard symbols used in installation drawings to identify the components of an aluminium pole feeder system are given in Fig 18.29.

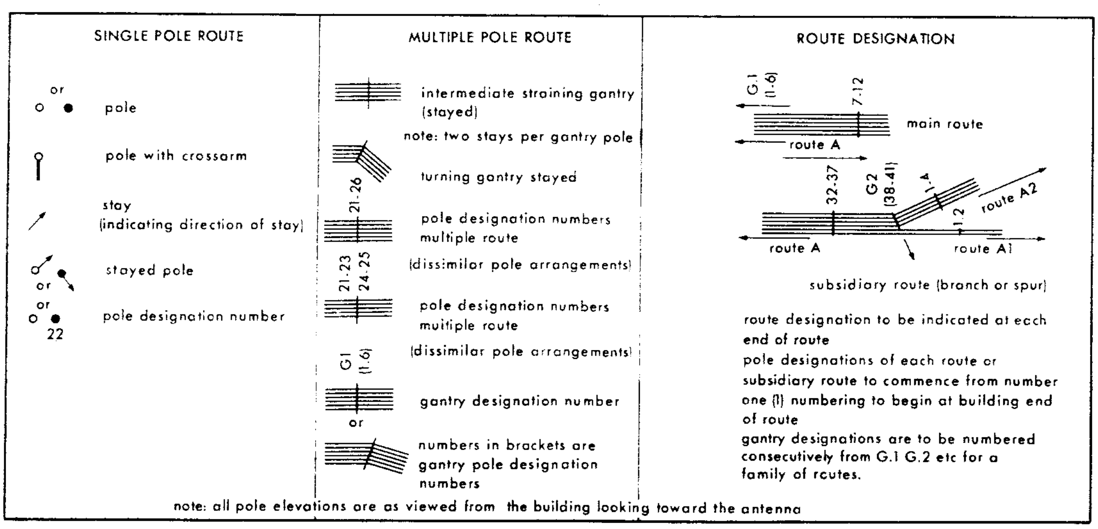


Fig 18.29 Standard Symbols

Erecting a Feeder Line over an Existing Line

The procedure to follow is identical to that described on p18.9.

Method of Erecting Feeder Lines

The method used is identical to that described on p18.7.

Division of Long Routes

Routes of excessive length shall be divided into sections not exceeding 530 metres (580 ft). The feeders at the end of each section shall be terminated on intermediate straining gantries and these gantries shall be stayed (*see* Fig 18.26a).

Bends

Where a deviation from a straight run involves a turn of more than 10 degrees, the feeders must be turned vertically as described on page 18.10.

All cross arms at turning poles and beams at turning gantries are to bisect the included angle between the feeders, as shown in Fig 18.30.

The stays supporting the poles and gantries at bends must be aligned with the cross arms or beams and oppose the direction of the turn (Fig 18.23).

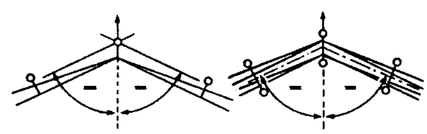


Fig 18.30 Alignment of Cross Arms at Bends

Pole Spacing

Poles should be equally spaced along all straight runs, the spacing not to exceed 38 metres (125 ft). Adjacent poles of parallel runs must be spaced at a minimum of 1.5 metres (5ft) between centres.

Spacing of Pairs of Feeders

Adjacent pairs of feeders must be spaced at a minimum of 0.76 metres (2 ft 6 in) between centres of pairs. Adjacent pairs running straight shall be maintained on a level plane (Fig 18.31).

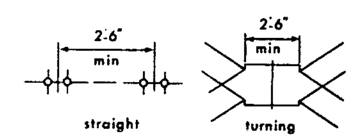


Fig 18.31 Spacing of Pairs of Feeders

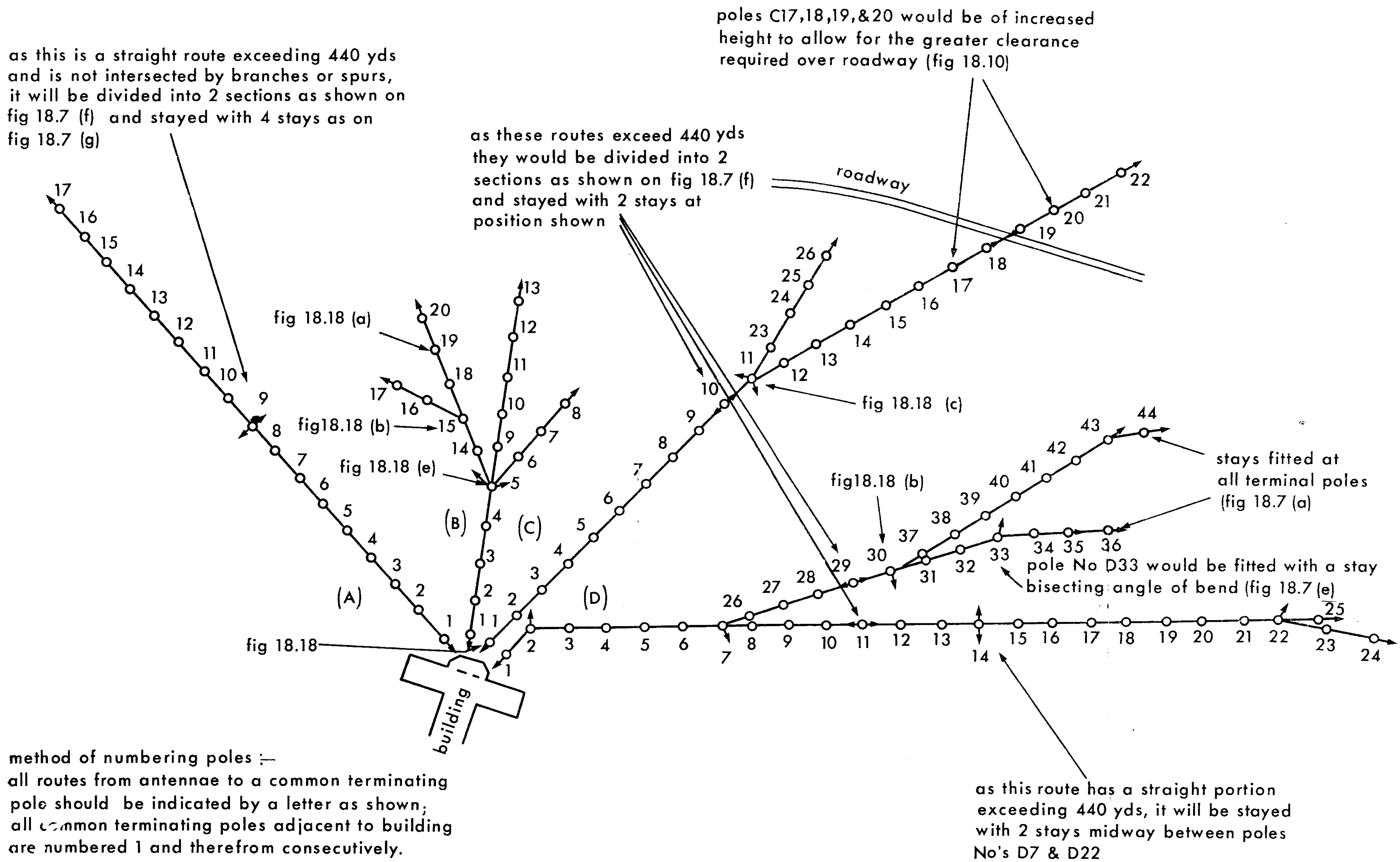


Fig 18.9 Identification of Feeder Routes

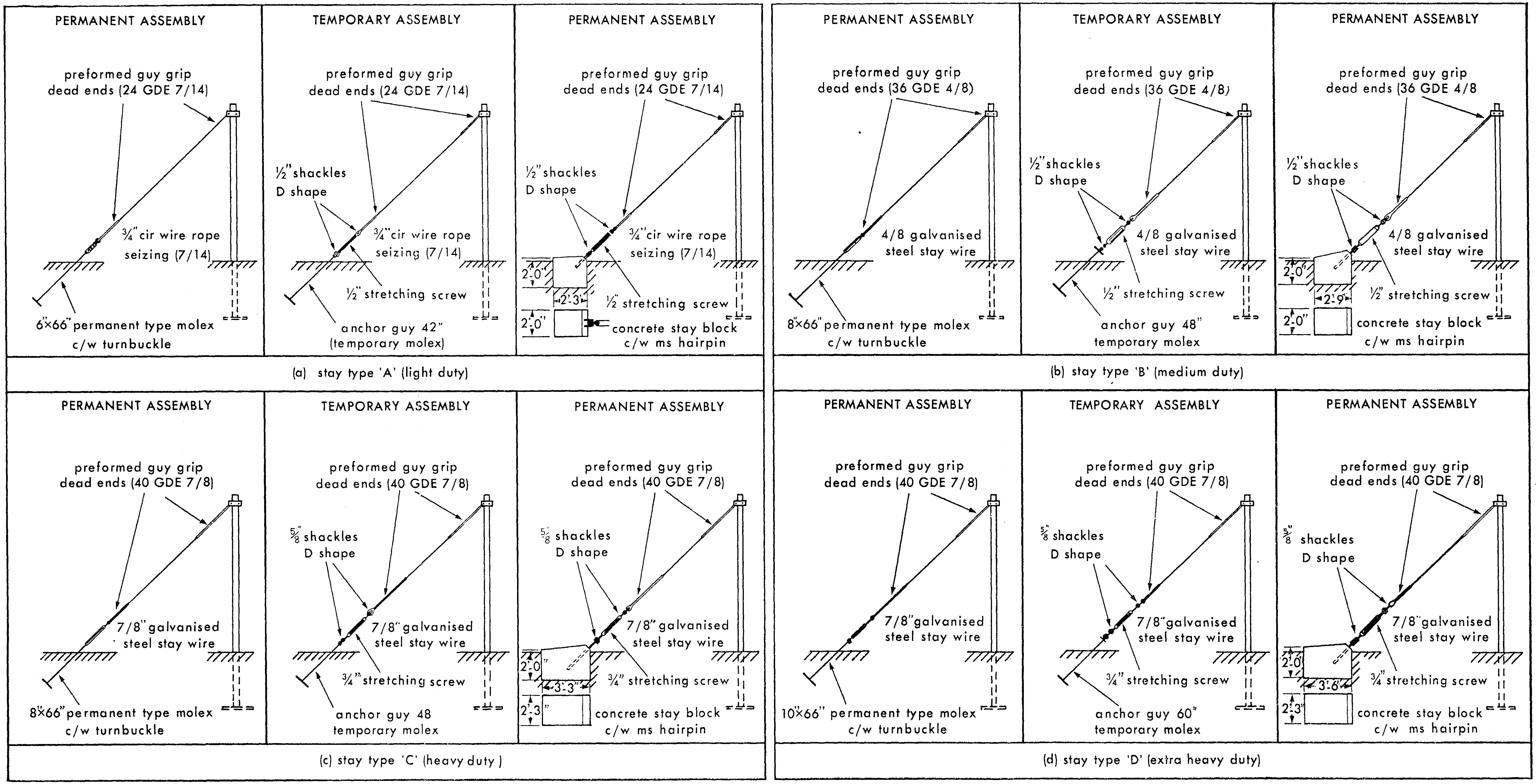
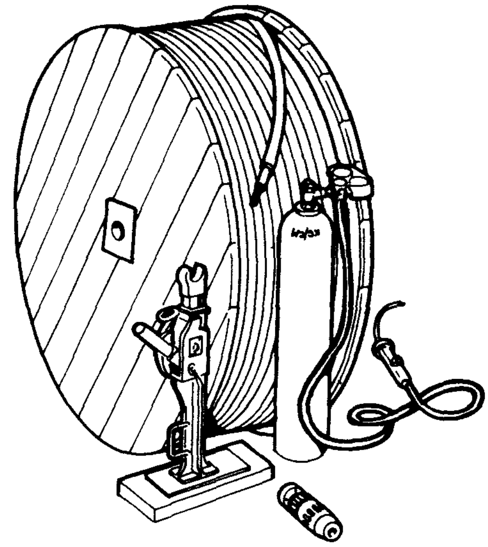


Fig 18.25 Pole Stays



CHAPTER 19

COAXIAL FEEDERS

Introduction

In the previous Chapter we saw how an open-wire feeder system is used to connect the transmitter to the antenna and the antenna to the receiver. In this Chapter a second method will be described—a method which uses a special type of cable known as a *coaxial cable*. In general, the two methods are used in conjunction, but some antennae systems, especially VHF and UHF, have feeder systems constructed entirely of coaxial cables.

Coaxial cable (Fig 19.1) consists of an inner conductor running along the axis of an outer conductor with the spacing between the two conductors maintained by the use of an insulating material known as the *dielectric*. The most common dielectric is polythene, used in one of the following ways:

- Completely filling the space between the conductors—used in VHF and UHF installations (Fig 19.1a).
- In the form of a helical membrane—used in HF installations (Fig 19.1b).

Coaxial cables with a helical membrane are pressurized with nitrogen gas, to prevent the ingress of moisture and maintain a high value of insulation resistance between the inner and outer conductors.

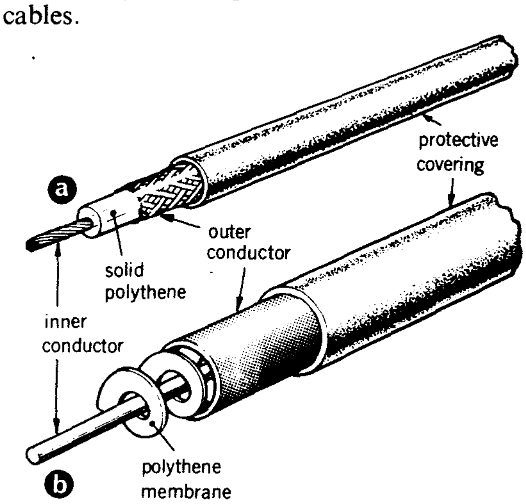


Fig 19.1 Coaxial cable

TABLE 1 Main electrical and mechanical properties of coaxial cables

Cable Type	Overall Diameter	Outer Cover	Outer Conductor	Dielectric Insulator	Inner Conductor	Impedance	Common Use
UR 57	10.29mm (0.405in)	PVC	Braided Copper	Solid Polythene	Single Strand Copper	75 ohms	VHF receive and transmit antennae HF receive only
UR 58	10.16mm (0.400in)	Lead	Lead	Solid Polythene	Single Strand Copper	75 ohms	As for UR 57 but where the cable is to be buried
UR 63 (HM 4)	21.72mm (0.855in)	PVC Hessian served or Aluminium	Aluminium	Helical Membrane Polythene	Solid Copper	75 ohms	HF receive antennae
UR 67	10.29mm (0.405in)	PVC	Braided Copper	Solid Polythene	Multi Strand Copper	52 ohms	HF Quarter Wave receive antennae
UR 74	22.1mm (0.870in)	PVC	Braided Copper	Solid Polythene	Single Strand Copper	51 ohms	UHF receive and transmit antennae
UR 79 (HM 9)	21.72mm (0.855in)	PVC Hessian served or Aluminium	Aluminium	Helical Membrane Polythene	Tubular Copper	50 ohms	HF transmit antennae (Low power ratings)
HM 11	41.28mm (1.600in)	PVC Hessian served or Aluminium	Aluminium	Helical Membrane Polythene	Tubular Copper	50 ohms	HF transmit antennae (High power ratings)
Flexwell (Large)	41.28mm (1.625in)	PVC	Corrugated Copper	Helical Membrane Polythene	Tubular Copper	50 ohms	HF transmit antennae
Flexwell (Small)	22.72mm (0.875in)	PVC	Corrugated Copper	Helical Membrane Polythene	Tubular Copper	75 ohms	HF receive antennae

Types of Coaxial Cable

A list of the cables most commonly used in antennae feeder systems, together with their mechanical and electrical characteristics is given in Table 1 above. The different constructions

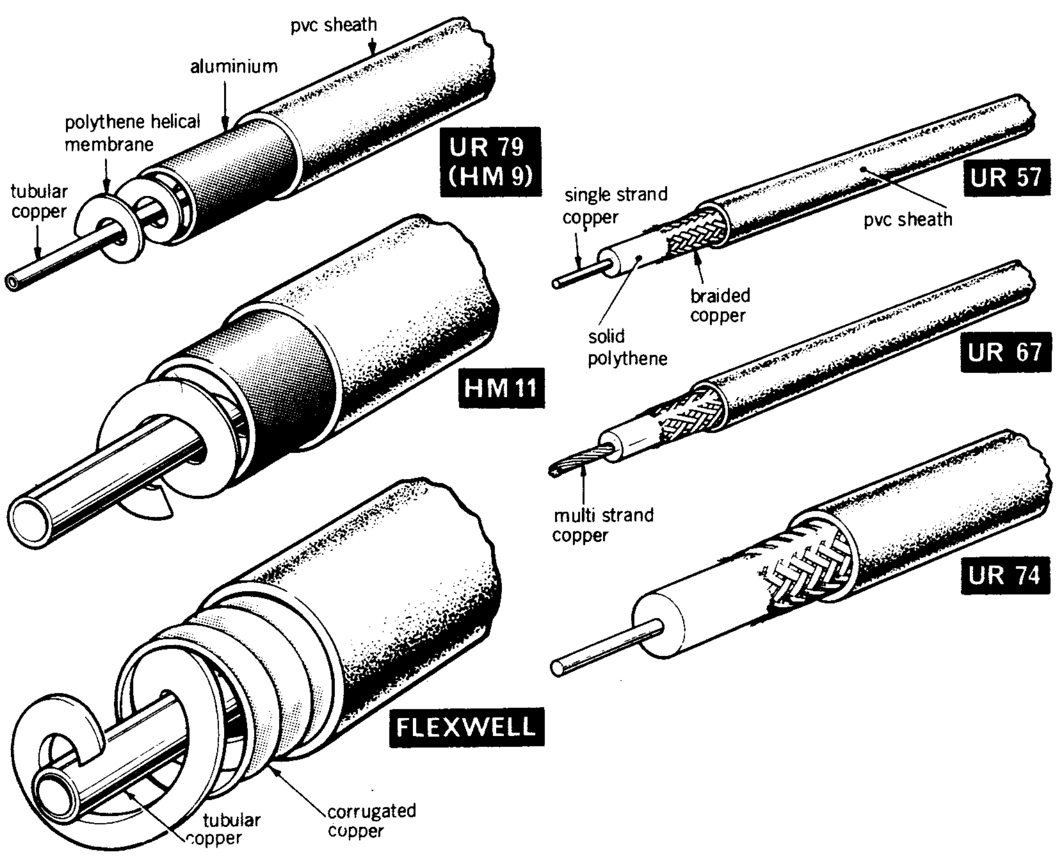


Fig 19.2 Types of coaxial cable

used for some of these cables are illustrated in Fig 19.2.

VHF and UHF Feeder Installations

In general, VHF and UHF antennae are mounted on wooden lattice towers with their feeder cables cleated to the tower at 610mm (2ft) intervals by rubber covered cleats and woodscrews.

VHF coaxial feeders. VHF feeder cables are taken from the antenna to the bottom of the tower and then into the receiver or transmitter building via a trench and an entry duct (*see* Chapter 17. Fig 17.12). Inside the building the cables are cleated to a batten secured to the wall and terminated at a Type 483 bracket. The cables connecting into the receiver or transmitter are cleated to battens secured to the wall and ceiling (Fig 19.3).

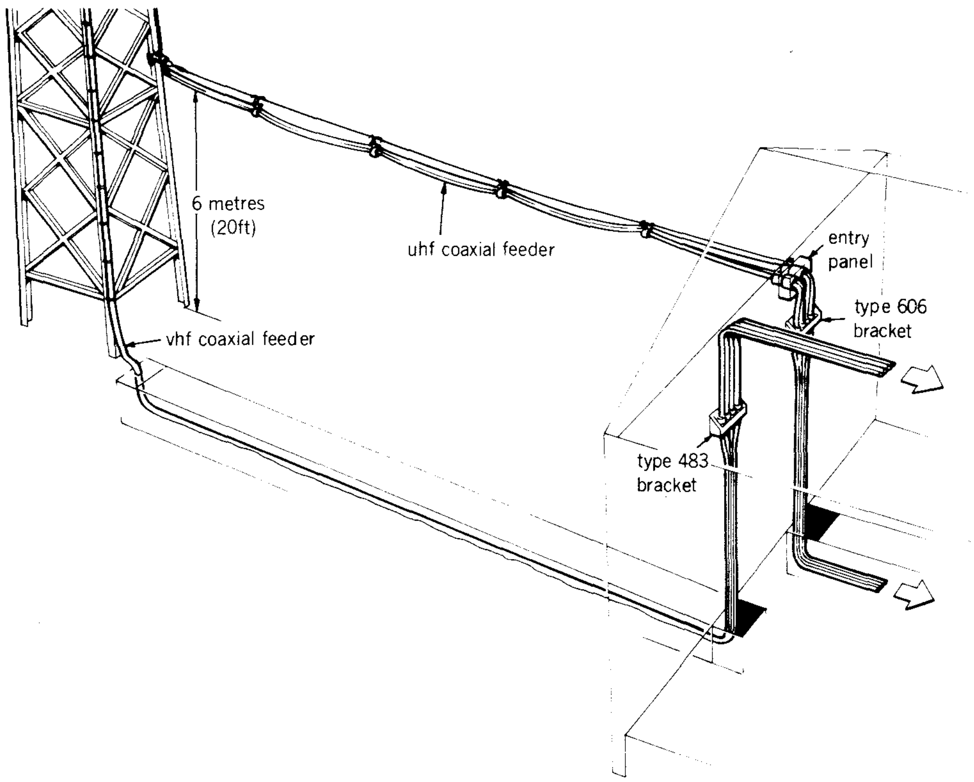


Fig 19.3 VHF and UHF coaxial feeders

UHF coaxial feeders. UHF feeders cables are brought down the tower from the antenna to a point approximately 6 metres (20ft) above ground level. At this point the feeders are taken across to the transmitter/receiver building on a *catenery* (Fig 19.3). Entry into the building is made through an entry panel and the feeders terminated at a type 606 bracket. The feeders connecting into the transmitter or receiver are cleated to a wall batten and taken along an underfloor duct.

HM Feeder Installations

General

Helical membrane (HM) coaxial cables are used to provide feeder lines for HF antennae. These feeders may be made up entirely of HM coaxial cable (*eg* for use with the discone antenna) or they may be used in combination with an open-wire feeder. HM coaxial feeders may be laid directly in the ground, in underground conduits or ducts, or above ground level on support assemblies. The installation techniques to be adopted for each of these methods are described in the paragraphs that follow.

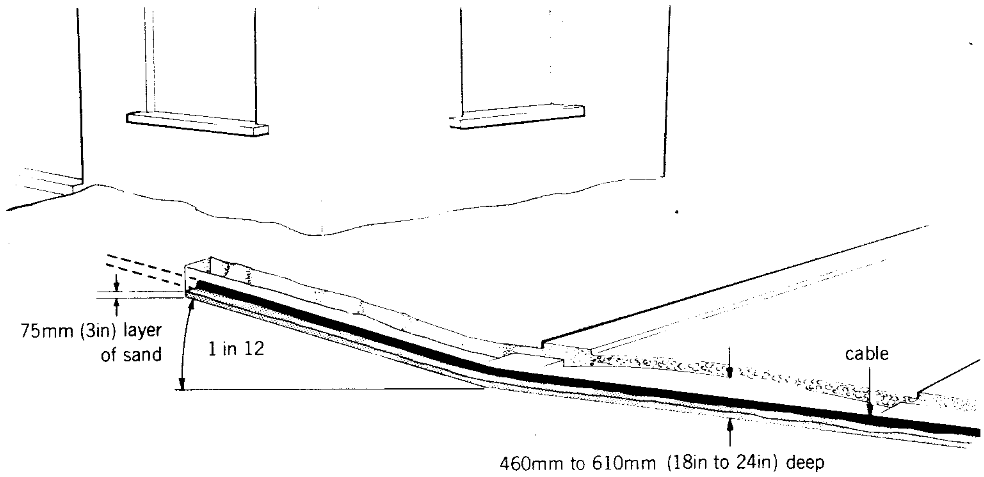


Fig 19.4 The cable trench

Laying HM Coaxial Cable Directly in the Ground

The trench. The trench is to be 460mm (18 inches) deep—610mm (24 inches) deep where the cable is to pass under a roadway. At no point must the trench be closer than 610mm (24 inches) from electric cables, gas and water mains or other service pipes or ducts. The bottom of the trench is to be carefully levelled and covered with sand to a depth of 75mm (3 inches). Where it is necessary to vary the depth of the trench, the rise and fall should be gradual, a suitable slope being 1 in 12.

Positioning the cable drum. The drum carrying the coaxial cable (Fig 19.5) has to be positioned at the end of the prepared trench. During this operation, certain precautions must be observed if serious damage to the cable is to be avoided; these precautions are as follows:

- The cable drum must not be dropped or jolted.
- The cable drum must be conveyed as near as possible to the end of the trench to avoid the need to roll the drum.
- Where rolling the drum is unavoidable, care must be taken to ensure that the cable does not unwind—*ie* the drum must be rolled in the direction which tends to wind the cable *tighter* on to the drum.
- Position the drum over the trench so as to allow the cable to be fed into the trench from the top of the drum in a large radius curve and without twisting.
- Some form of brake mechanism must be provided for the drum—a small wedge brake of the type illustrated in Fig 19.5 will be adequate. It is important that there is someone in attendance at this braking device at all times during the cable laying operation to guard against too rapid a rotation of the cable drum and the subsequent damage to the cable.

When the cable drum is correctly positioned at the end of the trench, a spindle is inserted through the centre of the drum and the drum raised on jacks (Fig 19.5).

Laying the cable. To lay the cable in the trench a pulling-in rope is first secured to the end of the coaxial cable by means of a cable grip (dead-end—*see* Fig 10.9). The cable is then drawn into the trench over rollers placed at intervals along the trench (Fig 19.5). At the antenna end of the trench allow sufficient cable to permit connection either to an open-wire feeder or direct to the antenna and, at the other end of the trench, allow sufficient cable to feed into the transmitter/receiver building. Cut this length of cable from the drum and seal the ends of the cable both sides of the cut to prevent the ingress of moisture and dirt.

Laying coaxial cable in conduits. Where conduits are provided for the entry of coaxial cables into buildings, the conduits are to be cleaned in the following manner before passing cable through them.

- A length of rope is drawn into the conduit by means of a drawing-in wire or sweep rods. A cylindrical brush is then attached to the rope, with another piece of rope secured to the other

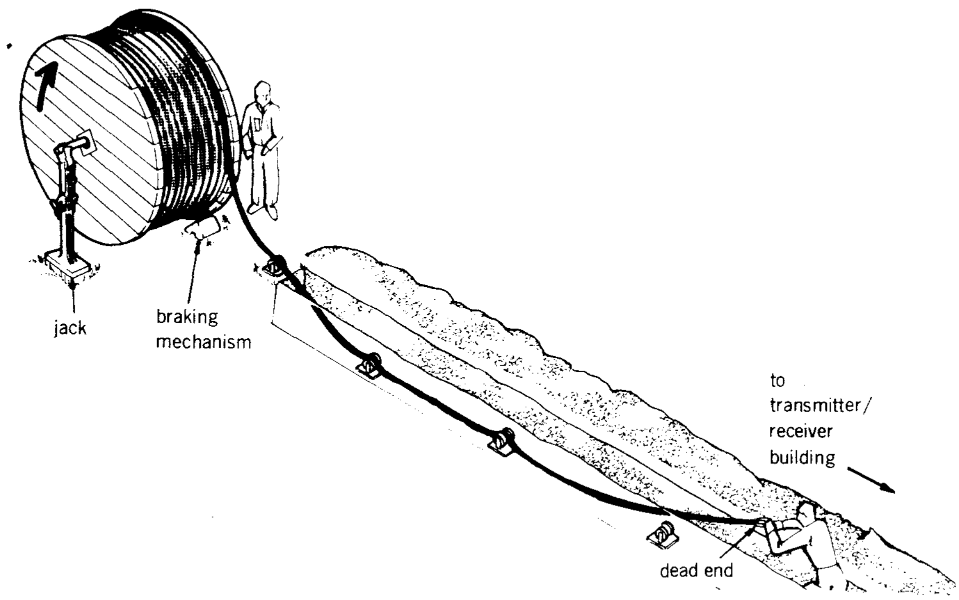


Fig 19.5 Laying the cable

end of the brush so that the brush can be pulled to and fro. Care should be taken to prevent the rope carrying dirt into the conduit—covering the earth with canvas sheets or other suitable material will help in this matter.

- Where the condition of an empty conduit is in doubt, a test piece of cable should be passed through the conduit and its condition examined to determine the condition of the conduit.

The cable can now be passed through the conduit by the pulling-in rope attached to the cable.

Identification of Cables and Cable Runs

Cables are to be identified at all accessible points by lead or zinc labels strapped around the cable. The labels must be indelibly marked to indicate the number of the cable run.

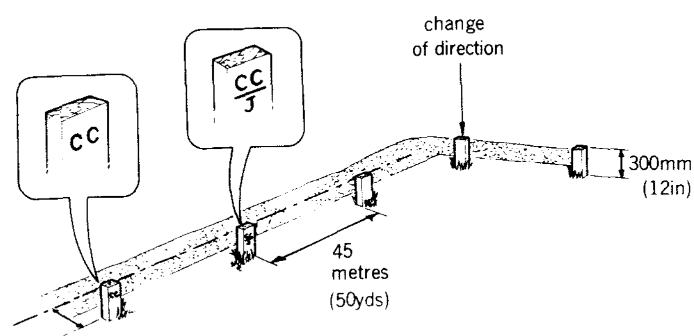


Fig 19.6 Identification of cables and cable runs

Cable runs must be marked by stout wooden poles projecting 300mm (12 inches) above the ground (Fig 19.6). These poles are to be marked with the letters CC (coaxial cable) in 25mm (1 inch) characters. A joint in the cable is to be indicated in a similar manner with the letters $\frac{\text{CC}}{\text{J}}$ (coaxial cable joint). The cable run marker posts are to be placed as follows:

- At 45 metre (50 yard) intervals along the cable run.
- At changes in direction of the cable run.
- At cable joint and joint chamber locations.

The posts must be placed so that the side carrying the lettering is parallel to, and 300mm (12 inches) from, the cable run. If this is not practicable, the face of the post must be marked to indicate the distance and, where necessary, the direction of the cable run from the post.

Cable Support Assemblies

It is not always possible to bury coaxial feeder cables. In these circumstances the feeders are carried above the ground on a 'Cablok' cable support system (*see* Fig 19.7).

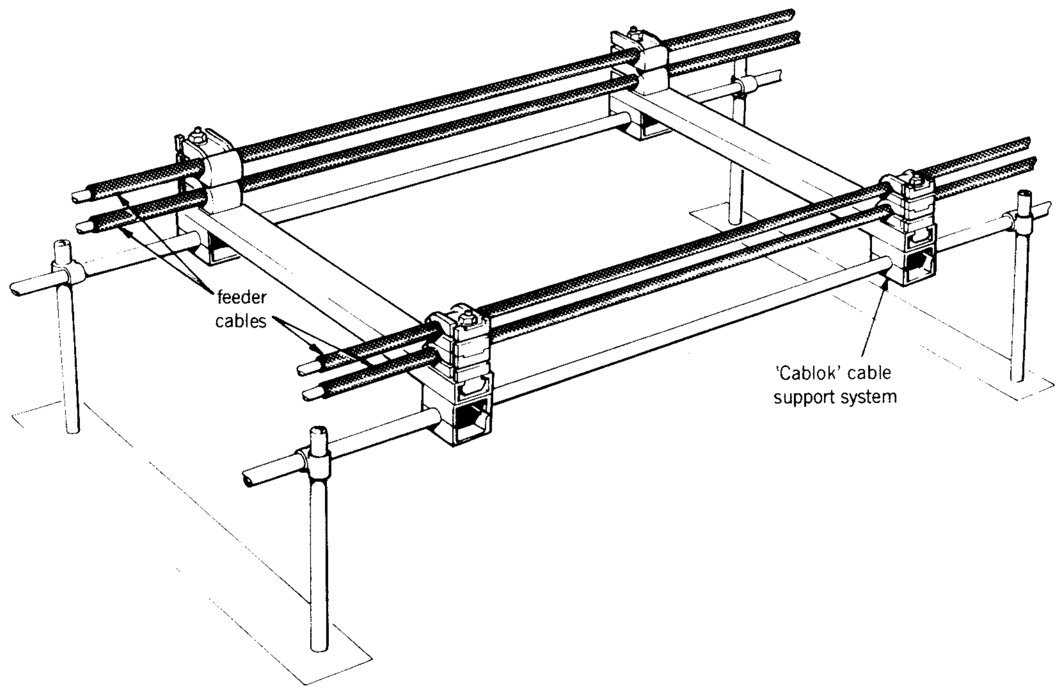


Fig 19.7 'Cablok' cable support system

Bending HM Coaxial Cables

The construction of HM coaxial cable does not permit acute bends to be made in the cable and the following minimum bending radii must not be exceeded.

Flexwell (small)	—	90mm (3·54 inches).
Flexwell (large)	—	180mm (7·1 inches)
UR 63 (HM4)	—	280mm (11 inches).
UR 79 (HM9)	—	280mm (11 inches).
HM 11	—	430mm (17 inches).

The HM cable bending and straightening machine (*see* p6.9) must be used when forming bends in the cables listed above when the required bending radii are within the following limits:

UR 63 (HM4)	—	280–610mm (11–24 inches).
UR 79 (HM9)	—	280–610mm (11–24 inches).
HM 11	—	All bends in this cable are to be formed using the bending machine.

In-line Joints

Jointing of HM cables should be avoided if at all possible, especially in relatively short cable runs. When an in-line joint is unavoidable it should be made in such a way that the electrical and mechanical characteristics of the cable are not impaired. This is achieved by the use of in-line couplers. A typical example of an in-line coupler is illustrated in Fig 19.8 and the method of assembly described below.

- Prepare the cable ends (Fig 19.8a).
- Slide the body nuts and 0-rings 'A' over the cables A and B (Fig 19.8b).
- Fit clamping rings on to cables A and B to register against pvc sheath.
- Fit the split collets into the chamfer on the front of the clamping rings.
- Locate the 0-rings 'A' in the rear of the clamping rings.
- Fit the inserts complete with 0-rings into the body of the coupler.
- Locate the inner conductor of one of the cables in the contact with moulded insert, ensuring that the aluminium sheath of the cable registers in the recess in the body.
- Screw the body nut on to the body of the coupler (Fig 19.8c).
- Repeat the last two operations for the remaining cable.

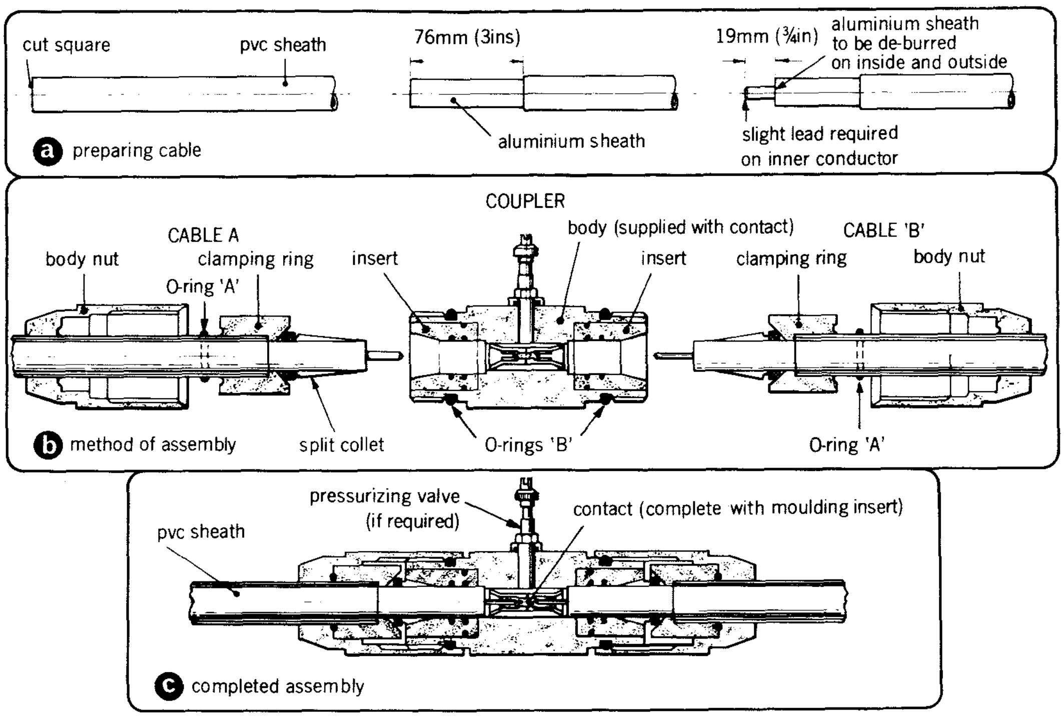


Fig 19.8 Making an in-line joint

Terminating HM Coaxial Cables

HM coaxial cables must be properly terminated at each end of the cable run using a terminating connector, a typical example of which is illustrated in Fig 19.9. The method of fitting this connector to the coaxial cable is described below:

- Prepare the cable as shown in Fig 19.8a.
- Fit the insert complete with 0-ring into the body of the connector.
- Slide the body nut and 0-ring 'A' over the cable.
- Fit the clamping ring on to the cable to register against the pvc sheath.
- Fit the split collet into the chamfer on the clamping ring.
- Slide the swivel flange body on to the cable to engage with the split collet and the clamping ring.

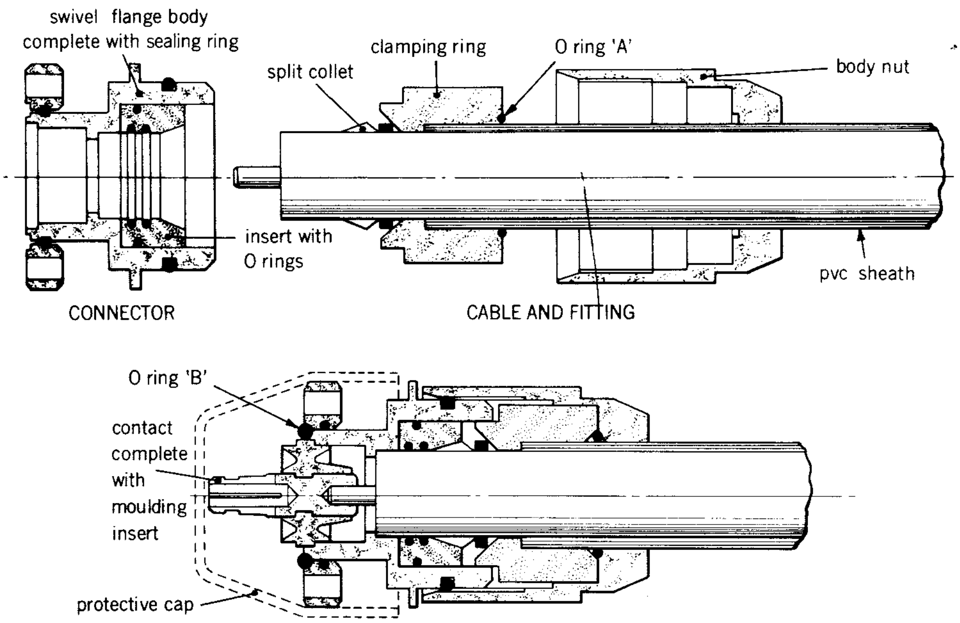


Fig 19.9 Terminating HM coaxial cable

- Locate 0-ring 'A' in the recess at the rear of the clamping ring and screw the body nut on to the swivel flange body.
- Push the contact complete with moulding insert over the inner conductor of the coaxial cable, leaving the longest end projecting outward.
- Fit the 0-ring 'B' in the recess in the swivel flange body and fit the protective cap.

Pressurizing HM Coaxial Cable

HM coaxial feeders are operated with the space between the inner and outer conductors filled with nitrogen gas to a pressure of 10 psi. The nitrogen gas is introduced into the cable through a 'schrader' type pressure valve using the equipment shown in Fig 19.10. Check that you have the correct gas cylinder before applying gas into the cable.

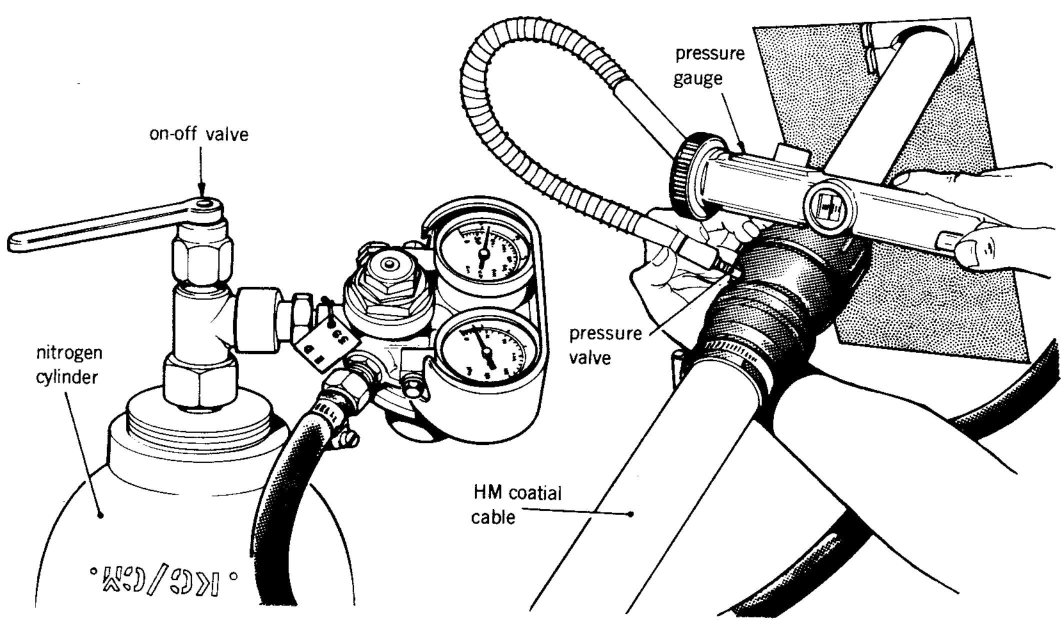


Fig 19.10 Pressurizing HM coaxial cable

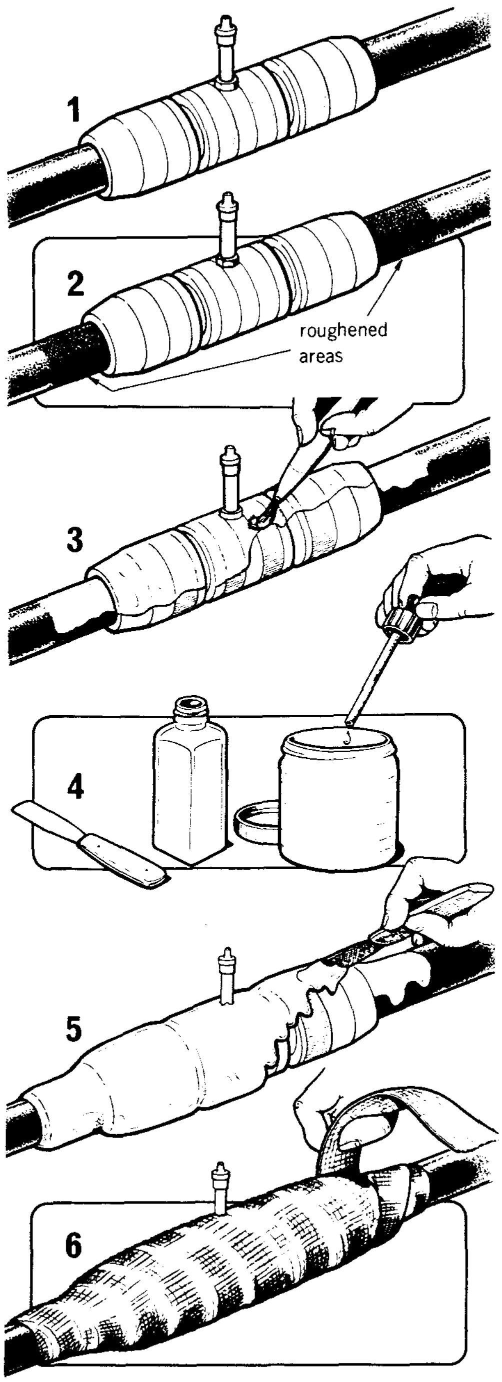
Before the cable is buried it must first be pressure tested by pressurizing it to 15 psi. The pressurizing equipment is then removed and during the following 24 hours there should be no measurable fall in pressure, allowance being made for any temperature changes.

Electrical Testing

On completion of the pressurization the cable is now to be electrically tested for insulation and continuity resistance (*see* Chapter 21).

Sealing Coaxial Cable Joints

All joints that are to be buried, and joints exposed to the weather are to be sealed. The method of sealing is illustrated in Fig 19.11.



STAGE 1

Thoroughly degrease the cable joint and adjacent cable with trichlorethylene.

STAGE 2

Roughen PVC outer sheath with clean glasspaper, taking care not to handle the roughened surface with bare hands.

STAGE 3

Paint over complete cable joint and the roughened PVC sheath with 'Silcoset' primer and allow to dry completely —60 minutes at 13°C. The primer is properly applied when the painted surfaces exhibit a faint pinkish bloom.

STAGE 4

Add the correct proportion of curing agent to 'Silcoset' 104 and mix with a flat spatula to ensure that the curing agent is evenly mixed. Ensure minimum amount of air trapped in the compound to prevent the formation of air bubbles.

- For 2–3 hour set, add 0·2% of curing agent 'A' (6 drops).
- For 1–2 hour set, add 0·3% of curing agent 'A' (9 drops).

STAGE 5

Spread the mixture evenly over the primed surface of the joint and build up to the required thickness by adding successive layers of the mixture (see notes).

STAGE 6

Before the outer surface has set, it is to be protected by wrapping on successive layers of woven glass tape. The tape is to be firm enough to permit the 'Silcoset' 104 to flow slightly through the weave. This stage may be omitted if the physical protection offered by the glass tape is not required.

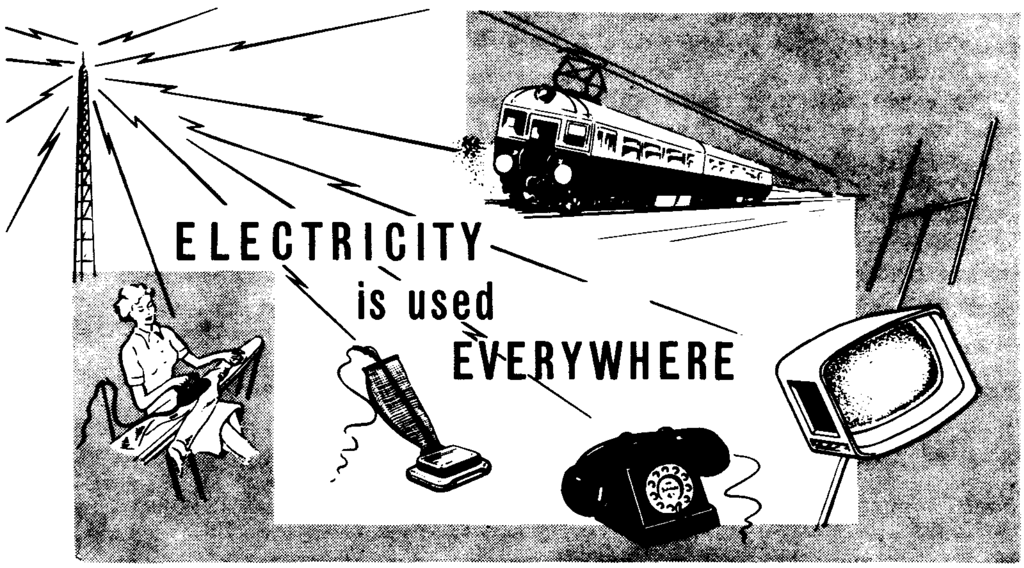
NOTES

- Do not exceed 6mm (¼ inch) thickness in one operation. Allow 24 hours between successive 6mm layers.
- The shelf life of 'Silcoset' 104 primer and curing agent A is normally 6 months when stored in temperate climates. Cool storage is essential when these materials are used in the tropics.
- On completion of the sealing operations, the cable is then connected into the antenna system and the trench filled in.

Fig 19.11 Sealing HM coaxial cable

CHAPTER 20

ELEMENTARY ELECTRICITY



Introduction

Without electricity, civilization as we know it could not exist. Electricity is used to make electric trains move; to operate electric motors in vacuum cleaners and washing machines; to generate heat in electric fires; to provide the power to operate radio stations, radios and television sets; and for a great many other things.

Simple Electric Circuit

Let us now look at a simple electrical circuit. We are all familiar with the electric light bulb and its wall switch, and it gives a very good picture of the essentials of any electric 'circuit'.

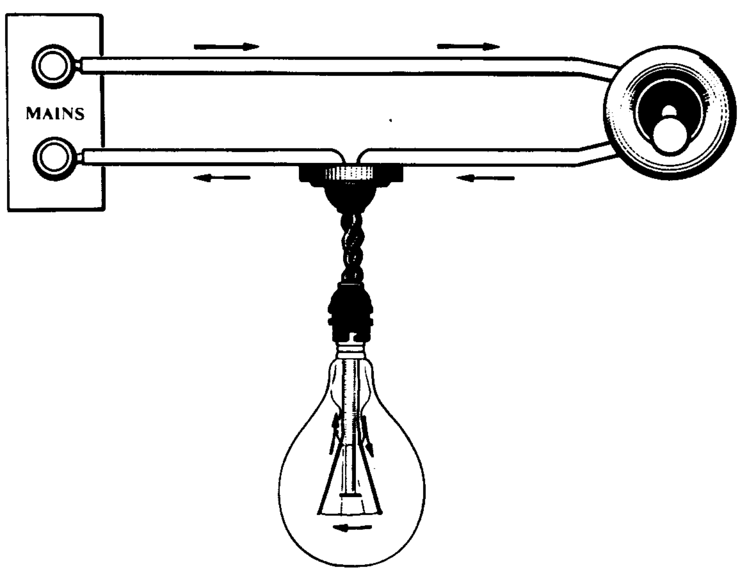


Fig 20.1 A simple electric circuit

In Fig 20.1 the closing of the wall switch causes the lamp to light. To understand why this happens we must take a closer look at the various parts which make up the circuit.

The cables and the flex are made of copper wire inside a rubber or plastic cover: the switch is a brass bar operated by a plastic knob: and the 'filament' of the lamp is a fine wire made of something like tungsten.

The closing of the switch provides a continuous path from one side of the mains, through the switch and the lamp filament, back to the other side of the mains. When a circuit is completed in this way it is called a *closed circuit*, and the mains can now cause a *current* of electricity to pass through the filament of the lamp making it become white hot and give out light. The mains supply provides the electrical force or pressure needed to drive the current round the circuit. This electrical pressure is called the *applied voltage*.

Metals such as copper, brass and aluminium in which current flows easily are called *conductors*. Current will not flow in materials such as rubber, plastic or glass, and these are called *insulators*. There are also substances like tungsten through which current flows with difficulty; these are poor conductors and this is the main reason why the lamp filament becomes white hot, while the conducting wires of the cable and flex remain cool.

Failure of the Circuit

Suppose that on closing the wall switch in the circuit of Fig 20.1, the lamp fails to light. We can limit the cause of failure to one of three things:

- **Failure of the mains supply**; if no voltage is present, current will not flow.
- **Break in the circuit**; this is called an *open circuit* and could be due to a break in the copper wire of the cable or the flex, a faulty switch or a broken lamp filament.
- **Faulty insulation**; if the rubber or plastic insulation wears through at point A in Fig 20.2 the wires would touch and current would flow back to the mains without passing through the lamp filament. This is called a *short-circuit*.

Before current can flow in a circuit we must have:

- A source of voltage.
- A closed circuit of conducting material.
- Adequate insulation between conducting wires.

If an item of electrical equipment is not working satisfactorily, these are the first things to be tested.

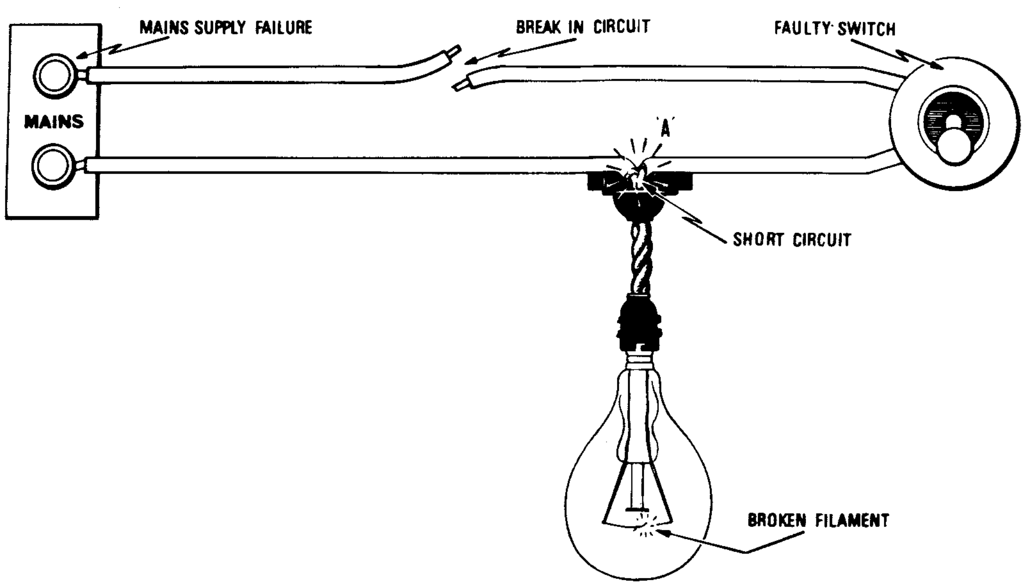


Fig 20.2 Circuit failure

What is a Current of Electricity

We have seen how closing the wall switch in the circuit of Fig 20.1 causes the source of voltage to supply a current to the circuit. This current flowing through the lamp filament causes the lamp to light. The question may well be asked, 'What then does an electric current consist of?' The answer is that an electric current is a movement of '*electrons*', and it is these tiny particles moving in the thin filament wire that causes the filament to become hot and give out light. To find out more about these electrons—what they are and what causes them to move—we must look more closely at the structure of conductors and other materials used in electric circuits.

Electrons

As we have just seen, the electric lamp lights because electrons are moving through the filament. *Moving electrons* can explain most electrical effects. First, let us see what an electron is, and then we can go on to find out how it is made to move in an electrical circuit.

All materials consist of tiny particles called *atoms*. Materials that are made up entirely of the same kind of atom are called *elements* (*eg* hydrogen and copper) and there are about 100 materials of this kind. Other materials are made up of different combinations of the available atoms. Water, for instance, is made up of two different kinds of atoms in combination—hydrogen and oxygen. Substances obtained by combining different kinds of atoms are called *compounds* and include water, salt and lime.

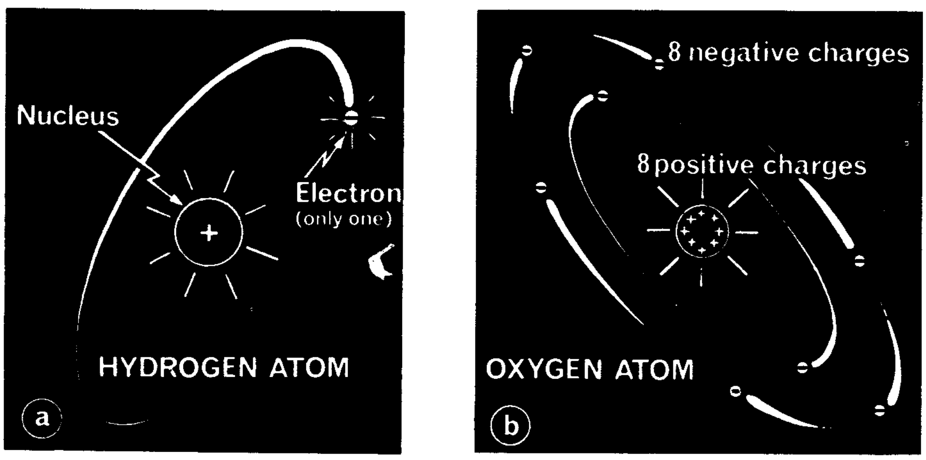


Fig 20.3 Atoms

Now let us examine an atom further; take a hydrogen atom. If this is magnified it will look like a sun with a planet spinning round it. The hydrogen atom in fact consists of a central core or *nucleus* with an electron moving at high speed in an orbit around the nucleus (Fig 20.3a). The nucleus has a *positive* (+) *charge* of electricity and the electron a *negative* (−) *charge* so that the atom as a whole is *neutral*.

The *number* of planetary electrons in an atom varies with the element; hydrogen, as we have seen, has one; oxygen has eight arranged in two orbits (Fig 20.3b). However, the nucleus of the oxygen atom has eight positive charges (protons) which exactly neutralize the negative charges of the eight electrons. Thus any atom, under normal conditions, is *electrically neutral*.

Free Electrons

Like charges repel each other and unlike charges attract each other; thus electrons are normally prevented from flying off because of the attraction between the negative charge on the electron and the positive charge in the nucleus. However, in atoms that have more than one electron in orbit, the electrons in the outer orbits are not so strongly tied to the nucleus as those closer in; these electrons may easily fly off. An atom which has 'lost' an electron in this way has lost one of its negative charges and is no longer neutral; it is called a *positive ion*

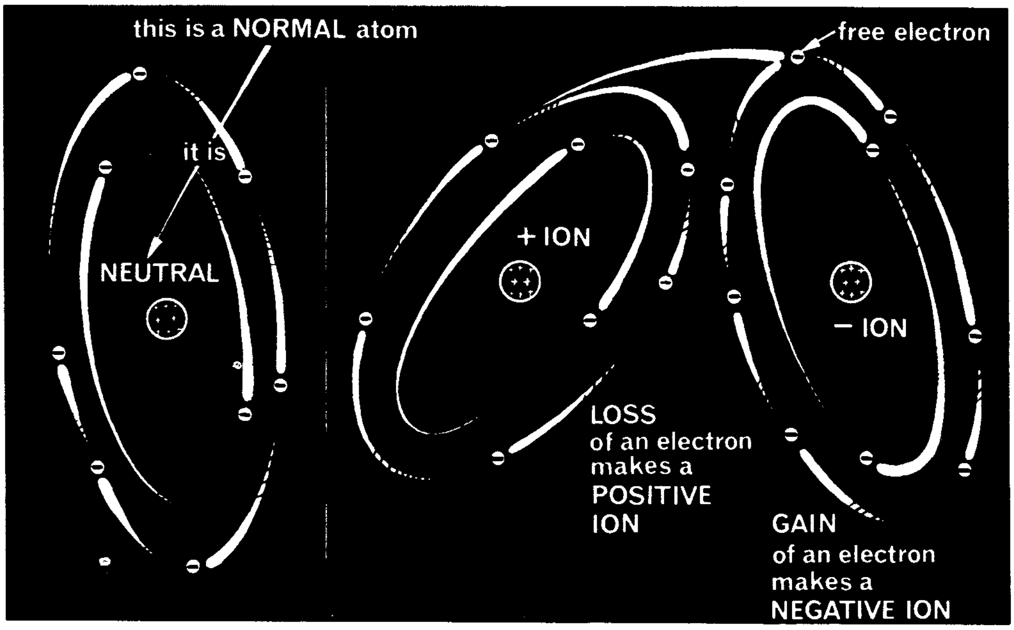


Fig 20.4 Ions and free electrons

(Fig 20.4). The electron stripped from its orbit may attach itself to a neighbouring atom in the material; this atom, having gained a negative charge, is no longer neutral and becomes a *negative ion*. The electrons stripped from their atoms can wander at random from atom to atom throughout the material; these are called *free electrons* and form the basis of electric current.

From this we see that any body which has more than its 'normal' number of electrons becomes *negatively* charged. Similarly, any body which has fewer electrons than normal becomes *positively* charged.

Conductors and Insulators

Materials in which the outer electrons are not firmly tied to the nucleus and which produce free electrons easily are called *conductors*. In conductors there is a constant movement of free electrons in all directions between atoms. Silver, copper and aluminium are good conductors and, as mentioned earlier in this chapter, current flows easily in them.

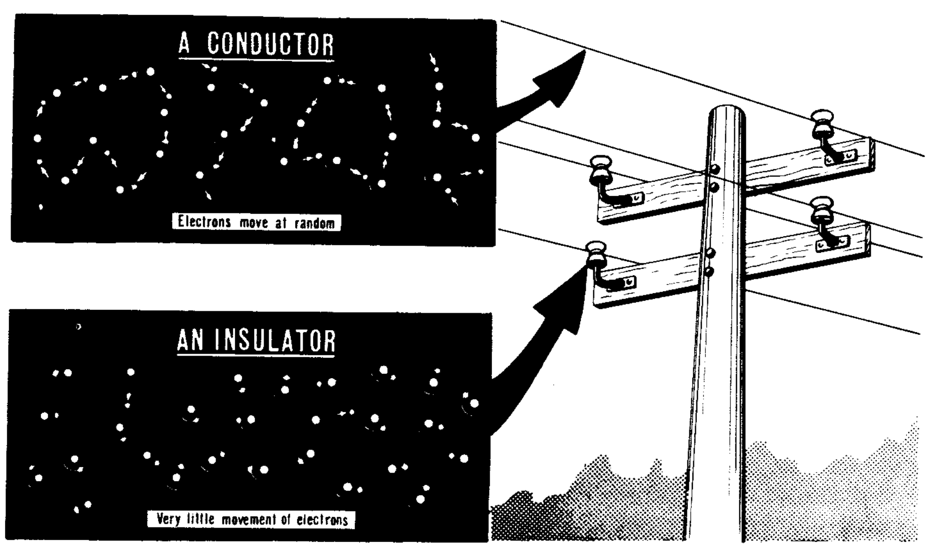


Fig 20.5 Conductor and insulator

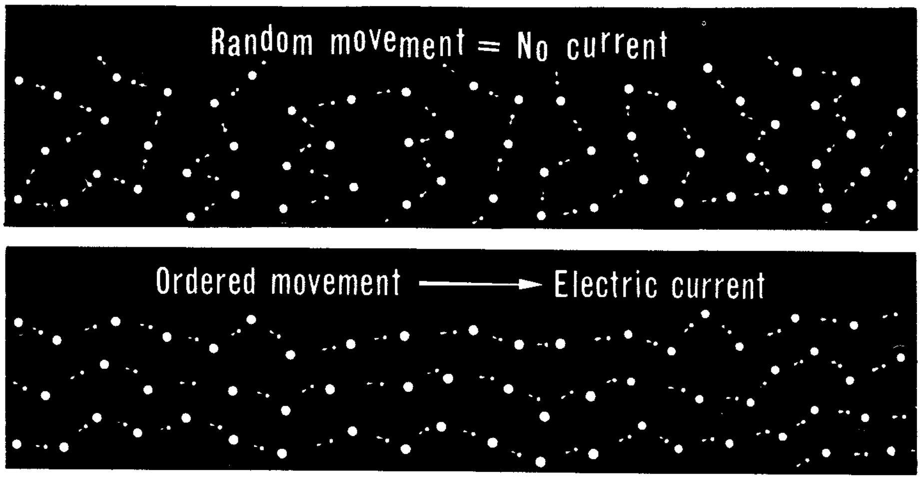


Fig 20.6 Electric current

In some materials the orbital electrons are tightly bound to the nucleus and will not normally break away. Materials which have strong binding forces in the atom produce very few free electrons and are called *insulators*. Examples of good insulators are rubber, glass, plastics and ceramics; as mentioned in Chapter 1, current will not easily flow in them.

Electrons in motion

In a conductor, under normal conditions, the random movement of free electrons is usually equal in all directions throughout the material so that the electrons are not lost or gained by any particular part of the material (Fig 20.6); this random movement of free electrons is *not* an electric current. If, however, the free electrons can be caused to move through the material in the same general direction, the net electron movement or flow is called an *electric current*.

How Electrons are Caused to Move

Since, as we have seen, like charges repel each other and unlike charges attract each other, free electrons can be caused to move through a wire by applying a positive (+) charge from some source at one end of the conductor and a negative (−) charge at the other end (Fig 20.7). The positive charge attracts the free electrons in the wire and the negative charge repels them so that we get a movement of electrons *in one direction* through the conductor from the negative terminal towards the positive terminal. An electric current has been produced. For practical purposes the movement of all the free electrons throughout the wire occurs simultaneously, so that when a light is switched on, it lights immediately.

Having produced an initial current in the wire the next thing to do is to *maintain* that current, otherwise the free electrons will congregate at the positive terminal and current will cease. To keep the current flowing, two things are needed:

- The excess electrons at the positive terminal must be removed, and electrons must be supplied to the negative terminal.
- The force which caused the electrons to move in the first place must be applied continuously.

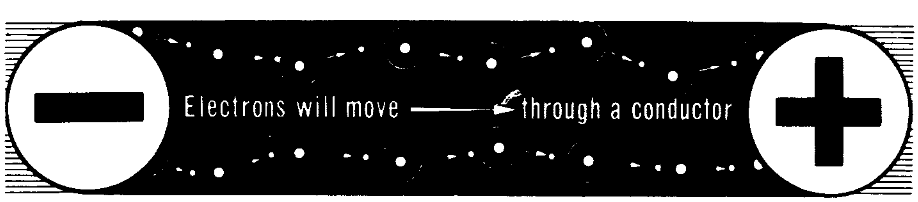


Fig 20.7 Electrons in motion

As we saw at the beginning of this chapter the first of these needs is met by having a closed circuit. The second is met by connecting the conductor to a *source of voltage* and maintaining this voltage. This is shown in Fig 20.8. The voltage causes the free electrons in the external circuit to move along the wire from the negative terminal to the positive terminal of the supply. At the same time, the source of supply functions in such a way that it absorbs the electrons at the positive terminal and transfers them through itself to the negative terminal. The current is thus maintained.

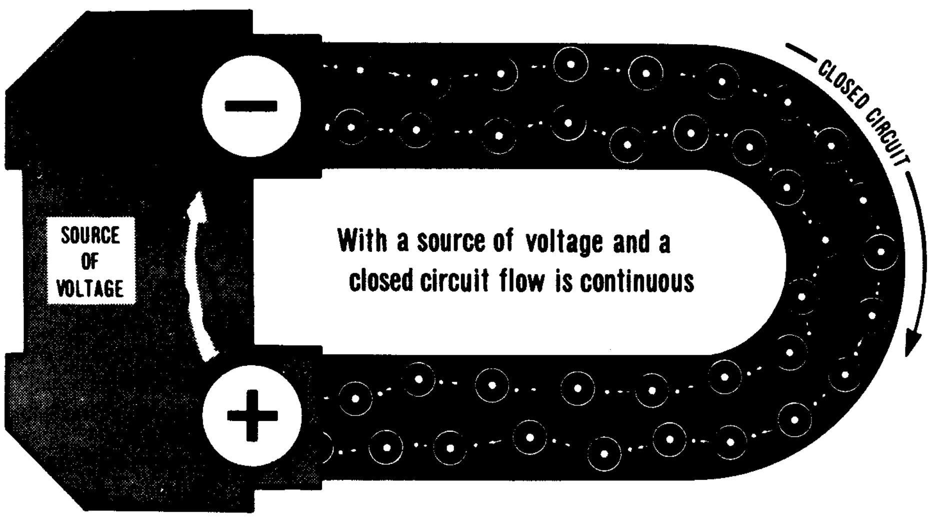


Fig 20.8 How a current is maintained

Direction of Current

An electric current is a movement of electrons in an external circuit from the *negative* to the *positive* terminals of the supply; this is the *electron flow* of current (Fig 20.9).

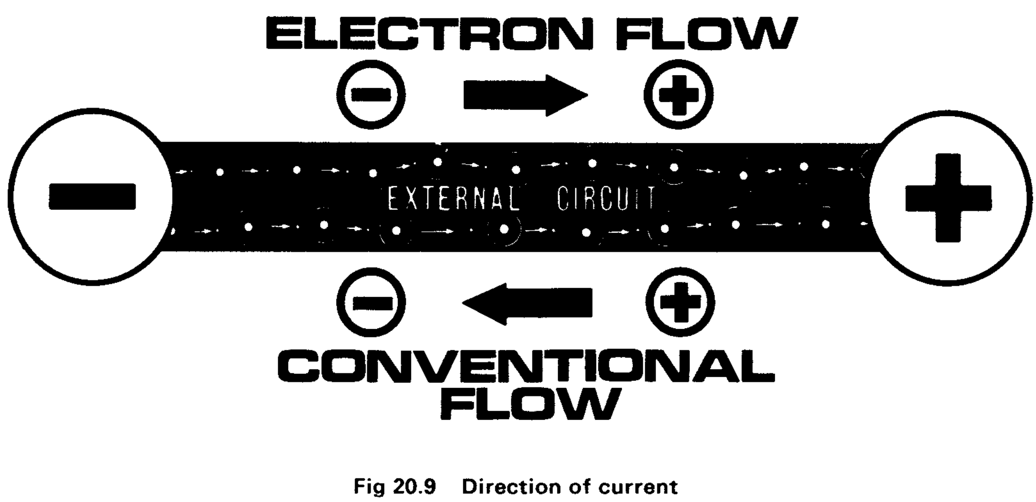


Fig 20.9 Direction of current

However, electricity had been in use long before the discovery of the electrons and it had been assumed up till then that the current was a flow of 'something' from *positive* to *negative* in the external circuit; this is the *conventional flow* of current and most electrical laws are based on this assumption.

In the study of electricity we assume the conventional direction of current (*ie*, from + to − in the external circuit and from − to + inside the supply) and use the basic laws in their original form. Only in the study of electronics does it help to assume the electron flow of current.

Units of Current

The current (symbol I) in a conductor is the number of electrons passing any point in a conductor in one second, and is measured in *amperes* (symbol A).

Currents of much less than one ampere are often met in practice, and smaller units are used.

Thus, $\frac{1}{1000}$ ampere is 1 milliampere which is abbreviated to 1mA.

$\frac{1}{1\,000\,000}$ ampere is 1 microampere which is abbreviated to 1μA.

Changes from amperes to milliamperes or microamperes and *vice-versa* are easily done by moving the decimal point or adding noughts. Thus

35 milliamperes = 0·035 ampere, which is abbreviated to 35mA = 0·035A.

Other examples are:

0·125A = 125mA = 125 000μA

125μA = 0·125mA = 0·000 125A

65mA = 0·065A = 65 000μA

Measurement of Current

An instrument used to measure current in amperes is an *ammeter*.

The circuit must be opened to insert the ammeter so that the total current carried by the circuit passes through the meter (Fig 20.10). Meters used for measuring milliamperes are called *milliammeters*; meters used for measuring microamperes are called *microammeters*. Thus, to measure currents larger than 1A, ammeters are used, to measure between 1mA and 1000mA milliammeters are used; and for currents less than 1mA, microammeters are used.

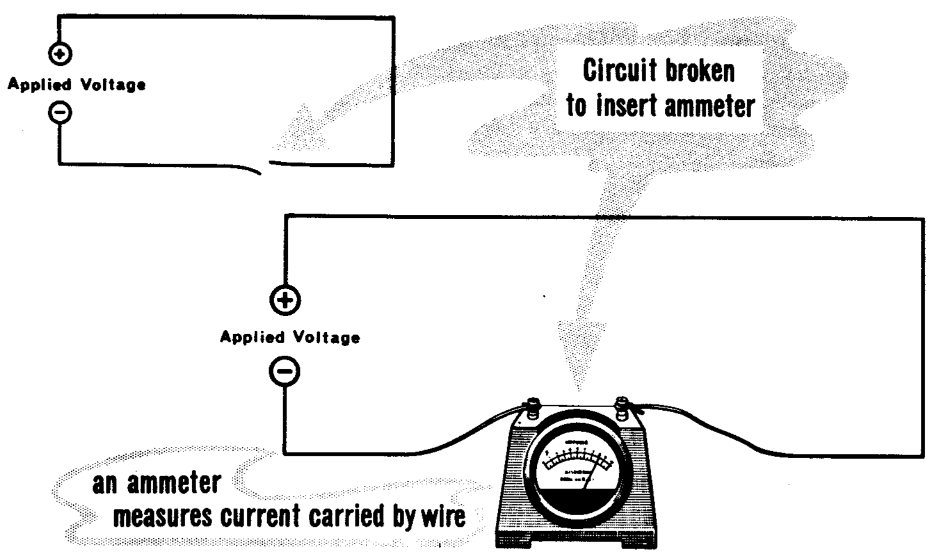


Fig 20.10 Measuring current flow

Effects of an Electric Current (Fig 20.11)

Heating effect. A current flowing in a conductor always causes heat to be produced in the conductor. The effect is made use of in electric fires, electric irons, electric light bulbs and fuses.

Magnetic effect. A current flowing in a conductor always produces a magnetic field around the conductor. This effect is used in such things as electric bells, electric motors, generators and transformers.

Chemical effect. When a current flows through certain liquids (known as *electrolytes*),

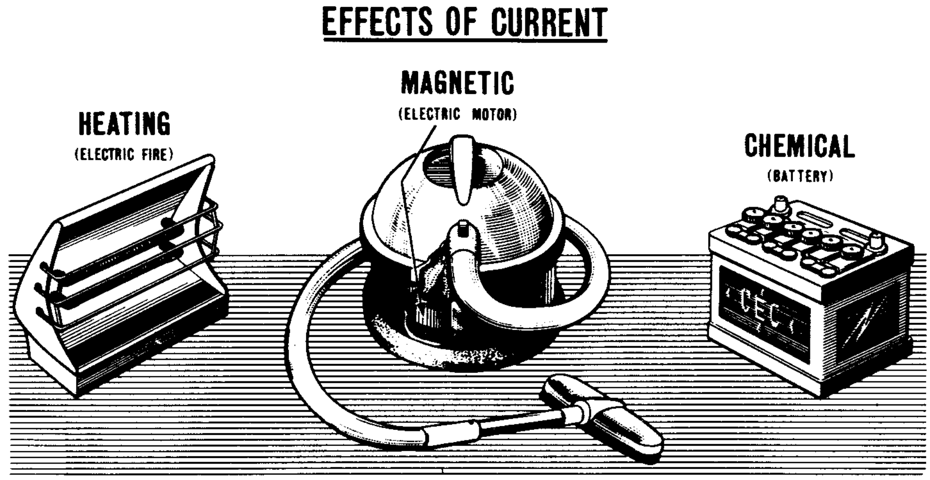


Fig 20.11 Effects of electric current

chemical changes occur in the liquid and in any metals immersed in it and connected to the circuit. This is used in battery charging and electroplating.

Applied Voltage

For an electron to move it must be given *energy* from somewhere. This energy comes from the cource of supply in the form of electrical energy. When current flows, the electrical energy contained in the supply provides a force which causes the electrons to flow. This driving force derived from the electrical energy of the supply is the *applied voltage* and it is measured in volts (symbol V). The applied voltage is sometimes called 'electromotive force' (emf) (Symbol E) (*see* note above Fig 20.18 on page 20.12).

By increasing the applied voltage, the number of electrons passing any point in the circuit in one second is increased; that is, *increase in applied voltage produces increase in current.*

Electrical equipment is designed for a certain value of current and if this rated value is exceeded, damage may be done. A 230V lamp, for example, needs 230V to give it the correct current flow (Fig 20.12). If the lamp is connected to a voltage higher than this, too much current flows and the lamp can be burnt out.

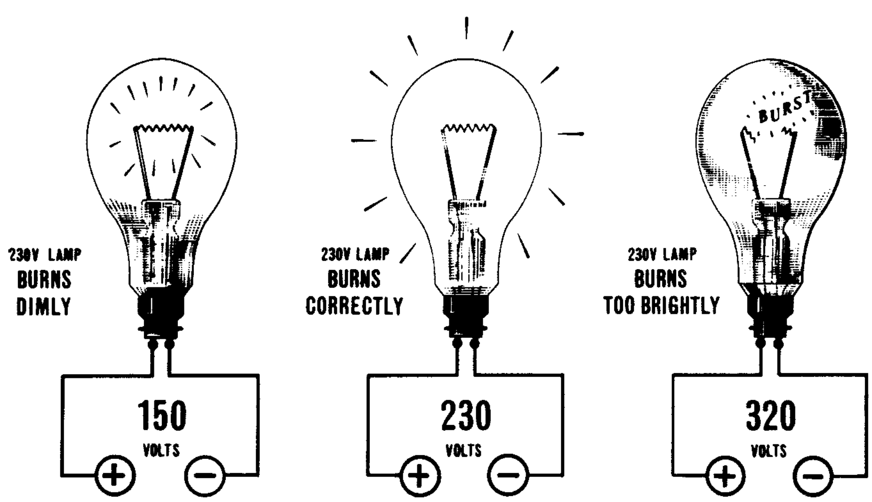


Fig 20.12 Current depends on voltage

Units of Voltage

Voltages much greater and much less than one volt are often met with in practice, and units larger and smaller than the volt are required. Thus:

1000 volts is 1 kilovolt, which is abbreviated to 1kV.

$\frac{1}{1000}$ volt is 1 millivolt, which is abbreviated to 1mV.

$\frac{1}{1\,000\,000}$ volt is 1 microvolt, which is abbreviated to 1μV.

Changes from volts to kilovolts, millivolts or microvolts and *vice-versa* are easily done by moving the decimal point or adding noughts. Thus:

$$2400\text{V} = 2{\cdot}4\text{kV}$$

$$0{\cdot}325\text{V} = 325\text{mV} = 325\,000\mu\text{V}$$

$$0{\cdot}25\text{kV} = 250\text{V}.$$

Measurement of Voltage

An instrument used to measure voltage in volts is a *voltmeter*. It must always be connected across the two points between which the voltage is to be measured, and is inserted without breaking the circuit. To measure voltage, the positive terminal of the voltmeter is connected to the positive terminal of the voltage source and the negative terminal of the voltmeter to the negative terminal of the voltage source (Fig 20.13). Meters for measuring kilovolts, millivolts and microvolts are known as *kilovoltmeters, millivoltmeters and microvoltmeters* respectively.

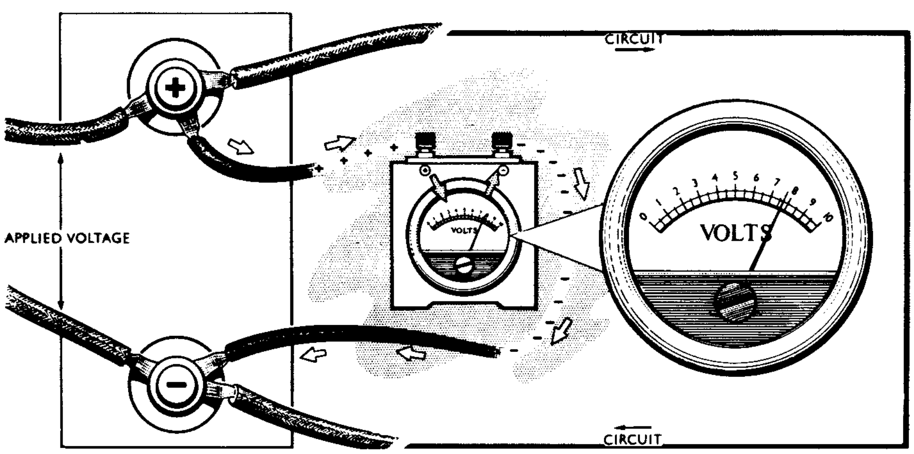


Fig 20.13 How a voltmeter is used

Generation of Voltage

We have seen that the applied voltage necessary to produce and maintain a current in a closed circuit is derived from the electrical energy of the source of supply. The electrical energy itself is obtained by converting energy *of some other kind*. When energy of some kind is converted into electrical energy an applied voltage is obtained. The kinds of energy normally used in practice to generate a voltage are chemical energy in a battery and mechanical energy in an electric generator (Fig 20.14 overleaf).

Resistance

As we have seen, current flow is the movement of free electrons in one general direction through a material. Different materials, however, have different numbers of free electrons. One conductor may have many free electrons; another material may have few. For a given voltage applied to each of them, the current in the first will be very much greater than that in the other. The first is said to have a lower *resistance* than the other (Fig 20.15 overleaf).

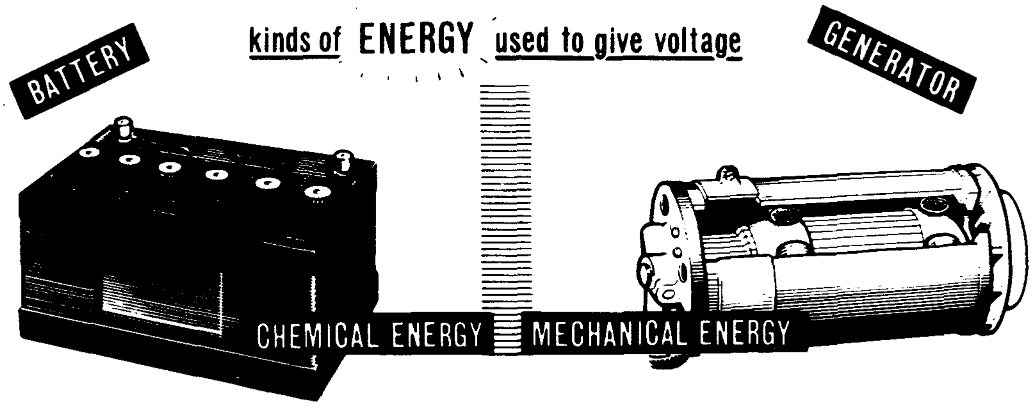


Fig 20.14 Generation of voltage

Note, however, that even the best conductors have some resistance (known as *conductor resistance*) and even the best insulators are not perfect: they have a high value of resistance known as *insulation resistance*.

With a constant voltage applied to a circuit, the *larger* the resistance of the conductor in the circuit, the *smaller* is the current. Using the same voltage, the *lower* the resistance the *greater* is the current.

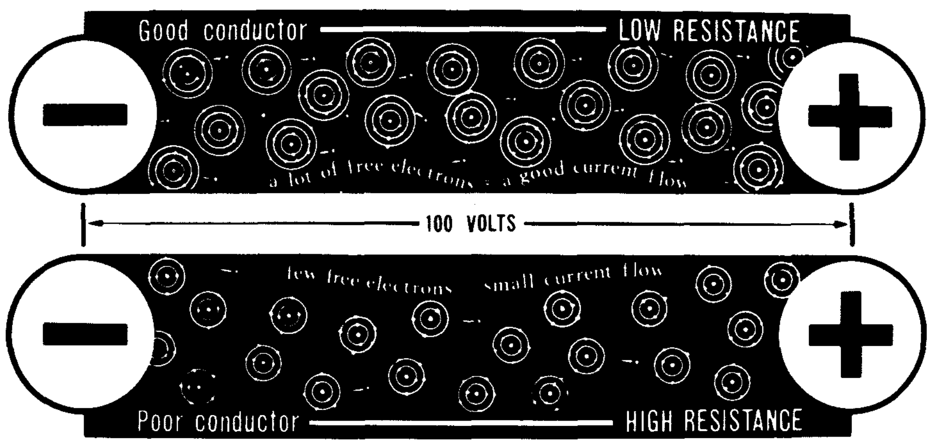


Fig 20.15 Resistance

So with a fixed voltage the current can be increased by decreasing the resistance, and decreased by increasing the resistance (Fig 20.16). The current in a circuit can therefore be adjusted by altering the resistance.

Factors Affecting Resistance

We have seen that even the best conductors have resistance. The resistance of a conductor depends on four things (Fig 20.17):

- **Material.** For example, silver is a better conductor than copper.
- **Length.** The *longer* the wire, the *greater* is the resistance.
- **Cross-sectional area.** The *thicker* the wire, the *smaller* is its resistance.
- **Temperature.** For most materials, the *hotter* the material the *greater* is its resistance (A few materials—notably carbon and electrolytes—actually *decrease* in resistance as the temperature rises).

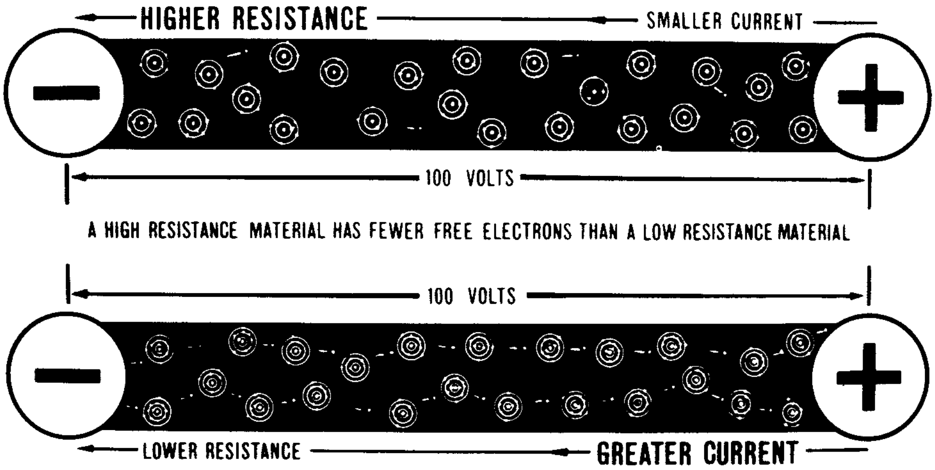


Fig 20.16 Effects of resistance on current

Units of Resistance

The unit of resistance is the *ohm* (symbol Ω). A material has a resistance of one ohm when a current of one ampere flows through it for an applied voltage of one volt. For larger and smaller resistance values we use:

$\frac{1}{1\ 000\ 000}$ ohm = 1 microhm, which is abbreviated to 1μΩ.

1000 ohms = 1 kilohm, which is abbreviated to 1kΩ.

1 000 000 ohms = 1 megohm, which is abbreviated to 1MΩ.

To measure resistance values up to about 10MΩ, a meter known as an *ohmmeter* is used. For measurement of insulation resistances greater than about 10MΩ, a special instrument called a *megger* is used.

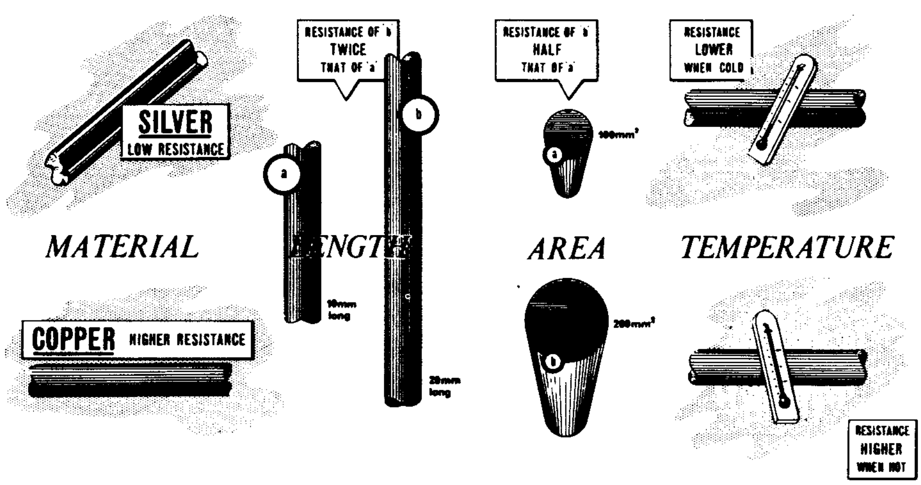


Fig 20.17 Factors affecting resistance

Ohm's Law

If we take a conductor and apply a voltage of 1 volt to it, the current will have a certain value, say 2 amperes; with 2 volts applied, the current will double to 4 amperes; with 3 volts applied, the current will be 6 amperes, and so on. In other words, *current is proportional to voltage*. If, for a given conductor, we divide the value of the applied voltage by the value of the current, we always get the same answer—in this case $\frac{1}{2}$. This answer is the resistance of the conductor, so that

$$\text{Resistance} = \frac{\text{Applied Voltage}}{\text{Current Produced}}$$

If we were to repeat this with any conductor we would find the same rule applies. This relationship is, in fact, the so-called Ohm's law formula.

The resistance of a circuit in *ohms* is written as R

The applied voltage in *volts* is written as E

The current flowing in *amperes* is written as I

Ohm's law formula is, therefore, expressed as:

$$R = \frac{E}{I}$$

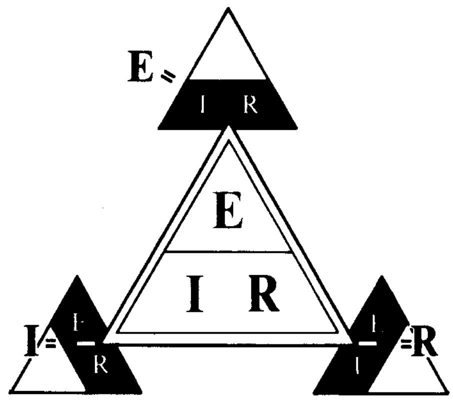
It can also be expressed in two other forms as indicated in Fig 20.18:

$$E = IR$$

$$I = \frac{E}{R}$$

The last expression shows that the current flowing in a circuit depends on two things — the *applied voltage* and the *resistance*.

In some textbooks the symbol E is used exclusively for EMF, and V is used for other voltages. In this book, to avoid confusion, E is used for voltage throughout.



This may remind you

Fig 20.18 Ohm's Law formula

If E is doubled so also is I, provided R remains constant.

If R is doubled, then for the original value of E, I is halved (Fig 20.19).

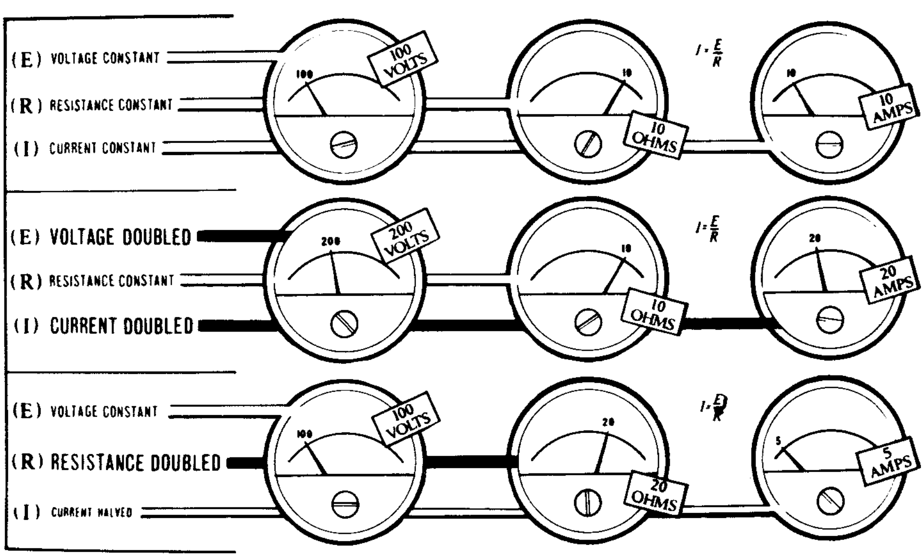


Fig 20.19 Effect of voltage and resistance changes on current flow

If the voltage applied to a circuit and the current flowing in the circuit are both known, the resistance can be calculated using Ohm's law. Similarly, if any two of the quantities are known, Ohm's law can be used to find the unknown quantity. Fig 20.20 illustrates examples.

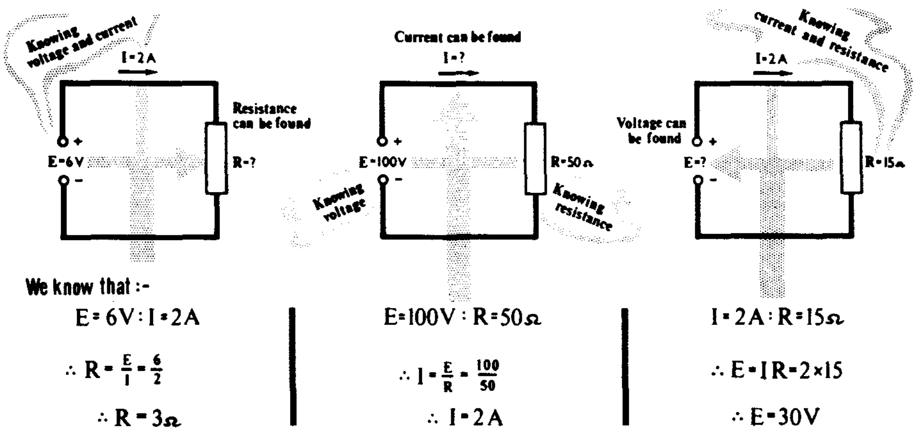


Fig 20.20 Ohm's Law applied to a simple circuit

Series Circuits

A circuit may contain more than one device having resistance. When several devices are connected end to end in such a way that there is *only one path* for the current, the *same* current flows through each and we have a *series* circuit (Fig 20.21).

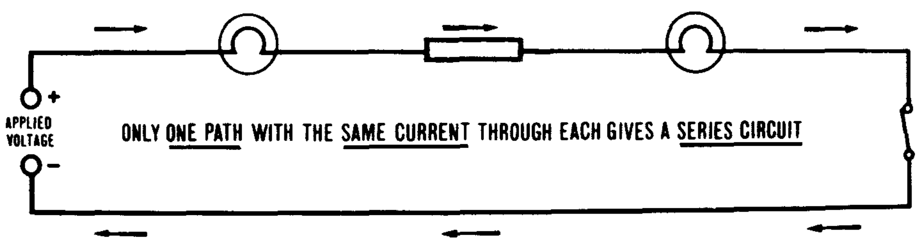


Fig 20.21 Series circuit

When components are connected in series, the total resistance between the ends of the circuit is the *sum* of the individual resistances (Fig 20.22); that is:

$$\text{Total resistance R} = R_1 + R_2 + R_3.$$

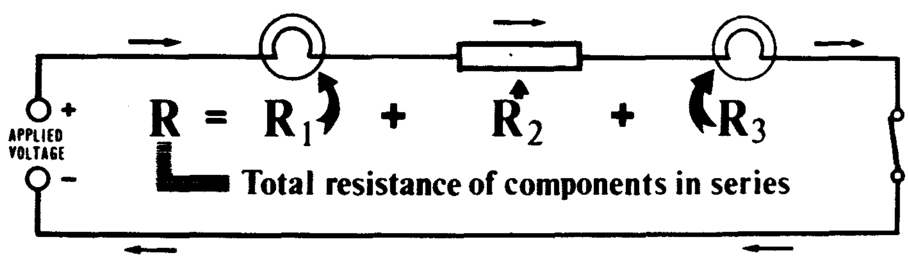


Fig 20.22 Total resistance in a series circuit

Ohm's Law and Series Circuits

Let us now look at two examples to show how Ohm's law is used in series circuits.

Example 1. In the circuit of Fig 20.23 overleaf, find the value of R_3.

The total resistance $R = R_1 + R_2 + R_3$

The total voltage $E = 120V$.

The total current I = 2A

From the voltage and current, the total resistance can be found:

$$R = \frac{E}{I} = \frac{120}{2} = 60\Omega$$

But $R_1 = 15\Omega$ and $R_2 = 20\Omega$

$\therefore R_1+R_2+R_2 = 60\Omega$

so that $R_1+R_2 = 35\Omega$

Therefore, R_3 equals the total resistance minus the resistance of $R_1 + R_2$.

That is, $R_3 = 60-35 = 25\Omega$

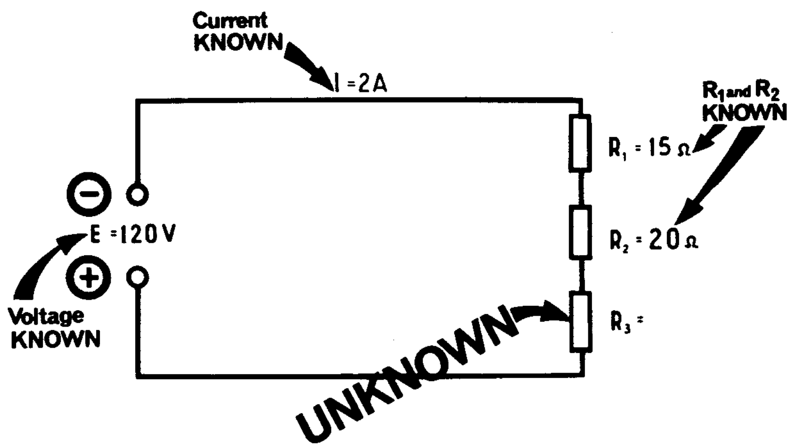


Fig 20.23 Example 1

Example 2. Three similar lamps are connected in series across a 6V supply (Fig 20.24). The current flowing is 0·2A. Find the resistance of each lamp.

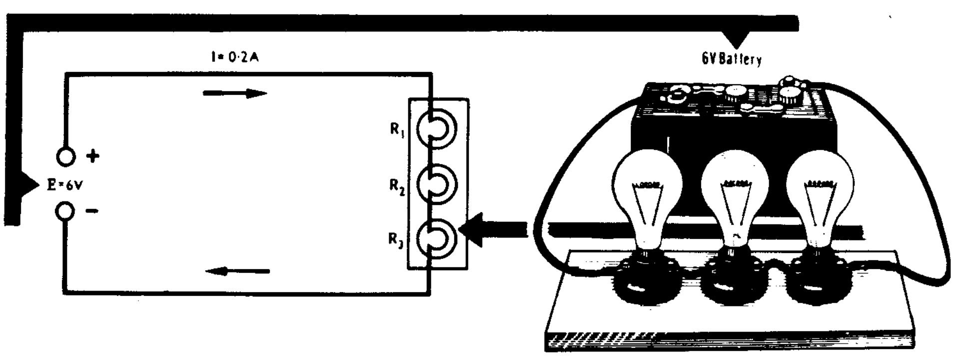


Fig 20.24 Example 2

We know that the supply voltage is 6V and the current is 0·2A.

From this we can calculate the total resistance

$$R = \frac{E}{I} = \frac{6}{0{\cdot}2} = 30\Omega$$

But $R = R_1 + R_2 + R_3 = 30\Omega$

And R_1, R_2 and R_3 are equal in value since the lamps are similar.

Therefore, $R_1 = R_2 = R_3 = 10\Omega$

Parallel Circuits

Components are '*in parallel*' when they are connected to a *common voltage* source in such a way that they provide *alternative* paths for the current. The current in each component will depend only on its resistance (Fig 20.25).

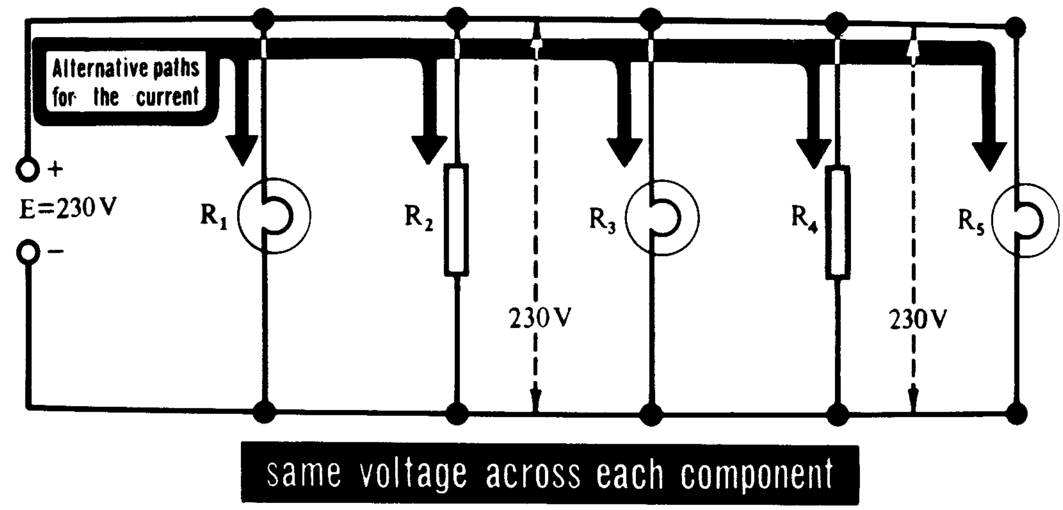


Fig 20.25 A parallel circuit

In a house, for instance, the various electrical appliances are connected in parallel across the voltage of the mains supply (normally 230V in this country) but each provides a different path for current flow between the mains connections (Fig 20.26).

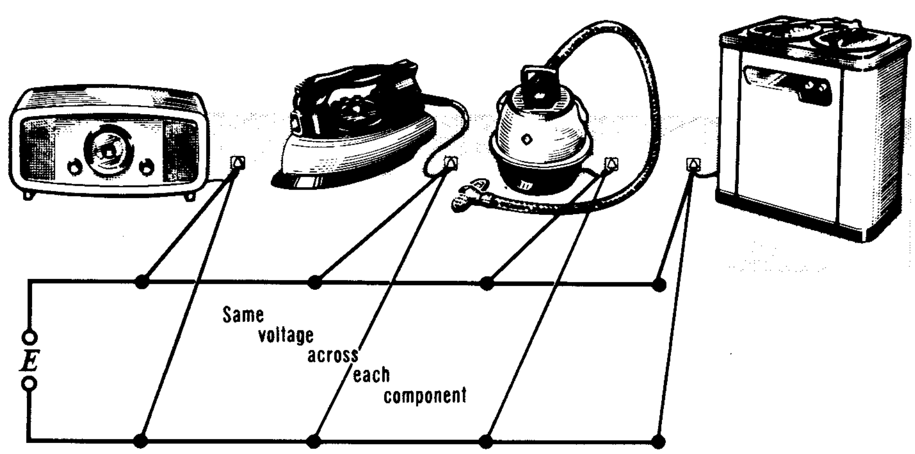


Fig 20.26 Components in parallel

Current in Parallel Circuits

In a parallel circuit, the current divides among the various branches according to the resistance of each branch (Fig 20.27 overleaf). The total current into and out of a group of resistors in parallel is the sum of the currents in the separate resistors.

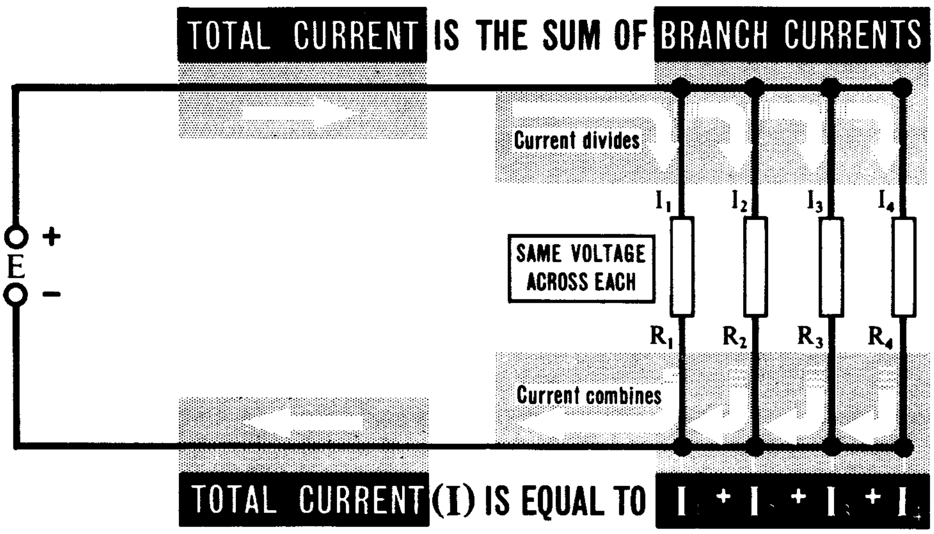


Fig 20.27 Total current in a parallel circuit

If two resistors of unequal value are connected in parallel across a voltage source, the *greater* current will flow through the *smaller* resistance. Thus, if R_1 and R_2 are two resistances in parallel (Fig 20.28) and R_1 is half R_2, then R_1 will take twice the current of R_2 whatever the value of the applied voltage.

If the parallel circuit has equal resistances in each branch, the current through each branch will be the same since the resistances are all connected across the same voltage source (Fig 20.29). In this case, the current through each resistance is the total current divided by the number of resistances in parallel.

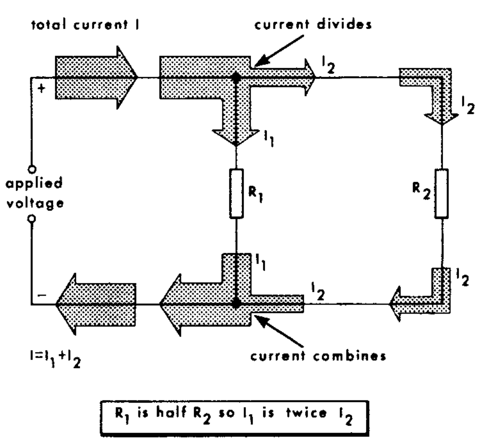


Fig 20.28 Division of current —unequal resistances

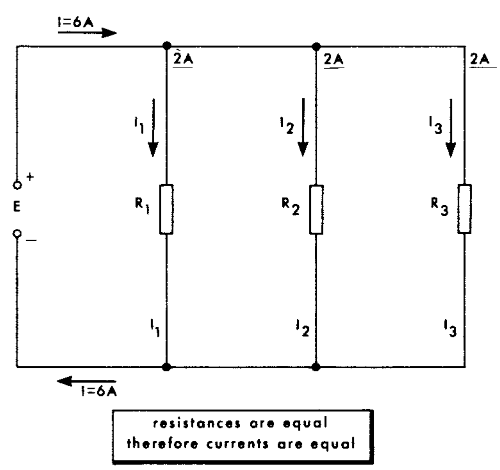
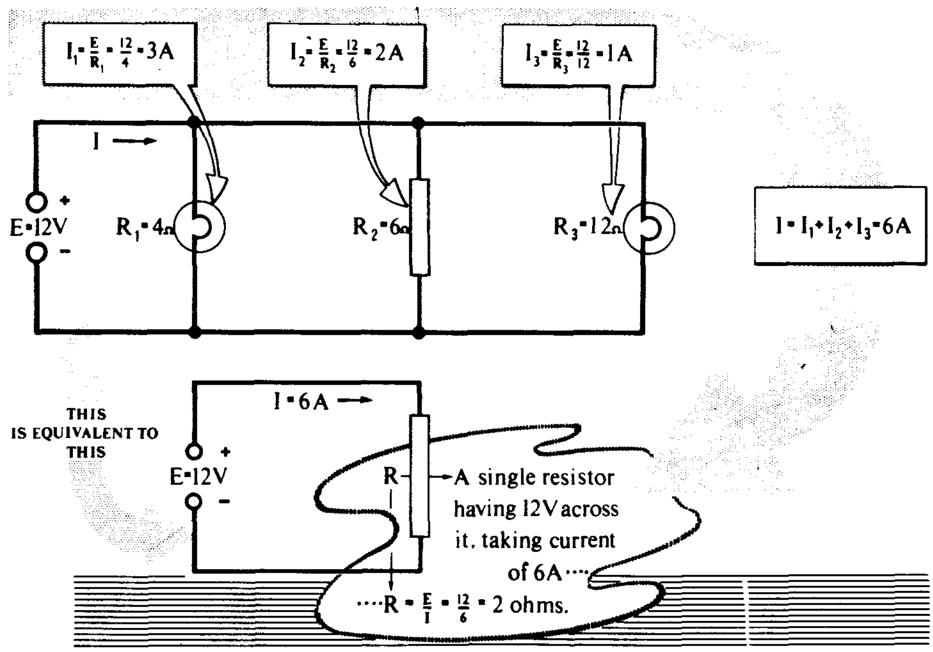


Fig 20.29 Division of current —equal resistances

Resistance of Parallel Circuits

We can find the effective resistance of several components in parallel in the following way. Calculate the current in each component using Ohms' law (Fig 20.30).

The total current flowing into the combination is the sum of the separate currents. The combination is therefore equivalent to a single resistance which would take a current of this magnitude when connected across the voltage source.



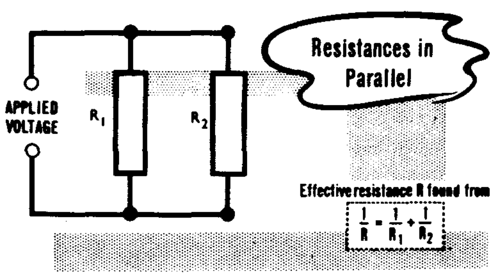


Fig 20.31 Resistances in parallel

The effective resistance of the two components in parallel (Fig 20.31) can be found more directly by using the expression

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

In dealing with parallel resistances it always pays to work 'upside-down' in this way, but note that the larger R_1 becomes the smaller is $\frac{1}{R_1}$; thus $\frac{1}{3}$ is obviously larger than $\frac{1}{100}$.

Example. Find the effective resistance of a 3 ohm resistor and a 6 ohm resistor connected in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\therefore \frac{1}{R} = \frac{1}{3} + \frac{1}{6}$$

The lowest common denominator is 6.

$$\therefore \frac{1}{R} = \frac{2+1}{6} = \frac{3}{6}$$

To find R turn this result upside down

$$\therefore R = \frac{6}{3} = 2 \text{ ohms.}$$

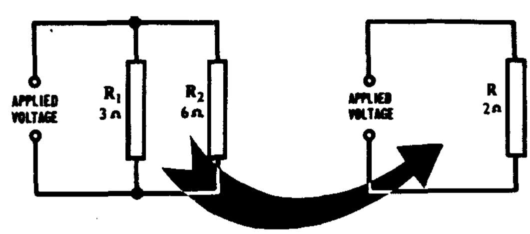


Fig 20.32 Effective resistance of two resistances in parallel

Thus the 3 ohm resistor and the 6 ohm resistor connected in parallel are equivalent to a single resistance of 2 ohms (Fig 20.32). Note that the total resistance of the combination is *smaller* than the *smaller* individual resistance. This is always the case in a parallel circuit.

The basic formula for resistances in parallel can be extended to cover any number of resistances. For three resistances in parallel:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Example. Find the effective resistance of three resistors valued 300Ω 200Ω and 60Ω connected in parallel (Fig 20.33).

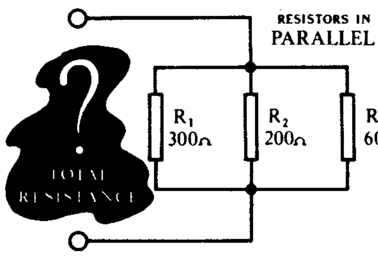


Fig 20.33 Effective resistance of three resistances in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{300} + \frac{1}{200} + \frac{1}{60}$$

The lowest common denominator is 600.

$$\therefore \quad \frac{1}{R} = \frac{2+3+10}{600} = \frac{15}{600}$$

To find R turn this result upside down.

$$\therefore \quad R = \frac{600}{15} = 40\Omega.$$

Again, the effective value of the three resistors connected in parallel is *smaller* than the *smallest* individual resistance.

Series/Parallel Circuits

We shall often find simple series and parallel arrangements of resistances combined in resistance networks. Two simple series/parallel combinations of resistances are shown in Fig 20.34.

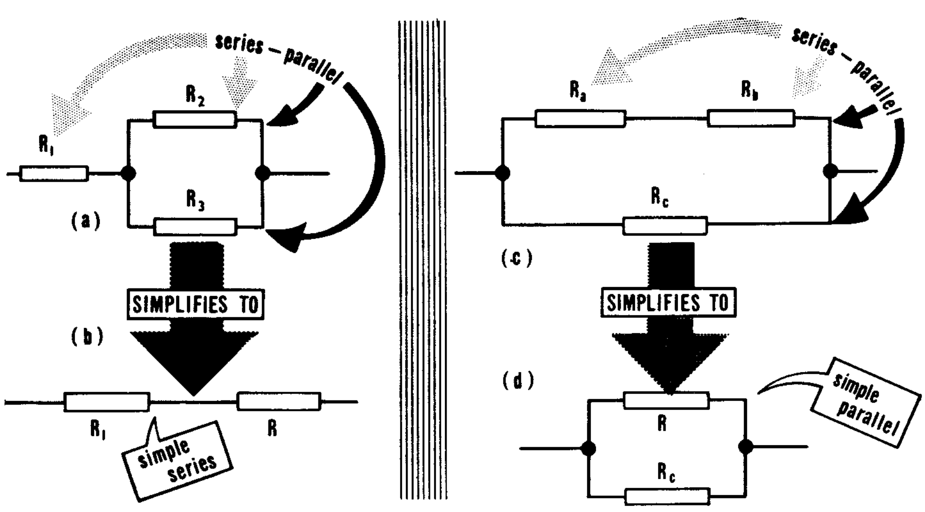


Fig 20.34 Series/parallel resistance network

In (a) R_2 and R_3 in parallel can be combined to give an effective resistance R. The circuit is then simplified to that shown in (b) and the total resistance is $R_1 + R$.

In (c) Ra and Rb in series can be combined to give R = Ra + Rb. The circuit is then simplified to that shown in (d) and the total resistance can be found using $\frac{1}{R_t} = \frac{1}{R} + \frac{1}{R_c}$. More complicated circuits can be dealt with in the same way. Thus, to find the effective resistance of the combination shown in Fig 20.35a, the circuit is redrawn and reduced in stages (b) to (e) as shown to give a final effective resistance of 12 ohms.

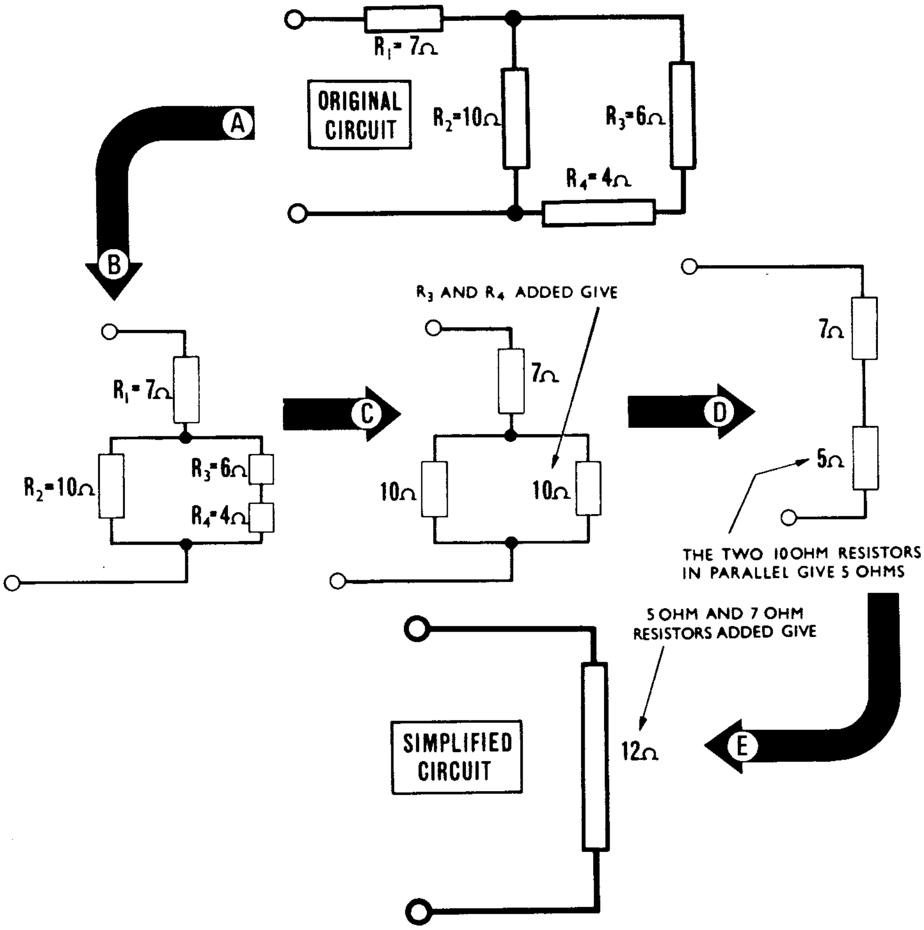


Fig 20.35 Reduction of complicated circuits

SUMMARY—REVIEW

Q What are the two methods of defining the direction of current flow? (p20.6).

Q What is the unit of current and its symbol? (p20.7).

Q What are the three effects of an electric current? (p20.7).

Q What is the unit of voltage? (p20.8).

Q What are the four factors affecting the resistance of a conductor? (p20.10).

Q What is the unit of resistance and its symbol (p20.11).

Q What is Ohm's law? (p20.12).

Q What is the total resistance of a circuit containing three resistances R_1, R_2 and R_3 in series? (p20.13).

Q What is the total resistance of a circuit containing three resistances R_1, R_2 and R_3 in parallel (p20.18).

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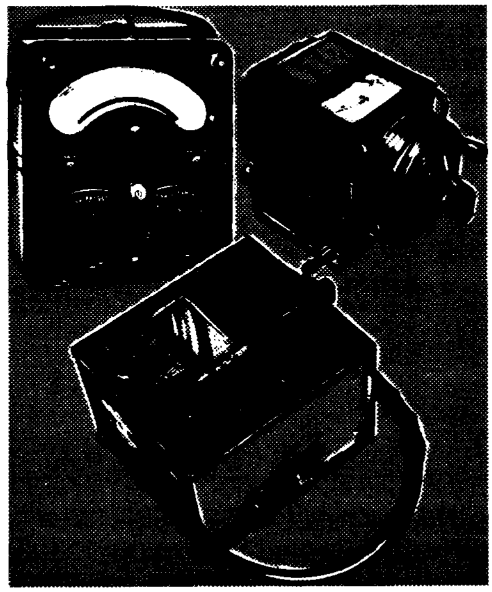

CHAPTER 21

TEST INSTRUMENTS

Introduction

In Chapter 20 we saw that before current can flow in a circuit we must have:

- A source of voltage.
- A closed circuit of conducting material (continuity).
- Adequate insulation resistance between the conducting wires.

If an item of electrical or radio equipment is not working satisfactorily, these are the first things to be tested.

In electrical and radio engineering, although we can often *see the effects* of current and voltage in a circuit, we cannot actually see the current and voltage. This is a disadvantage when we are trying to find a fault in a circuit, and so we have to use instruments to do the 'seeing'—and also the measuring—for us.

In general electrical testing and fault-finding; we want to be able to measure current, voltage and resistance at various points in a circuit. We shall normally need several ammeters and several voltmeters to cover the required range of measurement, plus an ohmmeter to measure resistance. The job would, of course, be much easier if we had a single instrument that could give all three measurements. A multimeter does just that, and in this chapter we will consider a particular multimeter known as the Multimeter Type 1.

The insulation resistance of a component may appear satisfactory when checked with a multimeter, but a high voltage applied to the component may cause the insulation to break down completely. Because of this we must check insulation resistance with a high voltage instrument and, to be on the safe side, we use a voltage higher than the normal working voltage of the component. The instrument used to measure insulation resistance is the Insulation Tester or 'Megger'.

Note: The word 'Megger' is a trade name that is to be found in the whole range of resistance-measurement equipment made by one particular manufacturer, including intruments of a low-voltage nature which are certainly not designed for insulation resistance measurements.

The Multimeter Type 1 is a general purpose test instrument used to measure resistance and a wide range of dc and ac currents and voltages, Fig 21.1 shows a front view of this instrument.

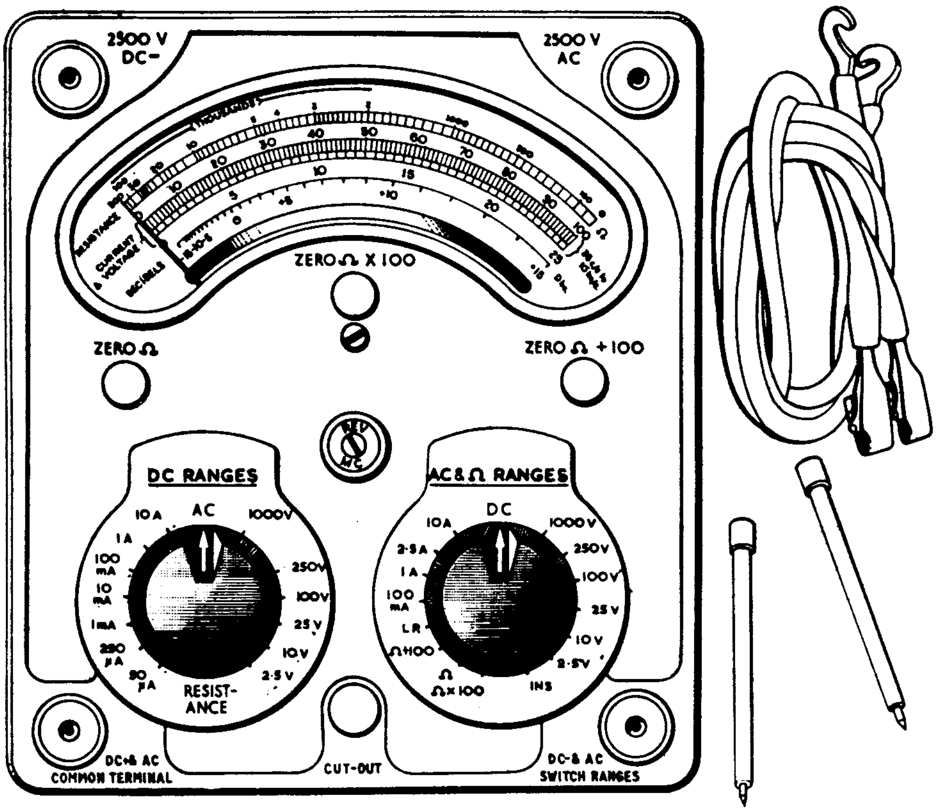

Fig. 21.1 Multimeter Type 1

DC ranges. To measure dc currents or voltages, one test lead is connected to the bottom left hand terminal (DC+) and the other lead to the bottom right hand terminal (DC–). The 'AC & Ω RANGES' switch is set to 'DC' and, with the 'DC RANGES' switch, we select the current or voltage range we want (Fig 21.2).

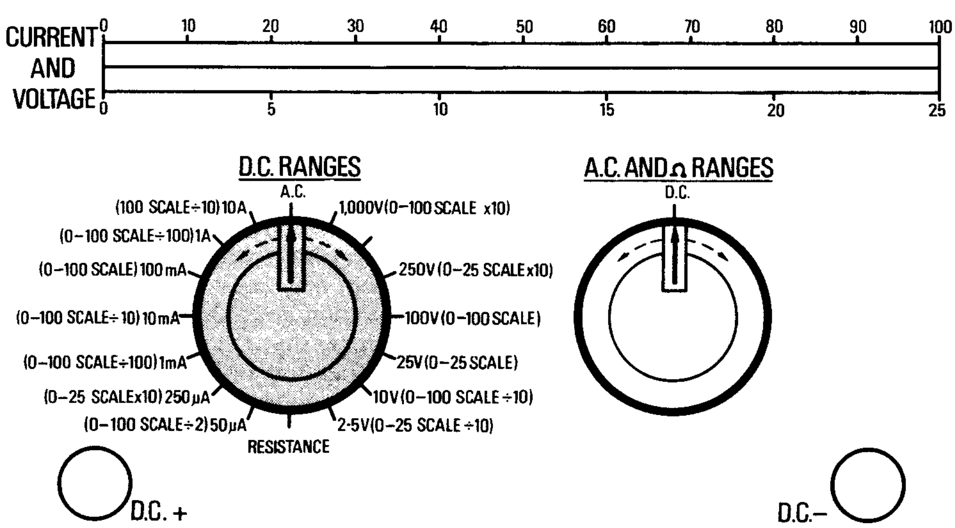

Fig. 21.2 Selection of DC Current and Voltage Ranges

There are six dc voltage and seven dc current ranges available on this switch, but there are only two scales; the scale to use is shown in Fig 21.2.

DC voltages between 1000V and 2500V can be measured with the 'DC RANGES' switch at 1000V by taking the test lead from the bottom right-hand terminal (DC−) and connecting it to the top left-hand terminal (2500V DC−). The 0-25 scale multiplied by 100 is used. The circuit to be tested *must be switched off* before connections are made or changed, and it is commonsense to examine the test leads closely, before use, to ensure that their insulation is in impeccable condition. It is recommended that the test leads should be braided together and given a core-to-core test with an insulation tester before they are used on high voltage ranges (*see* page 21.6).

AC ranges. For ac current and voltage measurements, the test leads are connected to the two bottom terminals; the 'DC RANGES' switch is set to 'AC' and, with the 'AC & Ω RANGES' switch, we select the current or voltage range we want (Fig 21.3). There are four ac current ranges and six ac voltage ranges available on this switch and again we must use the correct scale (Fig 21.3).

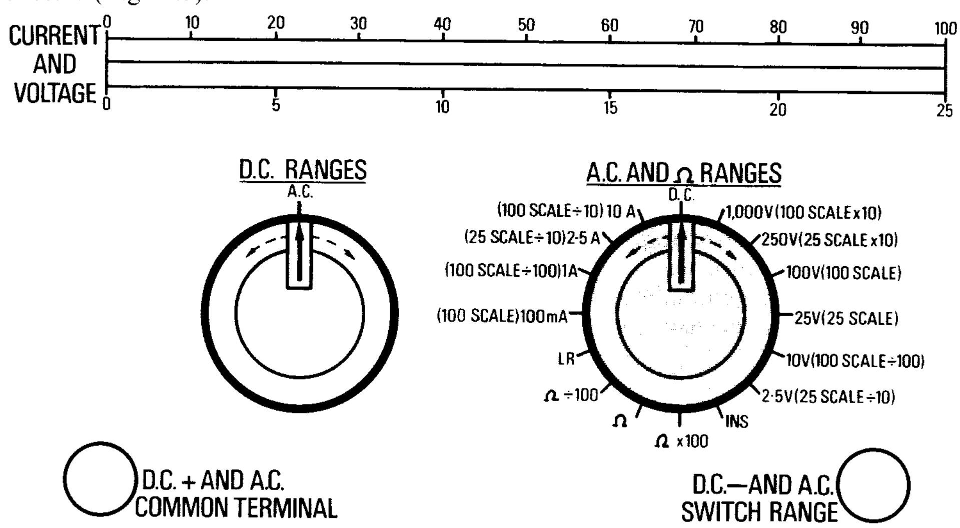

Fig. 21.3 Selection of AC Current and Voltage Ranges

AC voltages between 1000V and 2500V can be measured with the 'AC & Ω RANGES' switch at 1000V by removing the test lead from the bottom right-hand terminal and connecting it to the top right-hand terminal (2500V AC). The 0-25 scale multiplied by 100 is used.

Resistance measurement. For measurement of resistance, the test leads are connected to the two bottom terminals, the 'DC RANGES' switch is set to 'RESISTANCE' and, with the 'AC & Ω RANGES' switch, we select the range of resistance measurement we want (Fig 21.4).

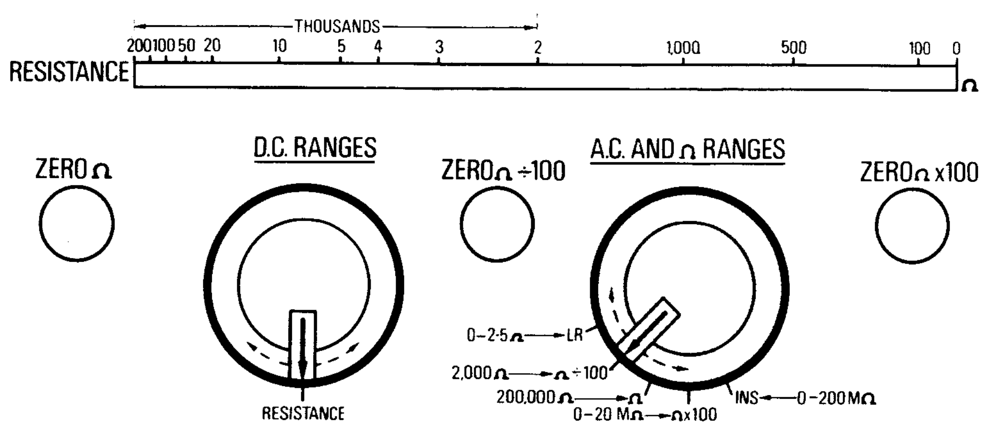

Fig. 21.4 Selection of Resistance Ranges

Before measuring resistance on any of the ranges, the full scale deflection (fsd) for zero ohms must be set. This is done by connecting the two test leads together and adjusting the appropriate zero ohms control.

There are five resistance ranges:

- **'Ω ÷ 100'.** This measures resistance in the range 0-2000 ohms. The internal 1.5V battery is used and the reading on the resistance scale is divided by 100. The fsd reading is adjusted for zero ohms by the 'ZERO Ω ÷ 100. control.
- **'Ω'.** This measures resistance in the range 0-200 000 ohms as indicated on the scale. The internal 15V battery is used and the 'ZERO Ω' control adjusts the fsd reading on this range.
- **'Ω × 100'.** This covers the range 0-20 megohms. The internal 15V battery is used and the scale reading is multiplied by 100. The 'ZERO Ω × 100' control adjusts for fsd on this range.
- **'INS'.** This is used to measure high resistance (insulation) in the range 0-200 megohms. An external 130-160V dc supply is now required in series with the meter and the scale reading is multiplied by 1000. The 'ZERO Ω × 100' control adjusts for zero ohms on the scale in this range.

Cut-out. As a precaution against passing excessive current through the meter, a mechanical cut-out is provided. If the meter is overloaded, the cut-out knob springs out and breaks the circuit to the meter. Do not reset this cut-out with the instrument still connected to the circuit that caused the overload.

Decibels scale. The bottom scale of the meter is marked in 'decibels (dbs)'. This scale is used when it is required to compare the power at one part of a circuit with that at another point. In fact, in our work we are not required to make such measurements. We need not, therefore, know anything about the dbs scale.

Precautions. To get the best results from this testmeter, we must observe certain 'rules';

- For accurate readings, the testmeter should be used face upwards.
- Do not tap the glass covering the scale.
- When the meter is not in use, set the 'AC & Ω RANGES' switch to 'DC' and the 'DC RANGES' switch to 'AC'.
- When the range of a voltage or current to be measured is not known, set the meter to the *highest range* and work downwards if necessary; this protects the meter.
- Always set to zero on the appropriate ohms range before measuring resistance and make sure that the circuit under test is not 'live'.
- Use the mirror on the scale of the instrument to make sure that the pointer is read at the correct angle. The viewing angle is correct when the pointer and its image in the mirror coincide.
- Check the ohmmeter batteries regularly and remove them if the meter has to be stored.
- Ensure that the polarity of the voltage or current to be measured is the right way round for the meter movement.

INSULATION TESTERS

General

The insulation tester or megger is a special type of ohmmeter. To measure insulation resistance with a Multimeter Type 1 we need an external 130-160V dc supply. The insulation tester, however, has its own high voltage source consisting of a generator driven by a handle; when the handle is turned at a speed of 160 rpm the required high voltage is produced. This is our testing voltage and is either 250V or 500V depending on the model being used. Four types of insulation tester are illustrated in Fig 21.5.

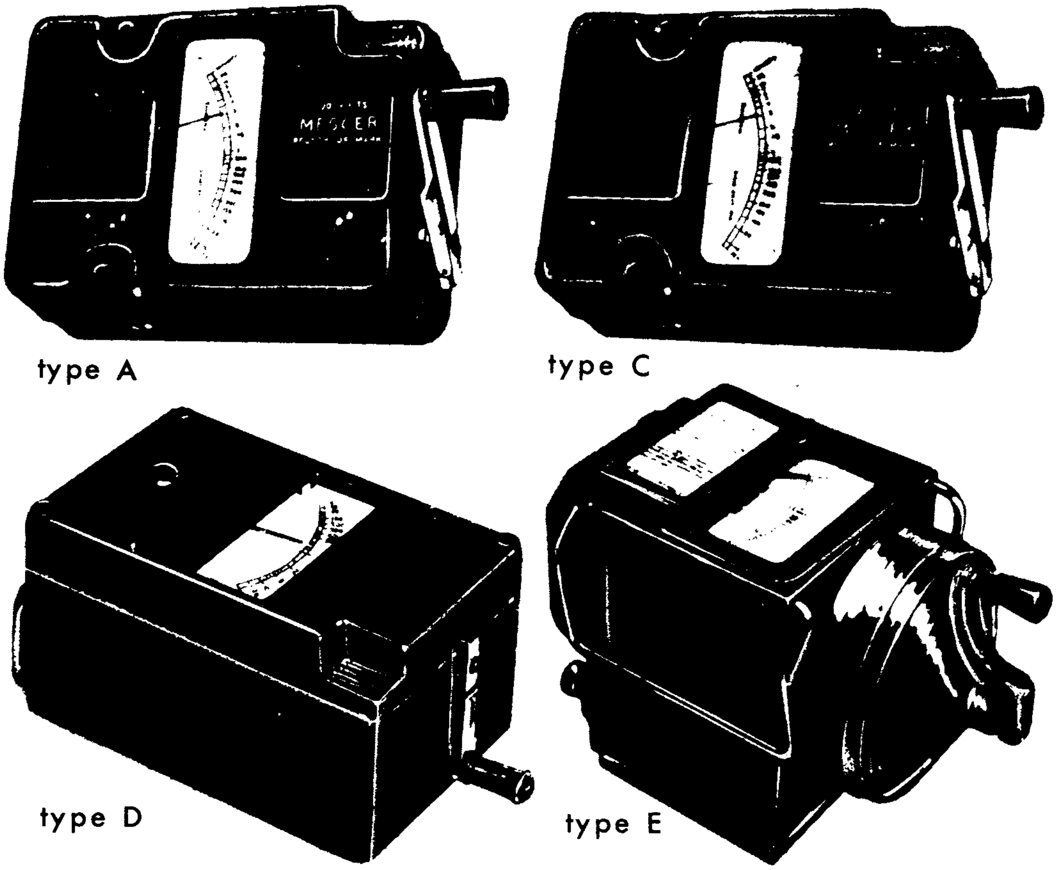

Fig. 21.5 Insulation Testers

Types A and C are identical in appearance but the Type D, which is of different manufacture, is slightly larger. The Type E tester is housed in a metal case and has a centrifugal clutch, preset to slip at a handle speed of 160 rpm to provide a constant 500V output. The output of Type C tester is limited electrically to 250V but Types A and D have an uncontrolled output which reaches a nominal value of 500V at a handle speed of 160 rpm.

Insulation Testing Procedure

Insulation testers must be kept away from magnetic influences (other than normal terrestial magnetism) while tests are being made. The tester should be placed on a firm base where it can be held steady—you must be able to turn the handle smoothly without any tendency to rock or slide the tester, and every effort must be made to keep the handle turning smoothly at the 'rated' speed of the tester (160 rpm).

A preliminary check on the insulation tester should always be made before starting on the actual testing procedure. The tester should be checked as follows:

- With the output terminals open-circuited, the generator handle should be turned at normal speed. The pointer should immediately move to the INFINITY position on the scale.
- Connect the test leads to the output terminals, twist the leads together, ensure that the exposed ends are not in contact (either directly or through any other conducting material) and repeat the previous test.
- Touch the ends of the leads together, then turn the handle slowly; the pointer should immediately move across the scale to the ZERO position.

The technique you adopt for practical insulation testing depends to a great extent on the nature of the component, circuit or installation that you have to investigate. The object of any insulation test is to determine the effective resistance between two points exclusive of the resistance of 'authorized' paths, such as load components *etc*, normally connected between the points. In some instances this point may not arise, *eg* we may have a conductor physically attached to a metal mast and need to test the insulation resistance between the conductor and the mast; in such circumstances there should obviously be no connection between the conductor and the mast. These two types of insulation test are illustrated in Fig 21.6.

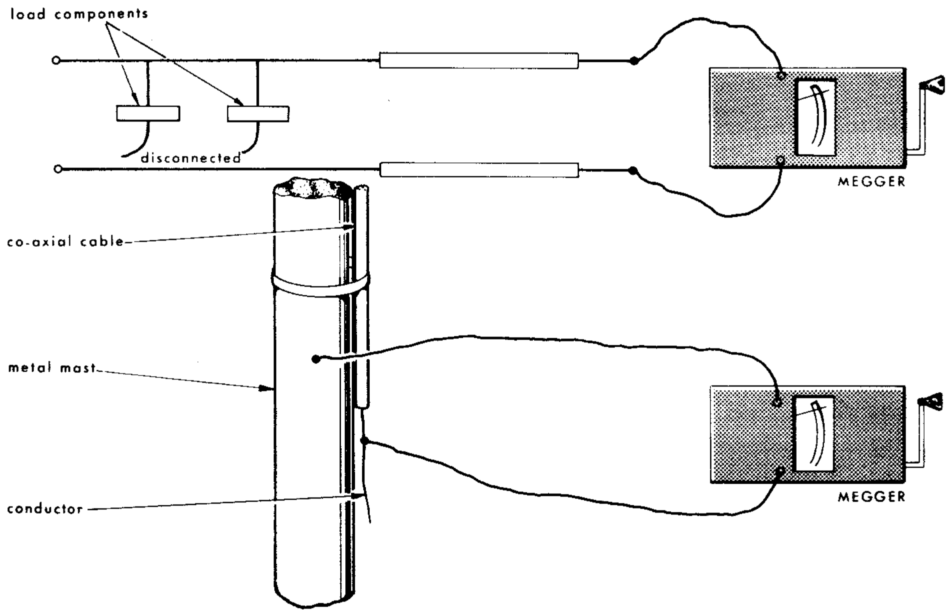

Fig. 21.6 Insulation Tests

One further point must also be borne in mind: an insulation tester can only disclose insulation faults between points that are in electrical contact with opposite terminals of the insulation tester: the entire portion of the network in contact with each test lead must be electrically continuous throughout its length. From this it follows that continuity testing of circuits as a preliminary to insulation testing is sound policy.

The following points should be borne in mind when making insulation tests:

- Always regard indications of INFINITY with suspicion. This ideal is rarely achieved in equipment that has previously been in service or has spent appreciable time in storage. If such a result is obtained, make a point of checking the connections, the tester leads, and the tester itself, then repeat the test for confirmation.
- Acceptable levels of insulation resistance are specified in all servicing schedules that call for insulation tests. Remember that these specified values are minimum values; if a test result is even slightly inferior to this value then it must be regarded as an unsatisfactory result.
- Accept only steady readings obtained after continuous turning of the handle at full rated speed for five seconds. Irregularities in indication are often attributable to decomposition or metallic contamination of the insulation, and they should be regarded as signs of insulation weaknesses that may, in the near future, lead to breakdown.
- Readings which decrease as the rate of turning the handle is increased, *ie* as the testing voltage is increased, are often a sign of moisture in the insulation. Repeat the test after trying to disperse the moisture by thorough ventilation and/or the application of gentle heat.

Servicing

Insulation testers are issued sealed. Beyond keeping a tester clean and dry, and handling it with reasonable care on all occasions, nothing is to be attempted in the way of servicing, repair or adjustment. Insulation testers are, in general, extremely reliable instruments if given fair treatment. What might appear to be an instrument fault is, in many cases, simply evidence of incorrect handling on the part of the person making the tests. The following points are applicable to all insulation testers:

- Although the insulation tester is robustly constructed, it is nevertheless a precision mechanism and it should always be treated as such. Keep it in its carrying case at all times. Testing can be done effectively with the tester in its case, and always carry it slung from the shoulder.
- The insulation tester is as good as the test leads that connect it to the circuit or component under test. The leads must be kept dry and free from kinking, and any superficial evidence of defective insulation or doubtful continuity (either at the end fittings or in the body of the leads) should be investigated immediately. 'Standard' test leads are provided for certain types of insulation testers, and these must always be considered as an integral part of the instrument. If they become damaged, or in any way defective, they must be replaced by items of the same Stores Ref Number. Repair of damaged 'standard' leads is not permissible.
- The accuracy of each insulation tester should be checked periodically. This can be done by connecting suitable resistors, of marked value and tolerance, across the terminals and carrying out a test sequence in the usual manner. The readings obtained should agree with the marked value of the resistor, allowing for the tolerance indicated by its marking.

THE BRIDGE-MEGGER TESTER TYPE B

Introduction

The Bridge-Megger Tester, Type B (Fig 21.7) is a self-contained unit which combines the functions of an insulation resistance tester and a bridge-type continuity resistance measuring device; in the latter mode of operation, use is made of a simple resistance network known as the *Wheatstone Bridge*. The Bridge-megger can also be used for the location of earth faults by the Varley Loop method. This mode of use is beyond the scope of this chapter and is, therefore, not described.

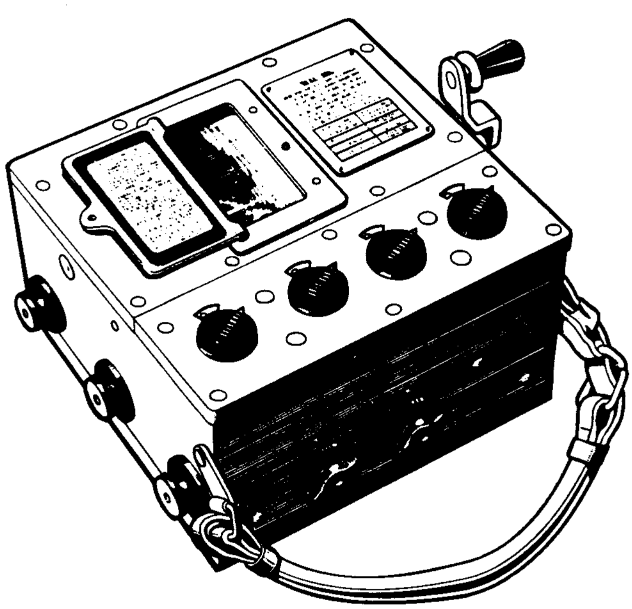

Fig. 21.7 Bridge Megger Tester Type B

The Wheatstone Bridge Principle

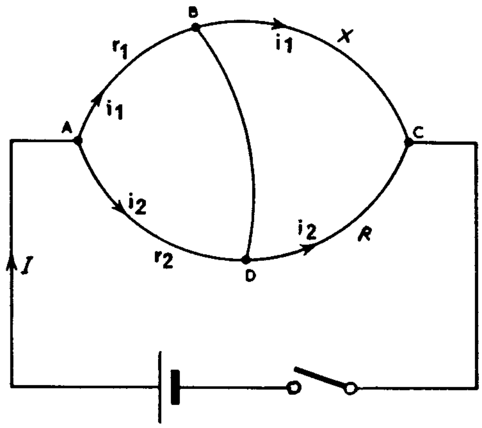

Fig. 21.8 Basic Wheatstone Bridge

If two ends of a conductor are held at different potentials, every intermediate point in the conductor will be at a potential somewhere between the potentials of the two ends. If a second conductor is now connected in parallel with the first, the same statement must apply to it also, and for any point on the first conductor there must be a *corresponding point* on the second conductor which is at the *same potential.* Since there is no difference of potential between these two points, a third conductor connected between them will carry no current. Fig 21.8 shows an arrangement of this kind. The conductor ABC, consisting of two resistances r_1 and X in series, is connected in parallel with the conductor ADC, consisting of resistances r_2 and R in series, and the intermediate points B and D are connected by a third conductor. The values of r_1, r_2, R and X are such that, on closing the switch, a current (I) flows from the cell and through ABC and ADC in parallel but does not pass through the conductor BD because points B and D are at the same potential.

If we examine the circuit conditions more closely we find that the current I divides at point A into two components, i_1 and i_2. The voltage drop between A and B is thus $i_1 r_1$ volts, while that between A and D is $i_2\, r_2$ volts; since points B and D are at the same potential it follows that:

$$i_1\, r_1 = i_2\, r_2 \quad \dots\dots\dots\dots\dots\dots \quad (1)$$

Similarly, the voltage drop between B and C is $i_1 X$ volts, while that between D and C is $i_2 R$ volts, hence:

$$i_1 X = i_2 R \quad \dots\dots\dots\dots\dots\dots \quad (2)$$

Dividing (2) by (1) we get:

$$\frac{i_1 X}{i_1 r_1} = \frac{i_2 R}{i_2 r_2} \quad \text{or} \quad \frac{X}{r_1} = \frac{R}{r_2}$$

$$\text{and } X = R \times \frac{r_1}{r_2}.$$

If X is an unknown resistance, its value can be calculated if the values of r_1, r_2 and R are known. Even more significant is the fact that the value of X can also be calculated if the *ratio* r_1/r_2 (not the actual values of these quantities) and the value of R is available. If, for example, r_1 and r_2 are equal then the ratio between them is unity and X = R; if r_1 is ten times the value of r_2 then the ratio is 10 and X = 10R; while if r_1 is one-tenth the value of r_2 the ratio is 1/10 and X = 1/10R.

A simple practical example of the Wheatstone Bridge principle to resistance measurement is shown in Fig 21.9. The 'bridge' comprises a pair of 'ratio arms' (r_1 and r_2), a pair of terminals to which the resistance under test (X) is connected, and a variable resistance (R). The points B and D, which are at the same

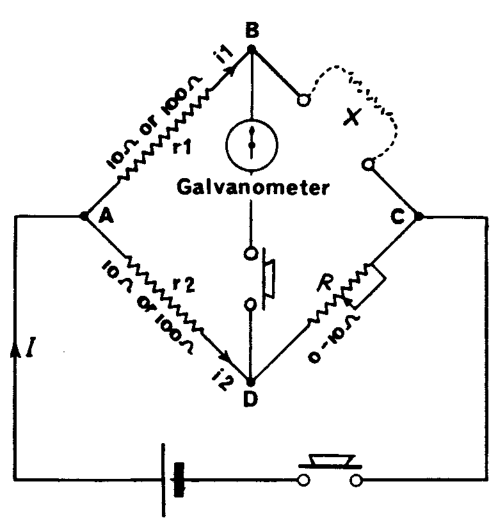

Fig. 21.9 Simple Bridge System for Resistance Measurement

potential when $X = R \times \frac{r_1}{r_2}$, are linked to a galvanometer which indicates the passage of current but does not measure it. In the arrangement shown, the ratio arms have alternative values of 10 ohms or 100 ohms each; the ratio $\frac{r_1}{r_2}$ can thus be 1/10, 1/1 or 10/1 and the bridge will be balanced (*ie* the galvanometer will not read) when X, the resistance under test, is equal to 0.1R, R or 10R respectively. R is variable from 0 to 10 ohms, in steps of 1 ohm. The alternative ranges of measurement are, thus, 0-1 ohms in steps of 0.1 ohms, 0-10 ohms in steps of 1 ohm, or 0-100 ohms in steps of 10 ohms, according to the ratio arm values. By making available additional resistors of 1000 ohms each for the ratio arms, the possible ratios are extended to include 1/100 and 100/1, giving two further ranges of measurement, 0-0.1 ohm in steps of 0.01 ohm and 0-1000 ohms in steps of 100 ohms. Each individual range could, of course, be extended by substituting a variable resistor of 0-1000 ohms (again in 1 ohm steps) for the existing 0-10 ohm variable resistance; the lowest range would then be 0-1 ohm in steps of 0.01 ohm, and the highest range from 0-10 000 ohms in steps of 100 ohms.

The substitution of individual resistors in the ratio arms of a practical resistance measurement bridge is, at best, a cumbersome process, and the selector-switch system shown in Fig 21.10 is much more convenient. The switch has five positions, and six resistors, whose individual resistances are in the ratios shown, can be grouped to give an r_1/r_2 ratio of 1/100, 1/10, 1/1, 10/1 or 100/1—the individual switch positions are marked to correspond to those ratios. The value of the resistance under test (X) is found by applying the ratio-switch setting to the observed value of R when the bridge has been balanced by adjusting R.

The resistance bridge is essentially a wide-range system of resistance measurement embodying a high degree of accuracy and, to exploit this feature to the fullest possible extent, it is necessary to use a variable resistance for the 'R' arm of the bridge which, although of very wide range, can be adjusted in very small steps, *eg* a range covering 0-10 000 ohm adjustable in steps of 1 ohm. A single variable resistor of this description is not a practicable proposition, especially for portable equipment, and the 'decade' system of multiple variable resistors shown in Fig 21.11 is generally used in the 'R' arm of practical resistance bridges. Four variable resistors are used in tandem. Each unit consists of nine identical resistors, each of 1000 ohm, 100 ohms, 10 ohms or 1 ohm, connected in series. The exposed ends, and the inter-resistor connection points, are taken out to the terminals of a 10-position rotary selector switch, the various positions of which are numbered in sequence from 0-9; the selector position is shown by the corresponding number appearing in a small aperture adjacent to the switch knob (Fig 21.12). The complete assembly thus covers the range of 0-9999 ohms in steps of 1 ohm.

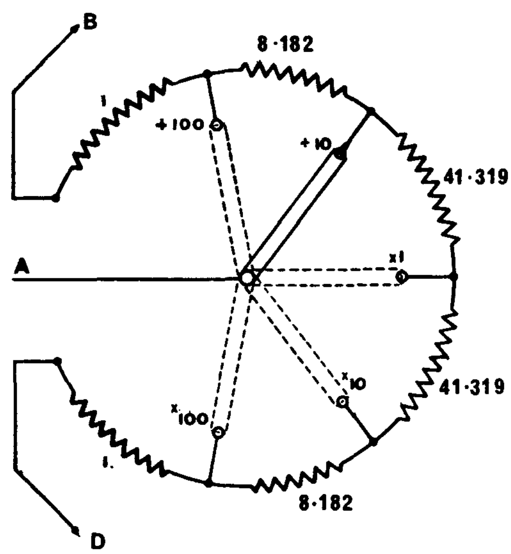

Fig. 21.10 Ratio Switch for Wheatstone Bridge

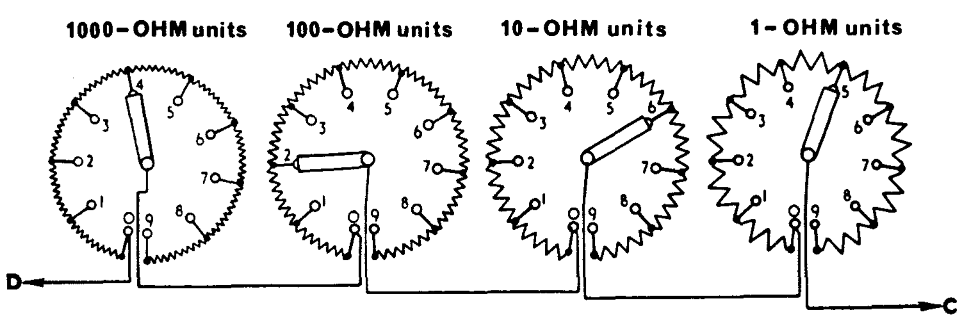

Fig. 21.11 Decade Resistance Unit

Description

The testing voltage is produced by a hand-driven generator, and direct indications of insulation resistance values are given by an ohmmeter, which also functions as a galvanometer during bridge tests. A rotary change-over switch (Fig 21.12) mounted on the side of tester (marked MEGGER, BRIDGE and VARLEY) enables the required test circuit to be selected. Three terminals are fitted at the end of the tester remote from the generator handle: two of these are marked EARTH and LIVE respectively, and are used for both insulation resistance testing and bridge tests, while the third terminal is marked VARLEY EARTH and is used in conjunction with the other two during Varley Loop tests.

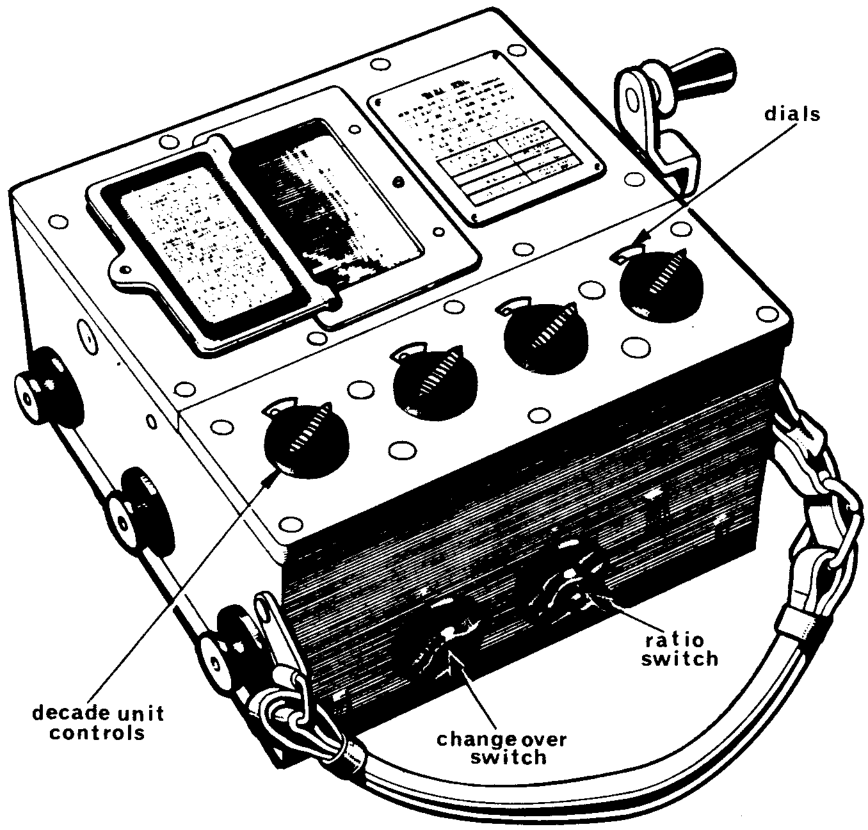

Fig. 21.12 Bridge Megger Tester Type B

A decade-type resistance unit within the tester for use in bridge tests, is controlled by four knobs on the top of the tester case—this unit has an effective range of 0-9999 ohms, and is variable in steps of 1 ohm. The value of the effective resistance in circuit is shown as a row of figures adjacent to the resistance control knobs. The available range of resistance measurement on bridge tests is selected by means of the ratio switch adjacent to the test selector switch; the lowest range (0-99.99 ohms in steps of 0.01 ohms) is obtained with the switch set to '÷ 100' and the widest range (0-999 900 ohms in steps of 100 ohms) at the 'X 100' setting.

The hand-driven generator is driven through gearing and a centrifugal clutch, the clutch ensuring a constant voltage output when the handle is turned at speeds not less than 160 rpm. The armature has two windings which, by operation of the test selector switch, are connected in series to provide a controlled output voltage of 500 volts for insulation tests, and in parallel to allow a lower voltage for bridge tests. The scale markings are much more comprehensive than those found on the scales of the smaller types of insulation testers. The INFINITY mark is also used as the 'zero-current' indication when the instrument is used as a galvanometer for bridge tests.

Insulation-Resistance Testing Procedure

The procedure to be adopted for insulation testing with the Type B Bridge-megger follows the same general pattern as that described earlier in this chapter for the Insulation Tester. During the initial check on the tester it may be found that the pointer is not aligned exactly with the 'INFINITY' mark on the scale: in such cases the required slight adjustment should be made by turning the INFINITY ADJUSTER, located above the tester terminals, in the appropriate direction using a non-magnetic screwdriver. When operating the generator handle, let the speed build up naturally until the clutch can be felt to be slipping, then keep the handle turning at a sufficient speed to sustain the slipping action while observing the pointer indication.

Wheatstone Bridge Tester

The Bridge-megger is converted into a wheatstone bridge tester by turning the change-over switch to the BRIDGE position.

Before making any connections to the tester, set the change-over switch to MEGGER and carry out the preliminary check for INFINITY alignment, and make any slight adjustment that may be found necessary. After this has been done, set the change-over switch to BRIDGE and connect the component or circuit that is to be tested across LINE and EARTH terminals. If the task is simply a matter of checking the continuity resistance of a component of known 'reputed' value, put the ratio switch to the appropriate setting for maximum accuracy of measurement and adjust the controls of the decade resistance to show the reputed value on the dials. If, for example, the reputed resistance of the component is 85 ohms, the ratio switch should be set to '÷100' and the decade controls adjusted until the dials, reading from left to right, show 8500. With the generator handle turning steadily, note the position of the pointer on the scale relative to the INFINITY mark; then, with the generator handle still turning steadily, adjust the decade resistance to bring the bridge into balance (pointer at INFINITY).

The actual resistance of the component under test is then shown by the dial readings corrected for the ratio-switch setting. If, in the example just mentioned, a balance is achieved with dial readings 7937, the actual resistance of the component is 7937/100 = 79.37 ohms.

Where the value of the resistance to be tested is completely unknown, and there is any possibility of damage to the component by excessive current from the tester, the following procedure is recommended:

a. Set the ratio-switch to 'X 100' and the decade controls to show 9 on all dials.

b. With the generator handle turning steadily, note the position of the pointer as the left-hand (thousands) control of the decade resistance is moved down one step at a time. Continue until the pointer crosses the INFINITY mark; then return the decade control to the previous position, *eg* if the pointer crosses the INFINITY mark when the decade control is moved from '5' to '4', return it to '5'.

c. Repeat the procedure detailed in b with the 'hundreds' control. Follow this with similar action on the 'tens' control, and then obtain a final balance with the 'units' control. The actual resistance of the component under test is then found by multiplying the dial readings by 100.

d. If, when operating the 'thousands' control, the pointer does not pass the INFINITY mark, return this control to the '9' setting and set the ratio-switch to 'X 10'. Now repeat b and c to obtain a balance; if this is successful the component resistance is given by the dial readings (when the bridge is balanced) multiplied by 10.

e. Failure to obtain 'cross-over' when operating the 'thousands' control of the decade resistance should be followed by the immediate return of this control to the '9' setting and the resetting of the ratio-switch to the next range below. Never try to shorten the procedure by omitting a range on the ratio-switch.

Note: The generator handle may usually be turned fairly slowly during the initial stages of seeking a balance, *ie* when operating the 'thousands' and 'hundreds' controls, but its speed should always be increased to the point where the clutch is definitely felt to be slipping before finally balancing the bridge with the 'tens' and 'units' controls. When dealing with components containing inductance, the handle should be kept turning at above slipping speed throughout the entire test procedure.

Servicing

The tester is sealed and requires no routine servicing beyond being kept clean. It must be treated with the consideration given to all precision instruments, and it should be given periodic checks to determine its service-ability. Instructions for those checks are given in AP3158 (RAF Technical Services Manual), Vol 2, Leaflet J2.

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CHAPTER 22

INTRODUCTION TO MAINTENANCE

Maintenance

1. *Maintenance* is defined as *all the engineering activities* necessary to keep materiel in, or restore it to, a specified condition. It is sometimes sub-divided:

- **Corrective maintenance.** Corrective maintenance is the action carried out to restore a defective item to a specified condition.
- **Preventive maintenance.** Preventive maintenance is the systematic and prescribed maintenance intended to reduce the probability of failure.

Note. If, while performing a preventive maintenance task, a defect becomes apparent, and no preventive action is prescribed, the equipment is to be regarded as defective. Preventive maintenance ceases and corrective maintenance must be carried out (and properly recorded) before preventive maintenance recommences.

Serviceable

2. *Serviceable* is the term used to describe the condition of materiel that is fit for its intended use. As a consequence of this, materiel which is *not fit* for intended use is said to be *unserviceable.*

- **Repair.** To repair an item is to restore it to a specified condition — *ie* to make it serviceable. It may be done by:
  - Replacing damaged or deteriorated parts.
  - Making parts good by the use of suitable tools or processes.
  - Adjustments to bring about the specified condition.
- **Reconditioning.** This is the process under which an item is completely overhauled, renovated, reassembled, and inspected to specified quality requirements. The materiel is then usually treated in exactly the same way as a similar brand new item.
- **Inspection.** Inspection is the process of measuring, examining, testing, gauging, or otherwise comparing materiel with the applicable quality requirements.
- **Preventive maintenance.** This term has previously been defined in para 1. Although 'preventive maintenance' is the correct term, *'routine servicing'* or just *'servicing'* is still commonly used.

Maintenance Terms

3. To ensure that maintenance instructions cannot be misunderstood, a limited number of verbs are used. These terms, which should be memorized, include the following:

- **Check:** make a comparison of a measurement (of voltage, pressure or some other quantity) with a known required figure for the measurement.

- **Examine:** scrutinize the materiel to determine its condition. The things to look for would include insecurity of attachment, cracks or fractures, corrosion, loose or missing rivets, faulty or broken locking devices, loose or damaged plugs and sockets, any chafing, fraying or scoring, discolouration due to overheating.
- **Fit:** correctly assemble one item to another.
- **Refit:** fit *the same item* which has previously been removed.
- **Replace:** remove an item and fit *another* of the same kind.
- **Replenish:** refill container to a predetermined level, pressure or quantity.
- **Test:** the trial of materiel to determine properties and characteristics or to check functioning or operation.

Maintenance Organization

4. **Depths of maintenance.** In order to cope with the vast maintenance task, the work is divided into four main stages called 'depths of maintenance'. These *depths* are a description of *'what is done'*.

- **Depth A.** This is that maintenance which is *directly concerned* with preparing end items for use, and keeping them in day-to-day order. It may include such operations as functional testing, replenishment, flight or daily servicing, diagnosis of defects, simple rectification by replacement or adjustment, rearming, and role changing.
- **Depth B.** This is that maintenance which is required on end items and assemblies which are temporarily unserviceable or which require servicing. This may include: calendar, operation or operating-hour based servicing; embodiment of prescribed modifications; bay servicing of assemblies; and rectification of defects beyond depth A.
- **Depth C.** This is defined as that maintenance which is the repair, partial reconditioning, and modification — all of which require special skills, special equipment, or relatively infrequently-used capability which is not economic to be provided generally, but which is short of complete strip, reconditioning and reassembly.
- **Depth D.** This is that maintenance which is full reconditioning, major conversion, major rework, or such repair as involves work of this depth.

5. **Lines of maintenance.** The manpower and organization needed to do the work is similarly subdivided into 'lines of maintenance'. These *lines* are a description of *'who does the work'*.

- **First line.** This is the maintenance organization *immediately* responsible for both the preparation for operation and the initial diagnosis of defects on complete aircraft, weapons systems, or ground installations. First line work is normally carried out at depth A but in some circumstances depth B work would also be undertaken.
- **Second line.** This is the maintenance organization under the control of the commanding officer of a station, established to provide support for those types of aircraft, weapons systems, or ground installations operated at that station, but excluding the organization within first line. Second line is normally carried out at depth B but some depth C work may also be undertaken on a limited range of equipment.
- **Third line.** This is the maintenance organization *within the Services,* but excluding the organization within the first and second line.
- **Fourth line.** This is the *industrial* maintenance organization providing repair, modification and reconditioning under contract.

6. **The Maintenance Data Centre.** A computer is used to store and analyse maintenance data for the Ministry of Defence. This computer is installed at the Maintenance Data Centre and is supplied with information from a standardized series of MOD forms. Liaison with tradesmen is through the unit's Servicing Control Engineering Records Section which is responsible for processing the MOD record forms.

7. **The Supply Control Centre.** Control of spare parts and equipment is directed from the Supply Control Centre where central stock records are kept on a computer. Liaison with tradesmen is through the station Supply Squadron (*see* Chapter 23).

8. **You and the Organization.** As a qualified tradesman you will join a section of the maintenance organization dealing with your particular trade. Your work will be supervised by appointed trade NCOs and Engineering Officers. Work is carried out as directed in authorized engineering publications which are described in Chapter 24.

Management Responsibilities

9. Tradesmen are termed junior managers, supervisors, or producers in accordance with their rank and the functions they are required to exercise (*see* Table 1). Unless NCOs are filling managerial posts, they may be employed as producers or supervisors.

TABLE 1

Function	Term	WO	FS	CT	SGT	CPL	JT	SAC	LAC
Management	Junior Manager/ WO or FS i/c	X	X	—	—	—	—	—	—
	NCO i/c trade	—	—	X	X	X	—	—	—
Supervision & Production	Supervisor/ Producer	—	—	X	X	X	—	—	—
Production	Producer	—	—	X	X	X	X	X	X

- **Management.** It is a managerial function to calculate, allocate, and direct resources in terms of manpower (supervisors and producers), materiels, tools, and time to a particular maintenance operation, and to be responsible for controlling the quality and quantity of work produced from an engineering team, bay, section, flight, squadron, or wing. The manager is to ensure that supervision is adequate and is properly exercised at all times.
- **Supervision.** It is a supervisory function to direct the tradesman to do a job in accordance with the manager's directive. The supervisor is to ensure that the tradesman is competent to do the job, that he is adequately briefed, and that he has the necessary tools, equipment, publications, and instructions. He is also to ensure that the tradesman is directed on the need for any necessary stage inspections and functional checks, that these are completed, and that any requirements for vital and independent checks are entered in the relevant maintenance documents. The supervisor, so far as is practicable for him to do so, is to ensure that the job is done correctly and in accordance with the relevant authorized procedures. When required, the supervisor is to certify, through his countersignature on the appropriate maintenance documents, that he has taken all reasonable care to ensure the quality and completeness of the job. In discharging his responsibilities, the supervisor is to spend sufficient time on a job to assure himself that the quality and completeness of the work is satisfactory. In deciding the extent to which his supervision must be exercised at the work face, the supervisor is to take due account of the difficulty and nature of the job, the skill and experience of the tradesman involved, and the prevailing circumstances.
- **Production.** Production is the actual performance of the maintenance task. Airmen undertaking this function are termed 'producers', and rank from chief technician to aircraftsman. The NCOs amongst them may also exercise the supervisory functions outlined above. It is the function of a producer to perform a job in accordance with the supervisor's directive and in accordance with correct trade practices and the relevant regulations and procedures. The producer is responsible for the quality and completeness of his work.

10. **Warrant Officers and NCOs.** Airmen in the ranks of warrant officer and flight sergeant are termed *'junior managers'*. Their duties may include the management of a flight or of several sections, bays, or teams under the control of NCOs i/c who, in turn, are responsible to them. NCOs in all ranks, up to and including chief technician, may be employed as either producers or supervisors as circumstances require. Some NCOs below the rank of flight sergeant may be required to fill managerial posts; such posts are termed *NCO i/c* and will normally relate to a section, bay, or team. NCOs i/c may also be required in the course of their duties to exercise engineering supervision. An NCO i/c is responsible for the control of his section, bay, or team

to the appropriate junior manager (or engineer officer, where no junior manager is established).

Signatures on Maintenance Records

11. In the interest of safety and efficiency, there is a chain of individual responsibilities for maintenance work undertaken within the RAF, and a supporting system of recording and certification which ensures that individuals connected with the work can subsequently be identified.

The signing of a maintenance record form affirms that an individual has completed his task in accordance with the applicable engineering orders and instructions, and that the serviceability state of equipment is as recorded. In some circumstances, particularly in the context of aircraft, it affirms that the equipment is in a state of operational readiness and is in a condition to which operators may entrust their lives. *The importance of correct recording and certification cannot, therefore, be over-emphasized.*

- **The tradesman's signature.** The tradesman's signature is given by the engineering tradesman who undertook the maintenance task and certifies that he has completed the task in accordance with the instructions given to him. In normal circumstances the task for which the tradesman signs must be within the range of work applicable to his rank and trade as described in the trade specification (AP3376A). In exceptional circumstances, the OC Engineering Wing may authorize individual tradesmen to undertake specified simple tasks outside their normal trade boundaries (AP100B Order 0701).
- **The countersignature of the trade NCO.** The countersignature is given by the supervising NCO of the trade concerned who is to be of the same, or higher, rank than the engineering tradesman who undertook the task. The countersignature certifies that the supervising NCO is satisfied with the completeness and quality of the work for which the tradesman has signed. (In exceptional circumstances, Air Officer i/c Engineering may permit other specified tradesmen to give a countersignature — AP100B Order 0701).
- **The co-ordinating signature of the NCO i/c the flight or section.** The co-ordinating signature is given by the NCO i/c the flight or section in which the maintenance work was carried out and certified that all the documentation applicable to the task has been properly completed and signed by the tradesmen and countersigning NCOs.

Note 1. All entries are to be made in ink, ball point pen, or indelible pencil. Errors are to have a single line drawn through them and the initials of the person making the correction.

Note 2. The meaning of the word *'signature'* is to be interpreted as including *'initials'* where appropriate to a particular document.

Note 3. The completion of any maintenance record form, together with signature or initials as appropriate, constitutes a certificate under the Air Force Act:
'By the Air Force Act it is a punishable offence to sign a certificate knowing it to be false (Sect 62) or to sign any certificate in relation to aircraft materiel without ensuring the accuracy thereof (Sect 50)'

Conditioning of Equipment

12. With the cost of modern aircraft and equipment being so great, and so as to protect life and limb, it is vital that we know exactly what condition our equipment is in at any given time. The consequences of fitting an *unserviceable* item to an aircraft, MT vehicle, or any other assembly could be disastrous. To avoid anything of this nature happening, we need an effective means of *'conditioning'* our items. In the next few paragraphs we shall see how this is achieved.

13. **Definitions of technical equipment.** Where used, the term 'technical equipment' (hereafter shortened to *'equipment'*) is to be interpreted as meaning all equipment having those management codes that are listed in the AP 830 leaflet as being the responsibility of an engineer officer.

14. The supply accounting terms, Class A equipment, Class B equipment and Class C equipment are used. For ease of reference, those parts of the approved definitions of the terms that are of immediate significance are paraphrased below:

a. *Class A equipment* is equipment for which the repair arrangements made include repair by third or fourth line maintenance organizations. Thus, it is equipment which is *sent off a station* if the depth of repair required is beyond that authorized to be undertaken by a user's supporting second line maintenance organization.

b. *Class B equipment* is equipment for which the repair arrangements made have been limited to repair by *second line* maintenance organizations. Thus, it is equipment which is scrapped if the depth of repair is beyond that authorized to be undertaken by a user's supporting second line maintenance organization.

c. *Class C equipment* is equipment that is consumable in use or is of such low value that its repair is not undertaken unless it is in short supply and its economic repair is within the resources of a user station.

15. **When equipment is to be conditioned.** Equipment is to be conditioned prior to its:

- Transfer from one line of maintenance to another.
- Move within the same line of maintenance from one work location to another for the purpose of further servicing or reinstallation.
- Return to the supply organization for any reason.

16. **Conditioning terms to be used.** The following terms are to be used when conditioning equipment:

a. *SERVICEABLE.* This is to be used for an item of equipment that is fit for immediate use and capable of performing its designed function.

b. *REPAIRABLE 2ND LINE (R2).* This is to be used for an item of equipment that requires servicing to a depth exceeding that which the user flight or section is authorized to undertake.

c. *TEST 3RD/4TH LINE (T3/4).* This is to be used when a second line maintenance organization cannot positively establish the serviceability state of a Class A item of equipment with the limited test facilities at its disposal. Use of this conditioning term indicates to the third or fourth line maintenance organization concerned that the item should be further tested to ascertain its serviceability state before being committed irrevocably to a repair or reconditioning programme.

d. *REPAIRABLE 3RD/4TH LINE (R3/4).* This is to be used when a second line maintenance organization confirms that a Class A item of equipment is unserviceable and requires servicing to a depth exceeding that which it is authorized to undertake.

e. *SCRAP.* This is to be used for an item of equipment that is unfit for its designed use to the extent that it cannot be repaired economically.

17. **Labels to be used.** The condition of an item of equipment is to be stated on an equipment label which is to be attached to the item. The equipment labels to be used are:

a. Forms in the MOD Form 731 series for all conditions *other than* SCRAP.

c. RAF Form 3910C if the condition is *SCRAP.*

18. A new MOD Form 731 is to be used to record a change in condition from REPAIRABLE 2ND LINE to TEST 3RD/4TH LINE or REPAIRABLE 3RD/4TH LINE. The unused side of an existing MOD Form 731 is, however, to be used to record a change in condition to or from SERVICEABLE, whenever it is practicable to do so; the superseded side is to be clearly crossed through in such cases.

19. **Personnel authorized to condition equipment SERVICEABLE.** When the condition SERVICEABLE results from a maintenance task, the person conditioning the equipment is to be the supervisor of the task or, if a MOD authorized concession has been invoked and the task is consequently not supervised, he is to be the individual who undertook the task.

20. When the condition SERVICEABLE *does not result* from a maintenance task, the person conditioning the equipment is to be:

a. Any corporal, or airman of higher rank, provided the equipment is within the servicing responsibility of his trade and, if applicable, his trade qualification annotation (TQA).

b. Any engineer officer of the appropriate specialization.

21. An individual who conditions an item of equipment SERVICEABLE is to enter all required details on the appropriate equipment label in the MOD Form 731 series and is to complete the label by signing the condition and safety certificate, and inserting clearly his name, rank and date of signing.

22. **Personnel authorized to condition equipment R2.** An item of equipment may be conditioned REPAIRABLE 2ND LINE by:

a. Any junior technician, or airman of higher rank, provided the equipment is within the servicing responsibility of his trade and, if applicable, his TQA.

b. Any engineer officer of the appropriate specialization.

23. An individual who conditions an item of equipment REPAIRABLE 2ND LINE is to enter all required details on the appropriate equipment label in the MOD Form 731 series and is to complete the label by signing the condition and safety certificate in the appropriate block in the column headed 'Signature/Stamps', and inserting clearly his name, rank and date of signing.

24. **Personnel authorized to condition equipment T3/4, R3/4 and Scrap.** Equipment is to be conditioned TEST 3RD/4TH LINE, REPAIRABLE 3RD/4TH LINE, or SCRAP only by personnel specifically authorized to do so by OC Eng Wgs. The following personnel may be authorized:

a. Sergeants, and airmen of higher rank, provided the equipment each is authorized to condition is within the servicing responsibility of his trade and, if applicable, his TQA.

b. Engineer officers of the appropriate specialization.

25. Each individual who is authorized to condition equipment TEST 3RD/4TH LINE, REPAIRABLE 3RD/4TH LINE, and SCRAP is to be provided with a *unique conditioning stamp* which he is to use instead of a signature when certifying those conditions on equipment labels. Each conditioning stamp is to bear the legend AUTHORIZED CONDITIONER and a combined letter and number code. The size and layout of each stamp are to be as illustrated in the example of Fig 22.1

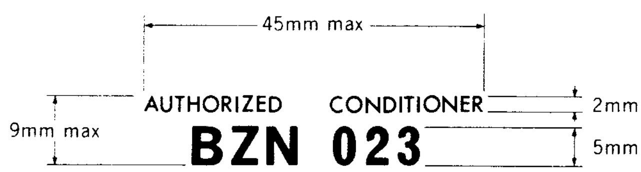


Fig 22.1 Example of conditioning stamp

26. The lettered element of the code (BZN in example) is to be the *station or unit designator* listed in AP 830 Volume 1 (7th Edition) Part 5 Leaflet E9/2; the numbered element (023 in example) is to be a unique 3-digit serial number identifying the *particular individual* to whom the stamp concerned has been issued.

27. The following regulations apply to the issue and use of conditioning stamps:

a. Stamps are to be signed for by recipients and are to be recovered:

(1) When the authority of an individual to condition equipment TEST 3RD/4TH LINE, REPAIRABLE 3RD/4TH LINE, and SCRAP is withdrawn.

(2) When an individual is posted.

b. When used for the purpose described above, a stamp impression has the same legal significance as a signature; stamp holders, are therefore, to safeguard their stamps and are not to lend them to other persons.

c. Stamps are not to be used when completing the condition and safety certificates for items of equipment conditioned SERVICEABLE or REPAIRABLE 2ND LINE.

d. Stamp impressions are to be made in black ink.

28. An individual who conditions an item of equipment TEST 3RD/4TH LINE, REPAIRABLE 3RD/4TH LINE, or SCRAP is to enter all the required details, including his name in block capitals, rank and date, on the appropriate equipment label and is to complete the label by applying his stamp to the condition and safety certificate.

29. OC Eng Wgs are to select and authorize personnel to condition equipment TEST 3RD/4TH LINE, REPAIRABLE 3RD/4TH LINE, and SCRAP, and are to arrange for their ranks, names, conditioning stamp codes, and details of the range of equipment each may condition to be promulgated in SROs. The number of personnel authorized on each station is to be the minimum necessary for efficient discharge of the engineer conditioning responsibility on that station.

30. **Inventory holders and the condition SCRAP.** An individual who has been authorized to condition items of equipment SCRAP is not to exercise that authority in respect of any item for which he is accountable by virtue of holding it on inventory charge.

CHAPTER 23

SUPPLY

Introduction

1. The regulations governing the handling and accounting procedures to be used for RAF equipment are set out in full in AP 830. Most of these regulations are the concern of the supply tradesmen only, but *all tradesmen* must have a background knowledge of supply procedures to enable them to carry out their work efficiently.

Supply Organization

2. The RAF supply organization is directed from the Supply Control Centre (SCC) where central stock records are kept on a computer. As part of this automatic data processing (ADP) system, each self-accounting RAF unit is equipped with a keyboard data terminal and visual display unit (VDU) located in the supply squadron. In this way the SCC is able to maintain an up-to-date record of stocks of equipment and show where these stocks are located.

3. **Unit supply organization.** The *supply squadron* usually forms part of the administration wing on a station. It provides a pool of equipment and spare parts which, together with the supply of petrol, oils and lubricants, enable the unit to fulfil its operational task. In addition to

this supply of technical equipment, the supply squadron provides personal clothing, furniture and other domestic needs, and is responsible for the efficient operation of services — *eg* laundry of bedding and cleaning of working overalls. Because of this very large task, the supply squadron is usually sub-divided into a number of operating departments, each of which is responsible for a specific part of the supply task. A supply squadron will always have at least three flights (Fig 23.1):

- Supply Control and Accounting Flight (SCAF)
- Technical Supply Flight (TSF)
- Domestic Supply Flight (DSF).

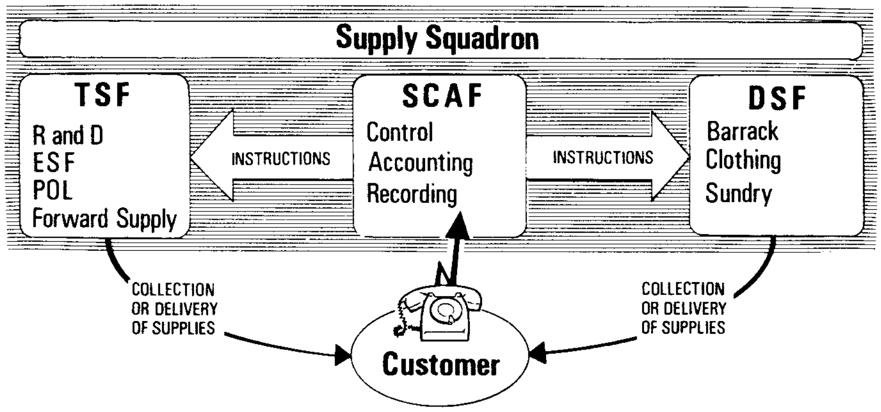


Fig 23.1 Unit supply organization

4. **SCAF.** This flight could be said to be the hub of the supply squadron and is responsible for the preparation and progression of all requirements, and the maintenance of all accounting records. A typical SCAF contains the following:

- *Keyboard data entry machine/visual display unit.* There are part of the 'demands section' of SCAF and are used to prepare the paperwork ('called vouchers') for all transactions, both internally on the station and to external sources. They also provide a means of communication to the Supply Control Centre and access to the centrally held stock records.

- *The 'Articles in Use' Ledger/'Master' Inventories.* These show the complete list of all equipment held on charge at the unit, how it is distributed amongst the various working sections, and who is responsible for its safe custody. A copy of his own inventory is held by the officer or SNCO nominated by the CO to be responsible for a particular part of the unit's equipment.

- *AP 1086* — Catalogue of general RAF equipment and the microfilm readers necessary for its use (*see* para 12).

5. **TSF.** The technical supply flight is responsible for the receipt, storage, issue, delivery, and stocktaking of technical ranges of equipment. These functions are often further sub-divided on large units; typical extra flights are:

- *R & D.* The receipt and dispatch flight is responsible for the receipt of all items into the unit and their distribution to the correct stock location. It also prepares and packages all items for dispatch to other units, and organizes their transit.

- *POL.* The petrol, oils and lubricants flight is responsible for receipt, storage, handling, and quality control of all aviation and ground fuels and lubricants, compressed gases, paints, and other associated products.

- *ESF.* The electronic supply flight is responsible for all avionic equipment (electrical, instrument, radio and radar) and associated spare parts.

- *Forward Supply.* This is a scheme in which the TSF ensures that an adequate supply of regularly used spares is maintained at each work centre on the station. In the first instance, each user section provides the Supply Squadron with an estimate of its requirements over an agreed period of time. Based on these estimates, a pool of these vital spares is acquired and held in the Technical Supply Flight to be distributed at regular intervals among the user sections by the Forward Supply truck. During these visits, supply tradesmen check the holdings of spares in the section dispenser racks, record the number used, and replenish accordingly. In this way, irritating shortages and wasteful surpluses are avoided.

6. **DSF.** The domestic supply flight has similar responsibilities to those of TSF — but for barrack and clothing ranges. It provides a clothing store for use by all ranks, and a barrack store which furnishes offices and married quarters. DSF also arranges most of the 'services' — *eg* window cleaning, laundry *etc.*

Classification of Equipment

7. **How items are classified.** For the purposes of supply and accounting, all items in the RAF are classified as being Class A, Class B or Class C items. This classification depends upon the degree to which an item is worthy and capable of repair and the degree of accounting applied to the item when in use. Some examples of the sort of items which would fall into each class are given in Fig 23.2. The approved definitions of Class A, B and C items are paraphrased in para 14 Chap 22. Further details are given below:

- **Class A.** Class A items remain on the charge of the supply squadron or of an inventory holder at all times. These items can only be replaced on their return to the supply squadron. They are items which are:
  - Considered to be capable of economical repair *beyond* the resources of the station — *ie* at repair depots or contractor's works.
  - Provisioned on the basis that the repair of unserviceable items will provide future serviceable assets.

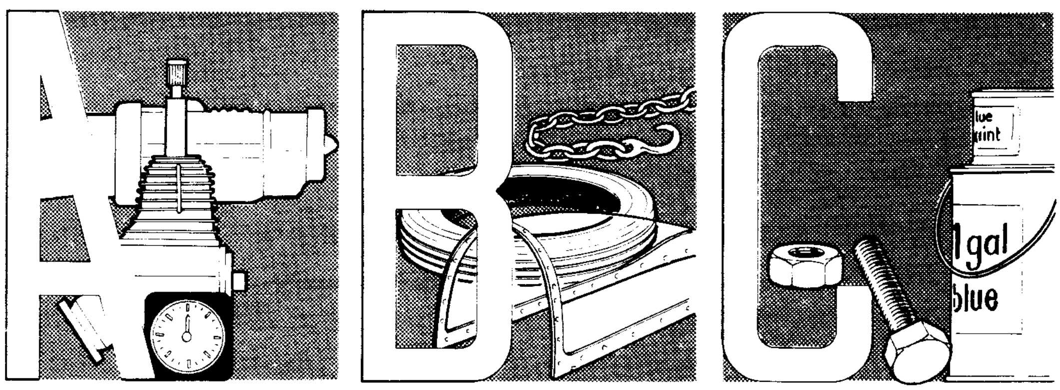


Fig 23.2 Items and their classes

- **Class B.** Class B items, like Class A, remain on charge and cannot be replaced except by return to the supply squadron. They are:
  - Attractive, but not so much as Class A.
  - Capable of repair — but only when it is economical to do so at unit level.
- **Class C.** Class C contains those items which do not fall into Class A and B. Once they are issued from the supply squadron, they do not remain on charge and can be replaced without return to store. Typical Class C items include:
  - Consumables — *eg* nuts, bolts, screws, wire, solder, paint *etc.*
  - Items costing less than £1 (but this figure could well change — as prices rise).
  - Certain low value and/or non-attractive items which, though not consumable in use, are not capable of economic repair — *eg* some inexpensive hand tools.

- Some low value items which are capable and worthy of repair at unit level — although they would only be repaired under exceptional circumstances or when it is economical to do so.

8. **Allocation of items to classes.** The allocation of items to the appropriate class is decided within the Ministry of Defence (Air). Occasions do arise when it becomes necessary to change the classification of a particular item or range of items. Any such changes are notified to all concerned by means of Defence Council Instructions (DCIs). The class of store is shown against each item in the AP1086 (Catalogue of General RAF Equipment) and in the Schedules of Spare Parts (Topic 3) of Technical Publications.

Identifications of Items

9. **The need for a numerical system.** When describing an item of RAF equipment we always make use of the main descriptive noun first. For example, a stainless steel hydraulic pipe would be described as:

PIPE, HYDRAULIC, STAINLESS STEEL

However, there are a lot of these pipes in RAF use and it is essential that we are able to identify one item from another by a simple method. Were there only 26 items involved, this would be easy; we could use a letter of the alphabet for each one. With the vast number of items used by the RAF, the problem is much more complex and a numerical code is used which:

- Saves writing time.
- Gives a standard length entry even for items with long and complex names.
- Provides a suitable filing order for documents — *eg* stock cards — which are associated with, or refer to, the item.

10. **The RAF identification system.** The numerical system used by the RAF identifies each item of equipment by a *management code* and a *stock number* (or *section* and *reference number* as it was previously known).

- The management code is in two parts:
  - The *section,* which indicates a general grouping under which a certain range of items is placed; for example, all items of RAF clothing come under section 22.
  - The *sub-section,* which breaks down even further the range of items within the general grouping. For example, within section 22, all items of flying clothing are contained in sub-section 22C, while in sub-section 22D can be found all items of footwear.
- The stock (or reference) number can contain up to seven digits and this allows up to 9 999 999 different items within any one sub-section of the management code — ample room for future expansion.

Example. The management code and stock number for a pair of shoes, airman, size 6, large, is 22D/9752225.

11. **The NATO codification system.** It is UK national policy that a common supply language should be introduced to enable identical items of equipment to be referred to *by the same number and name* in all UK services and within NATO. Furthermore, it is now defence policy that *all new items* are to be NATO codified, and most existing items have been re-referenced to facilitate NATO codification. Some ranges of items are excluded because they are not in any way common items (*eg* 26DC — Vulcan airframe spares). Any re-referencing of items is published in DCIs.

Fig 23.3 shows a codified number which has three parts:

- The first four digits are the *group* and *class* of the NATO code and correspond to the *section* and *sub-section* of the RAF Management Code.
- The next two digits are a Nation Code which indicates the country which originated the particular item (*eg* 99 is used for the UK — a full list is given in AP 830).
- The last seven digits are the item's identification number, which is the same as the RAF stock (reference) number.

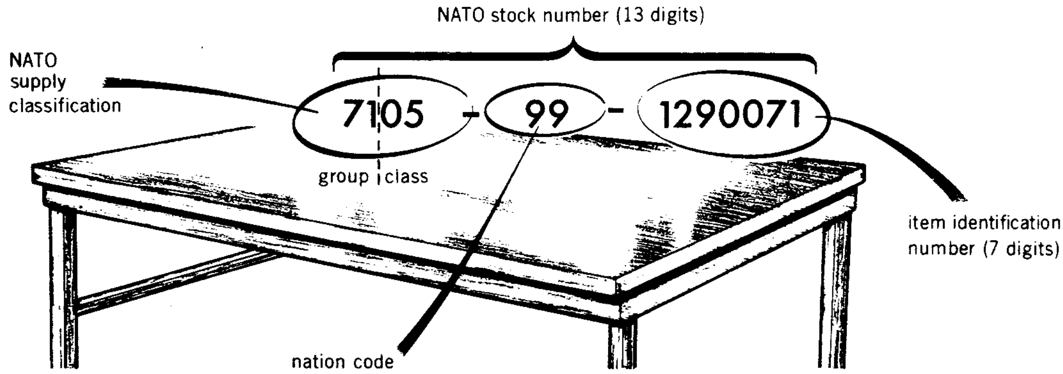


Fig 23.3 Example of a NATO codified number

Example: 8405–99–1270230 is the full NATO stock number for a particular raincoat which is 22F/1270230 within the RAF domestic management code system.

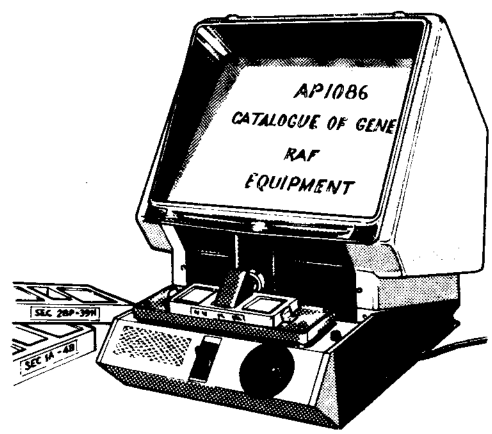


Fig 23.4 Microfilm viewer

AP1086 — Catalogue of General RAF Equipment

12. Having given each item an identification code, there is a need for a *catalogue* in which these codes are filed in numerical order. This catalogue, called AP1086, has been produced in microfilm form with the information in about 10 film cassettes. Each cassette contains certain sections and subsections which can be read through the viewer illustrated in Fig 23.4. In addition to the viewer and cassettes in SCAF, many units have other viewers in large user departments — *eg* Eng Wing HQ.

13. **Use of AP1086.** The AP1086 can be used to find the stock number of an item when its general description only is known, or to find the correct nomenclature, accounting and supply details for an item whose stock number is known. Instructions for operating the microfilm viewer are given on Poster 290. In summarized form:

- Insert the appropriate cassettes (the contents of a cassette are clearly marked — *see* Fig 23.4).
- Switch on.
- By means of the controls provided, turn the microfilm to the page required. To provide quick location, an index of stock numbers and page numbers is provided at the beginning of each *sub-section* on every cassette.

14. **Amending AP1086.** Up-dating of the main cassette is carried out on a 12 monthly cycle. In addition, a printed 'change list' is produced *every month* to show the changes which have occurred since the main cassettes were last amended. When using AP1086, *the change list must be consulted first.* If you find the item you are looking for in the change list, there is no need to look at the cassette.

15. **Contents of AP1086.** As its title indicates, AP1086 only lists items of 'General' RAF equipment and in fact contains only about one-third of the total number of items used in the RAF. Equipment peculiar to an aircraft (or radio set *etc*) is not included in AP1086. Details of such equipment can be found in the Topic 3 of the appropriate technical Air Publication (Fig 23.5). To assist in identification, many items are marked *by the manufacturer* with the appropriate RAF or NATO stock number. Identification details of items which are too small to mark are labelled on the packages in which they are supplied.

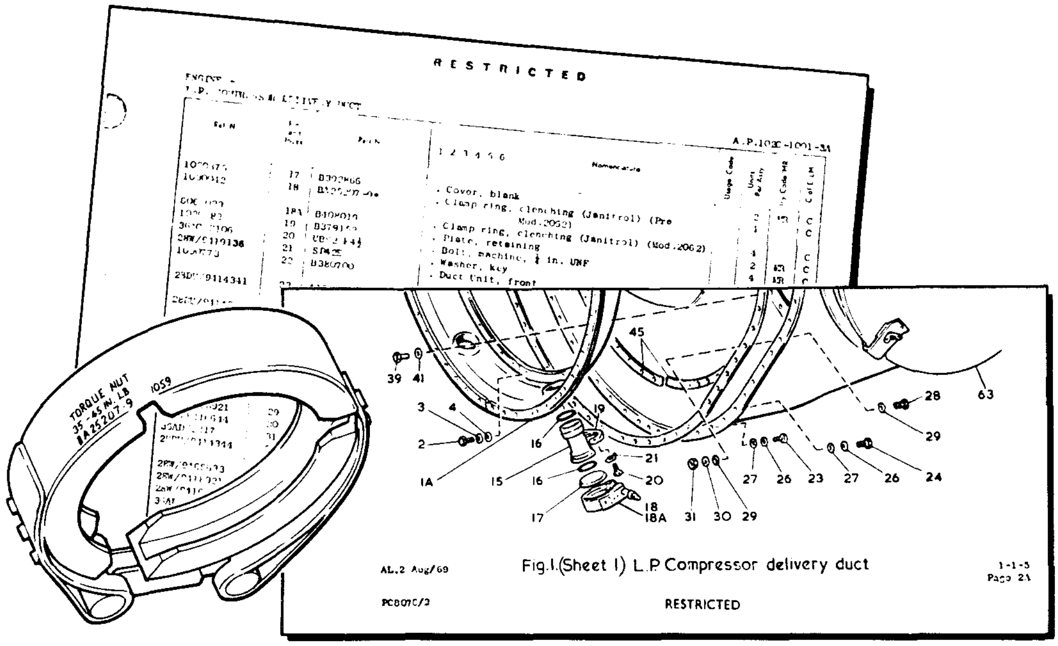


Fig 23.5 Part of Topic 3 of an AP

16. **Not in 'Vocabulary' items (NIV.).** There are certain items in use in the RAF which are not shown in the Catalogue of General RAF Equipment (AP1086) or in the Schedules of Spare Parts under a stock number, and these are allotted NIV numbers. (The AP1086 was formerly known as the *Vocabulary* of RAF Equipment — hence the term (NIV). Items manufactured by station workshops, or obtained by local purchase, and which are not interchangeable with standard RAF items, are allotted an NIV number for supply accounting purposes. Such numbers are prefixed by the letters NIV — *eg* 4D NIV 127 in which 4D is the management code and NIV 127 serves as the stock number. A register of NIV items on the unit is maintained by SCAF.

Authorized Holdings

17. The equipment that a unit/squadron/flight/section is authorized to hold to enable it to operate efficiently is known as a 'scale'. AP 830 Volume 3, titled 'Scales of RAF Equipment', lists the authorized holdings of 'general equipment' such as tool kits, GSE *etc.* The AP830 Vol 3 Part A has a very useful index at the front of the book which also tells you other publications in which items are scaled — *eg:*

- Topic 3 of the specialist engineering AP for the equipment covered by that AP.
- Authorized lists of test equipment (ALTEs) are issued when a new equipment comes into service use and list the quantities of test equipment necessary to maintain it.

Safeguarding Equipment

18. Many aircraft spare parts and most of the support equipment needed on a unit are expensive items of Class A or Class B equipment. It is clear that, in any servicing organization, some person must exercise control over the issue and be responsible for their safety when they are not being used.

Selected officers and senior NCOs are appointed as 'owners' of the equipment used in their working environment. All such items are taken 'on charge' and are listed in an Inventory of Equipment (RAF Form 37), a copy of which is held by the person responsible ('the inventory holder'). Form 37 shows the quantities of each item for which the holder is responsible listed by the stock number (in numerical order) as shown in Fig 23.6.

19. **Loans to individuals.** When inventory items are required by an individual tradesman, they are 'borrowed' from the inventory holder. The individual acknowledges such a loan and

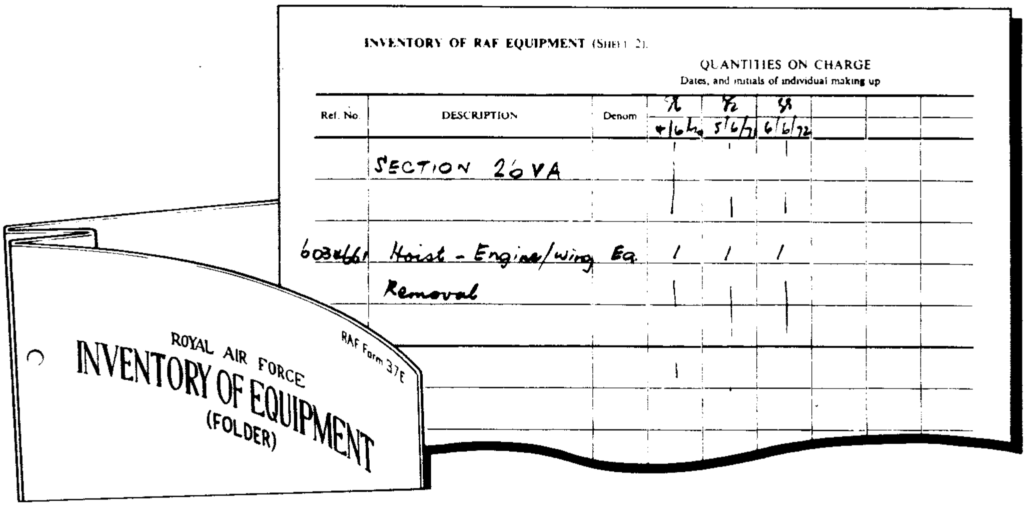


Fig 23.6 Inventory of RAF equipment

accepts temporary responsibility for safeguarding the equipment by signing an offical loan card. Depending upon the time for which the 'loan' is required, it may be recorded either on RAF Form 668 or on RAF Form 108.

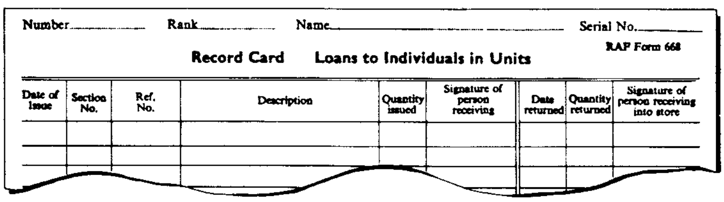


Fig 23.7 RAF Form 668

- **Form 668 — Record Card — Loans to Individuals in Units.** This is a buff-coloured card which is used when an item of equipment is to be borrowed for *more* than 24 hours (Fig 23.7). The individual signs on a separate line for *each item* of equipment on loan and the card is retained by the inventory holder. On return of any item of equipment, the appropriate entry is cancelled by another signature (or, in the case of a single entry, the form is destroyed).

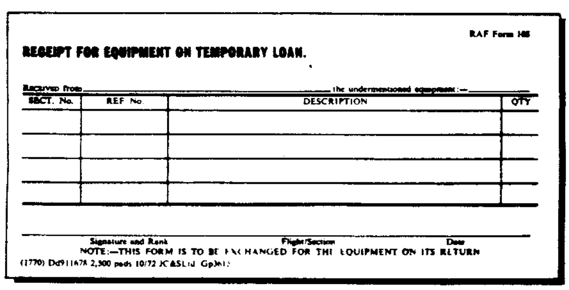


Fig 23.8 RAF Form 108

- **Form 108 — Receipt for Equipment on Temporary Loan.** This is a flimsy paper receipt used for short term loans (Fig 23.8). When completed, the form is retained in the flight or section lock-up until the borrowed items are returned. When the equipment is returned, the F108 is given to the borrower or is destroyed in his presence.

20. **Loss of equipment on loan.** Should an item on loan be lost, or be damaged through negligence on the part of the borrower, then the borrower must meet the cost to the RAF of a

replacement (or serviceable) item. The initial step towards recovery of the cost is taken by the inventory holder, and the borrower accepts responsibility for the cost by signing Form 664B (*see* para 29).

21. **Theft.** As a safeguard against embezzlement, and to assist in the detection of persons concerned in the theft of equipment, many items are marked by the manufacturer with the Government property mark — a broad arrow. This applies in particular to those items that are attractive and are likely to be pilfered. Fig 23.9 shows an item marked in this way. Where the Government property mark on items held in stock has become indistinct, such items should be re-marked in such a way that no damage is caused to the item. Similar action should be taken by inventory holders for items held by them.

22. **Valuable and attractive (V & A) items.** These are small attractive items of high value which experience has shown are likely to be stolen. Typical examples are stop watches, cameras, and binoculars. Special arrangements are made for the safeguarding of V & A items in the supply squadron, and at user level they are kept in a locked steel cupboard when not in use. All documents relating to V & A equipment are annotated 'V & A' across the top *in red ink.* If the item has an RAF serial number this must also be shown on all documents. The Commanding Officer has the power to classify some items as local V & A *for security purposes* at user level, and this often done with AVO multi-meters and similar items.

23. **Security of classified equipments.** The regulations for safeguarding equipment which has a security classification of CONFIDENTIAL or higher are laid down in AP3086 'RAF Manual — Security'.

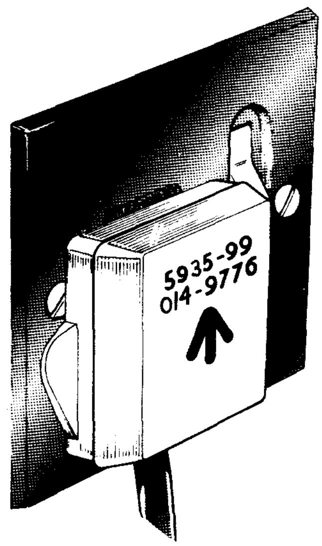


Fig 23.9 Government property mark

Inventory Management

24. **Inventory holders.** All Class A and B items issued to a section are listed in an inventory (F37) and taken on charge by the inventory holder. Responsibility for the safe custody of the equipment, and for such checks as are required to control and safeguard it, rest with the *inventory holder.* He is also responsible for the security and maintenance of his copy of the inventory, which is kept up-to-date by a system of periodic checks. A master copy of each inventory is also maintained by the Supply Squadron (SCAF) as a record of all transactions.

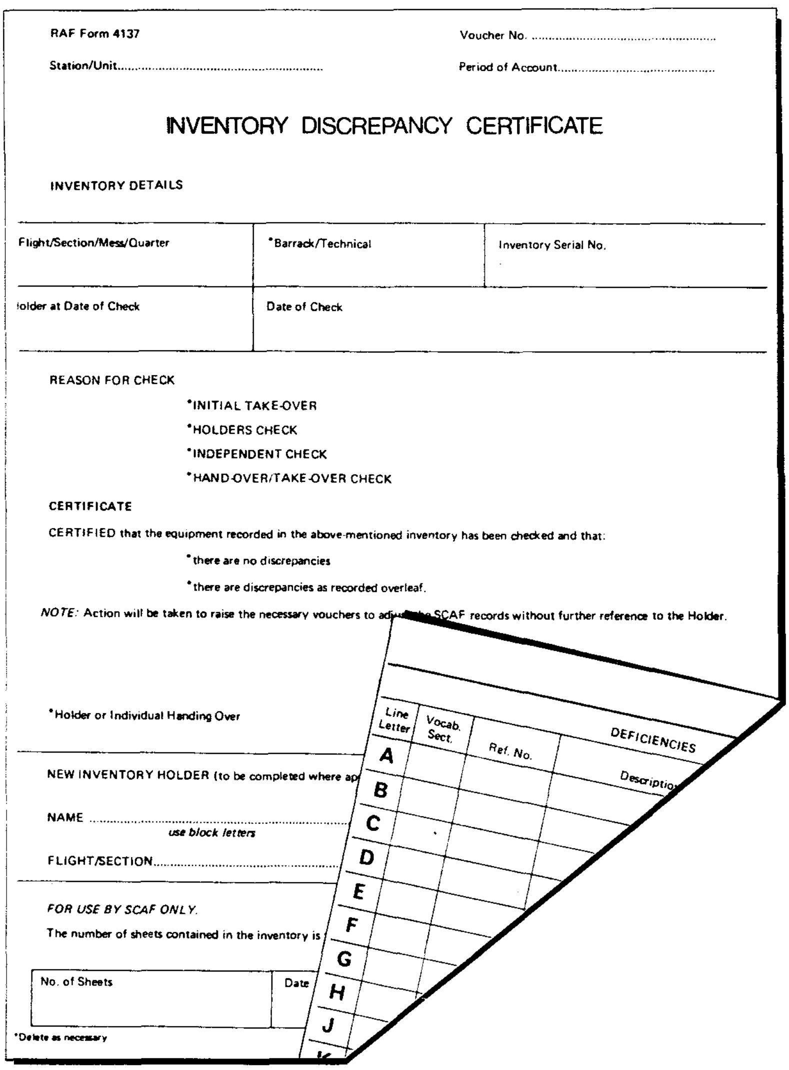
- Inventory holders are appointed by the Commanding Officer and are Service (or civilian) members of the Unit not below the rank of sergeant (or equivalent status). In special circumstances (with the approval of Command Headquarters) a corporal or civilian of equivalent status may be appointed as an inventory holder. Appointments of inventory holders are promulgated in Station Routine Orders as they take place.
- A *nominated deputy* to each inventory holder is also appointed and he assumes responsibility for the inventory during temporary absences of the holder.

25. **Inventory checks.** Inventories are checked on the following occasions:

- On change of inventory holder they are checked by the individual taking over in the presence of the individual handing over.
- All inventories must be checked at least once in the three year period commencing on April 1st. This check is usually carried out by planned change of inventory holder as above. Where this is not possible, the inventory will be checked by an independent officer or SNCO appointed by the Commanding Officer.

Before any check can be made, the holder's copy of the inventory must always be brought up-to-date by SCAF. Once it has been brought up-to-date, it should be checked without delay, otherwise the recorded quantities may no longer reflect the true physical holdings. The checks must be made systematically to ensure that no items are overlooked. Equipment held on Loan Cards is to be checked physically. Any surpluses or deficiencies revealed by the check are to be recorded on the reverse side of Form 4137 (*see* Fig 23.10) so that off-setting can take place with discrepancies revealed by other inventory holders.

26. When an inventory is taken over, it is the responsibility of the new inventory holder to ensure that all items listed in the inventory are produced for his inspection. The inventory sheets (Form 37B) should be counted to ensure that all are present in the folder (Form 37E); this can be ascertained by checking against the number of sheets recorded at the bottom of



RAF Form 4137

Voucher No. ....

Station/Unit ....

Period of Account ....

INVENTORY DISCREPANCY CERTIFICATE

INVENTORY DETAILS

Flight/Section/Mess/Quarter	*Barrack/Technical	Inventory Serial No.
Holder at Date of Check	Date of Check	

REASON FOR CHECK

*INITIAL TAKE-OVER

*HOLDERS CHECK

*INDEPENDENT CHECK

*HAND-OVER/TAKE-OVER CHECK

CERTIFICATE

CERTIFIED that the equipment recorded in the above-mentioned inventory has been checked and that:

*there are no discrepancies

*there are discrepancies as recorded overleaf.

NOTE: Action will be taken to raise the necessary vouchers to adjust the SCAF records without further reference to the Holder.

*Holder or Individual Handing Over

NEW INVENTORY HOLDER (to be completed where ap

NAME ....

use block letters

FLIGHT/SECTION ....

FOR USE BY SCAF ONLY.

The number of sheets contained in the inventory is

No. of Sheets	Date

*Delete as necessary

Fig 23.10 Inventory discrepancy certificate (F4137)

Form 4137 ('Inventory Discrepancy Certificate') — *see* Fig 23.10. Before signing Form 4137 (and so accepting responsibility for the inventory) the holder is to ensure that all items listed on Form 37B had been checked and that any discrepancies are recorded on Form 4137.

- In addition to the inventory checks called for above, the holder is responsible for carrying out a check of all equipment classified CONFIDENTIAL or higher at intervals not exceeding six months. The holder is to maintain a record of such checks, which show the date and result; any losses or compromise of classified equipment is reported to the unit Security Officer and dealt with in accordance with AP3086 (RAF Manual — Security). The responsibility for these checks is *not to be delegated* to a deputy inventory holder.

27. **Transfer between inventories.** Over a period of time, changes in inventories are inevitable. As items are modified they often change their official identity, stock number *etc.* Other items, because of a change of responsibilities, may need to be transferred from one

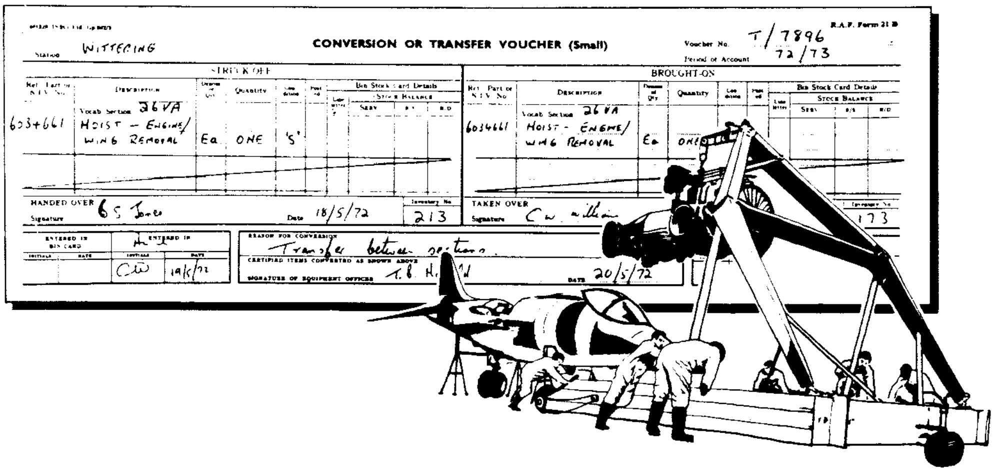


Fig 23.11 Conversion or transfer voucher (Form 21)

person's inventory to that of another. The facility to adjust inventories in this way is provided by RAF Form 21 — 'Conversion or Transfer Voucher' — *see* Fig 23.11. When completed by the inventory holders concerned, the change is authorized by the countersignature of the Supply Officer and the master copies of the inventories adjusted by SCAF.

28. **Records of loans to individuals.** Long-term loans to individuals on F668 loan cards are recorded in the inventory on sheet 2 of Form 37B (*see* Fig 23.12). The Forms 668 are given serial numbers by the inventory holder for ease of location and entry on Form 37B. If an airman is posted and his successor takes over the same items on loan, the new loan card can then be given the same serial number as the previous card and this avoids having to amend the F37B. Short term loans of a day or two made on Form 108 (temporary loan receipt) are not recorded in the inventory.

29. **Loss of inventory items.** Occasionally an item gets lost — even with the best managed inventory. The sooner the loss is investigated, the more likely it is that the item will be found or the blame for the loss established. If blame for the loss, or damage due to negligence, can be allocated to an individual (or group of individuals) then the inventory holder asks SCAF to take Form 664B action. The Form 664B ('Internal Repayment Voucher'), illustrated in Fig 23.13, is raised by SCAF and sent back to the inventory holder.

- The individual responsible for the loss signs the F664B, which is then passed back to SCAF for inventory action and eventual financial recovery. A copy of the actioned F664B is returned to the inventory holder either:
  - cross-referred to the issue voucher of a replacement item.
  - showing a minus quantity for correction of the quantity held on charge in the inventory.
- If the individual responsible refuses to sign F664B to acknowledge the charge, then the inventory holder passes the F664B through his Squadron Commander to the Commanding Officer, who will decide if the individual still pays even though the F664B is unsigned.

30. **Write-off against public funds.** If the inventory holder can prove that nobody (including himself) is responsible for the loss or damage and that negligence was not involved, then he

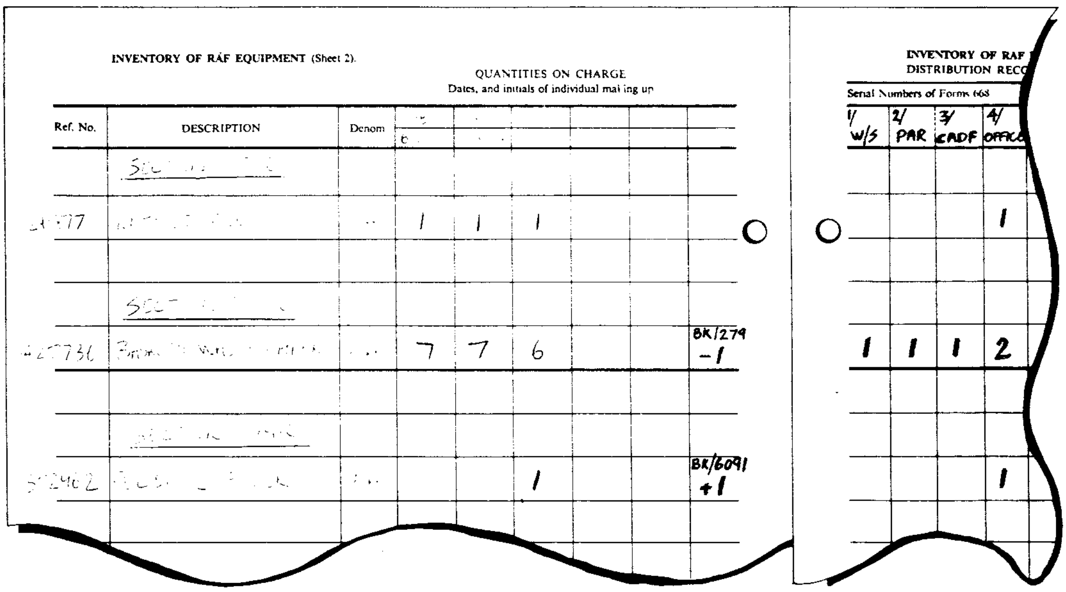
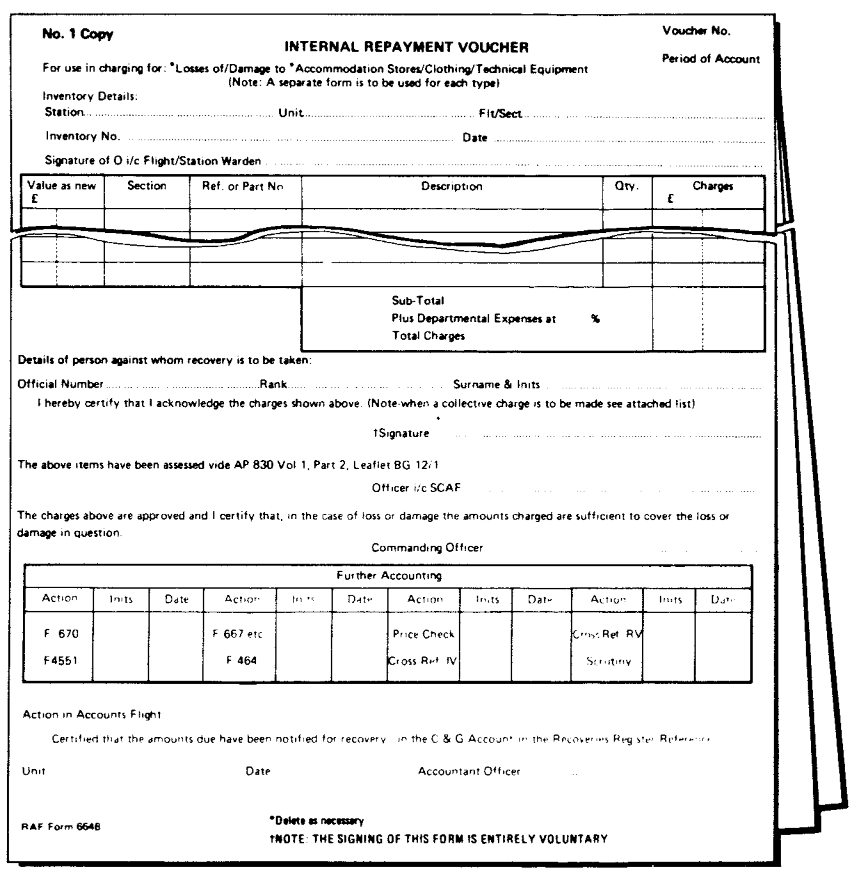


Fig 23.12 Record of loans to individuals

may submit a case for the item to be written-off against public funds. To do this a formal application is made to his superior officer giving full details of the loss (or damage), including the precautions he took to avoid it. If his case is supported by his superior officer, the formal application after being approved by the Commanding Officer, is passed to SCAF for inventory action or replacement of the item.


No. 1 Copy

INTERNAL REPAYMENT VOUCHER

Voucher No.

Period of Account

For use in charging for: *Losses of/Damage to *Accommodation Stores/Clothing/Technical Equipment
(Note: A separate form is to be used for each type)

Inventory Details:

Station .... Unit .... Flt/Sect ....

Inventory No. .... Date ....

Signature of O i/c Flight/Station Warden ....

Value as new £	Section	Ref. or Part No	Description	Qty.	Charges £
			Sub-Total		
			Plus Departmental Expenses at %		
			Total Charges		

Details of person against whom recovery is to be taken:

Official Number .... Rank .... Surname & Inits ....

I hereby certify that I acknowledge the charges shown above. (Note-when a collective charge is to be made see attached list)

†Signature ....

The above items have been assessed vide AP 830 Vol 1, Part 2, Leaflet BG 12/1

Officer i/c SCAF ....

The charges above are approved and I certify that, in the case of loss or damage the amounts charged are sufficient to cover the loss or damage in question.

Commanding Officer ....

Further Accounting

Action	Inits	Date	Action	Inits	Date	Action	Inits	Date	Action	Inits	Date
F 670			F 667 etc			Price Check			Cross Ref RV		
F4551			F 464			Cross Ref IV			Scrutiny		

Action in Accounts Flight

Certified that the amounts due have been notified for recovery in the C & G Account in the Recoveries Register Reference

Unit .... Date .... Accountant Officer ....

RAF Form 664B

*Delete as necessary

†NOTE: THE SIGNING OF THIS FORM IS ENTIRELY VOLUNTARY

Fig 23.13 Form 664B – Internal repayment voucher

Transactions

31. **Demands.** Demands are normally made by telephone to SCAF and can only be made by, or on the authority of, the inventory holder or his nominated deputy. Before making a demand, ensure that the information to be passed to SCAF is correct and that the item is not already on demand or held as a spare in the section lock-up. To process a demand, SCAF will require the following information:

- The required item's:
  - Management code and stock number (section/reference number).
  - Nomenclature.
  - Denomination of quantity (*see* Note below).
  - Quantity required.
  - Class of store.
- The urgency of need (priority) and required delivery date.
- The inventory identity (a code or a number) and the name of the holder.
- The reason for the demand — *eg* to replace an unserviceable item.
- Type of transaction — *ie* an issue or an exchange.
- Authority for the demand – *eg* AP scaling, DCI, modification leaflet *etc.*

Details of all demands placed on SCAF should be entered in a manuscript register which then provides the inventory holder with information on all outstanding demands and the latest position regarding their supply.

Note. 'Denomination of quantity' (D of Q) is the measurement of quantity in which an item is accounted. For many items, the D of Q is *each;* however this is not possible with all items and other D of Qs are in use — *eg* electric cable is accounted for in *metres.* To prevent confusion, and possible over/under supply, it is essential that the demands clerk in SCAF and the person placing the demand are quite clear about the D of Q and the quantity required.

32. **The Standard Priority System.** The Standard Priority System is a system which has been agreed by the three Services for the demand, processing, and movement of supplies. It ensures that supplies are processed and handled to the same time schedule, whichever Service is dealing with them. Its aim is to maintain the highest operational readiness state of the Royal Navy, Army and Royal Air Force. It achieves this aim by:

- Allocating priority codes to demands, based on the operational importance of the demanding unit and the urgency of the requirements. The urgency of requirement is determined by the effect which lack of the item has on the unit's operational task.
- Having specified standard processing and movement times for the distribution of equipment. This means that the delivery date can be forecast from the priority code allocated.

33. **The 'Station Supply Voucher' — Form 600 VDU.** This voucher (*see* Fig 23.14) is raised on a machine by the demands clerk in SCAF from the telephoned information given by the inventory holder. The item required is usually delivered by supply tradesmen to the inventory holder together with copy 1 (red) and copy 2 (blue) of the Form 600VDU.

- If the item is a Class C store, the Form 600VDU is left with the inventory holder as advice of issue and no further accounting action is required. (The inventory holder makes a note in his demand register that the item has been received).
- If the item is Class A or B, the inventory holder (or his nominated deputy) signs copy 2 (blue) of the Form 600VDU as concurring in the quantity received. This copy is then returned to SCAF for further accounting action. The red copy (copy 1) is retained by the inventory holder for identification of the issued item and for pencil amendment of the quantity held on charge in his copy of the inventory.

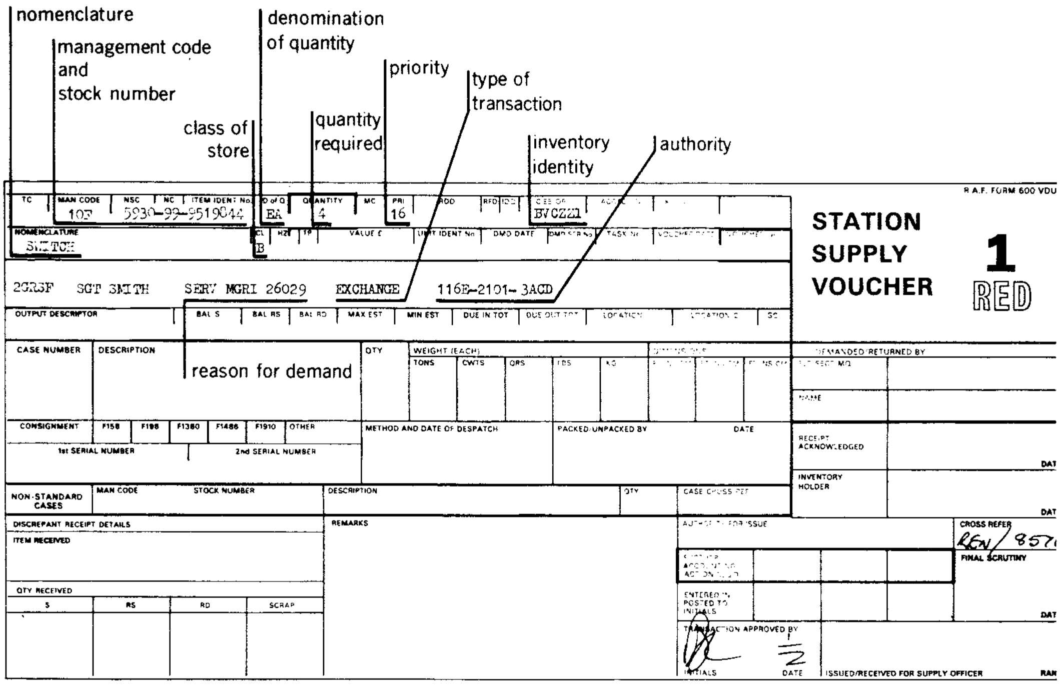


Fig 23.14 Station supply voucher (Form 600 VDU)

34. **Returns.** Items of equipment for return to the supply squadron are notified to SCAF in the same way as demands. Before informing SCAF that the item is available for return, ensure that the item is labelled with MOD Form 731 (Equipment Label) and that the label is signed by the appropriate specialist officer or NCO.

Fig 23.15 Some examples of 'danger' warning labels

- **Hazards to personnel.** To the supply tradesmen, any item is just a package with a number. It is clearly the responsibility of the person returning dangerous items to ensure that any appropriate warning label (*see* Fig 23.15) is attached to the items concerned.

Specialist Inventories

35. Specialist inventories (obtainable through APFS) are used for aircraft, marine craft, MT vehicles (including vehicles such as mobile radio installations), and air transportable installations. These inventories are handled in a different way to the normal inventory (F37) and full instructions for their use can be found inside the inventory. Issues and withdrawals for specialist inventories are recorded on RAF Form 464.

CHAPTER 24

SOURCES OF ENGINEERING INFORMATION

Introduction

1. Service aircraft (with their modern avionics equipment), ground radars, communications links, computer networks, and so on, are all complex devices having many varied and complicated parts to them. Because of this, it is impossible for any one person to have a detailed knowledge of all aspects of equipment within his trade specialization. Consequently, comprehensive technical books (or publications) are issued to cover the various aspects of equipment, and each tradesman uses appropriate publications to support him in his work.

The information contained in these publications often forms the basis from which maintenance instructions evolve to become the official authority for servicing and repair practices in the RAF. In addition, other types of engineering orders and instructions are necessary to satisfy all the varying requirements of the RAF. All such sources of engineering information are considered in this Chapter.

It is vitally important that all tradesmen form the habit of referring to authorized publications and appropriate orders and instructions. The various instructions must always be followed 'to the letter'.

AIR PUBLICATIONS

General Points

2. Air publications (usually referred to as APs) are the most commonly used sources of information. In addition, some general management publications (such as those providing definitions and specifications) are prepared or procured jointly for the three Services and are referred to as Joint Service Publications (JSPs). The complete list of available APs and JSPs is to be found in the 'Catalogue of Publications and Forms', which is itself an air publication (AP113).

Security

3. For security purposes, all official documents (including publications) fall into one of two categories: those that require security safeguards (classified publications) and those that do not (unclassified publications). Unclassified publications are usually contained in a blue binder. Classified publications have their security grading printed top and bottom of both sides of each leaf and are normally contained in a coloured cover (or have a coloured cover label) as follows:

• Top Secret	— deep red	In descending order of security importance.
• Secret	— red/pink	
• Confidential	— green	
• Restricted	— orange/buff	

4. *Classified publications must always be safeguarded.* When any document graded 'Confidential' or higher is not in use it is to be locked in an approved security container. Documents graded 'Restricted' are to be kept under lock and key outside normal working hours (*see* AP3086 for further information).

Note. Instead of being referred to as APs, confidential documents are referred to as CDs, and secret documents. SDs. Each copy is allocated *a copy number* and it is this copy that an individual signs for in accepting responsibility for its safe custody.

Specialist Publications

5. There are a number of 'specialist' APs (and JSPs) which provide information in given subject areas and are intended primarily for use by the specialists in those areas. Nevertheless, there are occasions when engineering tradesmen may need to refer to one of these publications. In such circumstances, it is advisable, first, to seek the advice of the appropriate specialist who will direct the tradesman to the relevant parts of the publication. The specialist publications of interest to engineering tradesmen include the following:

AP830 — RAF Supply Regulations

AP957 — RAF Manual — Fire Services

AP3086 — RAF Manual — Security

AP3090 — RAF MT Regulations (to be replaced by JSP341)

AP3224 — RAF Manual — Signals Organization

JSP101 — Manual of Service Writing

JSP328 — British Standard 3939 — Graphical Symbols for Electrical and Electronics Diagrams.

JSP341 — Joint Service Road Transport Regulations (will replace AP3090).

Structure of Technical (Equipment) APs

6. For large and complex equipment systems (*eg* a large ground radar installation), the information to be conveyed to engineering tradesmen is such that several separate, but inter-related, publications are needed. So that the various subject areas, topics, or categories of information within any given system can be properly co-ordinated, it is necessary to have some form of structure. The engineering tradesman then has a pattern from which he can learn to select the publication he needs for any particular aspect of his work. Three different forms of structure are in current use for technical APs. These are listed below and considered in the paragraphs that follow:

- The Six-volume System
- The Coded 'Topic' System
- The Coded 'Category' System.

The Six-volume System

7. This is a system that was introduced some years ago with the aim of standardizing the layout adopted for technical (equipment) air publications (Fig 24.1). The basic titles and contents of the six volumes are as follows:

- **Volume 1 — General and Technical Information.** This volume (which may be in more than one *part*) contains a general description of the equipment, followed by technical information on servicing, fault diagnosis, and testing after installation.

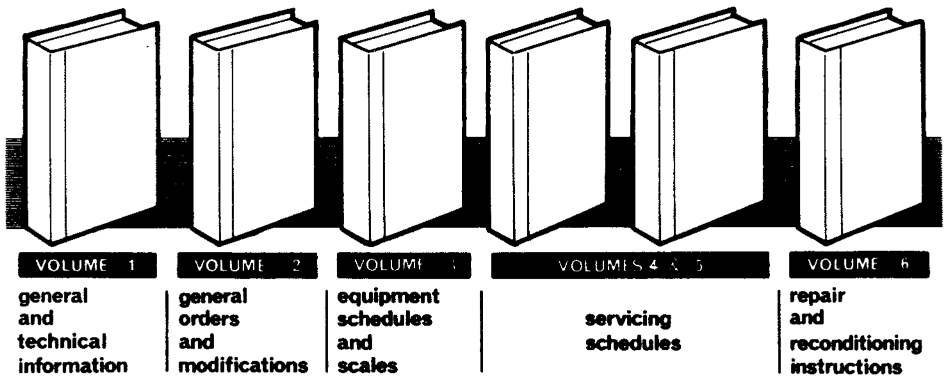


Fig 24.1 The six-volume scheme

- **Volume 2 — General Orders and Modifications.** This volume consists of separate *leaflets,* each of which is issued as an amendment to Volume 2. The modification of an equipment is a process designed to improve its reliability, or to adapt the equipment to some new function. Modifications may also be introduced to make maintenance easier and thus save man-hours. When a modification has been approved, a modification leaflet is issued to the user (as an amendment to Volume 2 of his equipment AP). This leaflet details the work sequence to be followed and also sets a limit on the time period allowed for embodiment action. Modifications to avionics equipment are usually carried out by a repair depot (Maintenance Unit — MU) or by the manufacturer; for such modifications, the information leaflet issued as an amendment to Volume 2 omits the work sequence.
- **Volume 3 — Equipment Schedules and Scales.** This volume contains a list of replaceable parts available for the equipment (*illustrated parts catalogue*) and also the scales of equipment and servicing spares which may be held by a user unit.
- **Volumes 4 & 5 — Servicing Schedules.** These volumes contain the safety and servicing instructions required for the maintenance of the equipment at unit level.
- **Volume 6 — Repair and Reconditioning Instructions.** This volume is normally used for the repair and reconditioning of equipment at repair depots (MUs) or at the equipment manufacturer.

8. **Quantity of information needed.** The information needed for the different equipment systems varies considerably. A small and relatively simple equipment may use only some of the six volumes; other, more complex, systems will almost certainly need the full scope of the scheme. Furthermore, if the information to be contained in one volume is large, several covers (books or parts) may be needed for that volume (*eg* the former AP2527QA Vol 1 was in two parts). Conversely, if the volumes are small, they may be grouped together under a single cover. Consequently, a technical AP issued under the six-volume system may consist of anything from one up to six or more separate books, depending upon the size and complexity of the subject equipment.

9. **Limitations of the six-volume system.** Among the limitations of the six-volume system are the following:

- A publication is allocated a number from a block of four figure numbers listed in a master index held by Air Publications and Forms Store, Woolwich. This number (*eg* AP2527, AP4343) has no meaning.
- Information about parts of an equipment tend to be grouped together under common general headings. One result of this is that, along with the *wanted* information about the particular part of the equipment in which he is interested, the user also has much information which is not of immediate concern to him.
- Location of specific information is often difficult.

It was for these, and other, reasons that the coded 'topic' system was introduced for equipment APs, with the six-volume system being gradually phased out. In fact, many publications issued under the six-volume scheme have now been transferred to the coded 'topic' system.

The Coded 'Topic' System

10. **General information.** In the coded 'topic' system introduced in 1965, all publications are identified by a three element code number, preceded by the letters AP, CD, or SD as appropriate (*see* para 4). Unlike publications in the six-volume system (where the AP number has no meaning), the code enables a user, with experience, to identify the subject area covered by the publication.

Another advantage of the coded system over the six-volume scheme is that information which was previously available only in bulky manuals is now available in much smaller 'units'. Each unit, not matter how small, is a complete publication, with its own code number, title page, and amendment record sheet. Any single unit can be demanded separately from the unit Stationery Publications and Forms Store (SPFS) and only those of interest need be held at the work face.

To assist the user to select the publications he requires, a catalogue of coded publications is kept at SPFS. To make sense of this catalogue, some understanding of the meanings of the elements in the code is necessary, and guidance on this is given in the paragraphs that follow.

11. **Basic code.** An example of an AP number in the coded 'topic' system is illustrated in Fig 24.2. Examination of this drawing will show that the code is made up of three elements, which are further sub-divided as necessary. Reading from left to right, the code progressively reveals more information about the subject dealt with in the AP.

CODED AP No. 113E-0129-1 Formerly AP4343D, Vol 1, Book 4, Sect 21, Chap 27.

113E - 0129 - 1

1st ELEMENT		2nd ELEMENT		3rd ELEMENT
GROUP	SUB-GROUP	CLASS	ITEM	TOPIC NUMBER (Based on 6 Vol scheme)
113 Electrical Equipment	E Rotary consumer equipment	01 Actuators, linear	29 AILERON TRIM STRUT, Plessey type 500/1/00299	1 VOLUME 1 General and Technical Information

CODED AP No. 101B-0101-1A

101 Aircraft	B Fixed wing	01 BELFAST C	01 Mark of aircraft Mk1	1 VOLUME 1	A BOOK 1

CODED AP No. 116B-0203-2

116 Radio Equipment	B Navigational and landing aids (airborne)	02 Radio Altimeters	03 RADIO ALTIMETER Mk7	2 VOLUME 2 General Orders and Modifications

Fig 24.2 Example of AP number in coded 'topic' system

12. **Groups.** A group number indicated in Fig 24.2 is '116'. For technical equipment APs, the group numbers run from 101 to 120 — each one dealing with a particular group of equipments. Those of concern to electrical tradesmen, for example, include:

AP101 — Aircraft	AP115 — Ground Radar
107 — Aircraft Environment Control	116 — Radio & Television

112 — Instrument & Photographic	117 — General Test Equipment
113 — Airborne Electrical	119 — Ground Support Equipment
114 — Airborne Radar	120 — Ground Electrical

13. **Sub-groups.** The letter after the group number indicates the equipment sub-group. It is not possible in a book of this type to list all the sub-groups; a catalogue is needed for this (*see* para 10). However, as an example, the sub-groups associated with equipment group 113 (Airborne Electrical Equipment) are:

AP113A — Airborne electrical equipment — general information
113B — Generators
113C — Batteries.
113D — Control and distribution equipment for power supplies.
113E — Rotary consumer equipment.
113F — Static consumer equipment.
113G — Armament consumer equipment.
113L — Engine ignition equipment.

14. **Class and mark.** The second element in the code indicates the class and mark (or variant) of the equipment. Again, it is not possible to quote the whole range in this book. But, as an example, in sub-group 116B (Radio Navigational and Landing Aids (Airborne)), the *classes* of equipment considered include the following:

AP116B—00— General information
—01— Radio compasses
—02— Radio altimeters
—03— Radio homers
—04— Instrument systems and VHF omni-range
—05— Leader cable systems
—06— Hyperbolic systems

The remaining digits in the second element of the code indicate the *mark* (or variant) of the equipment. For some classes of equipment, three additional digits may be necessary and this is allowed for in the code — *eg* the numbers allocated to radio compasses are AP116B–0100 to –01999.

15. **Topic.** The final element in the code indicates the 'topic' dealt with in the publications. In general, for third element numbers up to '6', the meaning of the digit is the same as that of the volume number in the six-volume system (*see* para 7). For topic numbers higher than '6', the meaning of the digits differ from one equipment group to another — *eg:*

Group 101 (Aircraft)

3rd element No	*Meaning*
— 7	Preservation
— 8	(Unassigned)
— 9	Weight and balance data
— 10	Servicing diagrams manual
— 11	Air transport Operations Manual
— 12	Ground handling notes
— 13	Modification lists
— 14	Flight reference cards
— 15	Aircrew Manual
— 16	Operating data manuals

Group 116 (Radio & Television)

3rd element No	*Meaning*
— 7	Preservation
— 8	User Handbook
— 9	(Unassigned)
— 10	Servicing diagrams & data

Notes.

(1) When it is necessary to place topic 1 information in more than one cover, the separate books are identified by topic *letters* — *eg* 1A, 1B, 1C.

(2) For some electrical and electronic equipments, it is possible to produce information on more than one topic within a single cover; in such cases the topic numbers are combined — *eg* AP114J–0102–16 includes both topics 1 and 6.

The Coded 'Category' System

16. Like the six-volume scheme before it, the coded 'topic' system has certain limitations — the main one being the lack of standardization for third element (topic) digits between different publications (*see* para 15). In an effort to provide a more ordered structure, the coded 'category' system was introduced in 1972. This system divides the total possible range of information for engineering equipments and systems into eight (8) categories. The arrangement is such that the categories form a pre-arranged structure covering the full range of information that can foreseeably be required.

17. **Categories.** The eight categories in this system are as follows:

Category	*Title*	*Meaning*
1	Purpose and Planning Information	(what it is for)
2	Operating Information	(how to operate it)
3	Technical Description	(how it works)
4	Initial Intallation and Preparation for Special Environments	(how to prepare it for use)
5	Maintenance Information and Instructions	(how to maintain it — including testing and repair)
6	Maintenance Schedules	(who does what — and when)
7	Parts Catalogue and Related Information	(what parts it consists of and/or what spares are provisioned)
8	Modifications and General Instructions	(how to change it)

18. **Applicability.** It is not intended, at the moment, to generally apply the coded '8-category' system to all equipment APs. However, publications for certain new equipments for multi-Service use have been prepared to the new specification outlined in para 17 and discussed in detail in JSP 182. APs issued under the coded 'category' system have the initial digit of the first element (the equipment group number) changed from 1 to 2 — *ie* AP 216B– for Radio Navigational and Landing Aids (Airborne) instead of AP 116B–. This change of the first digit indicates to users that the book follows the 8-category system of JSP 182 and that the third element of the code number indicates the information 'category' (as defined above) and not the 'topic'.

Cross-referencing of Publications Systems

19. The previous paragraphs have considered three systems that have been devised for the structuring of information in equipment publications: the six-volume scheme; the coded 'topic' system; and the coded '8-category' system. During your service you may be required to use publications prepared under any of these systems and you must, therefore, be capable of 'finding your way around the publications'. Table 1 shows where the various 'types' of information can be expected to be located in each of the three systems and also illustrates the correlation between the information in the three systems.

Manufacturer's Information

20. A large number of manufacturer's handbooks are used in the Service. Most of these are given an official AP number and are then kept up-to-date, and amended in the light of Service experience, in the same way as a normal AP (*see later*). Those handbooks which do not have an AP number should be regarded as *informative* only, and all servicing must be carried out in

accordance with official servicing schedules. When information is received from a manufacturer which conflicts with an AP, an unsatisfactory feature report (UFR) must be raised (*see later*) so that the matter can be investigated and the AP amended if necessary. The permission of Command HQ must be obtained before direct use is made of manufacturer's information.

TABLE 1 AP information referencing systems

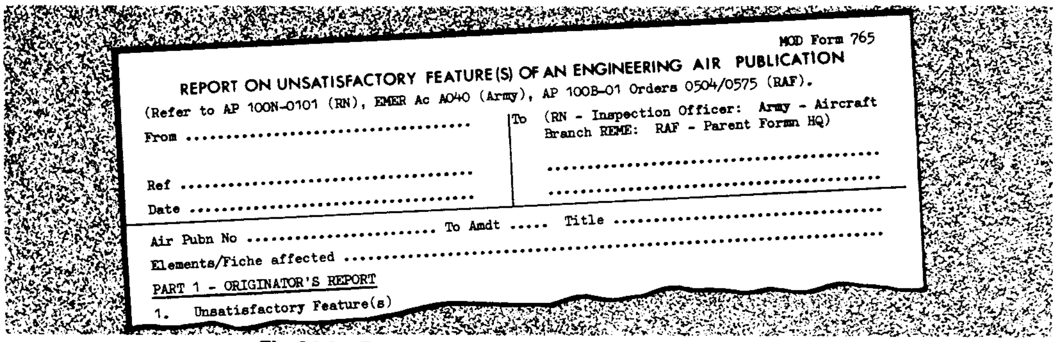
Type of Information *(Titles vary in the different systems)*	**Publications Reference** 6-Vol scheme *Vol*	*Pt*	**Coded Topic**	**Coded 8-Category**
• General description, with 1st and 2nd line servicing instructions	1	—	1	1,2,3,4,5
• Operating instructions	1	—	1	2
• General orders and modifications	2	—	2	8
• Illustrated parts catalogue	3	1	3A	7
• Schedule of airborne equipment (Appendix A to the aircraft specification)	3	2	3B	7
• Scales of unit ground support and/or test equipment	3	3	3C	7
• Scales of servicing spares	3	4	3D	7
• Planned (opportunity) servicing schedules	4	—	4	6
• Basic (periodic) servicing schedules	5	—	5	6
• Repair and reconditioning instructions	6	—	6	5
• Preservation and storage	1	—	7	4
• Aircraft weight and balance data	(Issued Separately)		9	2
• Wiring and servicing diagrams	1	—	10	5
• Air transport operations				
■ General info — personnel and cargo	(Issued Separately)		11A	2
■ Tie-down schemes			11B	2
■ Parachuting and air-dropped loads			11C	2
• Ground handling notes	GHN		12A	2
• Cross-servicing guide	—		12B	2
• Modification lists	ML		13	8
• Flight reference cards	FRC		14	2
• Aircrew manual	—		15	2
• Operating data manual	ODM		16	2

Note. A coded publication with a topic or category number of 0 contains ALL the information needed for the equipment concerned.

Amendment of an AP

21. **Introduction.** The majority of publications are continually being added to or revised as new equipment and techniques are introduced. This is made possible by a system of loose-leaf amendments which also keep the books up-to-date. The amendments usually consist of replacement leaves or completely revised chapters (to avoid handwritten alterations and the consequent possibility of error). Each amendment list (AL) is given a serial number and is issued with the authority of the Ministry of Defence. Issues are announced in 'The APFS Newsletter' which is usually published weekly.

22. **Unsatisfactory features of an AP.** Any errors found in engineering air publications should be reported on MOD Form 765 (Fig 24.3) in accordance with the instructions given in AP100B-01 Order 0504. AP holders are also encouraged to use this procedure to forward suggestions for improvements which would make the books more useful or easier to use. Unsatisfactory features will then be corrected by official amendment action.


MOD Form 765

REPORT ON UNSATISFACTORY FEATURE(S) OF AN ENGINEERING AIR PUBLICATION

(Refer to AP 100N-0101 (RN), EMER Ac A040 (Army), AP 100B-01 Orders 0504/0575 (RAF).

From ....

To (RN - Inspection Officer: Army - Aircraft Branch REME: RAF - Parent Formn HQ)

Ref ....

Date ....

Air Pubn No .... To Amdt ..... Title ....

Elements/Fiche affected ....

PART 1 - ORIGINATOR'S REPORT

1. Unsatisfactory Feature(s)

Fig 24.3 Form 765 – Unsatisfactory feature report

23. **Amending an AP.** The holder of an AP is the person responsible for keeping it fully amended. The ALs are *numbered consecutively* and are usually issued in sequence. It is wise, therefore, before actioning an AL, to check from the amendment record sheet at the front of the book that all previous ALs have been incorporated. ALs should be incorporated as soon as possible after receipt and the action recorded on the amendment record sheet (Fig 24.4).

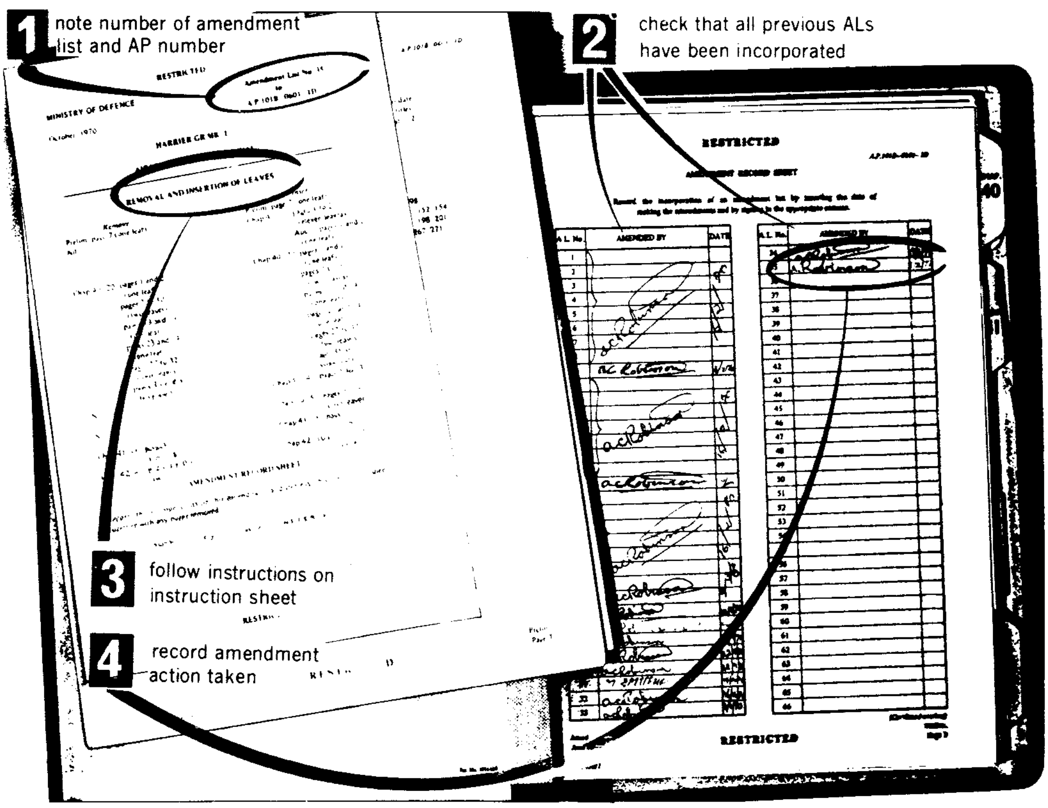


Fig 24.4 How to amend an AP

The reader's attention is drawn to the alterations made in the reprinted pages of an AL either by a vertical black line in the margin alongside the paragraphs concerned, or by two small black triangles used so ◀ ▶ to embrace any additions, and so ▶ ◀ to indicate where information has been deleted.

24. **Advance information leaflets (AILs).** These are leaflets which are used to speed up the publication of urgent, important information in advance of a routine formal amendment to engineering air publications. AILs are distributed through APFS to all holders of the

publications concerned. The leaflet is normally inserted to face the appropriate page in the AP (Fig 24.5) and remains there until an amendment list containing the same (or modified) information is issued. The formal amendment list contains instructions to cancel the AIL. To emphasise the importance of AILs, and to attract the readers attention to them, they are printed on blue paper.

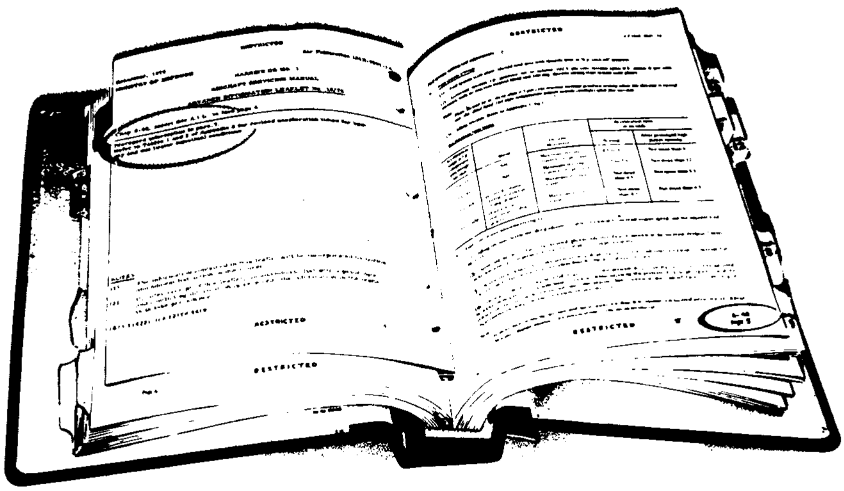


Fig 24.5 Advance information leaflet

25. **Command Temporary Amendments to Engineering APs.** Command HQs have the authority to issue command temporary amendments (CTAs) when the urgency of the requirement is such that it cannot await completion of permanent amendment or AIL action. *They are an interim measure only* and are withdrawn as soon as official amendment action is taken by the Ministry of Defence.

GENERAL ORDERS AND INSTRUCTIONS

Types of Orders

26. As noted earlier, most of the necessary information, orders and instructions required by tradesmen appear in permanent publications. However, there are occasions when a publication is not a suitable vehicle for the promulgation of instructions, either because:

- The information is of a *temporary* nature, or —
- Although, of a long standing nature, the information can be classed as *miscellaneous* and is *not appropriate* to any existing permanent publication.

The first of these gaps is filled by issuing Defence Council Instructions (DCIs); and the second, by the issue of General and Administrative Instructions (GAIs).

Defence Council Instructions

27. DCIs are issued as required (usually two or three issued each month) and are used for the promulgation of temporary instructions and announcements that have a wide application or are of general interest. They may also be used occasionally to draw attention to permanent publications or amendments to the latter. DCIs have a 'life' of *one year,* after which they cease to have any legal authority.

28. For the RAF, there is a single series of DCIs (referred to as RAF DCIs), with similar arrangements for the Army and the RN. Those DCIs that are agreed on an inter-Service basis will be indicated by a 'J' (for Joint Service) before the serial number (*see* Fig 24.6). There is no separate series of numbers of 'J' type DCIs; the serial number given is the next number in sequence in each *single Service* series.

Temporary orders, instructions, and other information of particular interest to MOD civilians are promulgated in a separate series of Civilian DCIs. The general points discussed in para 27 apply also to these DCIs.

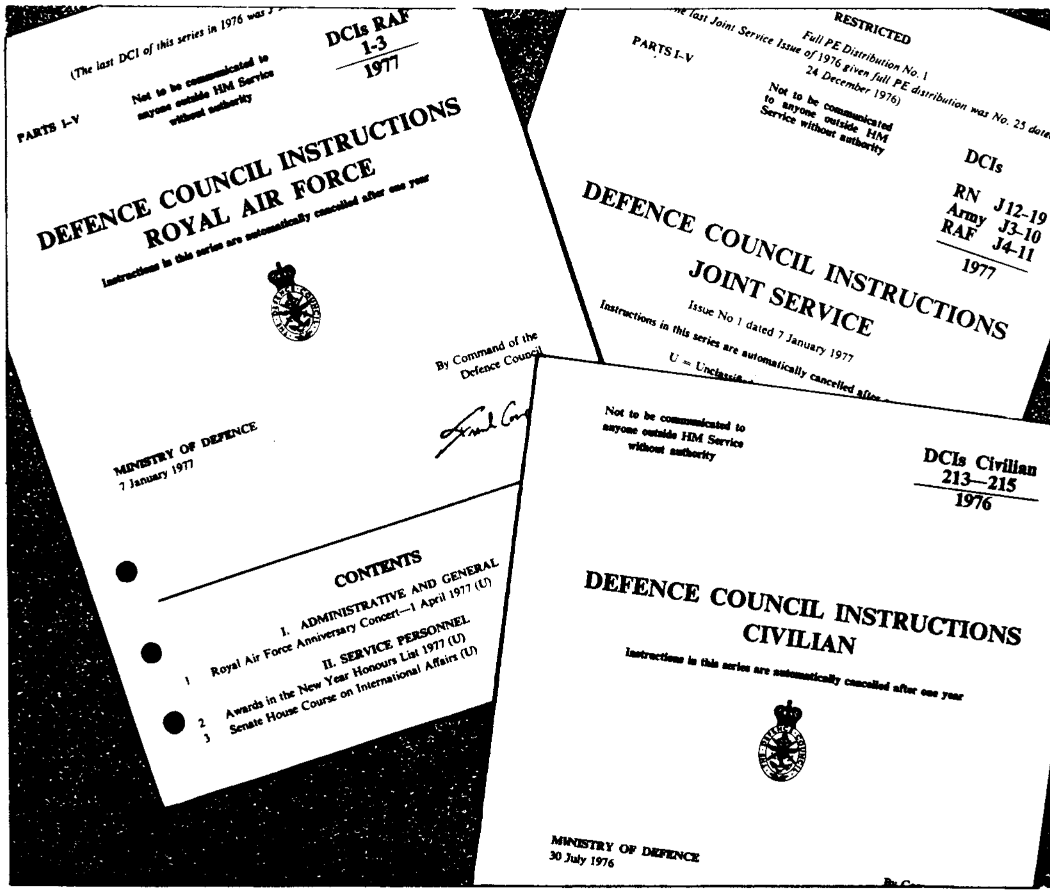


Fig 24.6 Defence Council Instructions

General and Administrative Instructions (GAIs)

29. Orders, instructions, and information that are expected to remain for *more than one year* may be promulgated as RAF GAIs, provided:

- No suitable permanent publication exists, or —
- It would be uneconomical to introduce a permanent publication to cover the subject.

RAF GAIs are issued as necessary. They are similar in format and style to DCIs but, unlike DCIs, they have *an indefinite life* — unless stated otherwise at the end of the text of the GAI. Furthermore, RAF GAIs are capable of being amended and, to make this task easier, each one is usually printed separately in loose-leaf form.

30. The different subject areas covered by GAIs are given a volume number, and a block of numbers is allocated to each volume as follows:

Volume	*Subject Area*	*Serial Numbers*
1	Operational	1001–1999
2	Training and Education	2001–2999
3	Engineering	3001–3999
4	Supply and Movements	4001–4999
5	Administration and Organization	5001–5999
6	Personnel and Accounting	6001–6999
7	Confidential	7001–7999

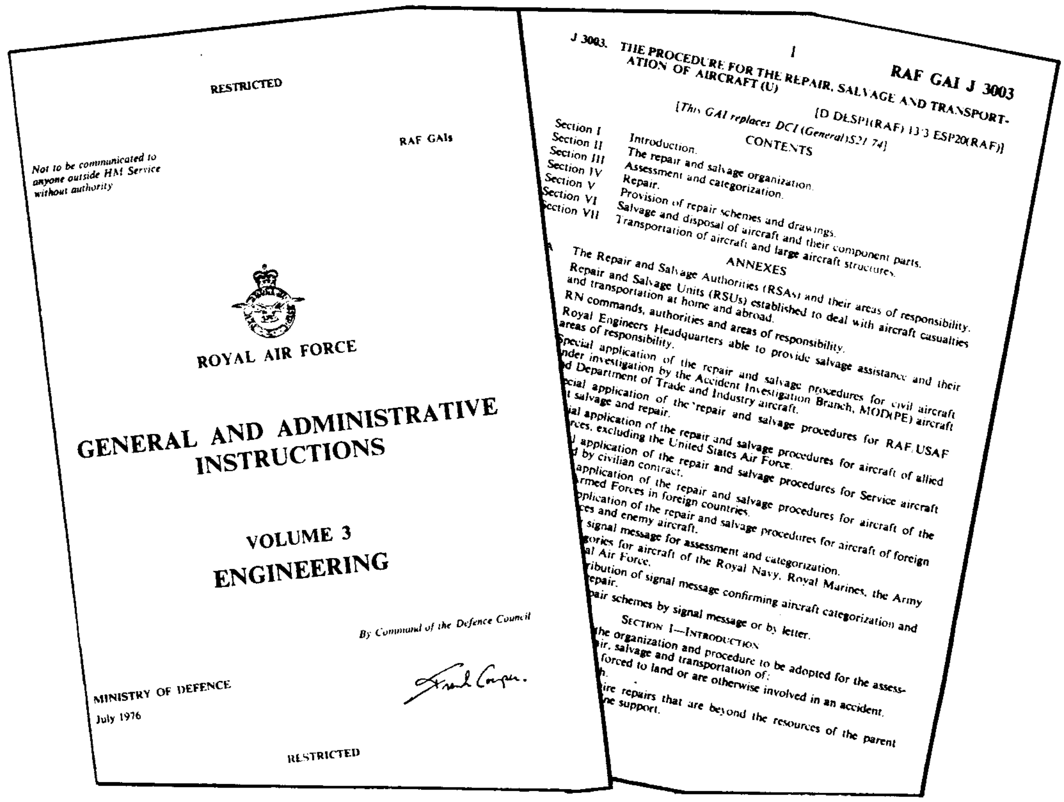


Fig 24.7 Example of GAI

The GAI number allocated for a given subject within the appropriate volume is *static and permanent,* so that reference can be made to the GAI in other documents. For example, information relating to Standard Trade Training Notes (STTNs) is given in RAF GAI 2009; this number will remain 'tied' to STTNs for as long as necessary. Separate binders are issued for each volume of GAIs, each one being identified by a cover label such as that shown in Fig 24.7.

ENGINEERING ORDERS AND INSTRUCTIONS

31. We have seen that technical information and orders for a particular type of aircraft or named equipment are to be found in a publication specifically written for the purpose. We also noted that orders and instructions of a *general nature* are published in DCIs or in GAIs. There are, in addition, orders and instructions that are mainly technical or engineering in nature and have widespread general application in the Service. Some of these sources of information are described in the paragraphs that follow.

MOD-Sponsored Engineering Publications

32. Engineering orders and instructions issued by appropriate authorities within the Ministry of Defence include the following:

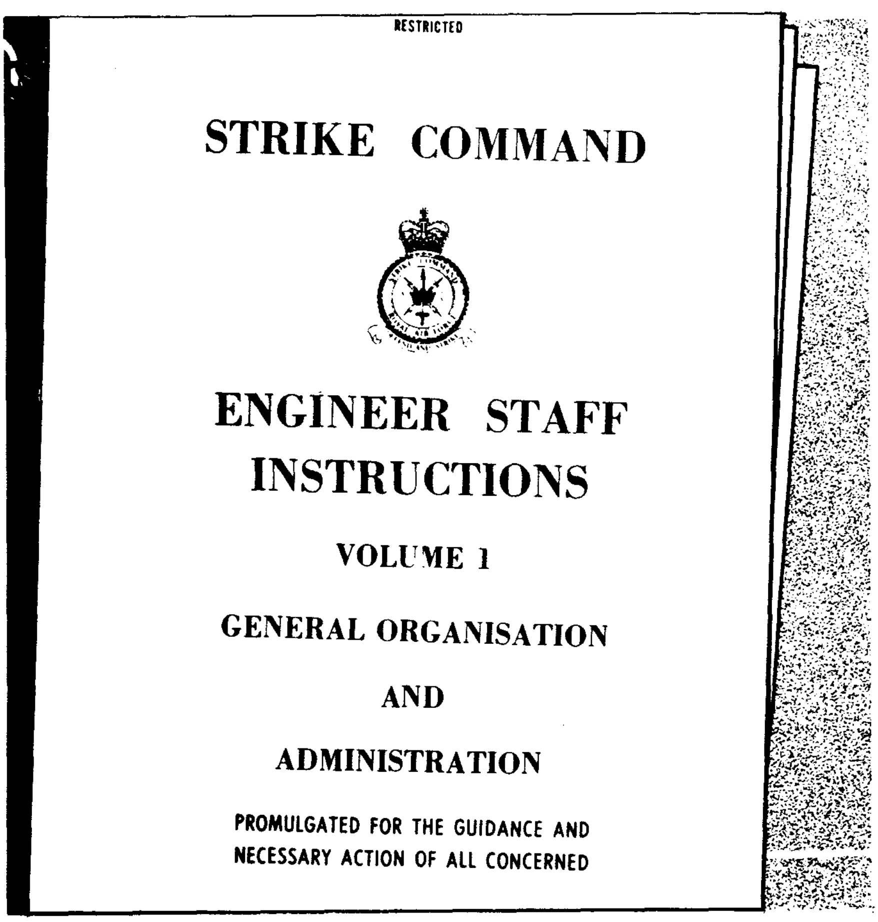
- **RAF GAIs Volume 3 (Engineering).** This publication is used for the promulgation of those orders and instructions that cannot find a logical 'home' elsewhere.
- **AP3158 — Technical Services Manual.** This AP is in two volumes:
  - *Volume 1* contains information on the organization and administration of the RAF technical services.
  - *Volume 2* contains mandatory technical orders and instructions in the form of 'leaflets'.

AP3158 is being superseded by publications in the AP100 series *(see below)* and information currently appearing in AP3158 is being phased out as it appears in up-dated form in AP100.

- **AP100 Series — RAF Engineering.** The APs in the AP100 series currently on issue include the following:
  - *AP100A — RAF Engineering — Organization and Policy.* This AP is superseding AP3158 Vol 1 and provides relevant and up-to-date information of concern mainly to those responsible for the *management* of engineering services at all levels.
  - *AP100B — RAF Engineering — Orders and Procedures.* When complete this AP will replace AP3158 Vol 2. The orders and procedures are in leaflet form and are directed to those directly involved in maintenance of equipment.
  - *AP100C — RAF Engineering — Maintenance Data System.* This AP provides information on the MOD Servicing Recording System and is directed at tradesmen involved in entering maintenance details on MOD Form 700 *etc.*
  - *AP100V — Joint Services·Aircraft Maintenance Agreements.* This AP has limited circulation and is aimed at managers requiring information on general repair policies for aircraft and associated equipments.

Command Engineering Staff Instructions (Eng SIs)

33. These are leaflets issued by the Engineering branch of a particular Command Headquarters (Fig 24.8). They are used to convey to persons within the Command, Command orders, special instructions, and modifications. They give the Command application of the technical orders and instructions contained elsewhere — *eg* in GAIs Vol 3 (Engineering). Command Eng SIs form the basis from which Unit Servicing Orders (USOs) can be compiled. Eng SIs are preceded by two or three letters which indicate the Command originating them — *eg* 'STC Eng SI' (issued by Strike Command). The instructions are amended in a manner similar to that of APs.


RESTRICTED

STRIKE COMMAND

ENGINEER STAFF INSTRUCTIONS

VOLUME 1

GENERAL ORGANISATION AND ADMINISTRATION

PROMULGATED FOR THE GUIDANCE AND NECESSARY ACTION OF ALL CONCERNED

Fig 24.8 Command Engineering Staff Instructions

Unit Servicing Orders (USOs)

34. The purpose of USOs is to describe the unit engineering organization and to define individual maintenance responsibilities. They are to be concise and may contain references to QRs, APs, GAIs and Command Eng SIs, as necessary. The responsible authority on the unit for the preparation (and annual review) of USOs is OC Eng Wg. Their presentation and scope will vary according to the engineering task of the unit concerned but they are to include, as appropriate, statements of:

a. Purpose of the orders.
b. Method of amendment.
c. Engineering Wing organization.
d. Function and organization of squadrons, flights, and sections having responsibilities to OC Eng Wg.
e. Terms of reference for officers and NCOs employed as engineering managers or supervisors.
f. Aircrew responsibilities for flight servicing and engineering aspects of flight testing.
g. Responsibilities of duty engineering personnel.
h. Organization and responsibilities for the servicing of visiting aircraft.

Engineering Order Book

35. This book, an example of which is illustrated in Fig 24.9, is normally maintained by all self-contained flights and sections on a unit. It contains local orders pertaining to the section and details the responsibilities of all section personnel. Physically, the book consists of a loose-leaf cover, a set of spacer cards, and order sheets. The book is amended from time to time and orders are cancelled when they have no further use.

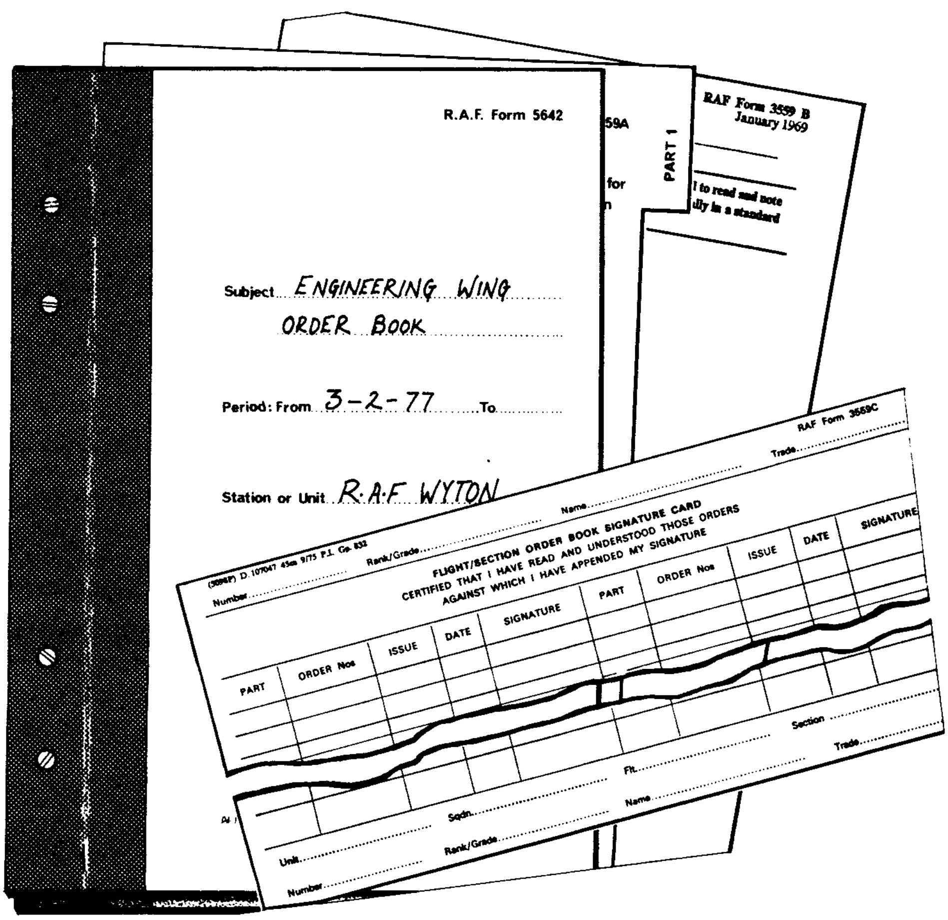


Fig 24.9 Engineering order book

36. Personnel are to sign as having read and understood the various orders appropriate to their trade and area of employment. They are to sign:

- On first joining the section.
- Whenever an applicable order is amended.
- After each annual review of orders.

TEMPORARY ENGINEERING INSTRUCTIONS

37. We have seen that DCIs may be used to promulgate information of a temporary nature. Other means are also used to advise personnel at RAF units of important technical matters and of any urgent remedial action that may need to be taken as a result of defects in equipment or of inadequate servicing. The information being communicated may call for a 'once only' action, in which case it is not appropriate for a permanent publication. Alternatively, although scheduled to appear in a particular publication, the matter may be so urgent that it is necessary to have a faster means of propagation than the conventional publication system. It is for these, and other, reasons that temporary engineering instructions are issued. The most important of these instructions are listed below.

Special Technical Instructions (STIs)

38. The development of a serious defect in equipment may necessitate the issue of immediate instructions to inspect, modify, or replace components. Such directives are known as STIs and are used to describe work to be accomplished *once only,* within a specified time, to seek and correct a fault.

Servicing Instructions (SIs)

39. This is an instruction which describes the *repetitive* work needed to find and correct a fault which is likely to occur again and again. An SI remains in force until either the appropriate servicing schedule is amended to include the SI information or the equipment is modified, making the SI no longer necessary.

Preliminary Warning Instructions (PWIs)

40. When a unit reports a serious defect in equipment, the appropriate RAF authority may issue, by signal, a Preliminary Warning Instruction (PWI).

A PWI is intended to inform other units that a serious defecct has been reported and to acquaint them with its nature; it will usually include a requirement for similar equipments to be examined and for the proportion found defective to be reported to the authority issuing the PWI. Additionally, since the STI/SI procedure outlined earlier may not react with sufficient speed to meet the urgency of the situation, the PWI may (exceptionally, and subject to certain safeguards) be used as *an interim order* for remedial action.

41. A PWI which calls for remedial action of any sort, including repeated inspections (as opposed to an initial examination), is to be superseded by an STI or SI, as applicable, *within one calendar month* of the date of issue of the PWI.

42. **Cancellation of PWIs.** All PWIs are to be cancelled or superseded as soon as possible:

- PWIs issued by an engineering authority, and requiring only initial examination, are cancelled *automatically* one calendar month after their date of origin.
- PWIs issued by an engineering authority, and requiring remedial action in addition to the initial examination, are superseded on issue, and as part, of the superseding STI or SI.
- PWIs issued by a Command Headquarters are superseded on issue, and as part, of the engineering authority's superseding PWI.

Local Engineering Instructions (LEIs)

43. The purpose of a Local Engineering Instruction is to enable OC Eng Wg to promulgate formal instructions for engineering tasks, of the type normally authorized by STIs, SIs or PWIs, when immediate on-the-spot action is necessary to overcome specific local problems.

The following points apply to LEIs:

- An LEI is valid only at the unit issuing the instructions and at other locations where that unit provides servicing support.
- An LEI is not to be used as a substitute for initiating more formal action — such as issue of an STI, SI, or PWI, transmission of a serious defect signal, or amendment of a publication.
- Each LEI is to contain a statement of the more formal action which will be, or has been, initiated and which will, if approved, supersede the LEI.
- A copy of each LEI is to be forwarded to the parent Command Headquarters (and, if applicable, the Group Headquarters of the unit).
- OC Eng Wg maintains a register of LEIs and reviews each one at least once every three months.

CHAPTER 25

DRIVING ON AIRFIELDS

Introduction

1. In the course of your RAF career is it likely that you will be required to drive a vehicle on an airfield. The principal regulations governing military airfields and the movement of vehicles and pedestrians on them are in JSP 318 — *Military Flying Regulations*. Service drivers who require regular access to the movement area of an airfield are issued with an airfield driving permit (*see* para 4) *specific to that airfield,* so that local hazards can be taken into account. Regulations governing the issue of airfield driving permits are contained in JSP 341 — *Joint Services Road Transport Regulations.*

2. **Movement area.** The movement area is defined as those parts of an airfield intended for the surface movement of aircraft. There are two components of the movement area:

- **The manoeuvring area.** The manoeuvring area is the part of the airfield used for the take-off and landing of aircraft and for the movement of aircraft associated with take-off and landing (excluding the apron). Vehicles are not to be driven on to the manoeuvring area except with the permission of air traffic control. When vehicles are within the manoeuvring area they are under the *direct control* of the airfield controller whose orders (issued directly or through the runway controller) must be obeyed immediately. At all points where roadways join the manoeuvring area, drivers will be warned by standard notice boards which read:

  STOP, MANOEUVRING AREA.
  VEHICLES ARE NOT TO BE
  DRIVEN PAST THIS POINT
  WITHOUT THE PERMISSION OF
  AIR TRAFFIC CONTROL.

- **The apron area.** This is a group of defined areas of an airfield intended to accommodate *aircraft* for the purpose of loading/unloading passengers or cargo, refuelling, parking, or maintenance. Vehicles within the apron are to be driven in accordance with local orders, and remain under the control of the officer having responsibility for the apron.

3. **Colour blindness.** Drivers employed within the movement area must have a colour perception standard of at least CP3 — *'colour defective safe'.* No individual is to be permitted to drive within the movement area if his colour perception is 'red/green defective' (CP4). Any MT drivers permit issued to such an individual will have a red ink entry 'CP4 RED/GREEN DEFECTIVE' on the front cover (*see* Fig 25.1).


F/MT 600

MINISTRY OF DEFENCE
UNITED KINGDOM

M.T. DRIVERS
PERMIT

★

Not valid for use on public roads in the United Kingdom except in conjunction with the appropriate Civil Driving Licences.

This Driver's Standard of
COLOUR PERCEPTION
is..
Not valid on SERVICE AIRFIELDS without F MT 600A.

Issued to conform with STANAG 2176

Fig 25.1 MT driver's permit

Airfield Driving Permit F/MT/600A

4. The airfield driving permit (F/MT/600A) contains various certificates liable to be required by drivers on the movement areas of service airfields (*see* Fig 25.2). An F/MT/600A is valid only on the *specific airfield* for which it is issued, and if a driver needs to drive on another airfield, a separate F/MT/600A will be required and will be issued by that airfield. The permit is valid for one year only but it can be renewed after a further briefing from the senior air traffic control officer (SATCO). An airfield driving permit that has not been endorsed by the SATCO within the previous 12 months is invalid. If a driver is not in possession of a valid F/MT/600A, he must not drive any vehicle on the movement area. Casual visitors requiring access to the movement area, but who do not hold a valid airfield driving permit for that airfield, are to report to air traffic control (or as otherwise directed). Before being permitted to proceed on to the movement area such drivers will be either:

- provided with a *qualified escort* who holds the necessary valid airfield driving permit, or —
- be given an adequate briefing *for that specific occasion* to enable them to conduct their business on the movement area in safety and without danger to aircraft.

F/MT/600A

AIRFIELD DRIVING PERMIT

No. .... Rank..............

Name ....

This pass is valid for the Movement Areas

of ....

Airfield as indicated, but only with FMT 600

Serial No. .... / .... / ....

AIR TRAFFIC CONTROL

Annual briefing under JSP 318 1-2-0411

Date	**SATCO Signature**
1.	....
2.	....
3.	....

Valid for 1 year only from date of last Signature

MT/AIRCRAFT REGULATIONS

The holder has been briefed in accordance with JSP 341 Chapter 14

.... M.T.O.

AIRCRAFT TOWING

The holder is competent to tow these Aircraft:

1.	4. ....
2.	5. ....
3.	6. ....

.... S.Engr.O.

EXPLOSIVE AREAS

The holder has been briefed for driving in the Explosive Areas of this Airfield.

.... S.Wp.Engr.O

330777 18M 9/77 838

Fig 25.2 Airfield driving permit

5. **Issue of F/MT/600A.** Procedures for the issue of airfield driving permits vary from airfield to airfield and are given in individual station regulations. These regulations contain details peculiar to the airfield concerned and it is for this reason that an airfield driving permit is valid only on the airfield for which it is issued. Detail in the regulations includes the following:

- The layout of the manoeuvring area and vehicular routes.
- The nature of ground control.
- The nature of marshalling in force.
- Where aircraft are normally to be encountered.

- Visual signals employed on the airfield.
- Methods of identifying the runway in use.
- Actions to be taken in an emergency or in the event of breakdown.

Standard Regulations for Drivers

6. **Control of vehicles by day.** The following standard regulations apply to all airfields during the day and night. At night, the *additional* regulations given in para 7 also apply.

- All vehicles are to give way to aircraft. There is only one exception to this rule — namely, vehicles in process of towing an aircraft are not bound to give way to taxying aircraft.
- All drivers are to report to air traffic control as specified in local orders before proceeding on to the manoeuvring area (RAF airfields only).
- On receiving permission, vehicles are not to proceed on to the manoeuvring area until the driver has made sure than no aircraft or vehicle is moving, or is likely to move, near the point of entry.
- Vehicles being driven on airfields are to conform to the normal rules of the road for the country in which the airfield is situated. Vehicles are always to give way to aircraft, by clearing the taxiway in such a manner as to afford maximum clearance to the aircraft, even at the risk of damage to the vehicles, which does not, however, absolve aircrews and air traffic control staff from taking all necessary precautions for the prevention of collisions.
- Vehicles are to be kept at least 50 metres behind taxying aircraft.
- While in the manoeuvring area vehicles are not to be driven in reverse gear unless they are being directed by a marshaller, nor are they to overtake moving vehicles, and they are to be halted as infrequently as possible.
- Vehicles are not to be parked on or near the taxiway.
- Vehicles are to be driven at speeds not in excess of 30 mph or such other lower speed as may be laid down locally.
- Engines are not to be run unnecessarily in the vicinity of the control tower or radio transmitter/receiver stations.
- In the event of a breakdown, a driver must on no account leave his vehicle unattended and is to indicate by suitable signals to approaching aircraft that his vehicle constitutes an obstruction. The driver is to notify air traffic control (direct or through the runway controller) by pre-arranged signals or by contacting a passing vehicle.
- Vehicles are not to be driven on any runway without specific permission from the airfield controller. When this has been given, drivers are to report to the runway controller before entering the runway. They are again to report to the runway/airfield controller when leaving the runway.
- Vehicles and pedestrians are to stop at *the holding position* or other designated point and are not to proceed unless the traffic lights show green or a green lamp signal is received from the runway control caravan or the control tower.

7. **Additional regulations by night:**

- The driver is to carry a serviceable red torch for use in the event of a breakdown.
- The headlights of the vehicle must be fully serviceable and properly in focus. When the vehicle is in motion the headlights must be on and dipped. Sidelights may be used when a vehicle is stationary, or when halted to allow an aircraft to pass, or when standing at a runway marshalling point. Sidelights are also to be used when directed by an aircraft marshaller.
- Vehicles towing aircraft during the hours of darkness are to display the correct illuminated triangle sign on the front of the vehicle; and a spotlight at the rear of the towing vehicle is to be used to illuminate the aircraft wing on the off side of the vehicle.

- Vehicles are to be driven at speeds not in excess of 20 mph or such other lower speeds as may be laid down locally.

8. **Briefing of drivers.** The airfield controller will brief all drivers on the following details:

- The layout of the airfield lighting.
- The runway in use.
- Direction of taxying aircraft and dispersals being used.
- Lamp signals in use.
- Red torch signals.
- Use of vehicle headlights.
- The occasions when it is necessary for a driver of a vehicle to report direct to air traffic control before proceeding on to the manoeuvring area.

9. **Signals used to control vehicles and pedestrians** (STANAG 3758). The standard lamp signals used by controllers are shown in the table below. These signals are usually given by the runway controller but, where no runway controller is deployed, may be made from the ATC tower or by a vehicle controller.

TYPE OF SIGNAL	MEANING OF SIGNAL	NOTES
Steady green light	Cleared to proceed	
Steady red light	Stop	In cases of emergency, a red Very light may be fired horizontally
Red flashing light	Clear the runway or taxiway immediately	
White flashing light	Return to starting point or do as briefed	

Towing

10. **Towing aircraft.** Only personnel who have been certified as competent by the senior engineering officer are permitted to tow aircraft. The individual types of aircraft which a driver is permitted to tow are entered on his airfield driving permit (*see* Fig 25.2).

11. **Towing ground equipment.** As part of your normal trade duties you may be required to tow items of ground support equipment. Many of these items can be towed safely only at walking speed; never exceed the speed limit laid down in the equipment AP when you have to tow ground equipment.

- Ensure that the equipment is serviceable for towing (*eg* check tyre inflation, towing arm, brakes *etc*).
- Check that there are no loose articles left on the equipment which would become a FOD hazard.
- Ensure that the equipment is in its towing configuration (*eg* output cables stowed, platforms lowered *etc*) and is secured to the vehicle with the correct type of towing pin/shackle.
- Ensure that the equipment brakes are off and that jacks, if any, are up and secure.
- Never exceed the speed limit and, if the equipment becomes unstable, slow down.

- Avoid making tight turns — be extra careful to prevent damage to the equipment or vehicle during turns.
- Park equipment in aircraft movement areas only in these areas set aside for that purpose.
- Before disconnecting the equipment from the towing vehicle, ensure that the equipment brakes are on, that the jacks are down, or that the wheels are chocked, to prevent it moving and thus becoming a hazard to aircraft or personnel.

Foreign Object Damage (FOD)

12. In the same way that minute particles of dust blown into the eyes can cause temporary blindness, so debris that is blown, sucked, or inadvertently dropped into an aircraft's vital parts can cause damage that will swiftly put it out of action. In most instances, the eyes recover quickly — a few blinks and the fluid beneath the eyelids washes away the offending grit, and sight is restored in a very short time. Unfortunately, an aircraft has no such built-in recovery device. The debris either stays undetected to become a serious flight safety hazard or, if discovered, has to be painstakingly removed and the resulting damage repaired. The damage sustained in such incidents is officially described as Foreign Object Damage or, more briefly, as FOD.

13. In spite of the widespread propaganda given at all units on the dangers of FOD, the RAF still manages to produce hundreds of occasions of such damage each year. The effects range from the superficial damage caused by the impact of wind and jet-blown dust, to severe internal damage resulting from tools and servicing debris being sucked into the gas turbine engine. The many FOD incidents cost millions of pounds each year, in lost aircraft, replacement parts, and servicing time. The total value of the three aircraft illustrated in Fig 25.3 is of the order of £10 million; but, as a result of FOD, this could very quickly be reduced to *scrap value.*

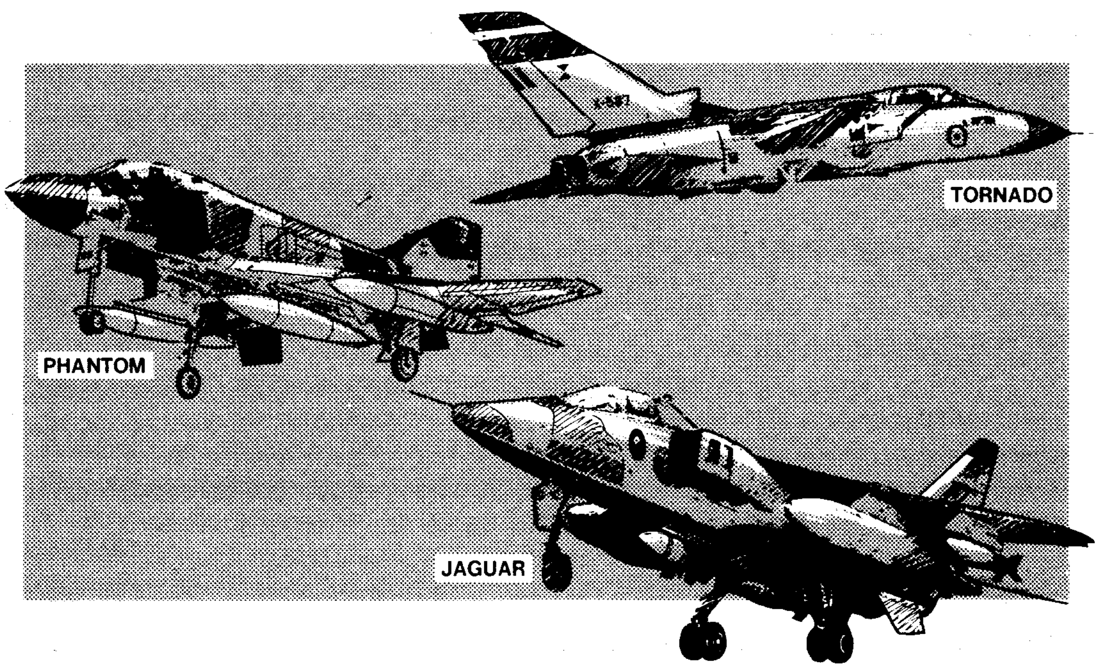


Fig 25.3 FOD could reduce these to scrap

Even more important — in terms of the personal injuries sustained by flying and servicing crew members and, on occasions, even death, the cost is clearly beyond measure.

14. Vehicles driven into the movement area are a potential source of FOD in that bits do sometimes drop off, doors may open and allow part of the load to fall off, and small pieces of metal may be picked up by the tyres and dropped in a more dangerous place. Do not allow

your vehicle to become a FOD hazard — check it over before you enter the movement area. If you should see FOD of any kind while driving on the movement area, stop and pick it up if it is safe to do so. FOD which you cannot pick up (it may be too big or on the runway) must be reported *immediately* to ATC so that they can cease aircraft movements until it is removed. If you see any FOD which looks as though it may be part of an aircraft, report it immediately to ATC; it is better to be safe, and you may even save the life of a pilot.

CHAPTER 26

WORKSHOP ADMINISTRATION

REPAIR & MANUFACTURE OF EQUIPMENT IN STATION WORKSHOPS

Introduction

1. Paragraphs 2 to 8 detail the procedure to be followed when items of equipment are repaired or manufactured in station workshops. They also detail the procedure to be followed when repair or maintenance of equipment is undertaken as a *repayment* service.

Documentation of Submitted Tasks

2. The procedures to be adopted for tasks involving repair or manufacture of equipment in station workshops are detailed below:

- The tasks are to be submitted on RAF Forms 6A, raised in triplicate by OC Supply Sqn (*see* Fig 26.1).

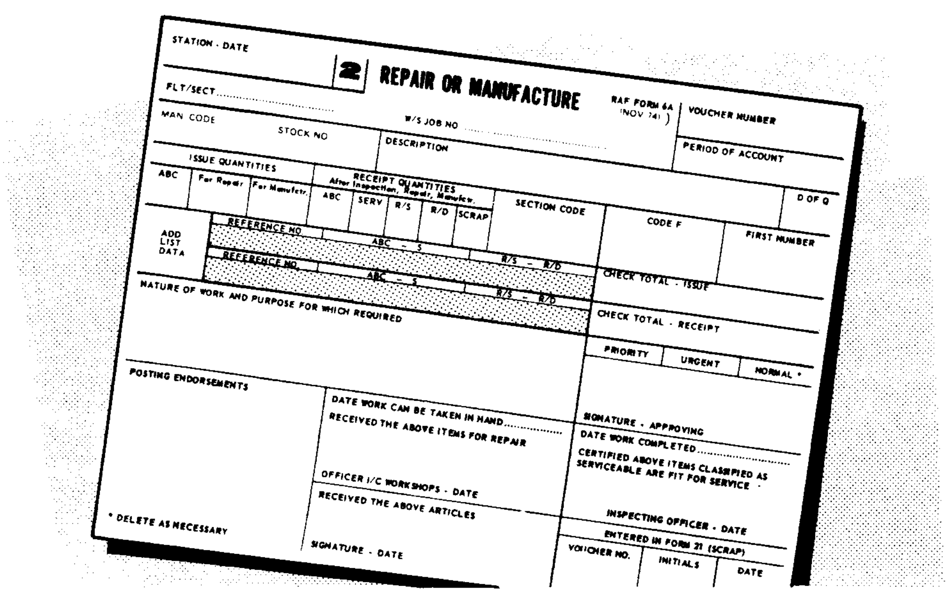

STATION - DATE
2 REPAIR OR MANUFACTURE
RAF FORM 6A (NOV 74)
VOUCHER NUMBER
FLT/SECT
MAN CODE
STOCK NO
W/S JOB NO
DESCRIPTION
PERIOD OF ACCOUNT
ISSUE QUANTITIES
ABC | For Repair | For Manufctr.
RECEIPT QUANTITIES After Inspection, Repair, Manufctr.
ABC | SERV | R/S | R/D | SCRAP
SECTION CODE
D OF Q
CODE F
FIRST NUMBER
ADD LIST DATA
REFERENCE NO | ABC - S | R/S - R/D
REFERENCE NO | ABC - S | R/S - R/D
CHECK TOTAL - ISSUE
NATURE OF WORK AND PURPOSE FOR WHICH REQUIRED
CHECK TOTAL - RECEIPT
PRIORITY | URGENT | NORMAL *
POSTING ENDORSEMENTS
DATE WORK CAN BE TAKEN IN HAND
RECEIVED THE ABOVE ITEMS FOR REPAIR
SIGNATURE - APPROVING
DATE WORK COMPLETED
CERTIFIED ABOVE ITEMS CLASSIFIED AS SERVICEABLE ARE FIT FOR SERVICE *
OFFICER I/C WORKSHOPS - DATE
RECEIVED THE ABOVE ARTICLES
INSPECTING OFFICER - DATE
ENTERED IN FORM 21 (SCRAP)
* DELETE AS NECESSARY
SIGNATURE - DATE
VOUCHER NO. | INITIALS | DATE

Fig 26.1 RAF Form 6A

- The triplicate copy of Form 6A is to be forwarded to OC Eng Wg who will inform OC Supply Sqn of the date on which the work can be undertaken.
- On the date when the work can be taken in hand, OC Supply Sqn is to arrange for the equipment to be delivered to station workshops, a signature for receipt being obtained on the duplicate copy of Form 6A.

Date	Job No	Requisition Serial No	Description	Date: Work Taken in hand	Date: Completed	To be completed for RAF Form 6 RV/CV No	Remarks

Note. Repayment jobs are to be entered in red ink. The date on which particulars of repayment jobs are passed to OC Supply Sqn for recovery action is to be entered in the Remarks column, and the entry signed by the Officer IC Station Workshops.

Fig 26.2 Job register

- On receipt of the task in the workshop:
  - Particulars of the job are to be entered in the 'RAF Form 6A Register' (*see* Fig 26.2).


Degree of Priority
ROYAL AIR FORCE
JOB SHEET
RAF Form 1083 (Revised Dec. 1966)
Group or Bay
Required by
Unit
on
No. of Continuation Sheets
Job and Sheet No.
Commenced
Full Description of Job
Subsidiary Sheets raised
Description of work
Man hours
Signature of Tradesman
Total Man Hours
Signature of Trade Supervisor

Fig 26.3 Job sheet, RAF Form 1083

- ■ A job sheet (RAF Form 1083) is to be raised (*see* Fig 26.3).
- ■ If more than one sub-section of workshops is involved, subsidiary Forms 1083 — numbered 1, 2, 3 *etc* — are to be prepared.

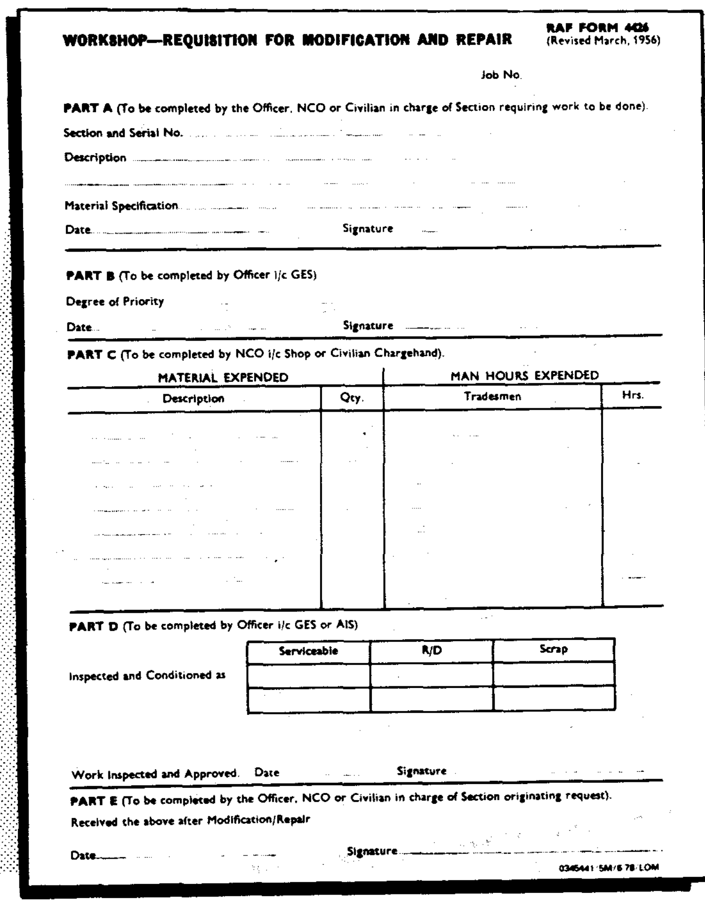
- RAF Forms 1083, when completed, are to include details of the work done and the appropriate tradesman's signature, quantities of accountable materials used, man-hours expended by trades, and a completed inspection certificate.
- These completed forms are to be retained, together with the completed triplicate copy of the RAF Form 6A.
- On completion of the work, OC Eng Wg is to inform OC Supply Sqn who will arrange for collection of the equipment, obtain the signature of the Office i/c Station Workshops on the duplicate copy of the Form 6A, and sign the triplicate copy of Form 6A as receiving the item.

3. Tasks which involve *reconditioning* of equipment are to be similarly recorded, except that documentation designed to meet the needs of reconditioning is to be used in lieu of RAF Form 1083.

Minor Jobs

4. When minor work is required to be done for Servicing Bays, Flights, or Sections, the following action is to be taken:

- RAF Form 4426 is to be prepared and submitted to station workshops (*see* Fig 26.4).



RAF FORM 4426
(Revised March, 1956)

WORKSHOP—REQUISITION FOR MODIFICATION AND REPAIR

Job No.

PART A (To be completed by the Officer, NCO or Civilian in charge of Section requiring work to be done).

Section and Serial No.

Description

Material Specification

Date　Signature

PART B (To be completed by Officer i/c GES)

Degree of Priority

Date　Signature

PART C (To be completed by NCO i/c Shop or Civilian Chargehand).

MATERIAL EXPENDED		MAN HOURS EXPENDED	
Description	Qty.	Tradesmen	Hrs.

PART D (To be completed by Officer i/c GES or AIS)

	Serviceable	R/D	Scrap
Inspected and Conditioned as			

Work Inspected and Approved.　Date　Signature

PART E (To be completed by the Officer, NCO or Civilian in charge of Section originating request).

Received the above after Modification/Repair

Date　Signature

0345441 5M/6 78 LOM

Fig 26.4 RAF Form 4426

- On receipt of Form 4426, the officer i/c Station Workshops is to decide the degree of priority, give the job a number, and enter it in the 'Minor Job Register' — which is to be maintained as shown in Fig 26.2.
  - ■ *RAF Form 1083 is not to be raised.*
- When the work is completed, details of the accountable materials and man-hours (by trades) spent on the work, are to be entered in Part C of Form 4426 and signed by the NCO, technician, or civilian charge-hand in charge of the shop.
- Part D of the Form is then completed by the Officer i/c Station Workshop, and also by an inspector (if inspection and conditioning by QAS has taken place — see para 7).
- The originator of the request is to sign Part E as a receipt for the completed job.
- The RAF Form 4426 is to be retained in workshops where it becomes a complete record of the minor job.

Repair or Manufacture on Repayment

5. Repair or manufacture of non-public equipment on behalf of non-public organizations or individuals on a station is a *repayment* service, *and is to kept to a minimum*. Requests are to be made in writing to OC Supply Sqn, through OC Admin Wg. If satisfied that the request is valid, OC Supply Sqn will pass it to OC Eng Wg. Before accepting the job, OC Eng Wg is to

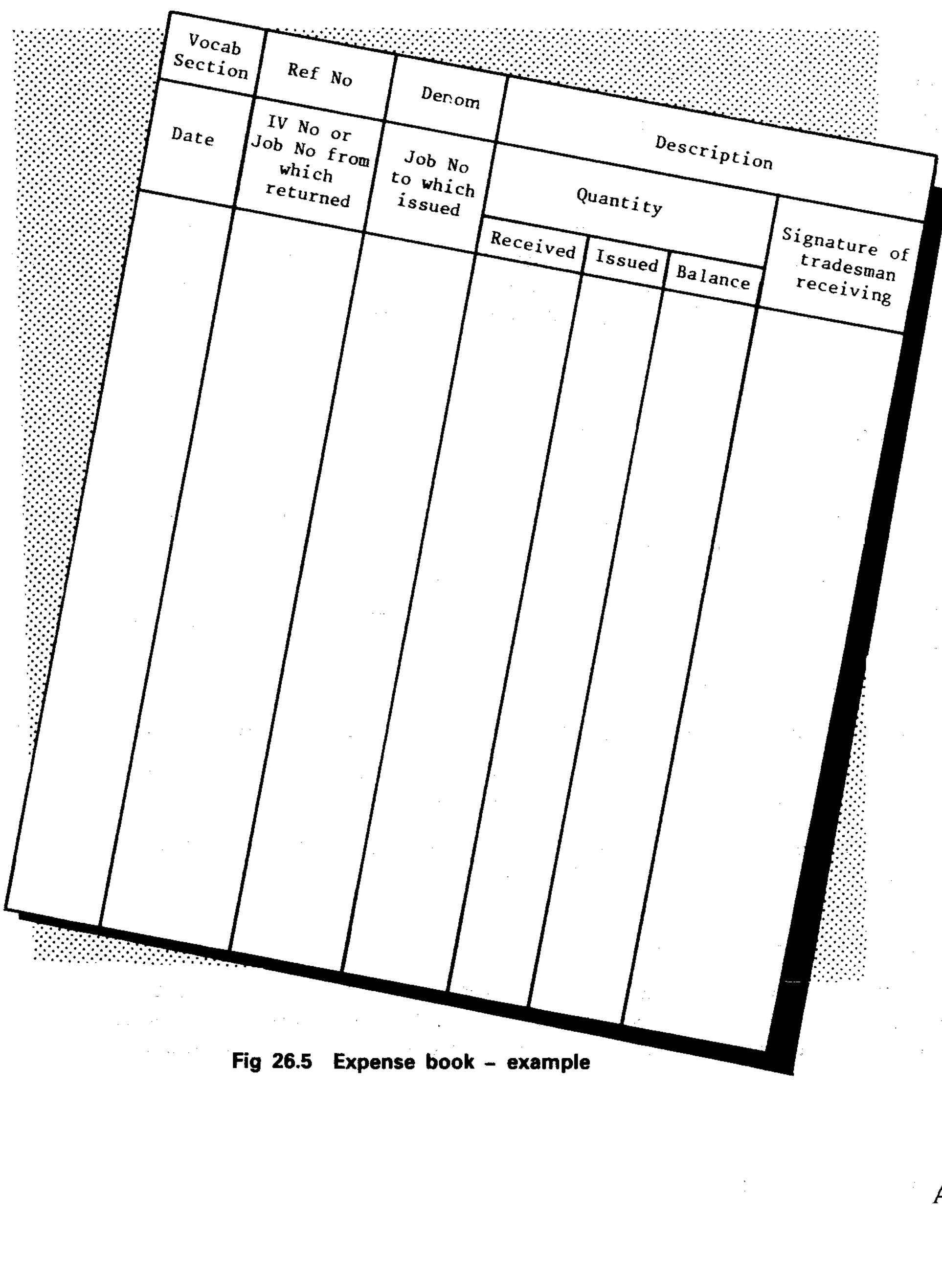


Fig 26.5 Expense book - example

satisfy himself that it does not interfere with any Service commitments. If the work is subsequently authorized, OC Supply Sqn is to prepare the RAF Form 6A in triplicate, annotated in red ink, 'REPAYMENT' (*see* Fig 26.2).

6. The procedure set out in paras 2 and 3 is then to be followed — except that the Officer i/c Station Workshops is to enter on the duplicate copy of RAF Form 6A full details of the materials used and man-hours expended. When it is impracticable for the completed work to accompany the duplicate copy of Form 6A to the Supply Sqn, the signature of the individual for whom the work was done is to be obtained by the Officer i/c Station Workshops on the triplicate copy of RAF Form 6A before releasing the item.

Inspection

7. On units where QAS or Contractor's Servicing Inspection is established, items repaired or manufactured as described in this Chapter are to be subject to inspectional clearance by the appropriate inspector.

Expense Books

8. Materials which are considered to be valuable and attractive, or which have to be demanded in bulk from the Supply Sqn — *eg* madapolan, linen, fabric, timber, metal (sheet and bar) — are to be further accounted for in an Expense Book. Separate Expense books for each shop are to be maintained at the discretion of OC Eng Wg. The form the Expense Book is to take is shown in Fig 26.5.

CALIBRATION OF MECHANICAL PRECISION MEASURING EQUIPMENT & TESTING OF MATERIALS

Introduction

9. Operational equipment and systems will not achieve their design performance if they are tested or measured with worn or inaccurate test equipment. Accuracy of test and measuring equipment is an essential quality assurance requirement, and verification by periodic recalibration is necessary for the maintenance of accuracy.

Objectives and Limitations

10. The paragraphs that follow define:

a. The *periodicity* of recurrent checks of accuracy of mechanical test equipment.

b. The *procedures* to be followed when it is necessary to submit mechanical precision measuring or other test equipment for *check* or *recalibration* because it is beyond the standard of accuracy attainable within the unit.

c. The *procedures* to be followed when *tests* are required to determine physical properties of materials.

11. The procedures do not apply to:

a. Explosives, which are to be submitted in accordance with AP2608A, Part 3, Leaflet G5.

b. Electrical engineering test equipment, including stop watches and compasses, which are recalibrated under the regulations given in AP3413.

c. Petroleum fuels, oils, lubricants and associated products (POL), for which samples are to be submitted in accordance with AP3160, Vol 2, Leaflet C1.

Periodicity of Recurrent Checks

12. The periodicity of checks and recalibration of mechanical test equipment, measuring equipment, and gauges (including armament gauges) is to be based on the *usage* of the item. Experience has shown that check and recalibration *once each year* is adequate for items in

normal use. Items used only on rare occasions may require checking at *less frequent intervals,* whereas items subject to heavy usage, or those which are used in conditions detrimental to their continued accuracy, will almost certainly require to be checked *more frequently.* Quality Assurance Officers (QAOs), or officers in charge of engineering sections, armament sections, or workshops are to determine the periodicity in the light of local conditions and usage. Whenever an item is damaged, or is suspected of inaccuracy, it is to be withdrawn from use until its accuracy has been certified.

Application for Test or Recalibration

13. **Routine recurrent tests.** Ordinary tests or recalibrations are to be carried out (at the intervals set in accordance with paragraph 12, or as authorized in relevant technical publications) in certain test centres, standards rooms, or calibration laboratories established in the Royal Air Force or elsewhere. Applications for test are to be submitted on RAF Form 3811 (Application for Test or Recalibration) — *see* Fig 26.6 — the Form being forwarded to QAS Test Centres located at RAF Stafford and RAF Akrotiri. Stafford serves units in the United Kingdom, Germany, and Gibraltar, whilst Akrotiri serves appropriate units overseas. Four copies of the form are to be raised: one is for retention, and the other three are to be dispatched, with the item(s) for test, to the Unit Supply Squadron. The Unit Supply Squadron will then take action in accordance with AP 830 Vol 1 (6th Ed), Part 2, Leaflet BG 13/1.

ROYAL AIR FORCE

RAF Form 3811
(Revised Nov 1972)

APPLICATION FOR TEST OR CALIBRATION

UNIT REFERENCE ________ DATE ________ SERIAL No

TO:	FROM:	FOR USE OF TEST ESTABLISHMENT ONLY
		Allocated to ________ Laboratory
		Test No ________ Date ________
		Sample Ref ________ Date ________
		Completed ________ Date ________
	TELEPHONE No.	Test Report No ________

RAF EQUIPMENT IDENTIFICATION			MATERIAL, PART, INSTRUMENT, IDENTIFICATION				
Reference No.	Item Identification	Number of samples submitted	Identification Mark on Each Sample	Drawing No. Part No.	Specification Reference	Manufacturer or Supplier of Samples	Contract Order or Batch No

Reasons for Tests: (in the case of P.O.L., if special tests are required, full details of the source(s) of the samples, and the circumstances which give rise to their submission, are to be given below).

Details of Tests Required (including for Petrol, Oils and Lubricants any additional information called for by AP 3160).

Signed ________

Command or MOD Authy ________

D8721 344938 2,000 Pads 12.74 O.Ltd. Gp.844

Fig 26.6 RAF Form 3811 – Application for test or recalibration

14. **Special tests.** When tests are required to determine physical properties of materials, or special tests or recalibrations are required to support some special facility, or to meet a specialist requirement in support of the operational role of the RAF, the requirement is to be submitted to DQAS (RAF) by units in the United Kingdom and Gibraltar, and CQAOs NEAF or Germany for appropriate units overseas. The submission is to be made on RAF Form 3811 (Fig 26.6) before any formal request is made to any test or recalibration establishment. Initially two copies of the form are to be despatched to DQAS (RAF) or CQAO as appropriate. On receipt of the forms, DQAS (RAF)/CQAO will decide where the test is to be undertaken and will return one copy with the information and approval. Thereafter, three copies of the form are to be raised and passed, with the material for test, to the Unit Supply Squadron for action in accordance with AP 830 Vol 1 (6th Ed), Part 2, Leaflet BG 13/1.

15. **Preparation of RAF Form 3811.** There are two important points which must not be overlooked when preparing RAF Forms 3811 (*see* Fig 26.6):

a. All RAF Forms 3811 are to be given a *serial number,* in addition to the unit reference number. This is to prevent any subsequent difficulty in relating the test result to its appropriate request, if it is one of a series.

b. All items, other than non-rationalized armament gauges and materiel for physical test, are considered to be submitted *on loan for test.* It is important that they should be readily identifiable as items on loan for test because, if they are not, they can very easily be taken into the stock of the unit to which they are consigned. This especially applies when the QAS test centre is located at a station which also serves a Maintenance Unit. Therefore, to ensure proper registering and accounting, all items for test, and their associated RAF Forms 3811, are to be prominently marked *'For the Attention of the Unit Supply Squadron'.*

Identification and Recording

16. Test equipment is to be identified by *serial numbers,* and equipment which does not bear a *manufacturer's* serial number is to be marked with a unit serial number.

A record of serviceability and date of test is to be kept on RAF Form 2976 ('Precision Equipment Record Card') — one for each item (*see* Fig 26.7). The Form 2976 is to accompany the equipment when submitted for test, or returned to an equipment supply depot for storage.

Section	Reference No.	QAS Unit Serial No.	Nomenclature	Card Serial No.

Inspection Periodicity			
Period	Authorised By	Date	Rank

RAF Form 2976
(Revised May, 1959)

PRECISION EQUIPMENT RECORD

Holder

Unit: | Flight/Section:

Test Specification/Drawing

Date		Errors at Position					General Condition, and Corrections or Adjustments made	Inspector's Stamp
Due	Inspected							

Continued overleaf

Fig 26.7 RAF Form 2976

A *card index* is to be maintained for progressing the periodic submission of test equipment for checking.

Accounting Procedure

17. AP 830 Vol 1 (6th Ed), Part 2, Leaflet BG 13/1 details the accounting procedure to be followed when equipment is sent for test or recalibration. When this is effected by *direct exchange,* no equipment accounting procedures are involved.

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