NEAR EAST UNIVERSITY

FACULTY OF ENGINEERING

Department of Electrical & Electronic Engineering

ELECTRICAL INSTALLATION OF NEAR EAST VILLAGE

Graduation Project
EE- 400

Bassel Ghuneim (970858)

Assist. Prof. Dr Kadri BÜRÜNCÜK

Nicosia- 2001

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This project is concerned with the ELECTRICAL INSTALLATION and was done under the supervision of Assist. Prof. Dr. Kadri BÜRÜNCÜK who thankfully gave me the basis to face such a subject in the practical life and supported me with the enough information needed for a beginner engineer to have it and more than that even.

ABSTRACT

The material of this project contains a background knowledge of the field of electrical installation engineering. This field is now emerging from obscurity and is being recognised as an important branch of electrical engineering and of the construction industry.

The contents of this project are aimed to those fresh engineers whose work lies more in the field of electrical maintenance.

Dedication

To my Dad and Mom who are giving me endless love, courage and hope to go ahead successfully in my life.

To all those who helped me by either way.

Bassel Hassan Ghuneim

CHAPTER ONE

GENERALS

1.1 CAREER OF THE ELECTRICIAN

Thoroughly how the spectacular increase in the use of electrical energy for virtually all-domestic and industrial purposes over the half past century or so is proof enough that the electrical industry plays a most prominent part in the economy of the country. The range of careers, which the industry offers, is extremely wide. But whatever the career, a fundamental knowledge of electrical engineering, its science and its technology, is necessary for any progress in the the career.

The electrician of today plays perhaps one of the most important roles within the electrical industry, and not only in the matter of providing a labor force of skills and abilities on many levels. He is definitely a key man with a fair degree of responsibility for work which can be carried out satisfactorily only with a background of sound technical knowledge.

Whatever the particular field of employment-supply, manufacturing or contracting-possession of technical knowledge forms the basis for the performance of the many varied tasks which today's electrician is called on by industry and the householder to do and do well.

Today's electrician works in the supply industry to provide services associated with the generation, transmission and distribution of electrical energy. The 'link man' between the supply industry and the user of electricity is the electrician employed in the vast filed of employment known as contracting industry. The function of electrical wiring basically to carry electrical energy to a point of use where it is converted into some other forms of energy: light, heat or mechanical power.

Wiring and so the contracting electrician thus occupies the unique position of being an essential link between the supply authorities on the one hand and the makers and the users of all kinds of appliances and apparatus on the other. Once, in years gone by, the idea existed that 'wiring' was hardly a respectable occupation for any but those without technical qualifications. The image has changed, however, and the electrician of today is required to have a minimum certificate to indicate his ability to do his job to a certain standard.

Indeed, in some countries overseas, it is impossible for anyone to setup a career as an electrician unless he has passed a theoretical and practical examination, which is a legal requirement.

Electricity is more than a national asset. It has a deep social importance. It has been the main influence for good in the field of improvement in our standards of living. Electricity has proved to be the most flexible form of power in existence; it can be generated easily and transmitted to whatever or whoever requires it, and in whatever quantity it may be required. The historian Trevelyan has said that the social scene grows out of economic conditions. It is true to say that with the aid of electricity, a livelihood and a way of life without drudgery have been won, with an attendant enrichment of the social scene. That electricity is now commonplace in out lives is proved by the fact that the ordinary user regards it as essential to his daily life and living, and his work, and accepts it completely without question.

Offering, as it does to the user, a clean and effortless way of life, electricity also offers to the electrician a means whereby an interesting and satisfying living can me made. The opportunities available are legion, but particularly to those who qualify for promotion by study. Emphases nowadays placed on the possession of some minimum qualifications are so insistent that progress in any electrical career is virtually impossible without it. But theory alone is not enough. Practical experience is also a vital necessity, for not only must a job be done, but also it must be understood and why it is done.

1.2: HISTORICAL REVIEW OF INSTALLATION WORK:

As one might expect to find in the early beginnings of any industry, the application, and the methods of application, of electricity for lighting, heating and motive power was primitive in the extreme. Large-scale application of electrical energy was slow to develop. The first wide use of it lighting in houses shops and offices. By the 1870s, electric lighting had advanced from a curiosity to something with a definite practical future. Arc lamps were the first form of lighting, particularly for the illumination of main streets. When the incandescent-filament lamp appeared on the scene electric lighting took on such a prominence that it severely threatened the use of gas for this purpose. But it was not until cheap and reliable metal-filament lamps were produced that electric lighting found a place in every home in the land. Even then, because of the low power of these early filament lamps, shop windows continued for some time to be lighted externally by arc lamps suspended from the fronts of buildings.

The earliest application of electrical energy as an agent for motive power in industry is still electricity's greatest contribution to industrial expansion. The year 1900 has been regarded as a time when industrialists awakened to the potential of the new form of power.

Electricity was first used in mining for pumping. In the iron and steel industry, by 1917, electric furnaces of both the arc and induction type were producing over 100,000 tons of ingots and castings. The first all-welded ship was constructed in 1920; and the other ship- building process was operated by electric motor for punching, shearing, drilling, machines and wood working machinery.

The first electric motor drives in light industries were in the form of one motor-unit per line of shafting. Each motor was started once a day and continued to run throughout the whole working day in one direction at a constant speed. All the various machines driven from the shafting were started, stopped, reversed or changed in direction and speed by mechanical means. The development of integral electric drives, with provisions for starting, stopping, and speed changes, led to the extensive use of the motor in small kilowatt ranges to drive an associated single machine e.g. a lathe. One of the pioneers in the use of motors was the firm of Bruce Peebles, Edinburgh. The firm supplied, in the 1890s, a number of weatherproof, totally enclosed motors for quarries in Dumfries-shire, believed to be among the first of their type in Britain. The first electric winder ever built in Britain was supplied in 1905 to a lanark oil concern. Railway electrification started as long ago as 1883, but it was not until long after the run of this century that any major development took place. Electrical installations in the early days were quite primitive and often dangerous. It is on record that in 1881; an aristocratic amateur carried out the installation in Hatfield House. That the installation was dangerous did not perturb visitors to the house.

Many names of the early electrical pioneers survive today. Julius Sax began to make electric bells in 1885, and later supplied the telephone with which Queen Victoria spoke between Osborne and and Southampton in 1878. He founded one of the earliest purely electrical manufacturing firms which exists today and still makes bills and signaling equipment.

The General electric Company had its origins in the 1880s, as a company, which was able to supply every single item, which went to form a complete electrical installation.

In addition it was guaranteed that all components offered for sale were technically suited to each other, were of adequate quality and were offered at economic price.
Specializing in lighting, Falk Stadelmann & Co. Ltd began by marketing improved designs of oil lamps, then gas fittings, and ultimately electric lighting fittings.

Cable makers W.T. Glover & Co were pioneers in the wire field. Gover was originally a designer of textile machinery but by 1868 he was also making braided steel wires for the fashionable crinolines. From this type of wire it was natural step to the production of insulated conductors for electrical purposes. At the curtail Palace Exhibition in 1885 he shoed a great range of cables; he was also responsible for the wiring of the exhibition.
The well know J. &P firm began with making telegraphic equipment, extended to generators and arc lamps, and then to power supply.

The coverings for the insulations of wires in the early days included textiles and gutta-percha. Progress in insulation provisions for cables was made when vulcanized rubber was introduced, and it is still used today. Seimens Brothers made the first application of a lead sheath to rubber-insulated cables. The manner in which we name cables was also a product of Seimens, whose early system was to give a cable of certain length related to a standard resistance of 0.1 ohm.

For many years ordinary VRI cables made up about 95% of all installations. They were used first in wood casing. And then in conduit. Wood casing was a very early invention. It was introduced to separate conductors. this separation being considered a necessary safe guard against the two wires touching and is causing fire. Choosing a cable at the run of the century was quite a task. From one catalogue alone, one could choose from fifty-eight sizes of wire, with no less than fourteen different grades of rubber insulation. The grades were described by such terms as light, high, medium or best insulation. Nowadays there are two grades of insulations: up to 600 V and 600 V/ 1000 V. And the sizes of cables have been reduced to a more practicable seventeen.

During the 1890s, the practice of using paper as an insulating material for cables as well established. One of the earliest makers was the company, which later became a member of the present-day BICC Group. The idea of using paper as an isolation material came from America to Britain where it formed part of the first wiring system for domestic premises. This was twin lead sheathed cables. Bases for switches and other accessories associated with the system were of cast solder, to which the cable sheathing was wiped, and then al joints sealed with a compound. The compound was necessary because of the paper insulation when dry tends to absorb moisture.

In 1911, the famous 'Henley Wiring System' came on the market. It comprised flat-twin cables with a lead alloy sheath. Special junction boxes, if properly fixed, automatically affecting good electrical continuity. The insulation was rubber. Indeed, it proved so easy to install that a lot unqualified people appeared on the contracting scene as electricians. When it received the approval of IEEE Rules, it became an established wiring system and is still in the use today.

At the time lead-sheathed system made its first appearance, another rival wiring system came onto the scene. This was the CTS system (cab-tire sheathed). It arose out of the idea that if a rubber product could be used to stand up to the wear and tear of motor car tires on roads, then the material would well be applied to cover cables. The CTS name eventually gave way to TRS (tough-rubber sheath), when the rubber sheathed cable system came into general use.

The main competitor to rubber as an insulating material appeared in the late 1930s. This material was PVC (polyvinylchloride), a synthetic material which came from

Germany. The material, tough concerned, could withstand the effects of both oil and sunlight. During the Second world War PVC used both as wire insulation and the protective sheath, became well established.

As experience increased with the use of TRS cables, it was made the basis of modified wiring systems. The first of these was the Calendar farm-wiring system introduces in 1937. This was tough robber sheathed cables with a semi-embedded abiding treated with green- colored compound. This system combined the properties of ordinary TRS and HSOS (house-service overhead system) cables.

So far as conductor material was concerned, copper was the most widely used. But aluminum was also applied as a conductor material. Aluminum, which has excellent electrical properties, has been produced on a large commercial scale since about 1890. Overhead lines of aluminum were first installed in 1898. Rubber-insulated aluminum cables of 3/0.036 inch and 3/0.045 inch were made to the order of the British aluminum Company and used in the early years of this century for the wiring of the staff quarters at Kinlochleven in Argyll shire. Despite the fact that the lead and the lead-alloy proved to be of great value in the sheathing of cables, aluminum was looked to for a sheath of, in particular, light weight. Many experiments were carried out before a reliable system of aluminum-sheathed cable could be put on the market.

Perhaps one of the most interesting systems of wiring to come into existence was the MICS (mineral-insulated copper0sheathed cable), which used compressed magnesium oxide as the insulation, and had a copper sheath and copper conductors. The cable was first developed in 1897 and was first produced in France. It has been made in Britain since 1937, first by Pyrontenax Ltd, and later by other firms. Mineral insulation has also been used with conductors and sheathing of aluminum.

One of the first suggestions for steel used for conduit was made in 1883. It was then called 'small iron tubes'. However, the first conduits were of itemized paper. Steel for conduits did not appear on the wiring scene until about 1895. The revolution in conduit wiring dates from 1897, and is associated with the name 'simplex' which is common enough today. It is said that the inventor, L. M. Waterhouse, got the idea of close-joint conduit by spending a leeples night in a hotel bedroom staring at the bottom rail of his iron bedstead. In 1898 he began the production of light gauge close-joint conduits. A year later the screwed-conduit system was introduced.

Non-ferrous conduits were also a feature of the wiring scene. Heavy-gauge copper tubes were used for the wiring of the Rylands Library in Manchester in 1886. Aluminum conduit, though suggested during the 1920s, did not appear on the market until steel became a valuable material for munitions during the Second World War.

Insulated conduits were also used for many applications in installation work, and are still used to meet some particular installation conditions. The 'Gilflex' system, for instance, makes use of a PVC tube, which can be bent cold, compared with the earlier material, which required the use of heat for bending.

Accessories for use with wiring systems were the subject of many experiments\many interesting designs came onto the market for the electrician to use in his work. When lighting became popular, there arose a need for the individual control of each lamp from its own control point. The 'branch switch' was used for this purpose. The term switch came over to Britain from America, from railway terms, which indicated a railway 'point', where a train could be 'switched' from one set of tracks to another. The 'switch', so far as the electrical circuit was concerned, thus came to mean a device, which could switch an electric current from one circuit to another.

It was Thomas Edison who, in addition to pioneering the incandescent lamp, gave much thought to the provision of branch switches in circuit wiring. The term 'branch' meant a tee-off from a main cable to feed small current-using items. The earliest switches were of the 'turn' type, in which the contracts were wiped together in a rotary motion to make the circuit. The first switches were really crude efforts: made of wood and with no positive ON or OFF position. Indeed, it was usual practice to make inefficient contact to produce an arc to 'dim' the lights! Needless to say, this misuse of the early switches, in conjunction with their wooden construction, led to many fires. But new materials were brought foreword for switch construction such as slate, marble, and later porcelain. Movements were also made more positive with definite ON and OFF positions. The turn 'switch' eventually gave way to the 'tumbler' switch in popularity. It came into regular use about 1890. Where the name 'tumbler' originated is not clear; there are many sources. Including the similarity of the switch action to the antics of tumbler Pigeons. Many accessory names, which are household words to the electricians of today, appeared at the turn of the century.

It was one thing to produce a lamp operated from electricity. It was quite another thing to devise a way in which the lamp could be held securely while current was flowing in its circuit. The first lamps were fitted with wire tails for joining to terminal screws. It was Thomas Edison who introduced, in 1880, the screw cap, which still bears his name. It is said he got the idea from the stoppers fitted to kerosene cans of the time. Like many another really good idea, it superseded all its competitive lamp holders and its use extended through America to Europe. In Britain, however, it was not popular. The Edison & Swan Co about 1886 introduced the bayonet-cap type of lamp holder. The early type was soon improved to the lamp holders we know today.

Ceiling roses, too, have an interesting history; some of the first types incorporated fuses. The first rose for direct attachment to conduit came out in the early 19000s, introduced by dorman &Smith Ltd.

Only Lord Kelvin, a pioneer of electric wiring accessories, brought the first patent for a plug-and-socket. The accessory was used mainly for lamp loads at first, and so carried very small currents. However, domestic appliances were beginning to appear on the market, which meant that sockets had to carry heavier currents. Two popular items were irons and curing-tong heaters. Crompton designed shuttered sockets in 1893. The modern shuttered type of socket appeared as a prototype in1905, introduced by 'diamond H'. Many sockets were individually fused, a practice, which was later, extended to the provision of a fuse in the plug. These fuses were, however, only a small piece of wire between two terminals and caused such a lot of trouble that in 1911 that the Institution of Electrical engineers banned their use. One firm, which came into existence with the socket-and-plug, was M.K. Electric Ltd. The initials were for 'Muti-Kontakt' and associated a type of a socket-outlet, which eventually became the standard design for this accessory. It was Sholes, under the name of 'Wylex', who introduced a revolutionary design of plug-and-socket: a hollow circular earth pin and rectangular currents-carrying pins. This was really the first attempt to 'polarize', or to differentiate between live, earth and neutral pins.

One of the first earliest accessories to have a cartridge fuse incorporated in it was the plug produced by Dorman & Smith Ltd. The fuse actually formed one of the pins, and could be screwed in or out when replacement was necessary. It is a rather long cry from those pioneering days to the present system of standard-socket and plugs.

Early fuses consisted of lead wires; lead being used because of its low melting point. Generally, devices which contained fuses were called 'cutouts', a term still used today for the item in the sequence of supply-control equipment entering a building. Once the idea caught on of providing protection for a circuit in the form of fuses, brains went to work to design fuses and fuse gear. Control gear first appeared incased in wood. But ironclad versions made their due appearance, particularly for industrial use during the nineties. They were usually called 'motor switches', and had their blades and contacts mounted on a slate panel. Among the first companies of the switchgear field were Bill & Co and the MEM CO., whose 'kantark' fuses, are so well known today. In 1928 this company introduced the 'splitter', which affected a useful economy in many of the smaller installations.

It was not until the 1930s that the distribution of electricity in buildings by means of bus bars came into fashion, though the system had been used as far back as about 1880, particularly for street mains. In 1935 the English Electric Co introduced a bus bar trunking system designed to meet the needs of motor0car industry. It provided the overhead distribution of electricity into which system individual machines could be tapped wherever required; this idea caught on and designs were produced and put onto the market by Marryat &Place, GEC and Ottermills.

Trunking came into fashion mainly because the larger sizes of conduit proved to be expensive and troublesome to install. One of the first trunking types to be produced was the 'spring conduit' of the Manchester firm of Key Engineering. They showed it for the first time at an electrical exhibition in 1908. It was semi-circular steel throughing in edges formed in such a way that they remained quite secure by a spring action after being pressed into contact. But it was not until about 1930 that the idea took root and is now established as a standard wiring system.

The story of electric wiring, its systems and accessories tells an important aspect in the history of industrial development and in the history of social progress. The inventiveness of the old electrical personalities, Crompton, Swan, Edison, Kelvin and many others, is well worth nothing; for it is from their brain-children that the present-day electrical contracting industry has evolved to become one of the most important sections of activity in electrical engineering. Any comparison of manufacturers' catalogues of, say, ten years ago, with those of today quickly reveal how development of both wiring systems and wiring accessories have changed, not only physically, in their design and appearance but in their ability to meet the demands made on them of modern electrical installations, both domestic and industrial. What were once innovations, such as dimmer switches, for instance, are now fairly commonplace where clients require more flexible control of domestic circuit. The new requirements of the Regulations for Electrical Installation will no doubt introduce more changes in wiring systems and accessories so that installations became safer to use with attendant reductions in the risk from electric shock and fire hazards. New developments in lighting, for instance, particularly during the last decade or so, herald changes in the approach to install work. Innovative changes in space and water heating, using solar energy and heat pumps, will involve the electrician in situations which can offer exciting challenges in installation work, not least in keeping up with the new face of technology. More and more is the work of the electrician becoming an area of activity where a thorough grasp of the technology involved is essential if one is to offer the client a safe, reliable and technically competent installation.

1.3 HISTORICAL REVIEW OF WIRING REGULATIONS:

The history of the development of non-legal and statutory rules and regulations for the wiring of buildings is no less interesting than that of wiring systems and accessories. When electrical energy received a utilization impetus from the invention of the incandescent lam, many set themselves up as electricians or electrical wiremen. Others were gas plumbers who indulged in the installation of electrics as a matter of normal course. This was all very well: the contracting industry had to get started in some way, however ragged. But with so many amateurs troubles were bound to multiply. And they did. It was not long before arc lamps, sparking commutators, and badly insulated conductors contributed to fires. It was the insurance companies, which gave their attention to the fire risk inherent in the electrical installations of the 1880s. Foremost among these was the Phoenix Assurance Co., whose engineer Mr. Heaphy, was told to investigate the situation and draw up a report on his findings.

The result was the Phoenix Rules of 1882. These rules were produced just a few months after those of the American board of Fire Underwriters who are credited with the issue of the first wiring rules in the world.

The Phoenix rules were, however, the better set and went through many editions before revision was thought necessary. That these rules contributed to a better standard of wiring, and introduced a high factor of safety in the electrical wiring and equipment of buildings, was indicated by a report in 1892, which showed the high incidence of electric fires in the USA and the comparative freedom from fires of electrical origin in Britain.

Three months after the issue of the Phoenix Rules for wiring in 1882, the Society of Telegraph Engineers and electricians (now the IEEE) issued the first edition of Rules and Regulations for the Prevention of fire Risks arising from electric Lighting. These rules were drawn up by a committee of eighteen men, which included some of the famous names of the day: Lord Kelvin, Siemens, and Crompton. The rules, however, were subjected to some criticism. Compared with the Phoenix rules they left much to be desired. But the society was working on the basis of lying down a set of principles rather than, as Heaphy did, drawing up a guide or 'Code of Practice'.

The rules have since been revised at fairly regular intervals as new developments and the result of experience can be written for the considered attention of those all concerned with the electrical equipment of buildings. Basically the regulations were intended to act as a guide for electricians and others to provide a degree of safety in the use of electricity by inexperienced persons such as householders. The regulations were and still are, not legal; that is, the law of the land cannot enforce them. Despite this apparent loophole, the regulations are accepted as a guide to the practice of installation work, which will ensure, at the very least, a minimum standard of work.

The IEEE was not alone in the insistence of good standards in electrical installation work.

While the IEE and the Statutory regulations were making positions stronger, the British Standards Institution brought out, and is still issuing Codes of Practice to provide what are regarded as guides to good practice. The position of the Statutory Regulations in Britain s that they form the primary requirements, which must by law be satisfied. The IEE Regulations and Codes of Practice indicated supplementary requirements. However, it is accepted that if an installation is carried out in accordance with the IEE Wiring Regulations, then it generally fulfils the requirements of the Electricity Supply Regulations. This means that a supply authority can insist upon all electrical work to be carried out to the standard of IEE Regulations, but can not insist on a standard which is in excess of the IEE requirements.

The positions of IEE regulations, is that f being the installation engineer's 'bible'. Because of the regulations cover the whole field of installation work, and f they are all compiled with, it is certain that the resultant electrical installation will meet the requirements of all interested parties. There are, however, certain types of electrical installations, which require special attention to prevent fires and accidents. These include mines, cinemas, theaters, factories and places where there are exceptional risks. The following list gives the principal regulations, which cover electricity supply and electrical installations:

Non-Statutory regulations:

1) Institute of electrical Engineers Regulations for Electrical Installations – This covers industrial and domestic electrical installation work in buildings.
2) The Institute of Petroleum Electrical code, 1963- this indicates special safety requirements in the petroleum industry, including protection from lighting and static. It is supplementary to the IEE Regulations.
3) Factories Ac, 1961. Memorandum by the senior electrical Inspector of Factories- Deals with installations in factories.
4) Explanatory Notes on the Electricity Supply Regulations, 1937- these indicate the requirements governing the supply and the use of electricity.
5) Hospital Technical Memoranda- indicates the electrical services, supply and distribution in hospitals.

Statutory Regulations:

1) Building Act, 1959- provides for minimum standards of construction and materials including electrical installations.
2) Building Standards Regulations, 1981- Contains minimum requirements for electrical installations.
3) Electricity supply Regulations, 1937- indicates the requirements governing the supply and the use of electricity and deals with the installations generally, subject to certain exemptions.
4) Electricity special Regulations, 1908 and 1944- Deals with factory installations, installations on constructions sites, and installations of non-domestic caravans such as mobile workshops. These regulations come under the authority of the Health and Safety Commission.
5) Coal and other Mines Regulations, 1956- Deals with coalmine installations.
6) Cinematograph Regulations, 1952- Deals with installations in cinemas.
7) Quarries Regulations, 1956- Deals with the installations at quarry operations.
8) Agriculture Regulations, 1959 – Deals with agricultural and horticultural installations.

Though these Statutory Regulations are concerned with electrical safety in the respective type of installations listed, there is other Statutory Regulation, which are also concerned with electrical safety when equipment and appliances are being used. Included in these is the Electricity at Work Regulations, which came into force on 1990. They are signet in their requirements that all electrical equipments used in schools, colleges, factories and other places of work is in a safe condition and must be subjected t regular testing by competent persons.

It should be noted that in addition to the above list, there are a quite a number of Statutory Regulations which deal with specific types of installations such as caravans and petrol stations.

CHAPTER TWO

CONDUCTORS AND CABLES

Introduction:

A ‘conductor’ in electrical work means a material which will allow the free passage of an electric current along it and which presents very little resistance to the current. If the conducting material has an extremely low resistance (for instance copper conductor) there will be only a slight warming effect when the conductor carries a current. If the conductor material has a significant resistance (for instance iron wire) then the conductor will show the effects of the electric currents passing through it, usually in the form of an appreciable rise in temperature to produce a heating effect.

A ‘cable’ is defined as a length of insulated conductor (solid or stranded), or of two or more such conductors, each provided with its own insulation, which are laid up together. The conductor, so far as a cable is concerned, is the conducting portion, consisting of a single wire or of a group of wires in contact with each other. The practical electrician will meet two common conductor materials extensively in his work: copper and aluminum.

As a conductor of electricity, copper has been used since the early days of the electrical industry because it has so many good properties. It can cope with onerous conditions. It has a high resistance to atmospheric corrosions. It can be jointed without any special provision to prevent electrolytic action. It is tough, slow to tarnish, and is easily worked. For purposes of electrical conductivity, copper is made with a very high degree of purity (at least 99.9 %). In this condition it is only slightly inferior to silver.

Aluminum is now being used in cables at an increasing rate. Although reduced cost is the main incentive to use aluminum in most applications, certain other advantages are claimed for this metal. For instance, because aluminum is pliable, it has been used in solid-core cables. Aluminum was used as a conductor material for overhead lines about 70 years ago, and in an insulated form for buried cables at the turn of the century. The popularity of aluminum increased rapidly just after the Second World war, and had now a definite place in the electrical work of all kinds.

2.1: Conductors:

Conductors are found in electrical work are most commonly in the form of wire or bars and rods. There is other variation, of course, such as machined sections for particular electrical devices. Generally, wire has a flexible property and is used in cables. Bars and rods, being more rigid, are used as bus bars and earthelectrodes. In special form, aluminum is used for solid-core cables.

Wire for electrical cables is made from wire bars. Each bar is heated and passed through a series of grooved rollers until it finally emerges in the form of a round rod. The rod is then passed through a series of lubricated dies until the final diameter of wire is obtained. Wires of the sizes generally used for cables are hard in temper when drawn and so are annealed at various stages during the transition from wire-bar to small0 diameter wire. Annealing involves placing coils of the wire in the furnaces for a period until the metal becomes soft or ductile again.

Copper wires are often tinned. This process was first used in order to prevent the deterioration of the rubber insulation used on the early cables. Tin is normally applied by passing the copper wire through a path containing molten tin. With the increasing use of plastics materials for cable insulation there was a tendency to use unpinned wires. But now many manufacturers tin the wires as an aid in soldering operations. Untined copper wires are, however, quite common. Aluminum vaires need no further process after the final drawing and nealing.

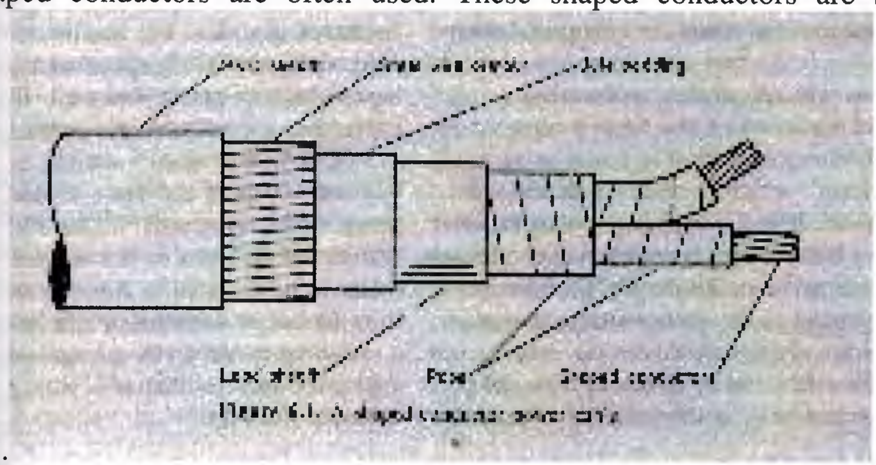
All copper cables and some aluminum cables have conductors, which are made up from a number of wires. These conductors are of two basic types: stranded and bunched. The latter type is used mainly for the smaller sizes of flexible cable and cord. The solid-core conductor in the small sizes is merely one single wire.

Most stranded conductors are built up on a single central conductor. Surrounding this conductor are layers of wires in a numerical progression of 6 in the first layer, 12 in the second layer, 18 in the third layer and so no. The number of wires contained in most common conductors is to be found in the progression 7, 19, 37, and 61, 127.

Stranded conductors containing more than one layer of wires are made in such a way that the direction of lay of the wires in each layer is of the reverse hand to those of adjacent layers. The flexibility of these layered conductors is good in the smaller sizes (e.g. 7/0.85 mm) but poor in the larger sizes (e.g. 61/2.25mm).

When the maximum amount of flexibility is required, the 'bunching' method is used. The essential difference of this method from 'stranding' is that all the wires forming the conductor are given the same direction of lay. A further improvement in flexibility is obtained by the use of small-diameter wires, instead of the heavier gauges as used in stranded cables.

When more than one core is to be enclosed within a single sheath, oval and sector-shaped conductors are often used. These shaped conductors are shown in figure



4.1.

It is of interest to note that when working out the dc resistance of stranded conductors, allowance must be made for the fact that, apart from the central wire, the individual strands in a stranded conductor follow a helical path- and so are slightly longer than the cable itself. The average figure is 2%. This means that if a stranded conductor is 100 m long, only the center strand is this length. The other wires surrounding it will be anything up to 106 m in length.

Because aluminum is very malleable, many of the heavier cables using this material as the conductor have solid cores, rather than stranded. A saving in cost is claimed for the solid- core aluminum conductor cable.

Conductors for overhead lines are often strengthened by a central steel core, which takes the weight of the copper conductors between the poles or pylons. Copper and aluminum are used for overhead lines.

Conductor sizes are indicated by their cross-sectional areas (csa). Smaller sizes tend to be single strand conductors; larger sizes are stranded. Cable sizes are standardized, starting at 1 mm square, increasing to 1.5, 2.5, 4, 6, 10, 16, 25 and 35 mm squared. As cable sizes increase in csa the gaps between them also increase. The large size of armored mains cable from 25 mm squared tends to have shaped stranded conductors.

2.2: Insulators

Many materials are used for the insulation of cable conductors. The basic function of any cable insulation is to confine the electric current to a definite path: that is: to the conductor only. Thus, insulating materials chosen for this duty must be efficient and able to withstand the stress of the working voltage of the supply system to which the cable is connected. The following are some of the more common materials used for cable insulation:

Rubber: this was one of the most common insulating materials until it was largely replaced by PVC. In old wiring systems it is found in its 'vulcanized form', which is rubber with about 5 % sculpture. It is flexible, impervious to water but suffers (it hardens and becomes brittle) when exposed to a temperature above 55 centigrade. Because the sulphur content in the rubber attacks copper, the wires are always tinned. About the only application for rubber as an insulation material for conductors nowadays is in domestic flexible used for hand appliances such as electric irons. The working temperature is 60 centigrade.

85 centigrades Rubber. This material is a synthetic rubber designed for working temperatures up to 85 centigrade it is in its flexible cord format used for hot situations such as immersion heaters and night storage heaters where the heat from elements can travel into flexi bible conductors. As a sheathing material it is susceptible to oil and grease and thus such flexible are sheathed with chloro-sulphonated polyethylene (CSP). This type of sheath is known as HOFR (heat and oil resisting and flame retardant). Often used for heavy-duty applications, it is found in its larger csa sizes feeding exterior equipment such as mobile cranes and conveyors.

Silicon rubber. This material is sometimes designated 150-centigrade insulation and can operate in a continuous temperature up to that level. Application one free-resistant cable include the wiring of the fire alarm, security and emergency lighting circuits where there is a need for these circuits to function in fire conditions. It is also useful when connections have to be made to terminals in enclosures in which heat might be considerable, such as in enclosed lamp fittings and heaters.

PVC. This material is polyvinyl chloride and is now the most common insulation material used for cables and flexible at low voltages. Its insulating properties are actually less than those for rubber. However it is impervious to water and oil and can be self-colored without impairing its insulation resistance qualities. The maximum working temperature is 70 centigrade, above which the PVC will tend to become plastic and melt. if PVC is exposed to a continuous temperature of around 115 centigrade it will produce a corrosive substance, which will attack copper and brass terminals. At low temperature, around 0 centigrade, the PVC tends to become brittle and is not recommended for PVC cables to be installed in freezing conditions. Apart from its use as a conductor insulation, it is used as a sheathing material. In most common form is in the cables used for domestic wiring and so for domestic flexible.

Paper. Paper has been used as an insulating material from the very early days of the electrical industry. The paper, however, is impregnated to increase its insulating qualities and prevent its being impaired by moisture. Paper-insulated cables usually of the large csa sizes, are terminated in cable boxes sealed with resin, or compound, to prevent the ingress of moisture. The cables are sheathed with lead and armored with steel or aluminum wire or tape. Such cables are mainly used for large loads at high voltages.

Mineral insulation. This is composed of magnesium oxide power and is used in the type of cable known as MIMS (mineral-insulated metal-sheathed) with the sheath usually made from copper. It was originally developed to withstand both fire and explosion, but is now used for more general applications. The cable is non-ageing and can be operated with sheath temperatures of up to 250 centigrade. Because the magnesium oxides hygroscopic (it absorbs moisture) the cables ends must always be sealed. The temperature limits of the seals depend on the cable's application.

Glass insulation. This material is very heat-resistant and is used for temperatures as high as 180 centigrade. As glass-fiber braiding. This insulation is found commonly in the internal wiring of electric cookers or other appliances where the cable must be impervious to moisture, resistant to heat and be tough and flexible.

2.3: Protection:

Sheathing. Only in exceptional circumstances does the insulation of a conductor offer some protection against attacks by water, oils, acids, and mechanical damage. Thus, it is common practice to protect the insulated conductor by a sheath or covering of some material which will enable the cable to be used in situations where some physical damage might result.

The basic purpose of the sheath is to prevent moisture from reaching the insulated core of the cable when in service. This implies that the sheath be impervious and resistant to corrosion. Once applied, a sheath must be sufficiently pliable to withstand a number of coiling and straightening operations during cable installation. Sheathing materials vary considerable, and are usually associated with the type of material used for conductor installation PVC-insulated conductors are sheathed with the same material. Mineral insulated conductors are enclosed within a metal sheath which can be copper (MICS) or aluminum (MIAS). Paper-insulated cables generally have lead-alloy sheath. Aluminum conductors are used are used with aluminum sheaths.

In many instances, the metal sheathing and armoring of cables are used to act as a conductor for earth-leakage currents.

Sometimes the wiring system acts as a sheath to protect against damage to the cables. For instance, conduit protects PVC-insulated cables and the cables need not be provided with a sheath.

Armoring. In certain circumstances it is necessary for a cable to be protected against the occurrence of machine damage. Protection by 'armoring' is defined as the provision of a 'helical' wrapping or wrappings of metal (usually wires or tapes), primarily for the purpose of mechanical protection. The type of damage against which the cable is protected is rough treatment, abrasion, collision. The materials used, in tae or wire form, for armoring cables is most often steel. But aluminum is also used.

2.4: Cable Types

The range of types of cables used in electrical work is very wide: from heavy lead-sheathed and armored paper-insulated cables to the domestic flexible cable used to connect a hair-drier to the supply. Lead, tough-rubber, PVC and other types of sheathed cables used for domestic and industrial wiring are generally placed under the heading of power cables. There are , however, other insulated copper conductors (they are sometimes aluminum) which, though by definitions are termed cables, are sometimes not regarded as such. Into this category fall for these rubber and PVC insulated conductors drawn into some form of conduit or trunking for domestic and factory wiring, and similar conductors employed for the wiring of electrical equipment. In addition, there are the various types of insulated flexible conductors including those used for portable appliances and pendant fittings.

The main group of cables is 'flexible cables', so termed to indicate that they consist of or more cores, each containing a group of wires, the diameters of the wires and the construction of the cable being such that they afford flexibility.

Single-core. These are natural or tinned copper wires. The insulating materials include butyl-rubber, silicon-rubber, and the more familiar PVC.

The synthetic rubbers are provided with braiding and are self-colored. The IEE Regulations recognize these insulating materials for twin-and multi-core flexible cables rather than for use as single conductors in conduit or trunking wiring systems. But that are available from the cable manufacturers for specific insulation requirements. Sizes vary from 1 to 36 mm squared (PVC) and 50 mm squared (synthetic rubbers).

Two-core. Two-core or 'twin' cables are flat or circular. The insulation and sheathing materials are those used for single-core cables. The circular cables require cotton filler threads to gain the circular shape. Flat cables have their two cores laid side by side.

Three-core. These cables are the same in all respects to single-and two-core cables except, of course, they carry three cores.

Composite cables. Composite cables are those which, in a addition to carrying the currency-carrying circuit conductors, also contains a circuit-protective conductor.

To summarize, the following group of cable types and applications are to be found in electrical work, and the electrician, at one time or another during his career, may be asked to install them.

Wiring cables. Switchboard wiring; domestic ad work shop flexible cables and cords. Mainly copper conductors.

Power cables. Heavy cables, generally lead sheathed and armored; control cables for electrical equipment. Both copper and aluminum conductors.

Mining cables. In this field cables are used for trailing cables to supply equipment; shot-firing cables; roadway lighting; lift –shaft wiring; signaling, telephone and control cables. Adequate protection and fireproofing are features of cables for this application field.

Ship-wiring cables. These cables are generally lead-sheathed and armored, and mineral-insulated, metal-sheathed. Cables must comply with Lloyd's Rules and Regulations, and with Admiralty requirements.

Overhead cables. Bare , lightly-insulated and insulated conductors of copper, copper-vadmium and aluminum generally. Sometimes with steel core for added strength. For overhead distribution cables are PVC and in most cases comply with British Telecom requirements.

Communication cables. This group includes television down-leads and radio-relay cables; radio frequency cables; telephone cables.

Welding cables. These are flexible cables and heavy cords with either copper or aluminum conductors.

Electric-sign cables. PVC-and rubber-insulated cables for high-voltage discharge lamps able to withstand the high voltages.

Equipment wires. Special wires for use with instruments, often insulated with special materials such as silicon, rubber and irradiated polythene.

Appliance-wiring cables. This group includes high-temperature cables for electric radiators, cookers and so on. Insulation used includes nylon, asbestos and varnished cambric.

Heating cables. Cables for floor-warming, road-heating, soil-warming, ceiling-heating and similar applications.

Flexible cords. A flexible cord is define as a flexible cable in which the csa of each conductor does not exceed 4 mm squared. The most common types of flexible cords are used in domestic and light industrial work. The diameter of each strand or wire varies from 0.21 to 0.31 mm. Flexible cord come in many sizes and types; for convenience they are groups as follows:

1) Twin-twisted: these consist of one single insulated stranded conductors twisted together to form a core-cable. Insulation used is vulcanized rubber and PVC. Color identification in red and black is often provided. The rubber is protected by a braiding of cotton, glazed-cotton, rayon-barding and artificial silk. The PVC-insulated conductors are not provided with additional protection.
2) Three-core (twisted): generally as two –twisted cords but with a third conductor colored green, for eating lighting fittings.
3) Three-core (circular): generally as twin-core circular except that the third conductor is colored green and yellow for earthling purposes.
4) Four-care (circular): generally as twin- core circular. Colors are brown and blue.
5) Parallel twin: these are two stranded conductors laid together in parallel and insulated to form a uniform cable with rubber or PVC.
6) Twin-core (flat): this consists of two stranded conductors insulated with rubber, colored red and black. Laid side by side and braided with artificial silk.
7) High-temperature lighting, flexible cord: with the increasing use of filament lamps which produce very high temperatures, the temperature at the terminals of a lamp holder can reach 71 centigrade or more. In most instances the usual flexible insulators (rubber and PVC) are quite unsuitable and special flexible cords for lighting are now available. Conductors are generally of nickel-plated copper wires, each conductor being provided with two lappings of glass fiber. The braiding is also varnished with silicone. Cords are made in the twisted form (two-and three-core).
8) Flexible cables: these cables are made with stranded conductors, the diameters being 0.3, 0.4, 0.5, and 0.6 mm. They are generally used for trailing cables and similar applications where heavy currents up to 630 A are to be carried, for instance, to welding plant.

CHAPTER THREE

Conductor Joints and Terminations

3.1: Basic electrical and mechanical requirements:

The following are the basic requirements which must be met in any electrical connection:

1) There must be sufficient contact area between the current-carrying surfaces (e.g. between wire and terminal). If this is provided, then the surface contact resistance will be minimized. There will also be a reduction in the voltage drop across the contacts and in the amount of heat generated. Note that the voltage drop is the product of the current (I) flowing through the joint or termination and the resistance (R) of the contact. The heat generated is calculated in watts and is the product of the square of the current flowing through the joint or termination and the resistance (R) of the contacts. In practice, the volt drop and the amount of heat generated are so small that they are ignored. However, a badly soldered joint a 'dry' joint for instance coils cause trouble and must be rectified before damage is done, particularly to any associated insulation.
2) There must be adequate mechanical strength. This aspect is very important where there is the possibility of leads being pulled. Thus the type of conductor termination must be considered from the point of view of mechanical damage being sustained by the joint or termination.
3) The third requirement is the ease which a connection can be made and unmade. Electrical wires are often' permanently' connected by soldering or crimping methods, usually where the currents to be carried are relatively low. Where, however. Permanent connections are a disadvantages in maintenance, then the detachable unions are selected.

These are invariably used in medium-and high-current work.

The resistance of two separable contact surfaces depends on the amount of pressure exerted to keep the surfaces together, and the conditions of the surfaces. Non-separable contacts soldered, brazed, depend on the effectiveness of the jointing method used to reduce resistance. The following are the main requirements of the IEE Regulations regarding terminations and conductor joints.

Cable terminations:

All terminations of cables connectors and bare conductors must be accessible for inspection. They must be electrically and mechanically sound. No stress should be imposed on the terminals. Where two dissimilar metals are being used for example copper and aluminum, care must be taken to prevent corrosion, particularly in damp situations. All installation damaged by heat-jointing processes (for example soldering jointing) must be made good. Soldering fluxes which remain acidic or corrosive at the completion of a soldering operation must not be used.

Joints in cables:

An electrically sound joint means that the resistance of the jointed conductor should not be greater than that of an unjointed length of a similar conductor. A mechanically sound joint means that any pulling on the finished joint will not disturb the joint. A soldering joint must be mechanically sound before soldering. A joint which is readily accessible is one which is located usually in a box of the inspection type and the box itself must not be readily accessible. The termination of a flexible cable or a flexible cord to an appliance must be done either y wiring direct onto the appliance terminals or by means of an inlet connector. If a joint must be made between a flexible cord and/or a flexible cable, an insulated mechanical connector must be used. Non-reversible cable couplers and connectors are desirable.

Often flexible cables are required to be extended in length by the use of couplers. Their use i.e. not regarded being good practice, but if the situation demands it, only couplers to BS 4343 should be used. Only the BS 4343 couplers are permitted on construction sites. Couplers should be non-reversible and so connected that the 'plug' is on the load side of the equipment.

3.2: Joint methods:

The many methods used to join conductors may be reduced to two definite groups. The first group involves the use of heat to fuse together the surfaces of the joint (e.g. soldering and welding). The second group uses pressure and mechanical means to hold the surfaces together e.g. clamping, bolting, riveting). The following are brief description of the types of jointing method in each group.

Soldering:

It involves the use of molten metal introduced to the two surfaces to be joined so that they are linked by a thin film of the metal which has penetrated into the surfaces. The metal used for joining copper surfaces is solder, which is an alloy of tin and lead. It melts at a comparatively low temperature. The grade of solder most suitable for electrical joints is tinman's solder (60 % tin, and 40 % lead; melting point is about 200 centigrade). The disadvantage of soldering is that it makes the joints in bus bars must be reinforced by bolts or clamps.

Welding:

This process is sometimes used for large-section conductors such as bus bars. Welding is the joining of two metal surfaces by melting adjacent portions so that there is a definite fusion between them to torch or an electric arc. Again, the welded joint is a non- separable contact.

Clamping:

A clamped joint is easy to make; no particular preparation being required. The effective csa of the conductor is not affected, though the extra mass of metal around the joint of termination makes a large bulk. However, the joint or termination is cooler in operation. Surfaces must be clean and in definite mechanical contact. Precautions must be taken to ensure that the bolts and nuts of the clamp are locked tight.

Bolting:

This method involves drilling holes in the material and has the obvious disadvantage of reducing the effective csa of the material. Contact pressure also tends to be less uniformly distributed in a bolted joint than in one held together by clamps. Spring washers are needed to allow for expansion and contraction as the material temperature varies with the current carried.

Riveting:

If well made, riveted joints make a good connection. There is the disadvantage, however, that they cannot easily be undone or tightened in service.

Crimping:

This is a mechanical method. For conductor joints a closely fitting sleeve is placed over the conductor and crimped by a hydraulically or pneumatically operated crimping tool. This method is very commonly used nowadays and provides a connection which is mechanically strong and virtually negligible in its electrical resistance.

Mechanical connectors:

These consist of one-way or multi-way brass terminals contained in blocks made from porcelain, Bakelite, nylon, polythene or PVC. Small screws are used to make the connection. The operating temperature of the block material is important. Porcelain cannot be used for high operating conditions, while PVC and polythene tend to become distorted as the melting-point of 160 centigrade is approached. In fact, polythene is not recommended for use as connector-blocks in fixed wiring systems, accessories, luminaries and appliances. Nylon has a good resistance to deformation at high temperatures.

3.3: Termination methods:

There are many methods for terminating conductors for connection to accessories and current-using apparatus. The following is a short survey of some of the ore common types of terminations.

Punched and notched tabs:

These generally accept a solid-core small-diameter conductor. The connection is soldered.

Screw head connection:

The end of the conductor is formed into an eye using round-nosed pliers. The eye should be slightly larger than the shank of the screw, but smaller than the outside the outside diameter of the screw head, nut or washers. The eye should be so placed that the rotation of the screw head or nuts tends to close the join in the eye. If the eye is put the opposite way round, the rotation of the screw head or nut will tend to untwist the eye to make a bad, inefficient contact. Sometimes saddle washers are used to retain the shape of the eye.

Claw-type terminals:

These are sometimes called segmented eyelet lugs. The conductor strands are twisted together tightly and formed into a loop to fit snugly into the circular claw. An associated brass or tinned copper washer is then placed on tope. The claws are then bent over the washer.

Sped terminals:

Theses are either performed terminals, or made from the conductor end as follows (seven-strand conductor):

1) Strip off a suitable amount of insulation from the end of the conductor. If VRI cable, strip off the braiding and tape for a further 12 mm.
2) Take one outer strand and twist round the base immediately above the insulation.
3) Separate conductor into two sets so three strands each.
4) Twist each set tightly together.
5) Form a spade end.

Lug terminals:

These come in many types as shown in figure 3.1. connection between conductor end and the terminal's socket is made either by soldering or crimping.

Crimping:

Select the correct terminal end. Strip the insulation from the cable end. Insert the wire into the open socket end of terminal and crimp using a crimping tool.

Soldering:

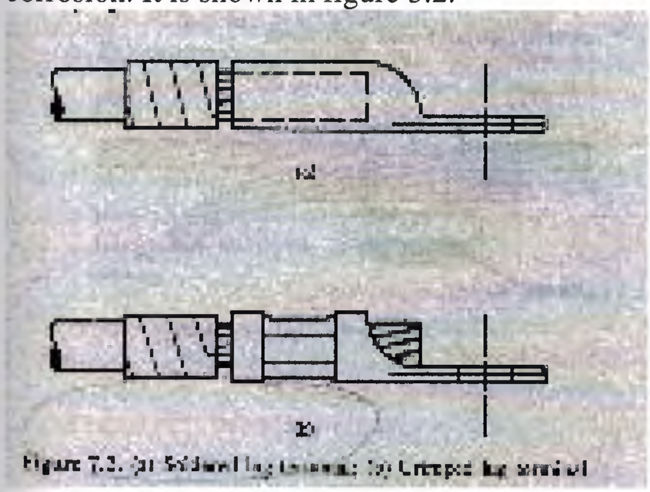
1) Strip the insulation back about 50 mm.
2) Tin the socket of the lug.
3) Smear both the inside of the socket and the conductor end with flux.

4) Fit the socket to the conductor. If the socket is too large, the conductor diameter should be enlarged with a tinned-copper wire binding.
5) Play the flame of a low-torch on the socket until the heat has penetrated to the conductor. Apply solder to the tip of the socket.
6) When the termination has cooled, cut back any damaged insulation and make good. Tape can be used to protect the original insulation.

A file should never be used to smooth or clean up a soldered connection. The solder should be smoothed by wiping it with a fluxed allot-pad while the socket is still warm.

Line taps:

These are used for making non-tensioned service or tee connections to overhead lines. They are available in a range of sizes suitable for copper conductors, a simple shroud is provided to insulate the line-tap when used on covered service cable. There are designs for use with aluminum conductors and for bimetallic connections between aluminum and copper conductors. In theses instances, the shroud is filled with weatherproof sealing compound, giving protection against climatic attacks and corrosion. It is shown in figure 3.2.



3.4: Joints and terminations on MICS cable:

This type of cable consists so conductors insulated with compressed magnesium oxide and enclosed in a seamless copper sheath or tube. Generally, the ends of the cable must be sealed against the ingress of moisture by using a suitable insulated sealing compound. The complete cable termination as shown in figure 3.3 comprises two sub-assemblies, each of which performs a different function:

a) The seal, which excludes moisture from the cable insulation.
b) The gland, which connects the cable to a conduit-entry box.

The seal consists of a brass pot with an insulated disc to close the mouth. Sleeves insulate the conductor tails. The gland consists of three brass components: a nut, a compression ring and a body.

There are three types of seal, each being designed for use depending on the application of the wiring system.

Terminating MICS cable for use in temperatures up to 70 centigrade:

1) Cut the cable to the length required and allow for an appropriate length of conductor trails. The cable end should be cut of squarely. If the cable has a PVC should be cut back before stripping the copper sheath.
2) Mark the point to which the copper sheath is to be stripped back to expose conductors.

CHAPTER FOUR

WIRING ACCESSORIES

There is an extremely wide range of wiring accessories now available, most of which the practicing electrician will install at some time or another. These include switches for lighting, water-heaters, socket-cutlets, cooker units, dimmer switches, ceiling roses and cord outlets.

4.1: Switches:

The most familiar switch is that used to control lighting circuits. Most are rated at 5/6 A, but ratings at 15 A are also available. They are ' single pole' which implies that they must be connected in the phase conductor only. Care should be taken that lighting switches are designated for use in inductive circuits, particularly when they are used to control fluorescent lighting. This is because such circuits take 80 % more current than the lamps' wattage might suggest. If switches are not rated for inductive circuits, they must be derated by 50 %.

Three types of switches are available: one-way, two-way and intermediate, each for the control of a particular circuit arrangement. Often a number of switches are contained within the same switch unit: two-gang, six-gang, etc. This allows the control of a number of different circuits from one position. One special type of switch is the 'architrave', which is mounted on door architraves.

Ceiling switches are rated at 6 A, 16 A and 40 A and are used for either lighting or wall/ceiling mounted heating appliances in bathrooms and are of the pull-cord type. Switches of water-heaters are of the double-pole type and rated to 20 A. Other ratings for double-pole switches are 32 A and 45 A, the latter being used to control cooker circuits where no socket-outlet is required in cooker-control unit.

Dimmer switches are used to allow control of the level of lighting from luminaries. Watertight switches are designed for conductor use while splash proof switches are found in situations where water is present, such as in shower rooms.

Most switches tend to be made from molded plastic, but metal-clad versions are available for industrial use. Some switches for domestic installations can be finished in stain chrome or polished brass. And here are these switches.

Lamp holders:

Cord grip lamp holders are used for pendant luminaries and are fitted with 'skirts' to provide extra safety when a lamp has to be changed. This is a requirement when pendant luminaries are used in bathrooms. For filament lamps rated up to 150 W, the connection is a bayonet cap (BC). Higher ratings require an Edison screw (ES) lamp holders in which the center contact must always be connected to the phase conductor. Batten holders are used for wall or ceiling mounting and can be 'straight' or 'angled'.

Ceiling roses:

Ceiling roses are used with cord grip lamp holders for pendant luminaries. They must not be used in circuits exceeding 250 V and must not have more than one outgoing flexible cord unless designed for loop-in terminal ('live'), which is required to be shock from direct contact.

Cocker outlet circuits:

These are units designed to accommodate the cooker supply cable from the control unit. The cable is terminated at terminals from which the cable going to the cooker is connected.

Shaver supply unit:

These are now commonly fitted in bathrooms and provide both 115 V and 240 V. They are often incorporated into a lighting unit for fitting above mirrors.

Cooker-control units:

These can be of double-pole type incorporating a 13 A socket-outlet, or simply a double-pole switch rated at 45/50 A. In a kitchen provided with an adequate number of socket-outlets there should be no need for the socket-outlet in the control unit as there is a danger of flexible cords (e.g. supplying a kettle) trailing over hot cooker hobs.

Socket-outlets:

These take 13 A fused plugs and can be non-switched, switched or switched with a pilot lamp. Socket-outlets intended to supply electrical equipment outside the house must have residual-current device (RCD) incorporated so that should an earth fault occur, the supply will be cut off. (RCDs operate at 30 mA but can trip at as low as 10 mA). Associated with socket-outlets connected to ring-main or radial circuits are fused or fused/switched connection units. The former are used where the appliances has its own switch. Switched/fused units are used where the connected appliance has no switch control. It should be noted that 2 A, 5 A, and 15 A round0pin socket-outlets are available for special purposes. Connection units can also be obtained with a cord outlet.

Outlet plates:

These accessories include: outlet plates with 3 A fuse used for mains-operated electric clocks; outlets plates for telephones; and TV coaxial socket-outlets. While the latter two are not directly associated with electrical installation, contractors are often required to install these services while the building is being hard-wired.

Mounting boxes:

These are designed to contain well-mounted accessories such as switches and socket-outlets and is either molded plastic or metal. The entries to the boxes are by means of 'knock-outs', which can accommodate conduit, flat cable MI cable. Depending on the accessory, the box depths range from 16 to 32 mm. The boxes are also designed for surface-amounted accessories or flush-mounted accessories. All boxes are normally provided with an earth terminal for the CPC.

Grid-switch system:

This system allows the control of a large number of different circuits from one position. It is often found in commercial premises, restaurants, public bars, offices and industrial situations. The system consists of a mounting box, and internally fixed grid which then accepts the switch or switches and cover plate. The system ranges from one-gang to twenty-four-gang units. The accessories include switches, bell pushes, indicator lights and key operated switches.

Industrial socket-outlets and plugs:

There are twp types available: BS 196 and BS 4343 with current ratings from 16 a to 125 A. Color identifications is used for different voltages: allow- 110 V; blue- 240 V; red 415- V. The socket-outlets are designed so that the earth contact position with respect to a keyway is varied for each voltage rating to ensure that the equipment of a given voltage cannot be plugged into the wrong supply.

4.2: Installation hints:

The following list is based on the requirements of the Wiring Regulations relating to accessories.

General. Al mounting boxes must be securely fixed, with no sharp edges on cable entries, screw head, etc, which might cause damage to cables and wires. Cable sheath should be fully entered into the box. All conductors are required to be correctly identified with bare CPCs sleeved with green/yellow sieving. All terminals should contain all the strands of conductors and be tight.

Lighting switches. Single-pole switches are to be connected in the pharos conductor only which must also be correctly identified by color. All exposed metalwork (e.g. the metal switch palate) is required to be earthed. In a bathroom, the lighting switch must be of the pull-cord operated type, or else mounted outside the bathroom door. If a switch is not rated to carry the current of inductive circuits (e.g. fluorescent luminaries) it must be derated by 50 %.

Ceiling roses. They should not be connected to a voltage more than 250 V and should not have more than one flexible cord coming from it. Loop-in terminals must be insulated and the rose should be suitable to take the weight of a luminaries.

Socket-outlets. They should be mounted at a height above the floor or working surface, which is convenient to the client. Note that in premises where disabled people live and work, the socket-outlets should be located at a level, which allows them access without strain. Correct polarity must be observed in wiring socket-outlets with an earthling tail provided between s/o earth terminal and the terminal provided if a metal mounting box is used. Socket-outlets are not allowed in rooms containing a bath and a shower. They should be more than 2.5 m away from a shower cubicle in a room other than bathrooms.

Cooker-control unit. These must be located within 2 m of the cooking appliances.

CHAPTER FIVE

INSTALLATION METHODS

5.1: General considerations:

All electrical installations are required to be properly designed with a number of important factors taken into consideration. These factors have a bearing on the type of wiring system to be installed, its flexibility, its maintenance aspects, the working environment and the degree of safety provided for the users of installation. The Wiring Regulations, Statutory Regulations and other recommendations all have an influence on the designer's approach to satisfying a client's requirements, whether the latter be the owner of a domestic dwelling, a small shop, a supermarket, school, an office block or a factory. Each has its own specific aspects, which both the designer and the installer have to provide to ensure tat the final installation meets the highest standards. Thus the golden rule is: ' good workmanship and the use of proper materials will meet these standards'. And here are the considerations:

Type of the building:

This can range from a domestic dwelling to a large factory, from a suit of offices to farming premises, form small shop to a shopping mall. All these incorporate a wide variety of building materials with which the electrician must be familiar. The users of the installation also have to be considered.

On the face of it, a domestic installation may seem straightforward. But if the installation is to cater for a disable person, then it must be designed in such a way that the person is not inconvenienced. Farm installation must take into account the fact that even 25 V is lethal to animals. A shopping mall installing may have to be designed to cope with vandalism. Some buildings may be of a temporary nature. Others may at some time in the future be extended, while the installation designer may have done his/her job correctly, it is the installer or electrician who comes face to face with practical aspects which at times may require to be notified the client's agent if something might not seem to be ' quite right'.

Installation flexibility:

A flexible installation is one, which can be altered or extended easily without undue disturbance of the fabric of the building. Some buildings may have different tenants during their lifetimes, all of which may have a wish to alter the installation to suit their needs. Even domestic installations may require to be extended as a family grows larger, or as rooms are altered to other purposes. Thus initial planning if done thoughtfully will save client extra cost.

Working environment:

Electrical installations can find themselves coping with dust, fumes, chemical vapors, dampness, weathering, and high or abnormal temperatures. All these operating conditions can have a deleterious effect on both wiring systems and electrical equipment. It is thus essential that consideration be given at the initial planning stages of an installation of the conditions expected in the installation. It is again the collaboration of the designer and the installer, which will ensure a problem-free installation.

Maintainability:

This is important where the installation is intended to have a long life without disturbance. The design requirement here is that the installation can be easily tested periodically and that repairs can be readily and safely and protective measures remain effective during the life of the installation.

Safety:

All electrical installations are required to have an in-built safety factor, to protect the users against the risk of electric shock, fire and burns. While this can be done at the design stage, much depends on the installer's approach to the work, ensuring that wiring is correctly installed and that equipment is correctly connected. An indication of the number of common faults, which appear in installations, can be seen in Sangs and Solutions published by the National Inspection Council for Electrical Installation Contracting. These faults have been detected over many years by the council's inspecting engineers- and they still occur.

5.2: Installation practice:

Conduit: (metallic)

The following is concerned with heavy-gauge screwed conduit. Lt-gauge is available but it is limited in its use in installation work to the protection of sheathed cables from mechanical damage. In any case, they must not be used as a circuit protective conductor (CPC). The heavy-gauge type of conduit is available as seam-welded or solid drawn. The former is the most commonly used while the solid drawn is, apart from being expensive, mainly used for special installation such as in gas proof or flameproof situations.

The conduit wiring system is a two-stage system: the conduit must be fully erected and supported before any cables are drawn in. It is thus a 'labor intensive' system, which contributes a significant element to the cost of a conduit installation. The advantages, however, far outweigh the cost because if its long life, its ability to allow rewiring, replacement of cables and adaptability to other systems such as trunking. That the conduit can be used as a CPC is an advantage, though its current practice to run a separate CPC within the conduit. The two essential requirements of a conduit system are: it must be properly constructed and it must be electrically continuous.

There are number pf practical points to be observed. All conduits must be squarely cut and all burns removed. Threading should be done carefully and no damage should occur to the finish, particularly if the black enamel type is used. No exposed threads are allowed except where running couplers are used; in this case threads should be treated to prevent rust and corrosion. The radius of site-made bends should be not less than 2.5 times the outside diameter of the conduit. All entries into enclosures should be bushed to prevent abrasion of insulated conductors. Al unused entries should be blanked off using brass plugs.

All cover of boxes should be in place and securely fastened. If these boxes are located under floors, trap doors should be provided for access at a later date. All bushes. Couplers, and accessories must be securely tightened. In long horizontal runs of conduit, where there is a risk of condensation collecting inside the conduit, drainage points should be provided. The capacity of the conduit must be not being exceeded. This is to allow space within the conduit for ventilation of heat from the conductors and to allow easy withdrawal and replacement of conductors.

The number of conductors allowed in a conduit depends on whether the run is short and straight (maximum 3 m) or whether the run is longer and incorporates bends or offsets.

Drawing in cables is carried out by using a draw-in tape made from steel to nylon, which is fed into the conduit. A draw wire is then attached to the tape itself drawn in. The cables are then firmly joined to the draw wire and fed into the conduit in parallel to prevent them crossing each other. This is a two-man operating with one person pulling and the other feeding. It is advisable to use a cable drum stand so that the cable from each drum can be pulled erectly off its drum and not allowed to spiral off, causing twists in the cable.

The method of fixing conduits included in the clip (a half-saddle), saddle, spacer-bar saddles and distance saddles, the later being used to take the conduit off the wall by about 10 mm. Other types of saddles are available for multiple runs and glider clips where conduits are run across girders. The 'Guidance Notes' stipulate distances between conduit fixings to ensure the conduit is securely erected.

Inspection fittings of the channel type are not generally recommended except in situations close to the conduit-entry points. They do not have sufficient space for drawing in cables. Draw-in boxes not only look better but have ampere capacity, not only for drawing in cables but to accommodate a turn or two of cable to provide some 'slack' in the conduit run.

Where the conduits have to be concealed, they are installed while the building is being erected. They can be buried in floors and walls in such a manner that the cables can be drawn in after the building work has been completed. Conduits running under floorboards and across joists should be accommodated in channels cut in the joints sufficient only tom accommodate the conduit.

The use of a solid elbows or tees is restricted to positions immediately adjacent to a conduit terminal box, a luminaries or conduit inspection fitting and in any case must be located not more than 500 mm from a fitting which affords permanent access.
Where conduit runs oases through or ceilings, the surrounding holes must be made good with fire resisting material, such as cement, as a fire precaution.

Galvanized conduit can be used as part of a system carrying cables from one building to another, provided that the maximum length does not exceed 3 m and the height is 3 m minimum, but higher if there is traffic. The conduit must be one unjointed length and be securely fixed at both ends of the span.

Conduit (PVC):

Many of the requirements for metallic conduit also apply to PVC conduit. Some requirements are, however, peculiar to PVC. The provision of expansion couplers is essential in long runs where abnormal temperatures are encountered. Separate CPCs are required. They must not be installed where they are likely to come into contact with materials, which might cause them damage, such as creosote and oil, unless the PVC is designed to withstand these contacts. If a plastic box is used to support luminaries the box must be suitable for the suspended load at the expected temperature.

Compared to metallic conduit, PVC conduit is easy to work with and virtually the same range of system accessories and supports used for metallic conduit is available for PVC. Bending can be done on site using bending springs, though it is essential that care be taken when working with PVC in cold weather. Expansion couplers are fitted every 6 m of the run. Jointing PVC conduits is by means of a push fit and sealed with PVC solvent adhesive used sparingly.

Flexible conduits:

The purpose of this conduit is to provide a flexible connection between a fixed conduit or trunking installation and some types of electrical equipment where there is a need for the equipment to be removed within small limits of its mounting position. The conduits are also used to absorb variation to prevent it being transmitted to rigid installation. Types include metallic, plastic flexible and reinforced, which is a heavy-duty double-walled conduit with spiral wire reinforcement. Adaptors are used at both ends of the conduit length. A separate CPC is required by the Wiring Regulations. Flexible metallic conduit should be of the waterproof type.

5.3: MI cables:

Perhaps the most important aspect of working with MI cables is the need to ensure that dampness has not entered into the cable insulation. Two there aspects are the danger of overworking the copper sheath in the bending and making offsets, and the protection of the copper sheath with a PVC over sheath in situations where there is a danger of corrosion. A point also to bear is that there are two grades of cable: light duty, up to 600 V, and heavy duty, up to 1000 V. The former is used for domestic and light commercial installations, the later mainly for industrial installations.

The small overall diameter of the cable allows it to be installed in walls without the need for deep chases, though the cable may need a PVC cover sheath to avoid any possible interaction between the copper sheath and the plaster or cement. The minimum internal bending radius must not be less than six times the overall diameter of the cable. The spacing of clips and saddles should conform to the requirements of the Wiring Regulations.

Before the seal is finally crimped the insulation resistance between the cable cores and the sheath must be measured and should be a minimum of 1 megohm. The cores or conductors must also be identified by color after the conductors have been checked by means of a continuity test. (Using the ohms scale on the instrument).

In industrial installations, MI cables are often carried on cable tray in multiple runs, for which multi-way saddles are available. Such saddles can also be side-made using narrow copper strip which is available with PVC covering as are clips, saddles and spacer-bar saddles.

Because the MI cable system is used with conduit fittings, pots are available with earth tails, which, joined together, provide a good electrical continuity between sections of the cable. This is particularly important if the MI cable is being used in earth-concentric wiring systems (TNC), where the sheath acts as a PEN conductor (that is, it is the neutral or return conductor and also the CPC).

MI cables may require surge voltage protection when used to feed certain types of inductive loads. These voltages, which are generated when the inductive loads are switched off, can be far in excess of the normal supply voltage and will cause the breakdown of the cable. Inductive loads include motor circuits and discharge lighting circuits as fluorescent lamps.

Earth-tailed pots must always be used if there is any doubt about the effectiveness of contact between the cable gland and an enclosure. If the enclosure is made from insulating material, the use of earth-tailed pots ensures a facility for making a 'through-joint' in the protective conductor. When the MI cable is being used for Category 3 circuits, the cable should have a PVC over sheath colored to indicate the function of the circuit: red for fire alarms and white for emergency lighting.

The correct polarity at socket-outlets terminals must be verified. This is particularly the case where black core sleeving is used. Recently, red colored sleeving has come on the market, which can be used and does anyway with the need for colored tape for the phase conductor.

Note that there are two installation conditions recognized by Wiring Regulations: sheath bare and exposed to touch, or sheath bare and not exposed to touch. There is, further, the insulation in which the cables can be clipped direct to a surface or in 'free air'. In addition it is essential to recognize the working sheath operating temperature: 70 and 150 centigrade, which governs the material used for filling the sealing pots.

5.3: Trunking:

Trunking, whether metallic or plastic, is basically a large-volume channel for housing cables. The range of trunking types available today makes it a versatile wiring system and in its various forms can be found in domestic, commercial and industrial situations. In its metallic from it is commonly used in industrial premises where it is associated with metallic conduit and MI cable systems.

Trunking can be fixed directly to a wall using round-head screws and washers to prevent damage to cables or can be run overhead supported at intervals by the bottom members of the roof trusses.

The spacing factor for trunking must always be observed. As in the case with conduit, cables are given a factor. The total sum of the cables factor must not exceed trunking factor, which are quite generous in view of the large capacity of trunking.

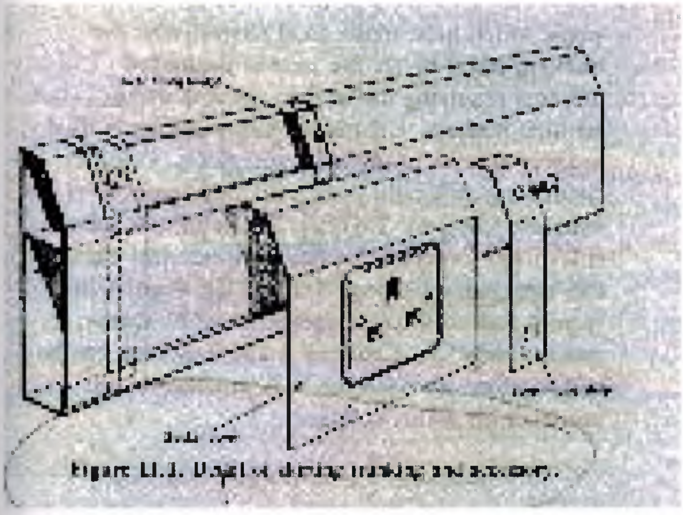
The wide range of trunking accessories available cut out the need for much work on site in making purpose-made accessories, though it is useful for trainee electricians to gain some experience in working with trunking.

Since trunking offers mechanical protection for cables, single insulated conductors can be installed. This is simply done by laying the cables for each circuit in the trunking either freely or by supporting the circuit conductors with cable-retaining straps. Care should be taken to ensure that the cables are not twisted, so that they can be lifted out easily should they need to be replaced. Vertical runs of cables in trunking require to be adequately supported by using pin racks, which support the cables by friction. They should be fitted at 1.5 m intervals.

When trunking is mounted vertically, the Wiring Regulations require that fire barriers be fitted at intervals not exceeding 5 m. This is to ensure that the trunking does not allow fire to spread, and also helps to reduce the rise in temperature at the top of the trunking run.

Metallic trunking can be used as CPC, though separate CPCs are recommended to be run with the circuit conductors. The sections of trunking are connected together electrically by means of earth straps which must make good contact with the trunking metal by (in the case of enameled finishes) removing the enamel, or else using serrated washers.

Figure 5.1 illustrates detail of skirting trunking and accessory.



CHAPTER SIX

ELECTRICAL SAFETY, PROTECTION AND EARTHING

6.1: Electrical safety:

The most common method used today for the protection of human beings against the risk of electrical shock is either:

1) The use of insulation (screening live parts, and keeping live parts out of reach.
2) Ensuring, by means of earthing, that any metal in electrical installation, other than the conductor, is prevented from becoming electrically charged. Earthing basically provides a path of low resistance to earth for any current, which results from a fault between a live conductor and earthed metal.

The general mass of earth has always been regarded as a means of getting rid of unwanted currents, charges of electricity could be dissipated by conducting them to an electrode driven into the ground. A lighting discharge to earth illustrates this basic concept of earth as being a large 'drain' for electricity. Thus, every electrical installation, which has metal work, associated with it (either the wiring system, accessories or the appliances used) is connected to earth. Basically, this means if, say, the framework of an electric fire becomes 'live', the resultant current will, if the frame is earthed, flow through the frame, its associated circuit-protective conductor, and thence to the general mass of earth. Earthing metalwork by means of a bonding conductor means that all metalwork will be at earth potential; or, no difference in potential can exist. And because a current will not flow unless there is a difference in potential, then that installation is said to be safe from the risk of electric shock.

Effective use of insulation is another method of ensuring that the amount of metalwork in an electrical installation, which could become live, is reduced to a minimum. The term 'double-insulated' means that not only are the live parts of an appliance insulated, but that the general construction is of some insulating material. A hair-dryer and an electric shaver are two items, which fall into this category.

Though the shock risk in every electrical installation is something with which every electrician must concern himself, there is also the increase in the number of fires caused, not only by faults in wiring, but also by defects in appliances. In order to start a fire there must be either be sustained heat or an electric spark of some kind. Sustained heating effects are often to be found in overloaded conductors, bad connections, loose-fitting contacts and so on. If the contacts of a switch are really bad, then arcing will occur which could start afire in some nearby combustible material, such as blackboard, chipboard, sawdust and the like. The purpose of a fuse is to cut off the faulty circuit in the event of an excessive current flowing in the circuit. But fuse-protection is not always a guarantee that the circuit is safe from the risk. The wrong size of fuse, for instance 15 A wire instead of 5 A wire, will render the circuit dangerous.

Fires can also be caused by an eat-leakage current causing arcing between live metalwork and, say, a gas pipe. Again, fuses are not always of use in the protection of a circuit against the occurrence of fire. Residual-current devices (RCD) are often used instead of fuses to detect small fault currents and to isolate the faulty circuit from the supply.

To ensure a high degree of safety from shock-risk and fire risk, it is thus important that every electrical installation to be tested and inspected not only when it is new but at periodic intervals during its working life. Many electrical installations today are anything up to fifty years old. And often they have been extended and altered to such an extent that the original safety factors have been reduced to a point where amazement is expressed on why 'the place has not gone up in flames before this'. Insulation, used, as it is to prevent electricity from appearing where it is not wanted, often deteriorates with age. Old, hard and brittle insulation may, of course, give no trouble if left undisturbed and is in a dry situation. But the danger of shock- and fire risk – is ever present, for the cables may at some time be moved by electricians, plumbers, gas fitters and builders.

It is a recommendation of the IEE Regulations that every domestic installation be tested at intervals of five years or less. The Completion and Inspection Certificates in the IEE Regulations show the details required in every inspection. And not only should the electrical installation be tested, but all current-using appliances and apparatus used by the consumer.

The following are some of the points, which the inspecting electrician should look for:

1) Flexible cables not secure at plugs.
2) Frayed cables.
3) Cables without mechanical protection.
4) Use of unearthed metalwork.
5) Circuits over-fused.
6) Poor or broken earth connections, and especially sign of corrosion.
7) Unguarded elements of the radiant fires.
8) Unauthorized additions to final circuits resulting in overloaded circuit cables.
9) Unprotected or unearthed socket-outlets.
10) Appliances with earthing requirements being supplied from two-pin BC adaptors.
11) Bell-wire used to carry mains voltages.
12) Use of portable heating appliances in bathrooms.
13) Broken connectors, such as plugs.
14) Signs of heating at socket-outlet contacts.

The following are the requirements for electrical safety:

1) Ensuring that all conductors are sufficient in csa for the design load current of circuits.
2) All equipment, wiring systems and accessories must be appropriate to the working conditions.
3) All circuits are protected against over current using devices, which have ratings appropriate to the current-carrying capacity of the conductors.
4) All exposed conductive parts are connected together by means of CPCs.
5) All extraneous conductive parts are bonded together by means of main bonding conductors and supplementary bonding conductors are taken to the installation main earth terminal.
6) All control and over current protective devices are installed in the phase conductor.
7) All electrical equipment has the means for their control and isolation.
8) All joints and connections must be mechanically secure and electrically continuous and be accessible at all times.
9) No additions to existing installations should be made unless the existing conductors are sufficient in size to carry the extra loading.
10) All electrical conductors have to be installed with adequate protection against physical damage and be suitably insulated for the circuit voltage at which they are to operate.

11) In situations where a fault current to earth is not sufficient to operate an over current device, an RCD must be installed.
12) All electrical equipment intended for use outside equipotent zone must be fed from socket-outlets incorporating an RCD.
13) The detailed inspection and testing of installation before they are connected to a mains supply, and at regular intervals thereafter.

6.2: Protection:

In electrical work the term 'protection' is applied to precautions to prevent damage to wiring systems and equipment, but also takes in more specific precautions against the occurrence of fire due to overcurrnets flowing in circuits, and electric shock risks to human beings as a result, usually, for earth-leakage currents appearing in metalwork not directly associated with an electric installation, such as hot and cold water pipes.

The initial design of any installation must take into account the potential effects on wiring systems and equipment of environmental and working conditions.

Mechanical damage:

This term includes damage done to wiring systems, accessories and equipment by impact, vibration and collision, and damage due to corrosion. Typical types of prevention include single-core conductors in conduit trunking, the use of steel enclosures in industrial situations, the proper supporting of cables, the use of armored cables when they are installed underground, and the supports required for conductors in a vertical run of conduit and trunking.

Some types of installation present greater risks of damage to equipment and cables than others, for example on a building or construction site and in a busy workshop. In general, the working conditions should be assessed at the design stage of an installation and, if they have not been foreseen, perhaps due to a change of activity in a particular area, further work may be needed to meet the new working conditions.

Electrical fires are caused by:

1) A fault, defect or omission in the wiring.
2) Faults or defects in appliances.
3) Mal-operation or abuse of the electrical circuit.

The electrical proportion of fire causation today is around the 20 % mark. The majority of installation fires are the result of insulation damage, that is, electrical faults accounting for nearly for three-quarters of cables and flex fires. Another aspect of protection against the risk of fire is that many installations must be fireproof or flameproof. The definition of a flameproof unit is a device with an enclosure so designed and constructed that it will withstand an internal explosion of the particular gas for which it is certified, and also prevent any spark or flame from that explosion leaking out of the enclosure and igniting the surrounding atmosphere. In general, this protection is effected by wide-machined flanges, which damp or otherwise quench the flame in its passage across the metal, but at the same time allows the pressure generated by the explosion to be dissipated.

One important requirement in installation is the need to make good holes in floors, walls and ceilings for the passage of cables, conduit, trunking and ducts by using incombustible materials to prevent the spread of fire. In particular, the use of barriers is required in trunking.

It was not some years after the First World War that it was realized there was a growing need of special measures where electrical energy was used in inflammable situation. Precautions were usually limited to the use of well-glass lighting fittings. Though equipment for use in mines was certified as flameproof, it was not common to find industrial gear designed especially to work with inflammable gases, vapors, solvents, and dusts. With progress, based on the results of research and experience, a class of industrial flameproof gear eventually made its appearance and is now accepted for use in all hazardous areas.

There are two types of flameproof apparatus:

1) Mining gear, which is used solely with armored cable or special flexible.
2) Industrial gear, which may be used with a solid-drawn steel conduit, MIMS cables, aluminum sheathed cables or armored cables.

Mining gear is one as 'group I' gear and comes into contact with only one fire hazard: firedamp or methane. Industrial gear, on other hand, may be well installed in situation where wide range of explosive gases and liquids are present. Three types of industrial hazards are to be found: explosive gases and vapors – inflammable liquids – and explosive dusts. The first two hazards are covered by what is called 'group II' and 'group III' apparatus. Explosive dusts may be either metallic or organic origin. Of the former, magnesium, aluminum, silicon, zinc and Ferro-manganese are hazards, which can be minimized by the installation of flameproof apparatus; the flanges of which are well greased before assembly.

All equipment certified as 'flameproof' carries a small outline of a crown with the letters ex inside it. The equipment consists of two or more compartments. Each is separated from the other by integral barriers, which have insulated studs mounted therein to accommodate the electrical connection. Where weight is of importance, aluminum alloy is permitted. All glassware is of the toughened variety to provide additional strength. The glass is fitted to the apparatus with special cement. Certain types of gear, such as distribution boards, are provided with their own integral isolating switches, so that the replacement of fuses, maintenance, and so on, cannot be carried out while a circuit is live.

All conduit installations for hazardous areas must be carried out in solid-drawn, with certified draw-boxes, and accessories. Couplers are to be of the flameproof type with a minimum thread length of 50 mm. All screwed joints, whether entering into switchgear, junction boxes or couplers, must be secured with a standard heavy locknut. This is done to ensure a tight and vibration-proof joint, which will not slacken during the life of installation, and thus impair both continuity of the flameproof ness. The length of the thread on the conduit must be the same as the fitting plus sufficient of the locknut. Because of the exposed threads, running couplers are not recommended. Specially designed unions are manufactured which are flameproof and are designed to connect two conduits together or for securing conduit to an internally thread entry.

Conduits of 20 and 25 mm can enter directly into a flameproof enclosure. Where exposed terminals are fitted, conduits above 25 mm must be sealed at the point of entry with compound. Where a conduit installation is subject to condensation, say, where it passes from an atmosphere containing one type of vapor to another, the system must be sectionalized to prevent the propagation of either condensated moisture of gas. Conduits stopper boxes, with two, three or four entries, must be used. They have a splayed, plugged filling spout in the cover so that the interior can be completely fitted with compound.

When flexible, metal-sheathed or armored cables are installed, certified cable glands must be used. Where paper-insulated cables are used, or in a situation where sealing is necessary, a cable-sealing box must be used, which has to be filled completely with compound.

The following are among the important installation points to be observed when installing flameproof systems and equipment. Flanges should be greased to prevent rusting. Special care is needed with alloy-alloy flanges as the metal is ductile and is easily bent out of shape. All external bolts are made from special steel and have shrouded heads to prevent unauthorized interference; bolts of another type should not be fitted should not be fitted as replacements. Though toughened glass is comparatively strong, it will not stand up to very rough treatment; a fully glass will disintegrate easily when broken. Protective guards must always be in place. Conduit joints should always be painted over with a suitable paint to prevent rusting. Because earthing is of prime importance in flameproof installation, it is essential to ensure that the resistance of the joints in a conduit installation, or in cable sheaths, is such as to prevent heating or a rise in voltage from the passage of a fault-current. Remember that standard flameproof gear is not necessarily weatherproof, and should be shielded in some way from rain or other excessive moisture.

Being essentially a closed installation, a flameproof conduit system may suffer from condensation. Stopper boxes prevent the passage of moisture from one section to another. Draining of condensate from an installation should be carried out only by an authorized person. Alterations or modifications must never be made to certified flameproof gear. Because flexible metallic tubing is not recognized as flameproof, cables to movable motors should be of the armored flexible cable type, with suitable cable sealing fitted at both ends. It is necessary to ensure that, as far as possible, contact between flameproof apparatus, conduit, or cables, and pipe work carrying inflammable liquids should be avoided. If separation is not possible, the two should be effectively bonded together. When maintain equipment in hazardous areas, care should be taken to ensure that circuits are dead before removing covers to gain access to terminals. Because flexible cables are a potential source of danger, they should be inspected and examined for mechanical faults, cracked glasses, deterioration of well glass cement, slackened conduit joints and corrosion. Electrical tests should be carried out at regular intervals.

Corrosion:

Wherever metal is used, there is often the attendant problem of corrosion and its prevention. There are two necessary conditions for corrosion: a susceptible metal and a corrosive environment. Nearly all of the common metals corrode under most natural conditions. Little or no specific approach was made to the study of corrosion until the early years on the nineteenth century. Then it was discovered that corrosion was a natural electromechanical process or reaction by which metal reverts in the presence of moisture to a more stable from usually of the type in which it is found in the nature. It was Humphrey Davy who suggested that protection against corrosion could result if the electrical condition of a metal and its surrounding were changed.

Corrosion is normally caused by the flow of direct electrical currents, which may be self, generated or imposed from an external source. When direct current flows from a buried or submerged metal structure into the surrounding electrolyte, no corrosion takes place. It is interesting fact to record that where pipe is buried in the soil there is 'natural' potential of from – 0.3 to – 0.6 V between the pipe and the soil. In electrical installations, precautions against the occurrence of corrosion include:

1) The prevention of contact between two dissimilar metals.

2) The prohibition of soldering fluxes, which remain acidic or corrosive at the completion of a soldering operation.
3) The protection of cables, wiring system and equipment against the corrosive action of water, oil and dampness, unless they are suitably designed to withstand these conditions.
4) The protection of metal sheaths and metal conduit fittings where they come into contact with line, cement and plaster and certain hard woods.
5) The use of bituminous paints and PVC over sheathing on metallic surface liable to corrosion in service.

Dampness can affect conduit systems both on the inside and externally. With enamel finishes, it is important that the enamel is preserved as intact as possible, particularly at the thread entry to fittings. Also, the breaking of galvanizing finishing on galvanized conduit presents a great risk of rusting simply because this type of conduit was specified to cope with damp or wet working condtions. Thus any breaks in the finish must be repaired with the use of suitable paint to prevent rusting.

Internal corrosion can occur in situations where the ambient temperature tends to fluctuate. Condensation thus occurs, even in what would otherwise be dry situations, and if the resulting condensate is not allowed to drain away out of the conduit run a build-up can occur. To deal with this problem, the drainage points are recommended in the form of conduit boxes either with the holes drilled to allow condensate to drip out or else, say, using a tee box with the T-outlet plugged with a plug which can be removed at intervals.

Special care is needed in the choice of materials for clips and other fittings for bare sheathed-sheathed cables, and for aluminum conduit, because aluminum is not particularly stable in damp situations and especially when in contact with other metals. For instance, fixing aluminum bulkhead luminaries with brass screws to an external wall can set up an electrolytic action between the fittings and the screws. Chromium-plated screws would be better in this situation.

While copper is fairly resistant to corrosion, there are situations in which the material will corrode. This is MI copper-sheathed cables are provided with PVC-sheaths and clips are also covered with PVC.

Over current:

Over current or excess current is the result of either an overload or a short-circuit. Overloading occurs when an extra load is taken from the supply. This load, being connected in parallel with the existing load in a circuit, decreases the overall resistance of the circuit with an attendant rise in the current flowing in the circuit. This increased current will have an immediate effect on the circuit cables: they will begin to heat up. If the overload is sustained the result will be an accelerated deterioration of the cable insulation and the eventual breakdown of it to cause an electrical fault or fire. It is obvious, then, that some means of protection must be incorporated in a circuit to prevent this overloading.

The short circuit is a direct contact or connection between a live conductor and a neutral or return conductor OR earthed metal work, the contact usually being the result of an accident. The result of a short-circuit is to present a conducting path of extremely low resistance which will allow the passage of a current of many hundreds of amperes. If the faulty circuit has no over current protection, the cables will heat up rapidly and melt, equipment would also suffer serve damage and fire would be the inevitable result.

Apart from the relays associated with circuit breakers, two methods of over current protection are in wide use: fuses and circuit breakers. The latter, so far as domestic and small industrial loads are concerned, are miniature circuit breakers.

Fuses:

A fuse is defined as ' A device for opening a circuit by means of a conductor designed to melt when an excessive current flows along it. The fuse comprises all the parts of the complete device.' Other terms relating the fuse are:

1) Fuse-element: That part of a fuse, which is designed to melt and thus open a circuit.
2) Cartridge fuse: A fuse in which the fuse-element is totally enclosed in a cartridge.
3) Fuse-link: that part of a fuse which comprises a fuse-element and a cartridge or other container, if any, and either is capable of being attached to fuse-contacts or is fitted with fuse-contacts as an integral part of it.

There are three main types of fuse: the rewirable, the cartridge and the HBC (high breaking capacity) fuse; the latter is a development of the cartridge type.

The rewirable type of a fuse consists of a porcelain bridge and base. The bridge has two sets of contacts, which fit into other contacts in the base. The fuse-element, usually tinned copper wire, is connected between the terminals of the bridge. An asbestos tube or pad is usually fitted to reduce the effects of arcing when the fuse-element melts.

Three terms are used in connection with fuses:

Current rating: This is the maximum current that a fuse will carry indefinitely without undue deterioration of the fuse-element.

Fusing current: This is the minimum current that will 'blow' the fuse.

Fusing factor: This is the ratio of the minimum fusing current to the current rating.

The rewirable fuse (BS 3036) is a simple and relatively cheap type of over-current protective device and is still widely used despite several disadvantages including:

a) The ease with which an inexperienced person can replace a 'blown' fuse-element with a wire of incorrect gauge or type.
b) Undue deterioration of the fuse-elements due to oxidization.
c) Lack of discrimination. This means that it is possible, in certain installation conditions, for 15 A fuse-element to melt before 10 A fuse-element. Also a rewirable fuse is not capable of discriminating between a momentary high current and a continuous fault current.
d) Damage, particularly in conditions of serve short-circuit.

6.3: Earthing:

The purpose of earthing is to ensure that no person operating an electrical installation can receive an electric shock, which could cause injury to fatality. In simple terms, 'earthing' involves the connection of all metalwork associated with the electrical installation with protective conductors (CPCs), which are terminated at a common point, the main earth terminal. This terminal is further connected to a proven earth connection, which can be the supply's authority's wire-armored supply cable, an overhead line conductor or an earth electrode driven directly into the soil. The availability of one of one or other of these connections depends on the type of electrical system used to supply electricity.

Apart from the 'exposed conductive parts' found in an installation, there is other metalwork, which has nothing to do with the electrical installation but which could become live in the event of a fault to earth. This metalwork is known as 'extraneous conductive parts' and includes hot and cold water pipes, radiators, structural steelwork, metal-topped sink units and metallic ducting used for ventilation. These parts are connected by means of a main bonding conductors OR supplementary bonding conductors. The former are used to bond together metallic services at their point of entry into a building. The latter are used to bond together metallic pipes and the like within the installation. These bonding conductors are also taken to the installation's main earth terminal. Thus all metalwork is at earth potential.

Once all CPCs and bonding conductors are taken to the main earth terminal, the building is known as 'equipotential zone' and acts as a kind of safety cage in which persons can reasonably assured of being safe from serious electric shock. Any electrical equipment taken outside the equipotential zone, such as electric lawnmower, must be fed from a socket-outlet, which incorporates a residual current device (RCD). The word 'equipotential' simply means that every single piece of metal in the building is at earth potential.

The earthing of all metalwork does not complete the protection against electric shock offered to the consumer. Over current devices are required to operate within either 0.5 seconds or 4 seconds if a fault to earth occurs. And the use of RCDs also offers further protection in situations when an earth fault may not produce sufficient current to operate over current protective devices.

Even before the days of electricity supply on a commercial scale, the soil has been used as a conductor for electrical currents. In early telegraphy systems the earth was used as a return conductor. The early scientists discovered that charges of electricity could be dissipated by connecting a charged body to the general mass of earth by using suitable electrodes, of which the earliest form was a metal plate. But the earth has many failings as a conductor. This is because the resistance of soils varies with their composition. When completely dry, most soils and rocks are non-conductors of electricity. The exception to this are, of course, where metallic minerals are present to form conducting paths. Sands, loams and rocks can therefore be regarded as non-conductors; but when water or moisture is present, their resistively drops to such a low value that they become conductors – though very poor ones. This means that the resistively of a soil is determined by the quantity of water present in it – and on the resistively of water itself. It also means that conduction through the soil is in effect conduction through the water, and so is of an electrolytic nature. Table 6.1 shows some typical values of resistively for some oils.

Table 6.1

Description	Ohm meter
Marshly ground	2 to 3.5
Loam and clay	4 to 150
Chalk	60 to 400
Sand	90 to 8,000
Peat	50 to 500
Sandy gravel	50 to 500
Rock	1,000 upwards

For all that the earth is inefficient conductoor, it is widely used in electrical work. There are three main functions of earthing:

1) To maintain the potential of any part of a system at a definite value with respect to earth.

2) To allow current to flow in the earth in the event of a fault, so that the protective gear will operate to isolate the faulty circuit.
3) To make sure that, in the event of a fault, apparatus normally ' dead' cannot reach a dangerous potential with respect to earth; earth is normally taken as 0 V, 'no volt'.

IEE Regulation 130-04 states that where metalwork, other than current-carrying conductors, is liable to become charged with electricity in such a manner as to create danger if the insulation of a conductor should become defective, or if a defect should occur in any apparatus, the metalwork shall be earthed in such a manner as well ensure immediate electrical discharge without danger. The basic reason for earthing is to prevent or to minimize the risk of shock to human beings. If an earth fault occurs in an installation it means that a live conductor has come into contact with metalwork to cause the metalwork to become live – that is, to reach the same potential or voltage as the live conductor. Any person touching the metalwork, and who standing on a non-insulation floor, will receive an electric shock as the result of the current flowing through the body to earth. If, however, the metalwork is connected to the general mass of earth through resistance-resistance path, the circuit now becomes a parallel-branch circuit with:

a) The human body as one branch with a resistance of, say, 10000 ohms
b) The CPC fault path as the other branch with a resistance of 1 ohm or less.

The result of properly earthed metalwork is that by far the greater proportion of fault-current will flow through the low-resistance path, so limiting the amount of current flowing through the human body. If the current is really heavy then a fuse will blow or a protective device will operate. However, an earth fault-current may flow with a value not sufficient to blow a fuse yet more than enough to cause overheating at, say, a loose connection to start a fire.

Regulations for earthing:

The basic requirements for good earthing are that the earthing arrangements of the consumer's installation are such that the occurrence of a fault of negligible impedance from a phase or non-earthed conductor to adjacent exposed metal, current corresponding to three times of the fuse rating or 1.5 times the setting of an over current circuit breaker can flow, so that the faulty circuit is made dead. The earthing arrangement should be such that the maximum sustained voltage developed under fault conditions between exposed metal required to be earthed and the consumer's earth terminal should not exceed 50 V.

The IEE Regulations detail the metalwork found in premises, called 'extraneous conductive parts', which are required to be connected to the installation main earthing terminal. Bathrooms and showers are also covered.

The CPC is the conductor, which bonds all metalwork required to be earthed. If it is a separate conductor it must be at least with csa of 1mm squared and need not be greater than 70 mm squared. Note that conduit and trunking may be used as the sole CPC except in agricultural installations.

Where metal conduit is used as a CPC, a high standard of workmanship in installation is essential. Joints must be really sound. Slackness in the joints may result in deterioration in, and even complete loss of, continuity. For conductor installations and where otherwise subjected to atmospheric corrosion, screwed conduit should always be used, suitably protected against such corrosion. In screwed conduit installations, the liberal use of locknuts is recommended. Joints in all conduit systems should be painted overall after assembly. In mixed installations (e.g. aluminum-alloy conduit with steel fittings, or steel conduit with aluminum-alloy or zinc-base-alloy fittings) the following are sound recommendations to ensure the electrical continuity of joints.

All threads in zinc or aluminum alloys should be cut using a suitable lubricant. A protective material as petroleum jelly should be applied to the threads in all materials when the joints are made up. All joints should be made tight. The use of locknuts is advised. In addition, it is recommended to apply bituminous paint to the outside of al joints after assembly. In damp conditions, electrolytic corrosion is liable to occur at contacts between dissimilar metals. To avoid this, all earthing clamps and fittings in contact with aluminum-base-alloy tubing should be of an alloy or finish, which is known from experience to be suitable. Copper, or alloys with higher copper contact, is particularly liable to cause corrosion when in contact with aluminum-base alloys. Fir this reason, brass fixing screws or saddles should be not is used with conduit or fittings with aluminum-base alloys. Periodical tests should be made to ensure that the electrical continuity is satisfactorily maintained. Flexible metal conduit should not be used as a CPC. Where flexible tubing forms part of an earthed metal conduit systems, a separate copper or copper-alloy CPC should be installed with tubing and connected to it at each end.

The earth conductor lead should be of a minimum size: 6 mm squared, except 2.5mm squared is accepted for connection to an earth-leakage circuit breaker. It must also be protected against mechanical damage and corrosion, and not less than half the largest size of the conductor to be protected, but need not normally exceed 70 mm squared.

There are different methods used to achieve the earthing of an installation:

1) Connection to the metal sheath and armoring a supply authority's underground supply cable.
2) Connection of the continuous earth wire (CEW) provided by a supply authority where the distribution of energy is by overhead lines.
3) Connection to an earth electrode sunk in the ground for the purpose.
4) Installation of a protective-multiple earthing system.
5) Installation of automatic fault protection.

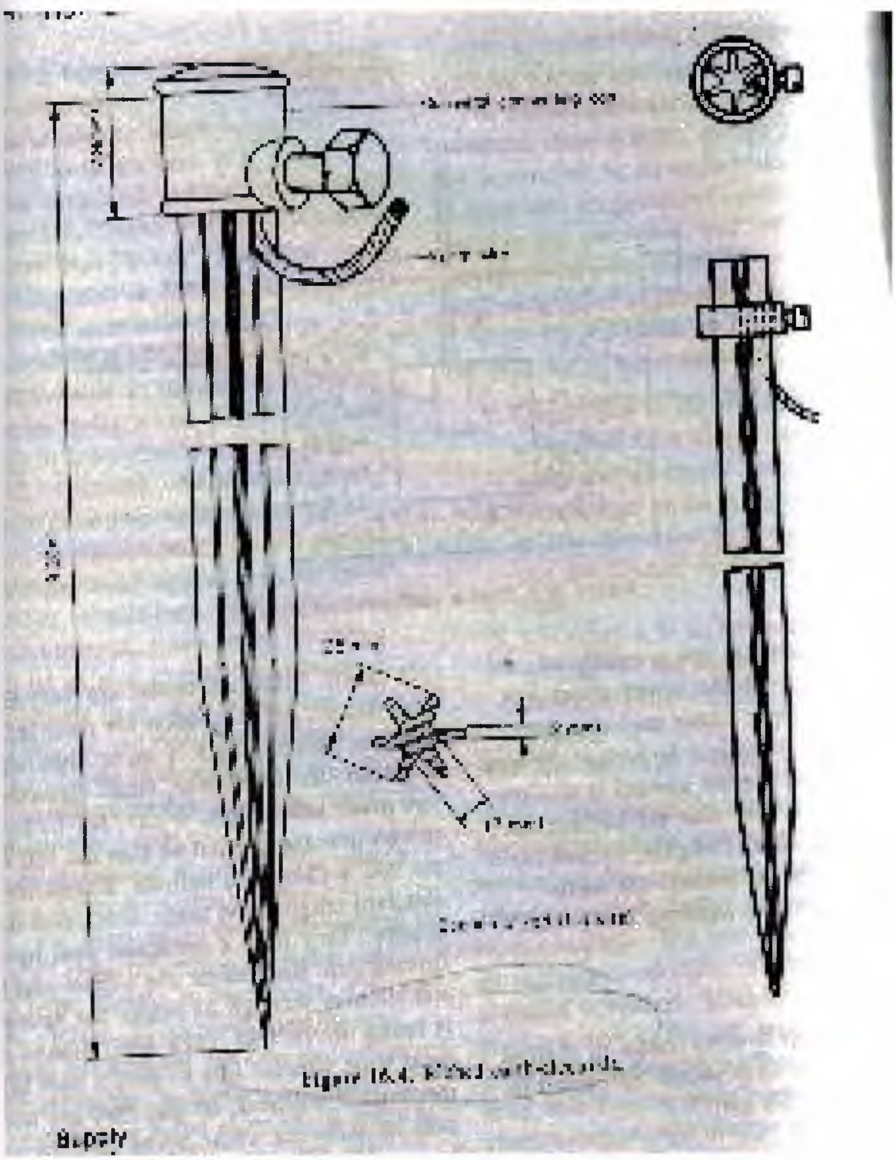
One disadvantage in using a mains water pipe is that sections of the pipe may be replaced by sections of non-conductive material (PVC or asbestos), which makes the pipe inconsistent earth electrode. The provision of a cable sheath as an earthing connection (method 2) is very common nowadays. Usually, however, it is accepted that if, for any reason, the earthing is subsequently proved ineffective, the supply authority is not to be made responsible. Continuous earth wires are not always provided by the supply authority, except in those areas, which have extremely high values of soil resistively as in peat and rock soils. The CEW is sometimes called an aerial ground is the most common means of earthing.

The earth electrode can be any one of the following forms:

1) Pipe: Generally a 200 mm diameter cast-ion pipe, 2 m long and buried in a cock-filled pot. This type requires a certain amount of excavation: iron is, of course, prone to corrosion, particularly if the coke has high sulphur content. Figure 6.2 shows the typical earth-electrode pit.
2) late: Plate electrodes are normally of cast iron buried vertically with the center about 1 m below the surface. Copper plates may also be used. Plate electrodes provides a large surface and are used mainly where the ground is shallow where the resistively is low near the surface but increases rapidly with depth. Again,

excavation is required. Care is needed to protect the earth electrode connection from corrosion.

3) Strip: Copper strip is most useful in shallow soil overlying rock. The strip should be buried to a depth of not less than 50 cm. Figure 6.3 shows the earthing using a copper strip.
4) Rods: Rod electrodes are very economical and require no excavation for their installation. Because buried length is more important than diameter, the extensible, small-diameter copper rod has many advantages. It can, for instance, be driven into the ground so that the soil contact with the rod is close and definite. Extensible rods are of standard lengths and made from hard-drawn copper. They have a hardened steel tip and a steel-driving cap. Sometimes the copper rod has a steel rod running through its center for strength while it is being driven into rocky soil. Ribbed earth rocks have wide vertical ribs to give a high degree of mechanical stiffness, so that they are not easily bent or deflected when driven into the ground. Figure 6.4 shows the ribbed earth –electrode.



CHAPTER SEVEN

CIRCUIT-CONTROL DEVICES

All electrical circuits are required to have some means whereby they can be energized and disconnected from their supply source. This is done by switches, of which there are a very wide variety of types available. A 'switch' is defined as mechanical device capable of making, carrying and breaking current under normal circuit conditions, which may include specified overload conditions. Switches in domestic installations are familiar devices used to control the supply to lighting, cooker and water-heating circuits. Socket-outlets may have switches incorporated. In a consumer unit, the main switch isolates the whole installation from the supply.

Certain types of circuit controls do not qualify as switches. These include thermostats for water-heaters and heating equipment, to touch switches, or electronic switches. Some switches are used as isolators, which are designed to disconnect a circuit usually when the circuit has no current flowing in it.

Some switches are operated by an electromagnetic; these include contactors used for switching heating loads, and large lighting loads are also incorporated in motor starters. A more specialized type of electromagnetic-operated device is the relay.

Although circuit breakers tend to be regarded as devices used for protection of circuits against over current, they also perform a duty as switches.

7.1: Circuit conditions and Contacts:

Every electrical circuit has its own characteristics, which means that it will show some peculiar electrical property depending on the type of load connected to it. For instance, a circuit, which has a purely resistive load, will show a current, which rises when the circuit is first switched on and then falls as the element reaches its normal operating condition. This means that the switch or other circuit-control device must at least be able to break the full-load current taken by the resistor. This applies particularly if the circuit has a dc supply. If, however, the supply is ac, when the switch contacts separate there may be a small arc drawn out between the contacts. This characteristic is even more noticeable when the resistor is in the form of a coil as in fire bar element. This effect is caused by the electrical property, which a coil has in an as circuit. It is called the 'inductive effect'.

If, instead of a resistive conductor wound in the form of a coil, a low resistance conductor is wound round a soft-iron core, the item is then known as a 'choke' or inductor, and the circuit is said to have 'inductive characteristics', which lead to switching problems. A fluorescent circuit is an inductive circuit.

If the circuit has a capacitor included in it, it will also show certain characteristics, which may be shown as arcing between switch contacts as they separate. The most pronounced effects of the inclusion of inductor a capacitor in a circuit is seen when an ac supply is used. However, small capacitors are often used connected across switch contacts to absorb the sparking caused by contact separation. Used in this way they are sometimes called 'radio-interference suppressors as in the starters found in fluorescent lamps.

Thus, therefore a circuit-control device is chosen the circuit to be controlled must be studied so that the device can handle, without damage to itself or the associated circuit wiring, the conditions in the circuits when it is connected or disconnected from its supply.

7.2: Switches and switch fuses:

A switch is a device for controlling a circuit or part of a circuit. The control function consists of energizing an electrical circuit, or in isolating it from the supply. The type of switch generally indicated the form, which this control takes. For instance, a single-pole switch usually called one-way switch controls the live pole of the supply. A double – pole switch controls two terminals.

A common type of switch is use today is the micro-gap with a rating of 5 A, to control lighting circuits. Switches with a 15 A rating are also used to control circuits, which carry heavier currents on both power and lighting arrangements.

Switches are designed for use on dc and/or ac. In a dc circuit, when the switch contacts separate, an arc tends to be drawn our between the separating surfaces. This arc is extinguished only when the contacts are far enough apart when the breaking movement is quick.

Investigation of a dc switch will indicate the length of the gap required when the switch is open. Compare this gap with the gap length on an ac-only switch; it will be found the latter is very much smaller. The reason for this is that the ac tends to be what is called 'self-extinguishing'. In an ac circuit, during the time taken for the contacts to open, the voltage, which is alternating, varies between zero and a maximum. It is at the zero position of the alternating voltage that the arc drawn between the parting contacts of an ac-only switch is extinguished – and it does not establish itself again in normal circuit conditions. Thus, a switch designed for use only on an ac system need have only a small gap and, furthermore, the contact movement does not require to be operated so rapidly as is the case with dc switches.

Quick-make-and-break switches are used for dc circuits. Quick-make, slow-break switches are recommended for ac circuits, particularly where the load is inductive one, for instance where fluorescent lamps are being used.

The most common lighting circuital are controlled but using one-way and two-way switches, double-pole and intermediate switches.

The one-way switch provides the ON and OFF control of a circuit – from one position only. When the switch is closed the lamp is on; when the switch is open the lamp is off. One-way switches are mounted with the word 'TOP', which appears on the back of the switch plate, at the top. This is to ensure that when the switch rocker is in the up position, the circuit is disconnected from the supply. The switch is, of course, connected in this phase conductor only.

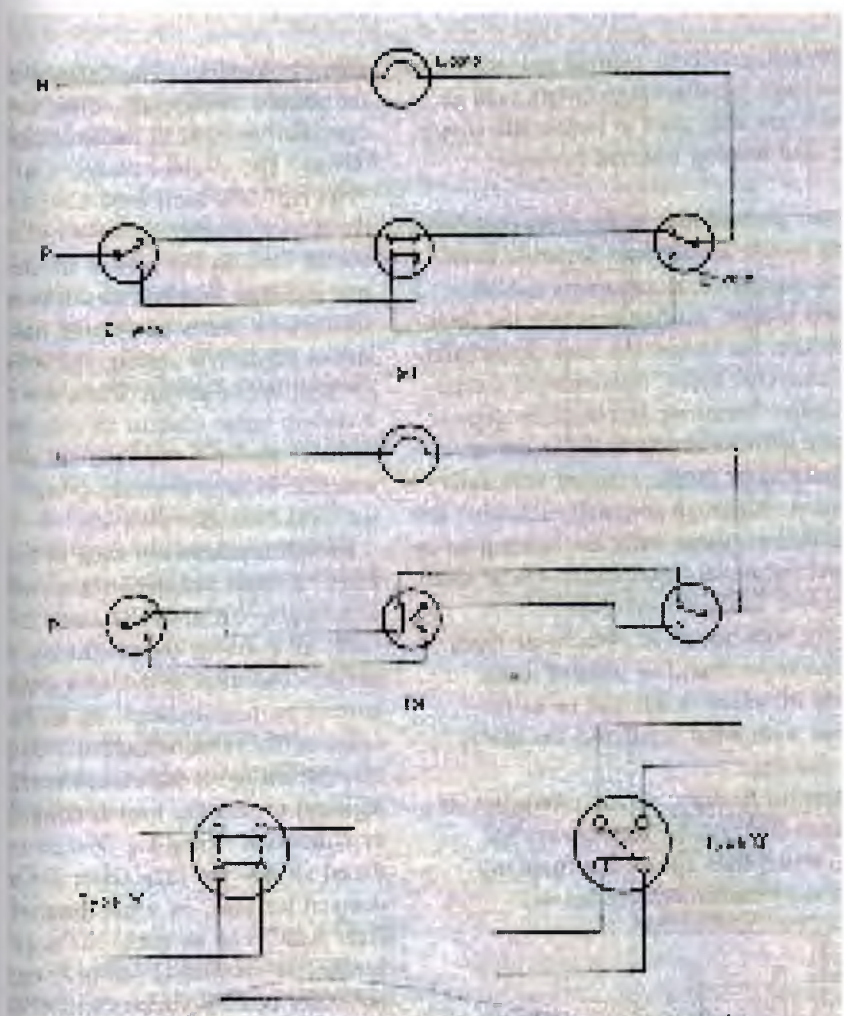
The double-pole switch is used in nay situation where the voltage of the neutral conductor of a supply system is likely to rise an appreciable amount above earth potential: use of the double-pole switch means that a two-wire circuit can be completely isolated from the supply. The usual application is for the main control of sub-circuits and for the local controls of cookers, water-heaters, wall-mounted radiators, and other used fixed current apparatus. The double-pole switch is often used for the 'master' control of circuits, the switch being operated by a 'secret key' attachment, and in consumer units for the complete isolation of an electrical installation from the supply.

The two-way switch is basically a single-pole changeover switch offering two alternative routs for the passage of a circuit current. These switches are sometimes known as 'landing' switches from the days when their application in the electrical installation was virtually limited to ' one in the hall, and one on the landing upstairs'.

Though the two-switch is still used extensively for stair lighting, it is also to be found in bedrooms (door and beside), long halls (at each end) and particularly in any room with two entry doors (one at each door).

In design the switch has four terminals, two of which are permanently connected together inside the switch by a small copper bar on what is called the 'bar' side. One of the bar terminals is blanked off to form a non-separate contact. The switch feed is taken to the other open terminal on the bar side. The two other terminals are connected to the 'strapping wires'. Two-ways switches are used in pairs, interconnected so that the switch wire of the light circuit is taken from the open terminal on the bar side of the second switch.

The intermediate switch offers control of a circuit from any one of three positions, the other two positions being at the two two-way switches with which the intermediate switch is often used. The intermediate wiring circuit is basically at two-way circuit in which the strapping wires are cross-connected by the two ON positions of the intermediate switch. There are two different kinds of intermediate switch, one of which is in common use. It is thus advisable to check the type with an ohmmeter, or bell-and-battery set, because the method of connecting up differs. Figure 7.1 shows the two common forms of connection made within each type of switch.



The application of the intermediate switch in electrical installations has so far been very limited. But there is no reason why it should not be used more extensively. Long halls, corridors and passageways with many doors are still wired up for two-way control. For reasonable convenience the light or lights should be controlled from every door and entrance. Thus, the user of this type of circuit can make his way through a house, switching on lights before him, and switching off behind him without have to grope about in the dark.

Two or more intermediate switches can be interconnected into the basic two-way circuit to offer control from an almost unlimited number of positions.

The switch fuse is often found as the 'main switch', near the supply-intake position. It is a unit in which the main switch (for installation control) and the main fuses (for the protection of installation) are combined. In all instances, the switch of the switch fuse cannot be operated when the cover is open, nor can the cover be removed or opened while the switch fuse is closed. The switch fuse, which usually controls a separate distribution board, is of the double- or triple-pole type, depending on the supply system. Double- and triple-pole switches are found in metal-clad units called isolators. An example is the fireman's emergency switch, painted red and found beside high voltage gas-discharge lamps such as neons. Isolators are also used to isolate the supply from motors, and heating and non-portable appliances.

The consumer control unit is the most common means used to isolate a complete domestic installation from the supply. It incorporates a double-pole switch and a 'live' bus bar to which the final circuits' protection are connected, and either semi closed fuses, cartridge fuses, or miniature circuit-breakers, the latter becoming increasingly popular because of their definite action in the event of overloading and circuit faults, coupled with safety in their operation. Although originally intended for domestic installations, these units are being used in commercial and industrial installations where small lighting and power loads are involved.

All circuit-control devices, whether switches or other types, must conform to the relevant BS specifications, which thus ensure a minimum guarantee of quality and suitability for use.

7.3: Circuit breakers:

The circuit breakers can be regarded as a switch, which can be opened automatically by means of a 'tripping' device. It is, however, more than this.

Whereas a switch is capable of making and breaking a current not greatly in excess of its rated normal current, the circuit-breaker can make and break a circuit, particularly in abnormal conditions such as the occasion of a short-circuit in an installation. It thus disconnects automatically a faulty circuit.

A circuit-breaker is selected for a particular duty, taking into consideration the following: (a) the normal current it will have to carry and (b) the amount of current which the supply will fed into the circuit fault, which current the circuit-breaker will have to interrupt without damage to itself.

The circuit –breaker generally has a mechanism which, when in the closed position, holds the contacts together. The contacts are separated when the realest mechanism of the circuit breaker is operated by hand or automatically by magnetic means. The circuit breaker 'tripping' employs a solenoid, which is in air-cooled coil. In the hollow of the coil is located an iron cylinder attached to a trip mechanism consisting of a series of pivoted links. When the circuit breaker is closed, the main current passes through the solenoid. When the circuit rises above a certain value the cylinder moves within the solenoid to cause the attached linkage to collapse and, in turn, separate the circuit-breaker contacts.

Circuit breakers are used in much installation in place of fuses because of a number of definite advantages. First, in the event of an overload or fault, all poles of the circuit are positively disconnected. The devices are also capable of remote control by push buttons, by under-voltage release coils, or by earth-leakage trip coils. The over-current setting of the circuit breakers can be adjusted to suit the load conditions of the circuit to be controlled. Time-lag devices can also be introduced so that the time taken for tripping can be delayed because, in some instances, a fault can clear itself, and so avid the need for circuit-breaker to disconnect not only the faulty circuit, but other healthy circuits which may associated with it. The time-lag facility is also useful in motor circuits, to allow the circuit-breaker to stay closed while the motor takes the high initial starting current during the run-up to attain its normal speed. After they have tripped, circuit breakers can be closed immediately without loss of time. Circuit breakers contacts separate either in air or insulating oil.

In certain circumstances, circuit breakers must be used with 'back-up' protection, which involves the provision of HBC (high breaking capacity) fuses in the main circuit-breaker circuit. In this instance, an extremely heavy over current, such as is caused by a short circuit, is handled by the fuses, to leave the circuit breaker to deal with the over currents caused by overloads.

In increasing use of modern electrical installations is the miniature circuit-breaker (MCB). It is used as an alternative to the fuse, and had certain advantages: it can be reset or recluse easily; it gives a close degree of small over current protection; it will trip on a small sustained over current, but not on a harmless transient over current such as switching surge. For all applications the MCB tends to give much better overall protection against both fire and shock risks that can be obtained with the use of normal HBC or rewirable fuses. Miniature circuit breakers are available in distribution-board units for final circuit protection.

One main disadvantage of the MCB is the initial cost, although it has the long-term advantage. There is also a tendency for the tripping mechanism to stick or become sluggish in operation after long periods of inaction. It is recommended that MCB be tripped at frequent intervals to 'ease the springs' and so ensure that it performs its prescribed duty with no damage either to itself or to the circuit it protects.

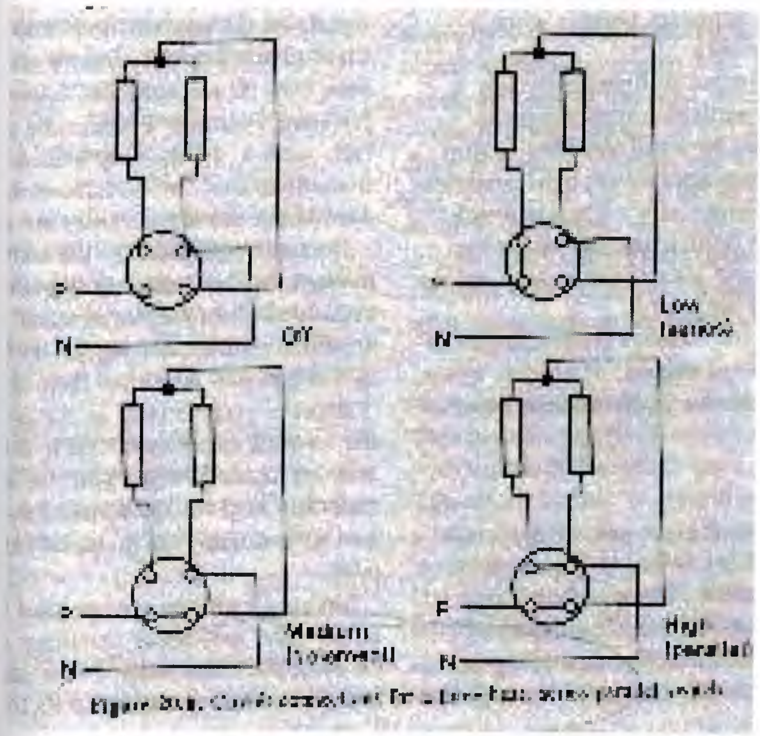
7.4: Special switches:

With the extensive use of electricity today, it is not surprising to find that there is a great variety of switches and other circuit-control devices with special installations. It is possible to indicate here only some of the most common types:

Three-heat switch:

This type of switch is most often associated with the grill-plate of an electric cooker, though it is also used for the heat control of boiling plates. The circuit controlled by the switch consists of two elements of equal resistance. The three-heat switch then offers low, medium and high heat values by its three positions.

Figure 7.2 shows the connections. For low-heat, both elements are connected in series to give 25 % available power. For medium heat, only one element is connected to give 50 % power. For the high-heat condition the elements are connected in parallel.
The three-heat switch is essentially a rotary or term switch. The positions are OFF, LOW, MEDIUM, HIGH. The switches are available as a single-pole type or double-pole type.



Time switch:

As indicated by its definition, the time switch introduces a ' time element' into an electrical circuit, so that the automatic control of the circuit is available at predetermined times. Time switches fall into two general groups: spring-driven and motor-driven. The former uses a mechanism similar to that found in clocks. The latter group uses as the driving unit a small electric motor whose speed is constant and varies only with the 50 Hz frequency of the mains supply. Similar motors are used in electric clocks.
There are many applications for time switches: shop-window lighting, driveway lighting, street lighting, staircase lighting in multi-tenanted buildings and heating loads, the latter being switched on during 'off-peak' periods when cheaper tariff is available.
The time-switch control of lighting circuits is often found in such particular applications as poultry houses, where banks of switches control the lighting to simulate summer-daylight conditions and so introduce a 'longer-day'. The same technique is also used in horticulture, to hasten the growth of seedlings and plants, particularly during off-season periods of the year.
For normal work, the contacts are silvered copper, or entirely silver. For heavy currents, mercury-contact time switches are used.

Mercury switch:

This is basically a sealed glass tube with a small amount of liquid mercury inside it.

Switches of this type have many advantages: low force required to operate them, low contact-resistance, high load-carrying capacity, low cost, and long life because of the 'no wear' characteristic of the contacts. It is also relatively insensitive to ambient temperature conditions; a range from – 4 centigrade to over 204 centigrade has been specified for some switches. Because the glass is hermetically sealed, the mercury switch is switch is effectively immune to dust, oil and condensation, and can be used where corrosive fumes are present.

Contact connections to the switch are made through flexible leads, or 'pigtails', attached to the embedded electrodes or contacts. Some switches are filled with a reducing gas to keep the surface of the mercury pool free from tarnish.

Because glass is used as the switch container, the contacts are always visible for inspection; and mercury tends to resist heat and arc effects. The materials used for the contacts include tungsten, iron or iron alloys and mercury pools.

Mercury switches are operated by a tiling motion: the method of mounting a switch depends on its application, shape of the actuating member and the motion produced by it. In the case of a single-throw switch, the glass tube is tilted from the horizontal. Mountings include bimetallic strips, cams and rotating levers. A time-lag element can be introduced by restricting the flow of mercury from one position to another; this is done by a well placed inside the tube. The wall contains a hall, the diameter of which determines the amount of time-delay.

Rotary switch:

The rotary or rerun switch offers the facility of controlling a large number of circuits from a local position by using one switch. The three-heat switch is one of the most common examples of the rotary switch. Others include the used on switchboards in conjunction with ammeters and voltmeters on three-phase system to indicate phase-to-phase currents and voltages.

Many banks of contacts can be fitted to a rotary switch so that complete control of circuits is available. Generally the currents are not large: 15 A is the usual limit.

Micro-gap switch:

This switch derives its type name from the fact when its contacts are open they are separated by an extremely small gap: anything up to 3 mm. Such switches can only be used in ac circuits. They have many applications apart from 'ac only' lighting circuits. One industrial application is where a motor overheats and a bimetallic, snap-acting device will switch off the energizing current to stop the motor and so protect its wending.

Starter switch:

Starters switches are used for starting fluorescent lamps. The glow-type starter switch consists of two separated bimetallic contact strips contained in a glass bulb filled with helium gas. The contacts are connected to the fluorescent lamp filaments. When the circuit-control is closed, the mains voltage appears across the two contact strips. This voltage is sufficient to cause a small gas discharge. The heat generated by the discharge affects the bimetallic contact strips, which bend forward to meet each other. When they make contact, the current flows through the fluorescent lamp filaments to heat them. The gas-discharge glow in the starter switch now disappears. After a few seconds the bimetallic contact strips cool down and separate. This sudden interruption of the circuit causes a high-voltage surge to appear across the ends of the main lamp electrodes to start the gas discharge.

The voltage, which now appears across the contact strips in the starter switch is, during running conditions, insufficient to cause further discharge in the helium gas, and so the contacts remain open while the main lamp, is burning.

Two-way-and-off switch:

This is a single-pole and changeover switch with an OFF position. It is also be found in hotels ships and hospitals where it is required to have two lamps in circuit while so arranging their control that both cannot be used at the same time.

The two-way-and-off switch can be used as a dimmer control, when in one ON position of the switch only one lamp is lit; in the other ON position two lamps are connected in series to give a 'dim' light. Other lamp-control arrangements are available when this type of switch is used with other types such as the two-way.

Series-parallel switch:

This is three-position switch with an OFF position when the switch knob or dolly is central. The switch is used to control two points, or one groups of points. In one ON position, the lam or lamps are connected in series (dim). In other ON position, the lamps are connected in parallel (bright). These switches are to be found in hotel corridors, hospital wards and in railway carriages.

Low-voltage contacts:

The most common type of low-voltage contact is the bell push, which is operated by the direct pressure of finger on a push-button: the contacts are copper or brass. One is fixed to the base of the bell push; the other is fixed at one terminal end, its other free and being raised. Pressure on the push-button depresses the contact's free end to complete the circuit. The contacts are usually natural copper; though they are sometimes given a coating of non-ox disable metal. Other low-voltage contacts use steel springs and phosphor-bronze springs, and are associated with various alarm circuits: burglar, fire, frost, water-level and smoke-density.

Relay:

The most common relay is a switch operated by an electromagnetic. It consists of an iron-cored coil and a pivoted armature. When the coil is energized, one end of the armature is attracted to the electromagnet and the other presses two or more contacts together; contacts may also be opened by this movement of the armature.

Relays are either normally closed (NC) or normally open (NO). In the first type, when the coil is energized the contacts are open, the contacts close when the coil is de-energized. In the NO relay, the contacts are closed when the coil is energized, and open when it is de-energized. In effect, the really is an automatic switch.

Relays are normally designed to operate when a very small current flows in the coil. Thus, a small current can be made to switch larger current or off, just a contactor functions from a distant point. They are also used in bell and telephone systems, and have a wide application in industry.

Other types of relays use a solenoid for their operation. In this instance a plunger is attracted when a predetermined value of current flows in the coil. A time-lag element can be introduced by the addition of oil – to air-dashpot to delay the movement of the plunger.

Fireman's switch:

This switch is used to isolate high-voltage lighting circuits usually found on the exterior walls of buildings, such as neon signs. The switch, which is painted red, is mounted on the outside of the building adjacent to the sign lamps. A label 'Fireman's switch' is required to be mounted close to the switch. The OFF position of the switch is at the top and there must be a catch to prevent its inadvertent return to the ON position. The mounting height should not be more than 2.75 m from ground level.

Emergency switch:

This is a requirement of the Wiring Regulations. The switches take the form of large mushroom head buttons, which can be knocked in the event of an emergency, say, in a workshop. The switch then disconnects the circuit machine.

7.5: General requirements:

Directly operated switches are not allowed in bathrooms or shower rooms where switches are within reach of a person in contact with the bath or shower. Pull-cord switches are recommended in these situations.

When the time switches are being connected up, it is essential to ensure that a CPC is also connected to earth terminal provided. From time to time the consumer may need to make adjustments to the switch settings, thus coming into contact metal parts such as the switch-operating levers. Correct use of the earthing terminal will prevent shock risks.

All lighting switches must be connected in the phase conductor only and the correct color-coding of the connecting wires is required by the Wiring Regulations. Any exposed metalwork must be earthed. The switch must be of an adequate current rating. If they are used for inductive loads such as fluorescent circuits, they must be fully rated for the value of inductive current take. If they are not, then they must not carry anymore than half their rating, e.g. 2.5 A in the case of a 5 a rated switch.

Where switches are used as isolators for motor circuits, they should be located close to the motor position. If this not possible, the switch handle should be able to be padlocked in the OFF position so that work can be carried out without fear of the circuit becoming live.

Protection:

The physical protection of circuit-control devices involves the provision of some method enclosing the contacts and the switch-movement mechanism. In most instances this is merely providing an insulating enclosure so that the device can be operated with safety from electric shock, hence 'shockproof'. Other enclosures include 'weather-proof' and 'watertight'.

For industrial installations, full protection is often is given to the operating dollies of switches by a corner-fixed cover-plate which is both dished and lipped, the dolly being located within dised part of the cover.

Dust proofing is necessary where there is the possibility of fine metal cuttings and dusts, fluff or oil-mists penetrating to the contacts.

CHAPTER EIGHT

SUPPLY DISTRIBUTION AND CONTROL

8.1: Supply distribution:

With few exceptions, the types of electricity supply normally available are alternating current single-phase-two-wire, and three-phase-four-wire. In large factories involved in certain kinds of processes as steel mills, the internal works supplies for much of the rotating plant is dc. Direct current supplies outside industry are rarely available from a supply company, although they are, of course, in wide use of emergency lighting, battery charging and similar applications where the power requirement involved is small. Where the amount of power is large as in metal refining, the voltage is small (e.g. 10 V) and the current is correspondingly is large (e.g. 10,000 A). The dc system in general use until the gradual changeover to ac supplies was the three-wire system. This consisted of a dc generator supplying a voltage of 500 V between two outer conductors known respectively as the 'positive outer' and the ' negative outer'. A middle wire, generally of smaller cross-sectional area, was earthed and thus provided a voltage of 250 V between any of the outer conductors and the neutral or mid-wire. Thus, a 500 V motor could be supplied across the outers, while a domestic requirement of 250 v was met by connecting the mid-wire and the positive or negative-outers. This two-voltage facility was developed from the older single-voltage systems evolved before the turn of this century.

The ac systems came into their own because it was found possible to transmit large amounts of ac electrical power over long distances provided high voltage was used. AC is generated in the power station usually at 25,000 V. This generated voltage is transformed by generator –transformers to transmission-line voltages of 132, 275 and 400 KV. The transmission line from apart of what is known as the NATIONAL GRID, which is an interconnected system of conductors (overhead lines and underground cables), which carry electrical power to points of use. All these points, the transmission voltage is reduced by transformers to 33 kV and 11 kV for large consumers. The voltage is further reduced to 415/240 V for small consumers.

The single phase, 240, 50 Hz systems is the normal supply for small dwellings, and other single-occupier premises where the load demand is relatively small.
The three-phase systems derived from a star-connected winding of a transformer, the star point being earthed. From this point a fourth conductor, the neutral, is taken to form a three-phase, four-wire system.

The voltage between any phase conductor and the neutral is 240 V. This system is the normal supply for commercial and industrial premises of medium size: schools, hotels, blocks of flats, hospitals and the like. The lighting and heating circuits of individual tenements in blocks of flats are normally supplied from low-voltage circuits derived from this system, the load across the three phases being balanced as far as practicable. High-voltage three phase supplies are fed to very large consumers where total electrical load exceeds 100 kW. The voltages are either 11 or 33 kV. The consumer is offered a cheaper tariff if he takes a higher voltage. A balance-load on a three-phase system is usually available only where three-phase motors are used. Heating loads, in most instances, can be connected across three phases and the neutral conductor omitted unless required for control purposes.

Cable sizes are dictated by the amount of electrical power to be carried. If a large power is to be taken to a consumer, high-voltage cable is used, to reduce the current and so the cross-sectional area csa of the cable conductors. Because of the high voltage, however, the cable must be of necessity cost more to insulate. Despite this, there are sound economic reasons for carrying as much power as possible at a high voltage, leaving the larger csa cables to carry larger currents associated with individual circuits in an installation at low and medium voltages. The main economic reason is to reduce the amount of power loss in a conductor. There is also the important aspect of the loss in voltage along the length of the conductor as it caries the load current.

Underground cables are used where there is a visual objection to overhead lines to where it would not be convenient to use lines. Both paper and PVC insulated cables are used, with copper and aluminum conductors. The latter has now come into favor because it costs less than copper and has its lightweight requires a smaller cable-laying labor force. Copper conductors are stranded. Aluminum conductors are found in both stranded and solid forms. Belted cables are cheaper than careened types and are used for systems up to 11 kV.

Protection of underground cables against mechanical damage is provided for by steel-wire or steel-tape armoring. Steel-tape armoring cables are cheaper in first cost than the wired-armored types, but the bending radius is less and they cannot be left 'bright', that is, with the jute serving removed to present a clean appearance n surface work. Also, tape armoring cannot be taken over plumbed or cone gland to the Armour clamp as in wire-armored cables.

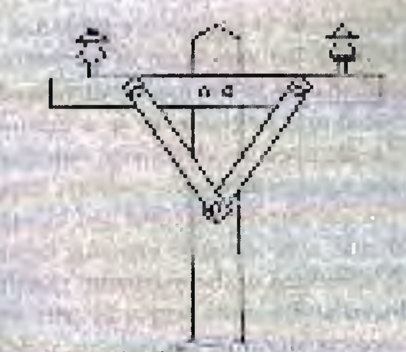
There are three methods of laying underground cables: direct lying, draw-in and solid. The direct-laying method involves the cable being placed in a trench and then covered with soil. In most instances, the cable is protected in wood planks, bricks, tiles or concrete slabs. Such cables should be armored, though if the risk of mechanical damage is small, bare-sheath cables can be used. Subsidence of the soil is an important factor in the installation of buried cables. And if the soil contains harmful chemicals, precautions must be taken to prevent the cable from being damaged by corrosion and electrolysis. Direct lying is cheap, but replacement or renewal of the cable involves completely new excavation, which could be costly in the long terms. In the draw-in system, a line of conduits is glazed stoneware, cement or concrete. The tubes can be of earthenware or iron. After the ducts are laid, the cables are pulled into position from manholes or brick pits. Armoring is not necessary, but the cables are usually given a covering of Hessian tape or use to protect them while drawing in. Ducts are usually multi-compartmented. In the solid system, the cable is laid in throughing in an open trench. The troughing is then covered with a bituminous compound, and the trench filled in.

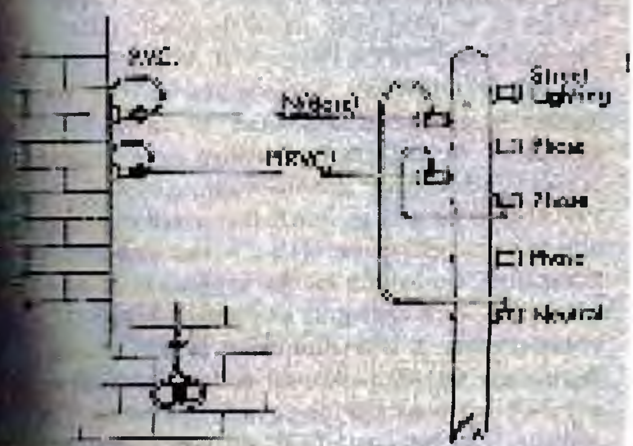
8.2: Overhead lines

The cheapest method of carrying power is by overhead line, particularly where light loads are concerned, as might be the case in a farm installation. Overhead line poles for low-and medium-voltage services are of wood, generally 8m in length some 7 m out of the ground. There are regulations, which govern the minimum lengths of span and minimum heights above ground for consumers' overhead wiring between buildings. In ordinary ground, the erection of poles presents no difficulty. The pole should be dug as narrow as possible in the direction of line. The pole should be positioned in one corner of the hole, so that in two directions it bears against undisturbed soil. Preferably, the butt of the pole should rest on a few inches of concrete or hard core, and be well rammed. In loose ground, cross-braces are necessary below ground level to present a larger *area to the yielding soil.*

Copper, owing to its high electrical conductivity, being second only to silver, and because it has good mechanical properties and resistance to corrosion, has for long been the most commonly used conductor for overhead lines. One limitation to its use is the excessive sag that is necessary on long spans. In such instances, conductors with a higher tensile strength are used e.g. a composite conductor employing copper or aluminum strands round a steel wire; or a conductor of cadmium-copper alloy. Overhead lines are subject to the requirements of the Overhead Lines Regulations, where a public supply is being carried. A conductor must have a breaking load at least 560 kgs. Thus the minimum size for a copper conductor is 8 SWG. The minimum permissible size of service line must be such as to have an actual breaking load of not less than 370 kg.

Conductors may be bare, or insulated PBJ, VR or PVC. Line conductors are attached to insulators carried on supports of wood, iron, steel, or reinforced concrete. Al wooden supports other oak or hardwood cross-arm must be impregnated with creosote. Two forms of insulators are used; the pin-type and the disk insulator for tension positions as shown in figures 8.2 and 8.3.





8.3: Supply control

It is a requirement of the Wiring Regulations that every consumer's installation shall be
Adequately controlled by switchgear which is readily accessible to the consumer and which shall incorporate:

1) Protection against electric shock.
2) Protection against over current.
3) Isolation and switching.

The type and size of main switchgear to be installed depends on the type of premises and anticipated load. For the average domestic premises, the service cable (underground) is two-core and PILC- or PVC-insulated. This is suitable for a load of about 20 kW at 240V, single phase and 25 mm squared csa; it is sufficient for the electrical requirements of most households. Industrial installations, unless they are very small workshops, are provided with three phases, four-wire services, usually 415V between phases, higher voltages are supplied where the load is large. The size of cable for an industrial load must cater for any future additions to the load or extensions to the factory. It is usual practice to install cables of sufficient capacity with appropriate switchgear; to save additional installation expense and outage time at a later date extensions are projected.

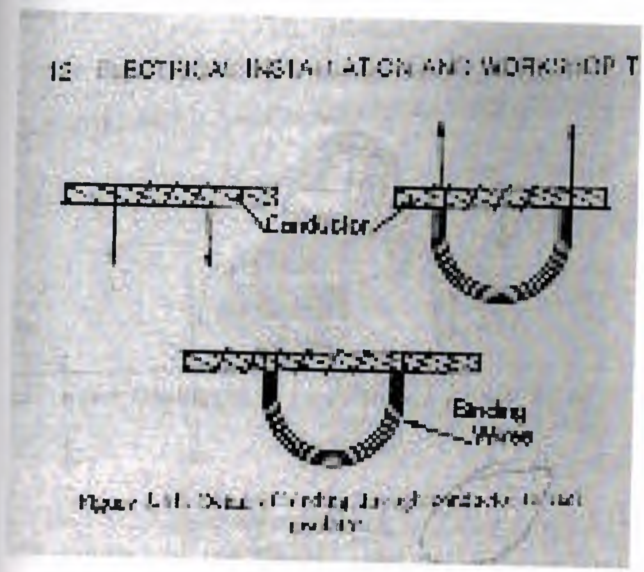
The location of the switchgear of a medium-voltage installation is at the main switchboard. This is situated in a substation or in a separate room on the premises to which any authorized persons have access and which is always kept clean and dry. The Switchgear, fusegear and circuit breakers should have adequate breaking capacity current
Obtainable from the supply system. For medium-sized installations, the switchgear is in the form of manually operate switch fuses. These units are available as metal clad, double- or triple-pole and neutral switches with HRC fuses. Capacities are up to 300A, and can safely handle faulty currents up to 25MVA at voltages up to 660V ac. Large industrial loads are handled by circuit-breakers which, of course, incorporate the facilities for handling large amounts of short-circuit automatically. A typical switchboard for a large installation usually consists of a main circuit breaker with a bus bar chamber from which are fed the various sub circuits of the installations, each having its own small-rated circuit breaker. It is a requirement of the IEE Wiring Regulations that all switchgear be labeled to identify their functions and the circuits they control. In addition, switches controlling emergency services such as fire alarms, firemen's' lifts and sprinkler systems should be distinctively marked, for example, by painting them red.

The memorandum by the Senior Inspector of Factories indicates the adequate passageways should be allowed to give access to al switchboards. Adequate means must also be provided for isolating the equipment to allow access for maintenance and other purposes. Where more than one phase is brought into a building, as in the case of industrial loads, special precautions must be taken to avoid the risk of shock. The Regulations insist that all live terminals between which low voltage exists should be shrouded with an insulating material or be enclosed in earthed metal. Single-phase distribution boards, which are connected to different phases, must be 2 m apart from each other.

The position of distribution fuse boards is important, and should be near the electrical center of the load they are intended to serve. This reduces of the cost circuit cables, though the length between the supply-intake position and particular distribution board should be taken into consideration so that the volt drop does not exceed the permitted maximum of 4 % of the nominal voltage of the supply.

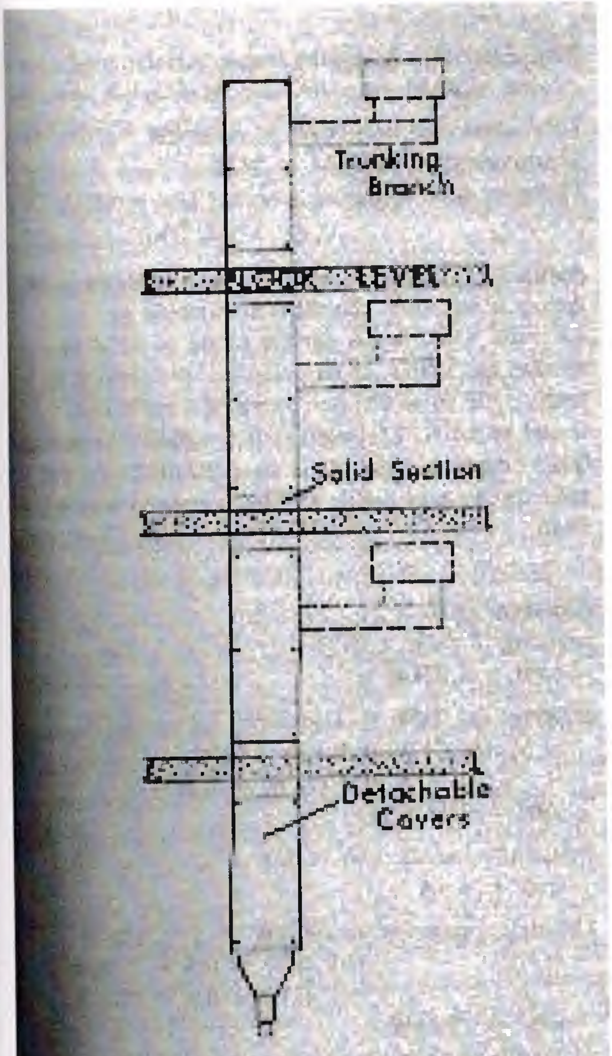
Sub-main distribution in industrial premises is generally by cables or by bus bar trunking systems. For machine shops and other parts of a factory where alterations in machines layout may occur frequently, the plug-in tap-off system is recommended. Separate sub-mains should be installed for special electrical services such as passenger and goods lifts and ventilating systems. Sub-main circuits should not be run within lift shafts. In small domestic and commercial installations, the distribution board is at the meter position. With the usual two-part tariff, one-meter records the energy used for lighting, heating and cooking, and only one main control switch or switch fuse is necessary. If a different tariff is applied, for example, for peak-off loads, a separate meter and switch must be provided. The off-peak loads are controlled by time switches and contractors.

Details of conductor make-offs at pole and house terminations, and conductor lead-in to building are shown in fig 8.4. The drip-loop prevents the ingress of rain and moisture to the building.



8.4: Rising mains

When rebuilding began after the last war, it was found necessary to erect numerous buildings of the multi-storied type. Originally, these buildings were five to seven storeys high. Since then, the height has been increased and, and to make the most of land available for housing, twenty storeys are common nowadays. The electrical problem here is the supply of the individual dwellings in these buildings. The usual method of mains supply is to run conductors to the full height of the building and to provide convenient tapping-off points to feed the flats on one more floors according to the number of flats per floor. It is shown below in fig. 8.5.



In essence, the rising mains are elongated bus bar chambers supplied in lengths to suit the heights of the floors. They incorporate expansion joints between the sections. The bus bars are either round or rectangular copper or aluminum bars. Boxes containing fuses may be fitted over the front of the trunking where required, or tapings can be taken off to boxes at the side, or else directed to individual flats. These systems can be provided with bus bars capable of carrying upwards 1000A. In the basement of the building the service is usually 415V, three-phase with a neutral conductor for single-phase services to the flats. The primary of the supply transformer is usually 11kV.

In deciding the system of rising mains for a particular installation, one of the most difficult problems is the determination of the allowable diversity. This diversity factor, as it is called, allows some reduction in both the size of conductors and switchgear supplying an installation. In general, the average demand of a flat is taken as 10kW, though this figure is increased if electric under floor heating is used, which is normal method of heating in multi-storey buildings.

In general, where bare conductors are used they shall be so installed that they are inaccessible to unauthorized persons and either be totally enclosed in earthed metal or fixed in a channel, trunking or shaft especially provided for the purpose, and be of adequate strength to withstand the electro-mechanical forces they may be set up by the prospective short-circuit, and be free to expand and contract as the temperature changes. In addition, where the mains pass through floors, walls, partitions or ceilings, they should pass through directly and be protected by enclosure in non-absorbent, incombustible insulating material, unless earthed trunking is used. If cables insulated with general-purpose rubber or PVC are to be connected to the bus bars of rising mains, the insulation must be removed for a distance of 15 cm from the connection and replaced, if necessary, by suitable-resisting insulation.

Diversity factor:

The diversity factor has an important place in the design of an installation and its final costing. Diversity factor is a factor which is applied to sub-mains and mains cables and their associated switchgear to reduce: (a) the csa of the cable conductors and (b) the capacity of the switchgear.

The factor is based on the assumption that the whole of the connected load will not be able at the same time. For example, the total lighting load in a dwelling house is rarely switched on at once. Thus, it can be taken that if the total lighting load is 1000W, at any one time during the life of the installation, only 66 % of the load will be switched on at any one time. The factor in this instance is 0.66. A factor for diversity shall not be allowed for when calculating the size of circuit conductors and switchgear of final sub-circuits, other than specified circuits such as cooker circuits. It is noted that the provision of an allowance for diversity is a matter calling for special knowledge and experience. Indeed, the application of diversity should be decided by the engineer responsible for designing each particular installation. The amount by which they are increased or decreased for each installation is a matter of the installation engineer to decide.

There are ten types of final circuits fed from wiring to which diversity applies: lighting, heating, cooking appliances which are permanently connected, motors, instantaneous- type, water heaters, thermostatically controlled water heaters, floor-warming installations, 13a fused socket-outlets and appliances fed there from, and other socket-outlets such as 15A. Three general groups of installation premises are also recognized:

1) Individual domestic installations, including individual flats of a block.
2) Hotels, boarding houses, lodging houses.
3) Shops, stores, offices and business premises.

In the case of lighting for each type of installation, it will be noticed that the more total lighting load is likely to be switched an over definite periods, the smaller is the allowance made for diversity. In a domestic installation, it is estimated that some two-thirds of the lighting load will be on at any one time. In a hotel, the figure is 75 %. And in a shop, where virtually all the lights are on for the most of the time the shop is open, the figure is 90 %. It should be noted that no diversity is allowable on the relevant wire supplying certain types of load.

CHAPTER NINE

FINAL CIRCUITS

Introduction:

A final circuit is defined as ' A circuit connected directly to a current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such an equipment'. In addition, the regulations require that where an installation comprises more than one final circuit, each circuit shall be connected to a separate way in a distribution board. They also require that wiring of each final circuit shall be electrically separate from that every other final circuit. To facilitate disconnection of each final circuit for testing, the neutral conductors shall be connected at the distribution board in the same order as that in which the live conductors are connected to the fuses or circuit breakers.

Final circuits make up the greater part of electrical installations and can vary from a pair of 1 mm squared cables feeding one lamp, to a heavy three-core PILC cable feeding a large motor from a circuit-breaker located at a factory switchboard. The main important regulation which applies to final circuits is that 'All conductors and apparatus must be of sufficient size and power for the work they are called on to do, and so constructed, installed and protected as to prevent danger'.

There are five general groups of final circuits:

1) Rated at not more than 16A.
2) Rated over 16A.
3) Rated over 16A but confined to feeding 13a socket-outlets with fused plugs.
4) Circuits feeding fluorescent and other discharge lamps.
5) Circuits feeding motors.

An industrial installation may have all five types; a domestic installation may have 1,2, and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at an early stage in the design of an installation. Before indicating the factors, which are involved in the choice of final circuits types, a few brief notes on planning aspects will be relevant.

9.1: Installation planning

Domestic installations seem to be the simplest to plan, but there are a number of points, which are not considering. And though these might seem obvious at first sight, a close survey of existing installations will reveal rather too many lapses in efficient planning, even a dwelling house. For example, a room which can be entered from two points should be wired for two-way switching; a two-landing staircase should be wired for intermediate switching; and a large house should have two or more lighting circuits. If an installation has two lighting circuits and one circuit fails, the house is to plug into darkness. It is often a good point to consider a slight 'overlap' of lighting circuits: to wire one lighting point from one circuit within the wiring area of the other circuit. If this is done, there should be a note to its effect displayed at the distribution board.

The lighting in houses should be regarded as an important aspect of interior decoration, as well as supplying lighting on purely functional basis. In living rooms and bedrooms, well-mounted fittings can be used, controlled by multi-point switches at the entrance doors. Thought should be given to the provision of 13A socket-outlets for supplying table and standard lamps. The use of local lighting over working surfaces in kitchens is an aspect of good planning. External lighting should not be overlooked, either to light up the front and back doors or to light the way to outhouses such as detached garages, coal stores and greenhouses. In very large houses, driveway lighting may have to be considered.

To facilitate the interchange of fittings and appliances throughout the house, it is recommended that 13A three-pin socket-outlets to BS 1316 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switch socket-outlets should be used. Because the past few years have seen a rapid increase in the use of electrical appliances, it is essential that an ample number of socket-outlets be provided, and situated wherever there might arise the need for an electrical outlet. Table 9.1 shows the provision of socket-outlets, both the desirable number and the minimum provision that can be considered as acceptable:

Part of dwelling	Desirable provision	Minimum
Working area of a kitchen	4	4
Dining area	2	1
Living area	5	3
First double bedroom	3	2
Other double bedroom	2	2
Single bedrooms	2	2
Hall or landing	1	1
Store/workshop/garage	1	0
	20	15
Single study-bedrooms	2	2
Single bed-sittings rooms in family dwellings	3	3
Single bed-sitting rooms in self contained bed-sitting room dwellings	5	5

It can thus be seen that the average house should have an adequate number of socket-outlets. In the living room, there should be a two-gang socket-outlet on each side of the fireplace. Additional socket-outlets should be located less than 2 m from the opposite corners of the room, where they are least likely to be hidden by furniture. In bedrooms, at least socket-outlet should be provided at each side of a be; two-gang units can be used to good advantage. Additionally, there should be socket-outlets for dressing-table lamps, a heating appliance or a portable television set.

The kitchen probably places the greatest demand on the electrical service. Outlets are required for such varied appliances as washing machines, refrigerators, waste-disposal units, food mixers, can-openers, flat irons, coffee percolators and toasters. As far as possible, the outlets should be located above working services and two-gang units are recommended.

In the dinning room, small plate-warmers may be required. In halls and on landings the outlet is generally used for a vacuum cleaner or floor polisher, and perhaps a hall heater. No provision is made for the use of portable appliances in a room containing a fixing bath or shower. However, an electric shaver unit to BS 3052 may be installed out of reach of a person in the bath or shower. Additionally, a bathroom heater or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

Commercial installations are often difficult to design because frequently the buildings are built as basic shells with the final requirements for lighting and other circuits not known until the office tenants sign their leases. The lighting in such building is 'general, special and building services'. The general lighting is supplied by a flexible wiring system which will allow for a specific area in a new building to be sectioned or partitioned off into smaller areas for offices, stores and the like. Special lighting may include external building, wall points, etc. The service lighting is that associated with lifts, corridors, stairs, and landings and is usually the responsibility of the landlord. Where a tenant's specific lightings requirements are not known when the building is being erected, the lighting outlets are laid on a 'grid' system, in which the outlet points are sited at regular intervals usually related to the module of the building. Generally, about 3 m are allowed between outlets. Outlets may be left on the ceiling for the ceiling switches. They may also be fitted on structural columns or on the ceiling along the line of future corridors from which extensions to switch positions can be made on future partitions.

The provision of adequate socket-outlets is a particular problem, for should the electrical load increase, it is often difficult to extend or alter an inflexible installation. Thus, the electrical services provision should allow the possibility of installing new outlets or revising the positions of existing outlets without difficulty or serious disturbance to the building and its occupants. Where a tenant's requirements for socket-outlets are not known, it is usual practice to install one socket-outlet on the external wall in each building bay and make provision for spur connections to two further outlets to be installed on internal partitions as may be required. Only a limited number of bays, not more than three, should be connected to each ring circuit.

Industrial premises require lighting installations, which cater for the intensity of lighting required for the process to be carried out. In addition, local lightings at reduced voltages are often a requirement on machines or for portable inspection lamps. The lighting installation within the factory area should be wired with a system, which will allow for extensive alteration and significant addition with ease of maintenance and rewiring when necessary.

Special types of premises include hospitals, theatres, cinemas, hotels, schools, and buildings of historic interest. Some of these, such as hospitals, have specific codes of practice laid down by the Ministry of Health. In places of entertainment, secondary lighting installations are required.

9.2: Circuits ratings

9.2.1 Circuits rated under 16 A:

A final circuit rated at not more than 16A may feed an unlimited number of points provided that the total 'current demand' does not exceed 16A. They include 15, 13, 5, and 2A socket-outlets, lighting outlets, stationary appliances and certain loads, which may be neglected because their current demand is negligible, provided that their rating is not greater, that 5VA. No diversity is allowed on final circuits. The current rating of the cable must not be exceeded. An important point to note is that if a cable size must be increased to avoid excessive voltage drop in the circuit; the rating of the fuse or circuit breaker protecting the circuit must not be increased correspondingly. The same condition would apply if the ambient temperature of a cable were to be taken into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favorable circuit conditions, but to provide the special conditions in which they are being installed. The lighting circuits of domestic installations are rated at 5A. Industrial lighting circuits are usually rated at 15/16A because of the higher wattage of the lamps used.

9.2.2 Circuits rated over 16A:

With two exceptions, circuits rated at over 16A should not serve more than one point. The exceptions are circuits, which feed 13a socket-outlets, and cooker circuits. Final circuits for cooking appliances are assessed for current demand as follows:

The first 10a of the total rated current of the connected cooking appliances, plus 30% of the remainder of the total rated current of the connected cooking appliances, plus 5A, if the cooker control unit has a socket-outlet.

Thus, a cooker with a total load of 11kW at 240V would be in fact be supplied by cables rated to carry about 26A, depending on the distance the cooker is away from the distribution board. If a large cooker, which exceeds 30A, is to be installed in domestic premises, and where protection is offered by fuses, a supply service of more than the normal 60A rating may be required. In this instance, the supply authority should be consulted. Water-heater circuits are terminated in a 20A double-pole isolating switch, fitted with an earthing terminal and a neon pilot lamp.

9.2.3 Circuits rated for 13A socket-outlet:

Final circuits which supply 13A socket-outlets with fused plugs and 13A fused connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maximum floor area of 100 m squared derived from a 30A protective device. Radial circuits serving a maximum area if 50 m squared are also protected by a 30A device, while if the area served is no more than 20 m squared a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

Each socket-outlet of a two-gang or multiple socket-outlet is to be counted as one socket-outlet.

Stationary appliances, permanently connected to a radial or ring circuit, must be protected by a fuse not exceeding 13A rating and controlled by a switch or circuit breaker.

It is important to realize that the conductor sizes recommended for ring circuits are minima. They must be increased if necessary where circuits are installed in groups, or in conditions of high ambient temperature, taking into consideration the class of excess-current protection provided.

The method of properly connecting circuit conductors of a ring circuit involves correct polarity and security of the terminals.

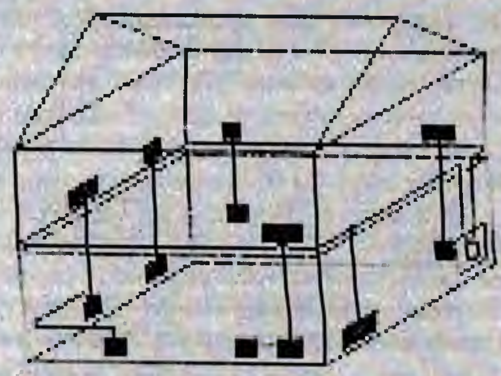
Except where a ring circuit is run throughout in metallic conduit, ducts or trunking, the CPC shall be run in the form of a ring, having both ends connected to earth at the distribution board.

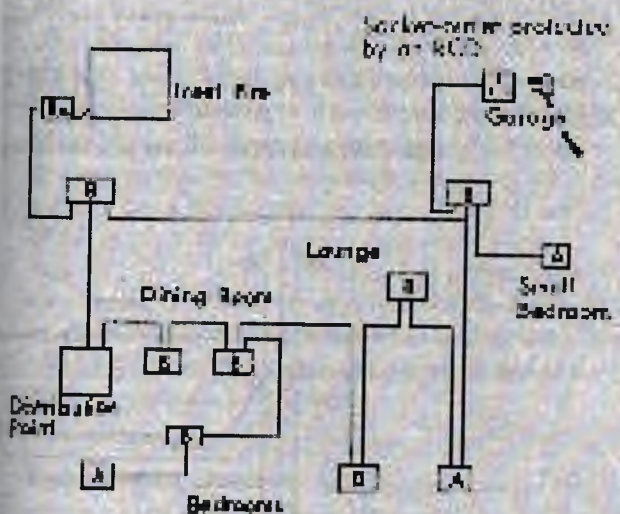
The total number of spurs shall not exceed the total number of socket-outlets and stationary appliances connected directly to the ring.

Fused spurs from ring circuits must be connected through fused spur boxes, and the rating of the fuse must not exceed the current rating of the cable forming the spur, and in any event must not exceed 13A.

One socket-outlet or one two-gang socket-outlet unit, or one stationary appliance fed from a connection unit, can be connected to each non-fused spur.

Fig 9.1 shows an ideal ring circuit serving two floors.
Fig 9.2 shows typical ring-circuit with spurs to outlying points.





9.3: Choosing cable size:

The selection of the size of a cable to carry a load current involves the consideration of the rating and type of the protective device, the ambient temperature and whether other cables are run alongside the cable. There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when over currents are carried due to overloading and when a short-circuit occurs. Others include the increase in temperature when a number of current-carrying cables are bunched together, for instance, in conduit and trunking, which is a situation in which each cable contributes its heat to that of others and which, because of the enclosed situation, produces an environment which can quickly lead to the deterioration of the cable insulation and lead to a possible source of fire. At about 80 centigrade, PVC becomes very soft, so that conductor can 'migrate' or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, wit an increase in the leakage current, which could prove fatal if the installation earthing arrangement is faulty. Eventually, when the insulation breaks down completely, a short-circuit occurs and the circuit is now dependant on the ability of the over-current protection device to operate to disconnect the circuit from its supply. As is probably realized, the time of operation of the protective device is crucial: a semi-enclosed fuse will take longer to operate than would a miniature circuit breaker. In some circumstances, particularly where PVC insulated cables are used, the time taken by semi-enclosed fuse to operate may be long enough for the cables to burn out and create a fire hazard.

Another problem, which has occurred in recent years, concerns the use of thermal insulation in buildings; with cables being installed in conditions where the natural heat produced by even their normal load currents cannot be dissipated easily.

The IEE Regulations recognize the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. These classifications are used in the tables, which give the current-carrying capacities of the cables. The installation conditions include 'enclosed', 'open and clipped direct'; 'defined conditions', which includes cables in free air; and cables 'in enclosed trenches'.

From this, it can be seen and appreciated that the selection of a cable to feed a circuit is now required to be undertaken with a number of factors to be considered carefully. Situations, which were formerly taken for, granted must now be investigated so that the cable is installed in the best conditions, which will allow the cable to carry its load current with the safety of the user of the installation in mind:

The IEE Regulations require that the choice of a cable for particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

1) The ambient temperature in which the cable is installed.
2) The installation condition; e.g. whether grouped or bunched with other current carrying cables, enclosed or installed 'open'.
3) Whether the cable is surrounded by or in a contact with thermal insulating material.
4) Whether the circuit is protected by semi-enclosed fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by IEE Regulations, is based on the ratings of the over current protective device. All factors affecting the cable in its installed condition are applied as divisors to the rating of the device.

In general, the size of every bare conductor or cable conductor shall be such that drop in voltage from the origin of the installation to any point in that installation does not exceed 4% of the nominal voltage when the conductors are carrying the full load current.

The following process for working out the correct size of cables as follows:

1) First find the load current of the circuit Ib.
2) Determine the correction factor of the ambient temperature which is of course does not include the heat generated in the cable itself, but is more concerned with the maximum temperature of the medium through which the cable runs.
3) Determine the correction factor of grouping.
4) Determine the correction factor if the cable is in contact with or surrounded by thermal insulation material and 0.5 if the cable is completely surrounded by the material.
5) Select the rating of the over current device. If this is offering what used to be called 'close' protection, the correction factor is 1. If, however, protection is by

means of a semi-enclosed fuse, the factor is 0.725. The rating of the device must at least equal the load current.

6) Determine the size of the circuit conductor by calculating its current rating. The actual size is obtained from the current-rating tables.
7) Check the volt drop does not exceed the maximum permissible allowed.

If Iz represents the current rating of the conductor and In the rating of the protective device, then:

Iz=In/(Cg.Ca.Ci.Cf) Amperes

Where:

Cg: is the factor of grouping.

Ca: is the factor of the ambient temperature.

Ci: is the factor of the thermal insulation (0.5 if the cable is surrounded and 0.75 if the insulation is in contact with only one side of the cable).

Cf: is the factor of the over current device. This factor is 1 for all devices except the semi-enclosed fuses, when the factor is 0.725.

CHAPTER TEN

SPECIAL INSTALLATIONS

Introduction:

Though the bulk of electrical installation work carried out in some countries does not involve the consideration special factors in the context of the wiring systems, accessories and the equipments to be used in an installation, there are some types of installation conditions, which call for special consideration. These conditions create the need for what are called in this chapter 'special installations', which tend to fall out with the general run of installations and require their special and particular requirements to be satisfied. These special installations are dealt with in the IEE Regulations in a rather general way and the electrician must therefore consult other sources of information as to installation procedures, techniques and recommended types of equipment.

10.1: Damp situations:

In general terms a 'damp situation' is one in which moisture is either permanently present, or intermittently present to such an extent as to be likely to impair the effectiveness of an installation conforming to the requirements for ordinary situations. These situations create a hazard from electric shock and the risks, which attend a gradual deterioration of the metalwork of the installation as the result of corrosion.

The IEE Regulations require that every cable installed in damp situation, and where it is exposed to rain, dripping water, condensed water, and accumulations of water, shall be of a type designed to withstand these conditions. In addition, all metal sheaths and Armour of cables, metal conduit, ducts or trunking, and clips and their fixings, shall be of corrosion-resisting material. In particular, they should not be placed in contact with other metals with which they are liable to set up electrolytic action. If steel conduit is involved in such damp installations, it must be of heavy gauge. Conduits threads should be painted over with a bituminous paint immediately after erecting. Cables, which are armored and destined for installation in a damp situation, are required to have further protection in the form of an overall PVC sheath.

Even though an installation is not classed as 'damp', there may occasionally arise a situation, which could place it in this category. This is one result of condensation, which, though it might occur intermittently, may well appear in the form of a considerable quantity of condensate. Condensation exists where there is a difference in temperature, for instance, where equipment is installed inside a room in which the ambient temperature is high, and the equipment being controlled by switchgear outside the room in a lower ambient temperature. If the switchgear and the equipment are connected by trunking or conduit, then condensation is likely to occur. It will also occur where a room has a high ambient temperature during the day and where the temperature subsequently falls when the room is unoccupied during the night.

Generally, whenever dampness, whatever its source, is present, galvanized or sherardised metalwork is recommended. In addition, site conditions may be such that fixing accessories and materials may also be required to withstand any corrosive action that might occur. If conduit is used, drip points should be provided so that water can drip away. Long runs of conduits should be slightly off level to allow any accumulated condensate to run to a drain point at the lowest level.

The problem of condensation occurs frequently in cold-store installations and around refrigeration plant. Switchgear and other control equipment should be installed outside the cold rooms in a position some reasonable distance away from blasts of cold air and clear of door openings where changes in temperature are likely to occur. Cables of the MICS and lead-sheathed types should be landed totally enclosed lighting fittings and run into cold chambers on wood battens. Cable entries into cold rooms should be sealed with some bituminous material. It is important to recognize that working PVC cables in low temperatures will injure the cables. At temperature below 0 centigrade crack if hit sharply. There is also a warning note regarding the use of cables with bituminous-compounded beddings or servings.

Electrostatic situations:

Static electricity is generated whenever two dissimilar surfaces are brought into intimate contact and then separated. When both surfaces are conducting, there is a little apparent separation of charge, since both will be maintained at the same potential until the last moment of contact. As soon as the surfaces part, however, a spark may be observed. Generally, considerable electrification though static occurs on the separation of a good insulator. Many of the flammable liquids in use today have high insulating properties. When they are handled, or being poured through a pipe opening, considerable static charges may be generated to produce serious static sparks. Although precautions are taken to prevent such liquids being disturbed and so to generate static electricity, e.g. restricting the rate of flow, the electrician may, in addition to his normal work, be called on to earth the metal pipes or tanks associated with these liquids.

Certain gases and vapors associated with the operating theatres of hospitals give rise to a risk of explosion. Static is a problem peculiar to hospitals, where rubber is often used for sheets, flooring, trolley tyres and so on. Generally the rubber is made conducting to reduce the incidence of static. All nylon and other materials, which easily generate static, are excluded, both from articles in the operating theatre and from articles of clothing worn by persons in the room. Humidification is often adopted to prevent static-all surfaces are made slightly damp to provide an overall conducting path to the general mass of earth.

The prevention of static generally involves the connection to the general mass of earth of all metal tanks, vessels, containers, pipes and the like, which are in contact with powders or fluids liable to produce static if they are handled or moved. Where a rubber belt runs on a metal pulley, the pulley should be bonded and earthed. Otherwise, anti-static belting is recommended; a belt dressing of graphite can also be applied, or a mixture of glycerin and water.

10.2: Temporary installations

A short-life or temporary installation is defined as one, which is designed to be in serve for not more than three months. Temporary installations are most often found on building sites, where electric services are required during the construction of a building or project. As might be expected, though the installation is temporary, it is still necessary and just as important to ensure that the safety aspect, in the use of electricity on the site, is always carefully considered. If the installation is required for use for periods longer than three months, then it must be completely overhauled at the end of three-month period. As soon as the installation is no longer required, it must be disconnected from the supply and dismantled completely.

There are certain types of buildings, and working conditions on site, which receive the attention of the insurance companies and also the subject of local-by laws. Thus, not only must the electrician comply with the full requirements of the BS Code of Practice for temporary installations, but extra requirements also. For example, though many temporary installations are carried out in some economical form of wiring system, certain types of buildings must be must be wired in conduit. This is particularly the case where the temporary installation is to supply services for exhibitions in permanent buildings. In many cases local-by laws and Fire Offices insist on the use of screwed conduit.

In virtually all aspects of temporary installations, there is no relaxation of the requirements of the 16^{th} edition of the Wiring Regulations. The reason for this simple enough: safety. There are many tempting situations, which could arise for the Regulations' requirements to be ignored or reduced. But in fact the very nature of a temporary installation often increases the risk of accidents, which could be fatal or give rise to serious injuries. Thus, not only have cables to be installed so that they cannot be damaged, but circuit protection must be fast acting and the provision for protection against earth-leakage currents adequate.

Where the wiring is exposed to weather conditions, the possibility of danger is increased considerably, particularly to building operatives handling electrical power tools. To ensure that the danger aspect is minimized, at least, the temporary installation must be in the charge of a ' competent person'. This person is generally accepted, particularly by the building industry, as a skilled, fully qualified electrician.

The electrician is thus fully responsible for the use of the installation and for any alteration and extension. The name and designation of such person shall be prominently displayed closed to the main switch or circuit-beaker. This responsibility is given a legal and normal aspect, which must be carefully considered by the electrician taking over the installation. Only he, or a suitably qualified delegate, is allowed to install new equipment or circuits, or make alterations to the installation. The new work must be supervised and finally checked and inspected by the electrician or his delegate.

Of course, all temporary installations must be inspected before they put into service. They must comply, in all respects, to the requirements of the IEE Regulations on insulation-resistance and earth continuity. In this respect there will be no difference between a temporary installation and a permanent installation.

In the interest of safety, it is always recommended that a low-voltage supply be used. The supply should be through a double-wound step-down transformer supplying not more than 110V.

A voltage of 110v is now regarded as the standard voltage for supply on building sites: the use of such a voltage on a correctly earthed supply system greatly reduces the risk of accident. The bulk of comprehensive range of power tools available for various aspects of building work is rated at 110V. However, 240V is sometimes required for special instances, which will require extra care being taken to ensure a good margin of safety against shock risk.

The electrician responsible for the distribution of electrical energy on a building or construction site has to attend to many aspects of safety. In many instances it is found that not enough socket-outlets have been provided with the result that operatives using powered tools have to use very long flexible leads, with cable colors. Cable couplers themselves, unless properly maintained, can give trouble with faulty connections. Excessive leads of lead can produce considerable voltage drops.

The main feature of any temporary installation is the provision of electrical services quickly and economically. This has too often meant PVC cables being strung on any convenient support to cut down the cost of the time spent on the job. But the hazards in a temporary installation are far greater in number and degree then those found in the more permanent installation, and so more care must be taken to see the installation methods used are those which will go along way to reduce, as far is practicable, the dangers arising from electric shock. Building sites, in particular, offer excellent conditions for shock: wetness, dampness, and exposure of cables to mechanical damage. Thus, great care must be taken with the earthing arrangements and the positions of lighting fittings, switches and the like. If trailing leads are to be used, then water light glands must be supplied. Fittings and accessories exposed to the weather should be of weatherproof and/or waterproof type.

Unless careful attention is paid to all aspects of temporary installations, the electrician in charge will find that much of his time is spent in repairing and maintaining the electrical system, with possible loss of building operatives' time.

On sites where electrician is not always available, the use of circuit breakers is recommended, rather than fuses of the semi-enclosed types. Socket-outlets should be provided with houseproof, spring-back covers so the socket contacts are protected when not in use. All plugs and sockets should have an indication of the working voltage and current, and colored so that they can be identified at a glance.

In many instances, the cable, wiring accessories and switchgear are often dismantled from one temporary installation to be used on another site. Secondhand equipment must always be tested to ensure that its condition is satisfactory. The insulation-resistance value must never be less than the IEE Requirements.

Electrical equipment found on building sites falls into three general groups:

1) Fixed, in which the equipment is permanently installed and reliably earthed.
2) Transportable, in which the equipment is usually fairly heavy and bulky, but which can be moved about while connected to a supply although not carried when in use.
3) Portable, in which the equipment is carried by the person operating it.

Low-voltage transformers supplying portable equipments should be of an approved type having an earth screen between the high and low voltage windings. Portable equipment, which operates at no more than 25V above earth need not to be earthed, and an s-core flexible cable can therefore be used. It is recommended that 'dead man' tiger-type double-pole switches to be used on portable equipment and they should have a safety catch to prevent inadvertent operation. Low-voltages plugs and sockets and lamps should not be interchangeable with those designed for any other voltage system. Since trailing cables at normal mains voltage are a source of danger, it is preferable to have low-voltage transformers fixed permanently and effectively earthed. If this cannot be done, the mains supply cable should be kept as short as possible and be well protected.

The metal frames of all transportable equipment should be effectively earthed through the trailing supply cable to the main earthling terminal of the site supply-intake position. The trailing cable should have both an earth care and a flexible metallic armoring or screen enclosing al the conductors. The armoring or screen should have a resistance of not more than the largest circuit conductor in the cable and should be protected overall with an insulating sheath. The screening or armoring must make sound metallic contact with the casting of the equipment and with the earth connection in the socket-outlet.

All transportable equipment and trailing cables should be identified by means of durable labels. They must be inspected regularly and a record kept of inspection, test results and repairs carried out. The recommended maximum period between inspections for both portable and transportable equipment should not emceed three months. For flameproof and intrinsically safe portable equipment the period should not exceed a month. An inspection must include an insulation-resistance between conductors and earth and the continuity of the earth-continuity conductor should be measured and recorded.

10.3: Fire alarm circuits

A fire-alarm is defined as ' an arrangement of call-points, detectors, sounders and other equipment for the transmission and indication of alarm and supervisory signals, for the testing of circuits, and where required, for the operation of auxiliary services'.

A fir-alarm system consists of a number of press-buttons or call-points are effective only if there are persons present to give an alarm. But if protection from fire is required when the premises are unoccupied, as at night and during weekends or during holiday periods, then automatic cal-points are necessary. On very large premises, additional circuitry is included in fire-alarm systems to give an indication of the location of the fire, so that firemen can go directly to the fire and allow staff to leave the building by safe routes which by-pass the fire area.

The closed-circuit type of system is used so that the circuit failure or breakage will at once be indicated by an audible alarm. Manual call-points consist of a par of contacts kept together by a thin sheet of glass, which, if broken, in the event of a fire, or maliciously, will cause the contacts to separate and, through a relay, energies a bell or alarm circuit. All call-points are required to be colored red. The method of operation must be clearly indicated either on the point itself or on a label beside it.

The alarm initiating points can be manual or automatic detectors. The sound signals should be such that they are audible throughout the whole of the building to be protected. The alarm stop/reset unit is used to silence the audible alarm after a suitable period by pressing a button, which diverts current from the general alarm to the supervisory buzzer. The unit should be installed in such a position that is always under responsible supervision.

Automatic call-points are known as 'detectors' and are heat-sensitive, which means that they are sensitive to a rise in the ambient temperature of a room. They come into operation at predetermined temperature.

There are two types of heat detector. The more common type is the 'point' detector, which, as its name suggests, is relatively small. The other type is the 'line' detector, which has a long continuous sensitive detecting element extending over large area of ceiling. The sensing elements used in heat detectors include:

1) Metal strips, rods, wires or coils which expand when heated.
2) Fusible alloys.
3) Conductors whose electrical resistance changes with a rise in the ambient temperature.
4) Hollow tubes containing a fluid, which expands on heating and applies the resultant pressure to diaphragm.
5) Thermocouples.

Some detectors are of the light-sensitive type: photoelectric cells, which operate when a beam of light illuminating the cells is scattered and absorbed by, smoke particles. Heat and smoke detectors are liable to give false alarms in certain conditions:

1) Heat detectors: false alarms may be caused by abnormal increase in temperature due to space heating equipment, industrial processes and sunshine.
2) Smoke detectors: false alarms may be caused by smoke or other fumes, dusts, fibers and steam produced by normal processes and activities, or by passing road vehicles. Those detectors, which use a beam of light to illuminate a photoelectric cell, may also give false alarms if the beam is accidentally obstructed.

Automatic call-points are sometimes designed to give an alarm and also to bring into operation an auxiliary fire service, such as a sprinkler system. Other examples of such services are the closing of windows and the closing of the covers of tanks, which contain inflammable liquids.

Some means of giving an audible warning of fire is a statutory obligation in certain premises under the Offices, Shops, and Railway Premises Act. Normally for these premises, an automatic fire alarm system must also be capable of manual operation, but this may not be necessary if the fire risk is low.

In a large installation a visual indicator panel sited in a position agreed with the local Fire Authority, is normally incorporated in the system. All circuits to which detectors are fitted are connected to it. Each circuit is connected to a separate enunciator, so that when a detector actuates, it indicates on the board that area in which the fire has occurred. The panels are also provided with test facilities, by means of which the circuits can be tested and certain faults indicated automatically.

Warning devices include bells, sirens, hooters, or whistles, they may be arranged to give either local or general alarms. In either case, the warning should sound continuously once a detector has operated, until the Fire Brigade arrives. An external audible warning device is recommended for mounting near the visual indicating panel. The device should indicate which building is involved, this being particularly necessary for premises, which comprise several buildings. In hospitals, department stores and other places where a general internal alarm is not thought desirable, an alarm may be given at a manned central point only and warning passed by telephone or light signal to other parts of the premises.

The object of an automatic fire-alarm system is to call the fire brigade. The most effective and reliable means of satisfying this requirement is the provision of a signal, which is automatically transmitted to the local fire brigade, through a direct-line connection. The line can be continuously monitored so that an immediate alarm is given as soon as a fault develops; regular testing can be arranged.

Some methods use an auto-dialing unit at the protected premises, which connects alarm calls in the form of a pre-recorded message, either via the public phone local number for emergency call service to the appropriate fire-control room, or direct via the automatic telephone system to a pre-selected telephone number. This method is cheaper than the direct-line method, but is less reliable. If, for some reason, connection to the appropriate fire-control point is not achieved at the first attempt, it is possible for an alarm call to be lost. Also, this system cannot be continuously monitored for faults because it is not permanently connected to the point where the alarm calls are received.

10.4: Installations in hazardous areas

There are three main types of hazard to be considered: explosive gases and vapors, flammable liquids, and explosive dusts. Flammable liquids produce explosive vapors in greater or lesser degree according to their temperature. A liquid, which is safe at normal temperatures, may be heated to its flashpoint, above which temperature is necessary to install flameproof equipment. Where flammable organic dusts or metallic dusts are liable to be present, the electrical equipment used should be of the dust-proof type. Similar precautions should be taken where explosives such as cordite and gunpowder are involved.

For the purpose of specification, flammable gases and vapors met with in industry are classified in groups; as follows:

1) Gases encountered in coal mining such as methane gas.

2) Various gases commonly found in industry, such as blast-furnace gas, propane, butane, pentane, ammonia, amylacetate and carbon monoxide.
3) Coal gas, coke-oven gas.
4) Acetylene, hydrogen.

Generally, the first group is referred to as applying to the mining industry. The second group usually refers to the petroleum industry and processes involving in the use of cellulose solvents.

Equipment, which is classed as 'flameproof', can withstand an internal explosion of the particular gas for which it is certified. It will also prevent any spark or flame from that explosion leaking out of the enclosure and igniting the surrounding atmosphere. In general, this is affected by wide machined flanges, which damp or otherwise quench the flame in its passage across the metal, but at the same time allow the pressure generated by the explosion to be dissipated. There are two types of apparatus: (a) mining gear which is solely used with armored cable or special mining type flexible cables; (b) industrial gear, which may be used with solid-drawn conduit, MICS cable, sheathed-sheathed cable or armored cable.

All flameproof gear is certified and consists of two or more compartments, generally constructed in either gray or malleable iron. Each compartment is separated one from the other by integral barriers having insulated studs mounted therein to accommodate the electrical connection. Where weight is important, certain articles are made in aluminum alloy. All glassware is of the toughened variety to give added strength. The glass is fitted to the item with special cement. Certain types of gear, such as distribution boards, are provided with their own integral isolating switches, so that the replacement of fuses, maintenance, and so on, cannot be carried out while the circuit is live.

All conduit installations for hazardous areas must be carried out in solid-drawn equipment, with certified draw-boxes and accessories. Couplers are to be of the flameproof type with a minimum length of 5 cm. All screwed joints, whether entering into switchgear, junction boxes or couplers, must be secured with a standard heavy lock nut. This is done to ensure a tight and vibration-proof joint, which will not slacken during the life of the installation, and thus impair both continuity and flameproofing. The length of the thread on the conduit must be the same as the fitting plus sufficient for the lock nut. Because of the exposed threads, running couplers are not recommended. Specially designed unions are manufactured which are flameproof and are intended to connect two conduits together or for securing conduits together or for securing conduit to an internally threaded entry. Conduits of 20 mm and 25 mm diameter can enter directly into a flameproof enclosure. Where exposed terminals are fitted, conduits above 25 mm must be sealed with compound at the point of entry. Where a conduit installation is subjected to condensation, say, where it passes from an atmosphere containing one type of vapor to another, the system must be sectionalized to prevent the propagation of either condensate moisture or gases. Conduit stopper boxes, with two, three or four entries must be used. They have a splayed, plugged filling spout in the cover so that the interior can be completely filled with compound.

When flexible, metal-sheathed or armored cables are installed, certified cable glands must be used. Where paper-insulated cables are used, or in a situation where sealing is necessary, a cable-sealing box must be used, which has to be filled completely with compound.

The following are among the important installation points to be observed when installing flameproof systems and equipment. Flanges should be greased to prevent rusting. Special care is needed with aluminium-alloy flanges as the metal is ductile and is easily bent out of shape. All external bolts are made from special steel and have shrouded heads to prevent unauthorized interference; bolts of another type should not be fitted as replacements. Though toughened glass is comparatively strong, it will not stand up to very rough treatment; a faulty glass will disintegrate easily when broken. Protective guards must always be in place. Conduit joints should always be painted over with a suitable paint to prevent rusting. Because earthing is of prime importance in a flameproof installation, it is essential to ensure that the resistance of the joints in a conduits installation, or in cable sheaths, is such as to prevent heating or a rise in voltage from the passage of a fault-current. Standard flameproof gear is not necessarily weatherproof, and should be shielded from rain or other excessive moisture.

Being essentially a closed installation, a flameproof conduit system may suffer from condensation. Stopper boxes prevent the passage of moisture from one section to another. Draining of condensate from an installation should be carried out only by an authorized person. Alterations or modifications must never be made to certified flameproof gear. Because flexible metallic conduit is recognized as flameproof, cables to movable motors should be of the armored flexible cable type, with suitable cable-sealing boxes fitted at both ends. It is necessary to ensure that, as far as possible, contact between flameproof apparatus, conduit, or cables, and pipe work carrying inflammable liquids should be avoided. If separation is not possible, the two should be effectively bonded together. When maintaining equipment in hazardous areas, care should be taken to ensure that circuits are dead before removing covers to gain access to terminals. Because flexible cables are a potential source of danger, they should be inspected frequently. All the equipment should be examined for mechanical faults, cracked glasses, and deterioration of well-glass cement, slackened conduit joints and corrosion. Electrical tests are carried out at regular intervals.

As might be expected, there are a number of statutory regulations, which are concerned with safety in hazardous areas, the areas being classed in three divisions:

Division 0: An area of enclosed space within which any flammable or explosive substance, whether gas, vapor or volatile liquid continuously present in concentration within the lower and upper limits of flammability.

Division 1: An area within which any flammable or explosive substance, whether gas, vapor or volatile liquid, is processed, handled or stored, and where during normal operations an explosive or ignitable concentration is likely to occur in sufficient quantity to produce a hazard.

Division 2: An area within which any flammable or explosive substance, whether gas, vapor or volatile liquid, although processed or stored, is so well under the conditions of control that the production of an explosive or ignitable concentration in sufficient quantity to constitute hazard is only likely under abnormal conditions.

An area, which falls into the category of Division 2, is sometimes known as a 'remotely dangerous area'. If an area contains the condition as described in Division 0, then electrical equipment is totally excluded from the area. But if such equipment is necessary in the area, it is possible to introduce special measures to reduce the risk, such as pressurization or the use of intrinsically safe equipment. The definition of the ' intrinsically-safe' is:

1) Applied to a circuit, the term denotes any electrical sparking that may occur in normal working under the conditions specified by the Certifying Authority, and with the prescribed components, is incapable of causing an ignition of the prescribed flammable gas or vapor; or

2) Applied to apparatus, the term denotes that it is so constructed that when installed and operated under the conditions specified by the Certifying Authority, any electrical sparking that may occur in normal working, either in the apparatus or in the circuit associated therewith, is incapable of causing an ignition of the prescribed flammable gas or vapor.

If there is any risk in division 1 area, the use is recommended of the flameproof or intrinsically -safe equipment.

CHAPTER ELEVEN

INSPECTION AND TESTING

Introduction:

One of the main requirements of both statutory and IEE Regulations is that all installations shall be tested on their completion, or after a major extension to them, and that any defects or faults revealed in the tests or the inspection shall be made good. To test and to inspect are two different requirements. The electrical properties of an installation cannot be seen: they can only be measured by instruments. To inspect involves looking closely at electrical work to discover if there are any defects, omissions, etc., which may result in the installation, or its associated apparatus, becoming a danger to human life, livestock and property.

The tests to made are:

1) Continuity of ring final circuit conductors.
2) Continuity of protective conductors, including main and supplementary equipotent ail bonding.
3) Earth electrode resistance.
4) Insulation resistance.
5) Insulation of site-built assemblies.
6) Protection be electrical separation.
7) Protection by barriers or enclosures provided during erecting.
8) Insulation of non-conducting floors and walls.
9) Polarity.
10) Earth fault loop impedance.
11) Operation of residual current devices and fault-voltage operated protective devices.

Earth-leakage circuit breakers must also be tries and tested to ensure that they perform their protective function when called on to do so.

11.1: Circuit conductor tests:

11.1.1 Verification of polarity:

One of the tests, which must be made, concerns a practical point: the need for all single-pole circuit-control devices to be connected in the non-earthed conductor of a two-conductor supply of which one pole is connected to earth. Also, the outer contacts of center-contact bayonet and Edison-screw lamp holders must be connected to the neutral or earthed conductor, and wiring must be connected correctly to plugs and socket-outlets.

Socket-outlets particularly require careful testing and inspection. With a socket-outlet properly connected to the supply in accordance with the regulations, there will be full voltage shown between the contacts L and N, and approximately full voltage between L and E. Between N and E there should be zero or negligible voltage, but impedance of the order of one ohm. However, it is possible to have a socket-outlet wrongly wired. In fact, there are no less than twelve possible configurations of socket-outlet connections which will seem satisfactory on a loop-test but which will show up on a polarity test. And only one of these configurations is the correct one. Regarding the wiring of plugs, only if an appliance is available for connecting up at the time the installation is being completed with the electrician be able to confirm that the plug is wired up correctly.

11.1.2 Insulation resistance:

The purpose of insulation-resistance (IR) tests is to prove the quality of the insulating materials used in the installation. Thus, the insulation should be such that there is no possibility of significant earth-leakage currents, not only between conductors, but also between the conductors and the general mass of earth. The test voltage is D.C. not less than twice the normal voltage of the supply. For tests on medium-voltage circuits the voltage need not exceed 500 Vd.c. The tests are to be made before a completed installation, or major alteration to an existing installation, is permanently connected to the supply. For these tests, large installations may be divided into groups of outlets, each group containing not less 50 outlets. An 'outlet' includes every point and every switch except that a socket-outlet, appliance, or lighting fitting incorporating a switch is regarded as one outlet.

The minimum accepted value of IR is one me ohm. The IR value of an installation will not always remain the same. A good deal depends on the amount of moisture and dirt being present on the wiring, fittings, and accessories at the time of testing. Deterioration of the insulation is usually the result of ageing and unsuitable operating conditions.

11.1.3 Insulation-resistance between conductors and earth:

All fuse links should be in place, all switches, including, if possible, the main switch, closed and all poles or phases of the wiring electrically connected together. The value of insulation-resistance to earth should not be less than one me ohm. This test does not apply to earthed-concentric wiring, for which a special testing procedure is required.

Insulation-resistance between conductors:

All parts of the wiring may be tested, all lamps should be removed and all current-using apparatus disconnected. All local switches controlling lamps or apparatus should be closed. If it is not practicable to remove lamps from their holders or to disconnect apparatus, their local switches should be left open. When the testing voltage is applied between the conductors, the value of the insulation resistance should not be less than one Meg ohm. Again earthed-concentric wiring is subject to a special test.

Circuits with two-switches should be tested twice, with one switch in each pair of stripper wires changed over before the second test. It is as well to remember that although faults can occur in straight runs of cables, they are more likely to be found at switches, ceiling roses, lamp holders and junction boxes. A zero reading will indicate either a short-circuit or perhaps a lamp not removed from a holder.

11.2: Ring, appliance and hazardous areas testing and cable-fault location

Ring-circuit continuity:

A test shall be made to verify the continuity of all conductors of every rating-main circuit in an installation, including the circuit-protective conductor. The test is also intended to ensure that there is no accidental interconnection between socket-outlets midway in the circuit. Such an interconnection would 'hide' an open-circuit in any of the ring conductors by creating an effective short circuit. The Regulation Guidance Notes detail two methods of carrying out the test to verify that the interconnection does not exist. Because of the very low values of resistance inherent in the conductors and required by the test to be obtained, the instrument used should be capable of measuring resistance in the milliohms ranges. Commercial instruments have been developed to carry out this particular test and are recommended to be used.

Appliance test:

All appliances and current-using apparatus not tested with actual installation should be subjected to separate testing to prove their IR between air current-carrying parts, and between these and earth. The value of insulation-resistance for a particular appliance will vary according to its type, but in any case should not be less than 0.5 Meg ohms. For fractional kW motors, the figure should be greater than one Meg ohm. Certain testing instruments are available which pass a current of 15-20 A for a few seconds through the CPC and the metal frame of portable appliances such as drills and similar electric tools. This test is made to ensure that the earthing arrangements will carry earth-fault currents.

Testing in hazardous areas:

All electrical apparatus and associated circuitry are required to be tested periodically in accordance with a definite testing routine; the test results should be recorded. Insulation-resistance, earth-resistance and earth-continuity resistance tests are required to be made, the last two in relation to the setting or rating of the protective devices associated with the apparatus and its circuitry. In its important that insulation resistance tests are not made in such a way that the safety devices and insulation used in intrinsically safe apparatus and circuits are damaged by excess test voltages.

It is very important to recognize that the testing methods described in the IEE Regulations may be inadvisable in hazardous areas, in view of the risk introduced by the test apparatus. However, if the area can be made gas-free or otherwise safe, then non-certified testing equipment can be used. Otherwise, insulation-resistance testing should be carried out using a 500 V tester or certified intrinsically safe characteristics. For earth-continuity testing, the tester should embody a hand-driver generator of certified intrinsically safe characteristics.

No apparatus should be opened in a danger area until it has been made dead, and effective measures have been taken to prevent its being made live again inadvertently. Where, for the purpose of electrical testing, it is essential to restore the supply before the apparatus is reassembled, tests should be made using a suitable gas detector and continued during the operation to ensure that the combustible vapor does not approach the explosive limit.

Certain self-contained insulation-testing instruments may be intrinsically safe when applied to circuits so small inductance or capacitance, but a risk may arise when these properties of a circuit have an appreciable value. When such instruments are used, the test leads should be firmly connected throughout and, on completion of the test, they should not be detached until the circuit has been discharged through the testing instrument.

Cable-fault location:

The most vulnerable part of any electrical system is its cables, and efficient methods of dealing with any faults that occur are of the greatest importance. Although there is no universal method of dealing with all different fault types that can occur, it is possible to arrive at some kind of system which makes the best use of the fault finding methods available. The basic steps to be followed in locating a fault in a cable are:

1) Analysis of the fault.
2) The localization test from the cable end.
3) Confirmatory test.

This is general procedure, however, which must be modified for work on cables which provide ancillary services such as pilot and telephone cables, where fault are generally due to moisture and therefore have different characteristics. All the localization tests normally involve calculations of some kinds and side-rule accuracy is sufficient for tests on short-length cables. Where cables are long, log tables or hand calculations are best for a really accurate pinpointing of the fault position.

The most common fault in a cable is a fault to earth, affecting either one or more cores. Open-circuit faults and short-circuit faults are mush less common, though the short- circuit type of fault usually involves a connection to earthed sheath/armoring of the cable, when it falls into the earth-fault category of fault.

The first step in the fault location procedure is to determine the characteristics of the fault, for instance, to test whether it is the type of fault in which the insulation is faulty, but where the conductors are unbroken; or whether it is a fault involving broken conductors. Three different types of test will give the necessary information. The first of these is an insulation-resistance test between conductors and finally by conductor-resistance tests with the remote cable and short-circuited. In general, tests from one end of the cable give the required information. But tests firm the far end may also be necessary when conductors have been burned apart. In some complicated fault types, it may be necessary to alter the fault resistance so as to produce more suitable test conditions. This is done by passing current from a d.c test set through the fault; the current will burn the insulation and reduce the insulation resistance of one core.

The two main methods of testing are 'loop tests' and 'fall-of-potential tests'. Loops tests are used for earth faults; the potential test is used for earth faults and short circuits. Other tests include capacitance tests for open-circuits; and induction tests for earth faults.

It has been found that in the region of 70 % of the cable faults are found by using a loop test. Twenty % of the faults involve open cores, found by capacitance test. The remaining 10 % of cable faults require their location to be found by using direct tests on the cable sheath and search-coil tests. The loop tests compares the resistance of the cable from the testing point to the fault position with that of the whole length of the cable, plus an additional length of cable connected to the faulty cable at the far end and coming back to the test position. If the cross-section of these cables is the same, the ratio of resistances is proportional to the respective lengths of cable. Having found these lengths, the distance of the earth fault from the testing position can be found. The complete testing circuit is known as a loop. The circuit includes a battery source, a resistance network, a galvanometer and some means of current adjustments to obtain a balanced-bridge condition.

The Murray loop test was first devised over a century ago and is responsible for locating the bulk of earth-faults today. It is used for the localization of earth or between-core faults, when the faulty core is unbroken and a return conductor is available. In its simplest form, the fault conductor is looped to a sound conductor of the same cross sectional-area. A slide wire or resistance box with two sets of resistance coils is connected across the open ends of the loop. A null-reading galvanometer is also connected across the open ends of the loop. A battery supplies the test current between the slider or common points of the two resistance coils and earth.

From this, the distance to fault can be determined easily and accurately. The voltage source needed for the test depends on the fault resistance. Generally a high-tension radio battery with a limiting resistance of 1000 ohms is used. If a higher voltage is needed, the hand generator of an insulation-resistance tester may be used.

The standard formula given above must be modified when cables of different cross-section have to be tested. A modification of the standard test can be used when the insulation of the return conductor is imperfect at the main fault position. Two tests must be carried out: one with the conductors unloosed and another with the conductors connected together as for the normal Murray lop test. Because the majority of cable faults are micro phonic, this characteristic is sometimes used for locating the fault position. A low-voltage battery is joined in series with a pair of telephones between the faulty core and sheath, or second faulty core. The cable is then tapped, or disturbed if it is buried, along its length. A signal will be obtained in the headset when the cable is disturbed at the position of the fault.

In the fall-of-potential set , a ratio of the fall of potential over sections of cable is given by the passage of a constant current. However, the fact that a constant current is vitally important for the accuracy of this test is often a limitation to the use of the method.

Once the position of the cable fault has been found to within few yards or so, the precise position must then be determined by confirmatory tests. One method of doing this uses the shock-discharge technique. This test is made by charging a 1 microfarad capacitor to a potential between 15 kV and 25 kV and then discharging it into the faulty core via a spark gap. The noise setup at the fault position may be detected at the surface of the ground with a seism phone. Where the route of a buried cable is uncertain, the search-coil method is used. The coil is a frame-type search coil connected to a telephone headset. A signal is obtained in the headset until the fault position is passed over. The alternative confirmatory test is the micro phonic test. Local heating, which produces smoke, water vapor, or the emission of compound, is another useful test.

CHAPTER TWELVE

BUILDING SERVICES

Introduction:

While the electrical contractor's interest in a contract tends to be centered on the provision of a power-fed electrical installation which meets the requirements of the client's specification; there are other services with which he may be involved; these are outlined in general in this chapter. The extent to which these services are part of the overall electrical provision of a client's premises depends on function of the building or buildings. When new buildings are being considered, the client or owner considers the extent to which additional services (e.g. radio and TV aerials, telephones) are required. There is of course the difficulty and cost incurred if these are installed after the main building is completed. The disturbance to decorations is an expected result of inadequate planning and adds further expense, which can be avoided in the initial stages of the electrical provisions.

Multi- tenanted office blocks require really detailed planning for provision of adequate socket-outlets for mains-operated machines, and for bell and telephone circuits with outlets placed in all possible strategic positions which will appear 'right' irrespective of alterations in sectional wall positions, changes in the position of desk and other office furniture, or changes in the functions of room. Separate mattering for different tenants may also have to be considered.

Industrial premises have their work areas reasonably stable ones to machinery and equipment is installed. Even so, the systems of the secondary electrical services have to be considered in the event of possible foreseeable changes.

Domestic premises present the least number of problems where the provision of services is required. However, it is common nowadays to cater for doorbells, radio and TV aerials and earth points, and telephone companies' telephones. Boarding houses and hotels may require extended bell-call systems, and extension phones connected to a small private exchange switchboard. Premises, which comprise a number of buildings, may require outdoor lighting, floodlighting provisions, or road lighting.

12.1: Clock systems

These clock systems are used where a number of clocks throughout a building are required to show the same time, or else used to operate time-recorders for stamping time-cards which indicate when work has been started or finished.

Most clocks found in small installations are independent units, run by a synchronous motor fed from mains voltage. Impulse-clock systems are independent of mains and operate from extra-low voltage supplies. The master clock is the name given to the primary unit, which controls all other clocks in the installation. It is pendulum-operated and has an impulse transmitter, which transmits electrical impulses of alternate polarity at one-minute intervals over a two-wire circuit to the subsidiary or 'slave clocks'. The slave clocks have movements, which accept these impulses and alter their clock hands accordingly.

The mechanism of one type of master clock consists of a pendulum of half-seconds beat operated by an electrically wound spring through a dead-beat escapement. At each one-minute interval, while a small synchronous motor is rewinding the main spring, an impulse is transmitted to the subsidiary clocks. The mains a.c supply is transformed to 48 V for operating the synchronous motor and gain reduced and rectified to provide 24 Vd.c for the transmitted impulses. Should the mains supply be interrupted for any reason, the main supply has a sufficient reserve to operate the escapement movement and hands for about 10 hours, though no impulses will be transmitted to the subsidiary clocks. The movement of a subsidiary clock is a one-minute polarized movement with a rotating armature, and incorporates a flywheel to render the hands 'dead-beat'.

The usual master-and-slave installation can cater for up to 60 clocks. To add clocks to the system, it is only necessary to connect a clock in parallel with the remainder. The clock load and the connecting cables should total a certain value of resistance so that the farthest-away clock has sufficient voltage at its terminals.

The impulse current is around 220 mA. In series-impulse clock systems, the voltage required for the installation is calculated at the total resistance of the clocks plus the line resistance multiplied by the impulse current of 220 mA. Sixty volts is the required maximum. Should the required operating voltage be above this, the installation should be sub-divided. As it is occasionally required to remove a clock from a series system, 'shorting-blocks' are provided.

12.2: Personnel call systems:

These systems are used in private dwellings, hotels, schools, factories and other premises where it is required to attract the attention of individuals to a situation or circumstance. The simplest system is where a person is called to a particular by a caller. In a private house, the householder is called to the door. A bell push or similar device is fitted at each such position and an indicator provided to show which push has been operated. A bell or buzzer is used to provide the sound, which will attract attention to the call. Bell pushes can be of the wall-mounted, table or pendant type; the contact points are of a metal, which gives long service without becoming pitted or corroded. If the bell push is to be installed outside, protection against the ingress of moisture must be provided.

Indicators are installed in a central position in the building. In large premises, such as hotels and factories, the indicator board is located in a room in which some person is always in attendance, e.g., kitchen or reception office. The use of lamps is necessary where the sound of bells might be either objectionable or unless, e.g., in hospitals at night or in noisy workshops. Hand-setting indicators should be mounted at a height convenient for access and visibility.

Multiple-call systems are used in very large hotels where call points are too many to be indicated conveniently on a single indicator board or panel. Pushes are fitted at each call point, but the circuits are grouped to serve corridor or floor. Each group gives the indication in a central service room. In these systems, arrangements must be made to have attendants on duty in corridors or floors to deal with the calls. Multiple-call systems use indicators, which have to be reset by the attendant.

Time-bell systems are common in schools and factories to indicate the beginning or end of a time or a period. These systems have usually one or two pushes or other switches connected in parallel. The bells can be controlled from a clock system, to eliminate the human element required with bell pushes.

The burglar-alarm system is also a call system. The switches in this case are sets of contacts mounted at doors and windows. There are two circuit types; open-circuit and closed circuit. The first type requires contacts to close to close to energies the bell circuit. In the closed-circuit type, all contacts are closed. A series relay with normally open contacts is energized by a circulating current. When a contact set is opened, this current ceases to flow, de-energizes the relay and close the relay contacts to ring an alarm bell. Some alarm systems operate from photoelectric cells, which work when an invisible light beam is broken. The large plate-glass windows of jewelers' shops often have a series length of very thin wire, which, if broken when the window is smashed in or a hole cut in it, will bring the relay into operation to ring a bell. In certain systems today, no bell rings, but a buzzer and light indication circuit is wired from the protected building and terminated at a nearby police station. Thus the intruder is not warned, and the police have the opportunity of catching the burglar red-handed.

The open-circuit system is seldom used because it can be interfered with. For instance, a cut in a wire will render the complete system inoperative, whereas such a break in the series circuit of a circulating-current system will immediately set an alarm-bell ringing. Supplies are sometimes from the mains, but in this instance standby-battery supply is provided in the event of a power failure. Alarm bells are often installed in a place inaccessible to unauthorized persons, and outside the building.

Another type of call alarm system is the watchman's supervisory service. It is designed to provide a recorded indication of the visits of watchmen or guards to different parts of a building in the course of the duty round. The system uses a clock movement of the impulse, synchronies-time controlled a.c or 8-day clockwork type installed at each contact station throughout the building. Each station has a box with a bell push operated by the insertion of a special key. Operation of the contact energizes an electromagnatically-operated marker which records the time of the visit on a paper marked off in hours. In some systems, an alarm is given after a predetermined time if the watchman fails to 'clock in 'at any constant station.

Luminous call systems are used instead of bells. Theses systems use colored lights, which summon staff to fulfill a service duty. They are largely used in hospitals and hotels. When the bell push is pressed in any position in the building, a small light lamp lights in a duty room to indicate the general area from which the call has come. Alternatively, a lamp outside the call room lights and remains so until an attendant extinguishes it by operating a reset push located just outside the room. Some systems incorporate a single-stroke bell. Call and indicating circuitry is also incorporated in life systems.

12.3: Telephone systems

These systems are either internal or are connected to the public telephone facilities. All installations, which have public connections, are subject to the supervision and approval of the telephone companies whose engineers normally undertake the final connecting-up. The electrical contractor is generally required to install conduit or trunking to facilitate the wiring of the building for telephone outlet. In large buildings a main switchboard is installed to receive incoming calls, which are then switched to the required extension phone. There are two types of private installations PMBX (private manual branch exchange) and PABX (private automatic branch exchange).

In the PMBX system, each extension phone is wired to the main switchboard and connection is made by sockets called 'jacks'. There are certain disadvantages associated with the system, which requires an additional internal phone system.

In the PABX system, all incoming calls are terminated at the manual switchboard and are answered by the telephone operator. All extension-to-extension calls are set up automatically and direct out-dialing on certain extensions is possible. All extension phones can call the operator who can identify the extension on a lamp-per-line basis. Direct access to the local Fire Bridge can be incorporated in the system, a special code being allocated for this purpose. A cordless switchboard (PMBX 4) is a more recent development of the PABX system. It has a switchboard with a translucent screen or lamp signaling. It enables the operator to supervise and connect all calls with full control given by a few levers and keys.

CHAPTER THIRTEEN

PRACTICAL APPLICATION

13.1: Technical work of the installation:

The flat consists of :
a) two bed rooms
b) one sitting room
c) bath room
d) kitchen
e) two balconies
f) pathway

The first step in the design for the installation for the flat is to choose the kind of lamps that are to be used in each place in the flat.
For the bed rooms and sitting room the normal lamps are to be used those as illustrated in previous chapter.
In the pathway and balconies the ceiling lights are to be used illustrated in previous chapter.
In the bathroom the wall lights are to be used which play the role of waterproof and illustrated in previous chapter as well.
In the kitchen the fluorescent lamps are to be used.
The second step in the installation process is to design the switches for the lamps and the mains source plugs as well with choosing the suitable places for them as well. All information is illustrated in previous chapter.
The circuit that to be used in the installation for this flat is the ring circuit method, which is the most suitable economical way.
For the bed room:
A single one-way switch is to be used for the lamp.
Two telephone plugs
Double electric mains source plugs
A TV plug to be placed.
For the sitting room:
Tow single two-way switches are pleaded for the lamp.
TV plugs are pleaded in the room with two different places.
Near each TV plug a double electric main source plugs are placed.
Two telephones plugs are placed.
A one way single switch is placed in the sitting room responsible for the lamp on the balcony near by the salon.
For the bath room:
A one-way switch is used where it is placed out the bathroom in order to avoid of short circuits in the switch.
For the pathway a one-way single switch is placed to control the lamp over there.
For the kitchen:
The job here is to be done with care that we have to be aware of choosing the places of switches and lugs here keeping in mind that the kitchen is of so importance for the house hold or whomever.
A one-way switch is placed for the control of the fluorescent lamp.
A one-way switch is to be paled for the lamp on the balcony near by the kitchen.

A double electric mains source plug is to be placed for the dish was machine and clothes machine as well.

A double electric mains electric source plug is to be placed for the cooker and the air exhauster.
Two double electric mains sources are to be placed for the use of other electrical machines that may be used in the kitchen.
Also we have to locate a suitable place for the control box and its place must be considered in a way that it is at a mid position among all switches and plugs in the house.
Near by the control box two switches are placed for the control of the heater and for the water pump as well.
And also we have to keep in mind that the circuit to be used here is the ring circuit distribution, which is illustrated, in previous chapters.

13.2: Cost of electrical installation of the flat:

The table below shows the cost of the electrical installation of the building where everything is included in the table.

1. Total cost : 5.767.200.000 TL
2. Description of work : Near East Village elk cost
3. Date : 19.01.2001

S.NO	Type of the work	N. units		Cost/unit	total
1	60A c/o-o/l automatic	7	times	76.000.000 TL	532.000.000 TL
2	6 way MCB type D/P	6	times	73.000.000 TL	438.000.000 TL
3	2 way MCB type D/P	1	times	37.500.000 TL	37.500.000 TL
4	Bell circuit	6	times	23.600.000 TL	141.600.000 TL
5	1x13A Plug circuit	42	times	15.600.000 TL	655.200.000 TL
6	2X13A Plug circuit	36	times	18.500.000 TL	666.000.000 TL
7	Wall/Ceiling lamb circuit	31	times	15.200.000 TL	471.200.000 TL
8	Cord lambs	18	times	12.700.000 TL	228.600.000 TL
9	TV plug circuit	24	times	20.800.000 TL	499.200.000 TL
10	Telephone plug circuit	24	times	16.900.000 TL	405.600.000 TL
11	Water pump circuit	6	times	46.500.000 TL	279.000.000 TL
12	Heater	6	times	37.800.000 TL	226.800.000 TL
13	Cooker	6	times	33.800.000 TL	202.800.000 TL
14	Fan	6	times	33.800.000 TL	202.800.000 TL
15	2x80w floresant circuit	6	times	40.600.000 TL	243.600.000 TL
16	Ground unit	30	times	11.700.000 TL	351.000.000 TL
17	2x16mm2+ecc cable	54	m	3.450.000 TL	186.300.000 TL

// Only seventeen lines //

In the table above in each work type cost everything is taken into consideration i.e., the cost of cables needed for the work the cost of the technicians who are responsible for the coverage of the job.

13.3: Information about the distribution of lamps

In fact the distribution of the lamps depends on the nature of the way that to be lighted. The general consideration of distribution of the poles that are holding the lamps that are these poles are to be separated by 30m to 40m and these poles are 5 to 7m in height. The lamps that are used for the outdoor lighting are of the 125 W lamps.

Along straight roads poles each carrying one lamp spaced by 35 m are placed and wherever a curve is being faced there should be taken into consideration the angle through which the pole has to be placed in order to let all be having the sufficient amount of lighting to enable them move freely without the risk of having any kind of dangers like car accidents or whatever alike.

On rounds, where more than one road is cutting across there a pole with four lamps must be placed to distribute light in the four directions.

All the lamps are lighted and controlled from a room made especially for the control of these lamps and for the power distribution for the place as well. The control room is divided into two parts the first for the generator, which operates automatically when the mains electricity supplied by authorities is off and the second part for the control of the lamps and for the power line carriers as well. The place of this room should placed in a situation where it will be economical for the distribution of cables and this place is preferred to be at the middle of the region.

The lamps because of their low power consume are connected in a one phase way but this will not be logical from the economical point of view so the cables responsible for the power feed are to be connected in a three phase way so as to reduce the amount of cables needed for that job. The cables are connected to a timer, which operates automatically when it is at the time to switch on the lamps and to switch them off.

The three-phase connection is of great use in the transmission of power because it helps to maintain the voltage at an accepted level because as it is known on the transmission of power on long distances the voltage begins to drop as the distance increases so that the tree phase connection is used.

CHAPTER FOURTEEN

MANAGEMENT

14.1: Introduction

Management implies a controlling operation, in that the need to 'manage' arises only when the final stage is left in the operation, i.e., when it is required that others do the work. There is an 'overseeing' management function when the manager physically observes the actions of those he manages; and there is the 'administration' management function, when the manager is no longer in direct contact with the situation and requires a reporting system to enable him to relate what is happening to what he intended should happen.

In general, to manage is to control several 'causal' factors which have an impact on a situation and which influences a situation in a positive or negative manner. There are also those factors provided by men, machines, materials, money, time and place. It is the manager's duty to 'manipulate' these factors to obtain some desired end. Some of these factors may behave in a predictable way. Other factors can be unpredictable. A manager is thus, in practical terms, required to achieve defined objectives by controlling a situation that he cannot fully understand and which is exposed to external influences over which he has little or no control.

In the modern situation, management objectives are achieved only through the co-ordinate effort of a large number of people all of whom perform different tasks of which many are inter-related. Some of these tasks operate in sequence; others operate in parallel. The modern manager often finds himself involved in situations in which his success, and even his prospects of promotion, depend on how well others in his company perform. These 'others' may be his subordinates or staff from other departments which whom he has little or no direct contact. It may also that the manager does not have full confidence in those on whom he depends. It is this latter aspect. The human relations side of management, which is often the most difficult to control. Of all the resources to be manipulated by the manager, the human resource in any company is the one, which is most likely to behave in an unpredictable and unexpected manner. In fact it is accepted that the failure of manager to understand those working of them is probably the root cause of a high percentage of industrial troubles.

What is called 'human relations' is a side of the relationship created by the work situation. An understanding of these relationships is vitally important for the manager, since so much his own effort must be directed to minimizing conflict, which could destroy the efficiency of enterprise.

The most successful managers recognize that their role in human relations is involved closely with the recognition with those under him. This means that the manger must be able to get on so well with the group working for him, and over which he has authority, that he can learn to apply the correct approach to meet each individual in each situation. Certain actions which tend to satisfy the 'recognition' requirement in a manager, or other person placed in charge of a number of individuals, either singly or in a group, include: consolation with subordinates before a decision is made; explanation of the importance of the part the subordinate plays in relation to the whole; loyalty to both the subordinate and to the managers own superior; delegation of management tasks; listening to volunteered ideas, personal problems and complaints; consistency in the treatment of individuals; positive approach to disc line; and encouraging subordinates to feel that they are members of a group. The process of management may be described as:

1) The setting up of objectives to be achieved by the co-ordinate effort of others.
2) The analysis of a situation and the preparation of plans to meet the defined objective.
3) The putting of plans into action.
4) The regular measurement of the results of action.
5) The comparison of these results with those desired as defined in the objective.
6) The initiation of corrective action, as necessary, to bring the actual results near to those desired.

14.2 : Construction site administration :

Whatever the size of construction project, organization of both labor and material resources is necessary not only for the completion of the project on time, but to ensure that the finished project meets with all requirements of the client's specifications. Any such project involves basically the translation of a designer's drawings into practical terms. This process requires a full understanding and appreciation of the designer's aims, by reference to the architect's specification drawings. Again, whatever the size of the project, it is necessary to appreciate the requirements of other trades involved in the project; this means, in most instances, close co-operation with the persons who are responsible for organizing these other trades. The building programmed must also be understood: its progress, the element of activity, which bring the project nearer completion, the need for alterations and new completion times. It is important that all personnel with responsibility on the site recognize the ultimate authority, which may require work to be varied, and also accepts the completed work either in stages or as a whole.

After the contracts had been signed by the principals involved, arrangements are made to establish a site office where the clerical work involved with the progress of the project is carried out. The site office also contains the project specification and drawings, and acts as a meeting place for dictions on the progress of work. Adequate, secure and weatherproof storage facilities must be provided on the site, and satisfactory arrangements must also be made for the welfare of the operative stuff, which includes toilet, washing and canteen facilities. These are usually supplied by the builder.

As soon as the specification is received by the sub-contractor, it must be studied carefully to note and unusual clauses or special requirements; otherwise, failure to do this at an early stage may cause delays later on when the matters are raised and are difficult and costly to deal with. The runs of cables conduits trunking and other wiring systems should be marked on relevant drawings, in the conjunction with the requirements of the other trades involved on the project. This liaison between the trades is necessary to ensure that electrical runs and holes do not conflict with other runs for, say, heating pipes. From this agreement between the trades, all necessary holes, chases and ways, and the provision of special fixing facilities, should be finalized with the builder to avoid unnecessary cutting and making good afterwards. If ways are to be provided, it is necessary to check with the local authority surveyor who may have some specific requirements, which ensure that the strength of the various building elements are not reduced below an acceptable and safe minimum.

The master programmed for any project is produced by the builder, as the main contractor. The programmed must be carefully studied to assess the workload over the timetable given to the project from start to finish. From this study of master programmed it is possible to work out the anticipated labor force at various stages during the contraction of the building. At this stage it is important to take into account those stages in the construction programmed where possible delays might arise so that the work programmed of the electrical trade can be adjusted to accommodate another trade. This is may mean that the programmed will have to be studied further to see whether the site labor force can be usefully employed else where on the site or perhaps off the site altogether. This is important particularly where bonus incentive schemes are operating.

A discussion with the local electricity supply authority engineers is necessary to agree on the position of main cable runs, substation, and various intake positions so that the builder can be notified of their requirements. Arrangements may have also to be made the electrical contractor for the provision of the site lighting and power supplies at various locations both outside and inside the building as its contraction proceeds.

The electrical labor force required for the project is generally divided into sections, each with its own charge hand if necessary. Instructions for these various sections should be prepared, together with a full set of drawings setting out the proposed runs and lay out of the work.

When all the paper-work has been concluded, the subsequent work involved is usually straightforward, involving the actual tasks of crevassing, wiring, fixing the accessories, testing and find handovers, all these stages being phased into the building contract.

Not all projects are straightforward, however, and thus regular attendance at site meetings is called for, particularly where difficulties arise which can be smoothed out and resolved only by meeting the people involved. Site meetings are also called to deal with request for special consideration and for the variation of the programmed times. Any variation of work, due to different materials being necessary, instead of those specified must be the subject of orders so that undisputed charges can be made by the sub-contractor. These can consist of an agreed price of the variations, or by direct measurements of the work, both in quantity of material and operative time involved. Arrangements must be made with the authority responsible for ordering the variation, for the necessary checking and certification of this work when it is completed.

The builder or his representative is normally responsible for taking the minutes of these site meetings, which should be carefully read by the electrical sub-contractor before final agreement. Any point which does not fit in with the contractor's understanding should be raised for clarification before the minutes are signed as a correct record of the meeting as agreed by all those involved.

The sub-contractor is responsible for ensuring that all his operatives are kept in touch with the progress of the part of the work with which their sections are involved, particularly where a stringent timetable for the completion of work stages is necessary. The skills of different operatives varies considerably and the aim should always be to use these differing skills as efficiently as possible, perhaps moving staff to other sections of the work which they are most suitable to undertake.

A minimum stock in hand of materials and accessories should be kept in store to ensure that work on site is never held up for the lack of materials. No stock should be allowed to stand in storage for an undue length of time, because it represents a capital commitment, which is not usefully employed. To prevent this, an intimate knowledge of stock delivery times is necessary on the part of the contractor.

The successful completion of a project on time is only a part of the aim of the contractor. The quality of the work done is just as important as finishing within the time scheduled for the contract. Rectification of faults is often very difficult and expensive. With this in mind, it is of the utmost importance to ensure that those responsible for the oversight of the work being carried out know how to establish first-class relations between themselves and those they have in charge. To this end, every operative must be kept informed of all changes witch affect him, and he must have his tasks and duties defined correctly so that he can recognize the work he carries out against the background of the whole project. This means that the staff on the site should not be moved about unnecessarily. The operative's task becomes meaningless if he cannot see its completion. In the progressive nature of electrical work, which is characterized by having to go back on it to complete its various phases, satisfaction is often encouraged by ensuring that the same teams return to the same part of the project of the next or ensuring phase.

CONCLUSION

The electrical installation is one of the most important and vital aspects of the electrical engineering. This field has been increasingly developed throughout ages. The electrical installation field give a great opportunity for people interested in this field whether they were ,technicians or engineers, a great opportunity of having jobs all over the world. To sum up the benefits i got from my project:

1) It gives me the sufficient knowledge to face such a work in the practical life.
2) The common sense plays an important role in the design of the of electrical installation for any place.
3) It needs a an intelligent sense so as to cover the required job with the shortest time and lowest possible cost in addition to get the profit from that job.
4) It needs a continuous careful observation from the responsible engineer for the job done by the technicians.
5) It needs a continuous reading for the inventions created in this field so as to introduce these inventions to the applicable fields.
6) The electrical installation is and the related things like illumination is an important factor which really shows the development of any country.
7) The electrical installation for countries plays an important role in life considering the common electrical station made between neighboring countries.

REFERENCES:

The following are the references which i refered to in my project:

1) Electrical Installation Workshop and Technology 1st volume 5th edition.
   Electrical Installation Workshop and Technology 2nd volume 4th edition.
   Electrical Installation Technology volume 3 3rd edition.

   By: F.G THOMPSON
   J.H SMITH.
2) Electrical Installation Theory and Practice
   By: E.L DONNELLY.
3) UNION OF THE CHAMBERS OF CYPRUS TURKISH ENGINEERS AND ARCHITECT
   CHAMBER OF OG ELECTRICAL ENGINEERS
   Which was the reference for the calculation of the cost of installation.