NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ELECTRICAL INSTALLATION

Graduation Project
EE- 400

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ABSTRACT

While human is living, electrical installation is important study. Design and make the installation is to be secure. The basics of genaration, transmmission and distribution are given.Installatıon work is considered. Circuits types is also investigated for insttallation works. Shortly insulators, conductors are given. Also what kind of cable can use for installation their types are investigated. Illumination for a building are consired. Earthing subject is given.

Protection and protection method are trying to be given. Building services are investigated what the necessay for a buildings. Some symbols which are used in the project are given. Cost calculations are considered and how much an enginner takes money is trying to be given.

INTRODUCTION

First important part is drawing in electrical installation project. It has to be carefully designed because it will use in the life. It is not just theoritical. So all the neccasary parts are told in this project.

Firstly electrical generation are considered. When dealing with high voltage everybody has to be carefull.and then in the same chapter distribution and transmission of this voltage is considered. Calculation of the voltage drops has to be good. In the second chapter installation works given. It started firstly historical review of installation and wiring.

In the third chapter circuits are investigated which is necessary for electrical installation. Circuits are very important also if it is not to be good designed, big faults can occur. After that chapter what matterials are using in the electrical installation are given. Insulator, conductor and cables what kind of cable we are using in the electrical installation are important. Choosing cable size has to be economical.In the I.E.E Regulations book gives the tables using in the electrical installation work.

In the sixth chapter, illumination subject are trying to be given and then again to be essential part of insttallation work is earthing are given. It is essential because all the safety for this job is dependent that. Protection and protection methods are investigated and then in the appendix part it showed to us, using some symbols in the electrical installation work and also cost calculations.

The conclusion presents the significant results of that project.

CHAPTER 1

1.1 GENERATION AND TRANSMISSION

The generation of electric is to convert the mechanical energy into the electrical energy. Mechanical energy means that motors which makes the turbine turn.

Electrical energy must be at definite value. And also frequency must be 50Hz or at other countries 60Hz. The voltage which is generated (the output of the generator) is 11KV. After the station the lines which transfer the generated voltage to the costumers at expected value. These can be done in some rules. If the voltage transfers as it is generated up to costumers. There will be voltage drop and looses. So voltage is stepped up. When the voltage is stepped up, current will decrease. That is why the voltage is increased. This is done as it is depending on ohm's law. Actually these mean low current. Used cables will become thin. This will be economic and it will be easy to install transmission lines. If we cannot do this, we will have to use thicker cable.

To transfer the generated voltage these steps will be done. Generated voltage (11KV) is applied to the step-up transformer to have 66KV. This voltage is carried up to a sub-station. In this sub-station the voltage will be stepped-down again to 11KV. At the end the voltage stepped-down to 415V that is used by costumers. As a result the value of the voltage has to be at definite value. These;

a-) line to line – 415V

b-) line to neutral – 240V

c-) line to earth – 240V

d-) earth to neutral – 0V

1.2 DISTRIBUTION AND CONTROL

There are three main sets of regulations to which the electrician must conform in order that an installation shall be safe from excess current, shock, fire, corrosion, mechanical damage, and leakage. These are as follows:

1.Electricity (Factories Act) Special Regulations, 1908 and 1944:

These regulations cover 'the generation , transformation, distribution and use of electrical energy' in factories and workshops. An explanatory leaflet ,*Memorandum by the Senior Electrical Inspector of Factories on the Electricity Regulations*, is issued by H.M. Stationery Office to explain the workkings of these regulations.

2.The Electricity Supply Regulations(1937):

The purpose of the Electricity Supply Regulations is to secure " the safety of the public and for ensuring a proper and sufficient supply of electrical energy ". Under these regulations, the Supply Authority (the Area Board) undertakes to supply the consumer at s stated voltage, phase, and frequency, with permissible variations. The Area Board has the right to withhold connection or disconnect a supply if their regulations are not adhered to.

*NOTE :*These regulations, or statutes, have the force of law and for an employer , consumer, or electrician to disregard them could lead to legal action being taken against him.

3.Regulations for the Electrical Equipment of Buildings:

These regulations (commonly called the LE.E, Regulations) have been devised by the Wiring Committee of the Institution of Electrical Engineers to " ensure safety in the utilization of electricity in and about buildings". The I.E.E. Regulations are of considerable assistance to electricians as they largely cover the requirements of the Electricity Supply Regulations. The I.E.E. Regulations consist of two parts: Part 1 contains "requirements for safety" and Part 2 contains "means of securing compliance with Part l"

It should be noted that the LE.E. Regulations are not legally binding but are generally accepted as an efficient standard by Electricity Boards, con- tractors, and industrial and domestic consumers. However, Electricity Boards may have their own particular rules which must be obeyed. Particular industries have their own regulations—for example coal mines and cinemas. These special regulations have the force of law.

Generally, if an installation complies with the I.E.E Regulations it complies both with the Factory Acts and with the Electricity Supply Regulations since the I.E.E

Regulations are based on the requirements of these statutory regulations.

1.3 SUPPLY SYSTEM

The Grid is made up of a series of power stations throughout the country which feed current into a system of conductors at a very high voltage. Overhead conductors, supported by steel towers (pylons), are used to carry the current over long distances.

There are three main types of power station: (1) coal-fired, (2) nuclear, (3) hydro-electric.

The most common type is the coal-fired station. Heat, obtained from the burning of low grade coal, is used to produce high-pressure steam. This high pressure steam is used to drive a turbine which is mechanically connected to a 3-phase a.c. generator (alternator) generating at 11,000V. The voltage is stepped up, by means of a transformer, to 132,000V (or on the super grid). High voltages are used in transmit high power with a cable of small cross-sectional area and also to increase the efficiency of transmission by decreasing copper losses ($(I^2)R$ losses).

1.The 132 kV **(1000 V=** 1 kV) 3-phase supply is terminated at an open air sub-station, containing switchgear and transformers, and stepped down to 11kV or 6.6kV.

2.These voltages (1lkV or 6.6 kV) are used to transmit supplies over shorter distances for bulk supplies to large factories possessing their own sub-stations.

3.These voltages are also used to supply pole transformers for agricultural consumers and isolated installations

4.The supply Authority's sub-stations step down the 3-phase 6.6kV or 11kV to 415 V 3-phase 4-wire(3-phase and neutral).

5.Consumers requiring 240V single phase (i.e phase or live wire and neutral wire), for example, a housing estate, are fed from a 4-core armoured cable (3-phase and neutral conductor).Each house is tapped from a diffirent phase (Fig 4.1) to balance the three phases (red, white, and blue).The underground cable is connected in a series of rings, thus decreasing the voltage drop and cross sectional area required.This interconnection also ensures a continuity of supply.

Fig.1.1 shows an open circuit at point X but all the consumers on the ring receive an uninterrupted supply.

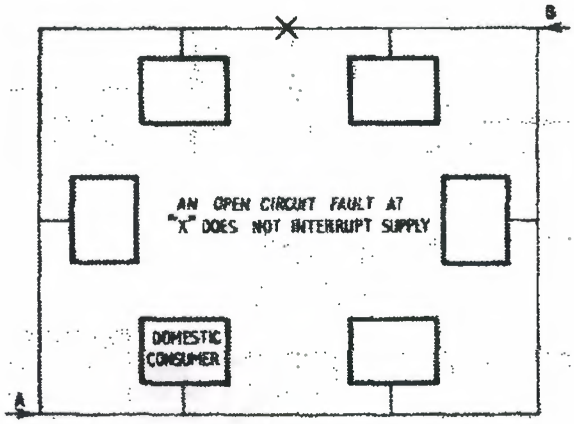

Fig 1.1 Open Circuit fault on ring system supply uninterrupted

1.3.1 Control of Supply at Consumer's premises

It is essential that the consumer's supply should be effectively controlled and also that all switchgear should be accessible.

NOTE:'All conductors and apparatus must be sufficientsize and power for the work they are called upon to do, and so constructed, installed and protected as to prevent danger.'

This quotation from the Electricity Supply Regulations also appears in substance in the Factories Act and the I.E.E Regulations.

The main switchgear in an installation must contain:

(a)Means of isolating the supply.

(b)Protection against excess current.

(c)Means of cutting-off the current if a serious earth fault occurs.

A main switch containing a fuse (or 3 fuses if 3-phase) fulfils these conditions as the switch isolates the supply and the fuse protects the circuit against excess current due to overload or serious earth fault.

Sequence of Control Equipment. Fig.1.2 shows two common methods of controlling the incoming supply.The earth leakage circuit breaker is used where it is difficult to get a good earth path {low-impedance earth return). The earth electrode of the E.L.C.B- must be placed outside the resistance area of any parallel path to earth.

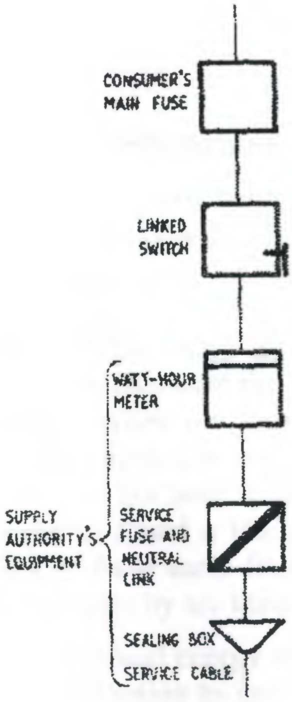

Fig 1.2 sequence of control equipment

1.4 TYPES of INTAKE POSITION

There are two types of intake position;

1.Over-Head Transmission Lines

2.Underground Transmission Lines

1.4.1. Over-Head Transmission Lines

The metal is put on to building, which is near to the transmission lines. We connect the lines, which are coming from pillar, to the "T Point", and, the lines will be gotten into the box of the metering units.

1.4.2. Under-ground Intake:

Lines are taken from pillar but here under-ground cable is used. When the cable put under-ground, it will be done in some rules. These rules are;

1. Earth will be dogged (depth nearly 100 cm)
2. Sand will be separated in channel
3. Plastic pipes will be put into channel
4. Again sand is separated onto pipes
5. And these are covered by cement
6. Cable will be passed through the pipes to the box of metering units.

After these the lines are connected to the HRC (High Rupturing Fuses) fuses. And then, Cutout, metering unit, operator, and distribution board.

CHAPTER 2

INSTALLATION

2.1. 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 was for lighting in houses, shops, and offices. By the 1870s, electric lighting had advanced from being 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 bean 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 ingot and castings. The first all-welded ship was constructed in 1920; and the other ship building processes were operated by electric motor power for punching, shearing, drilling machines and woodworking 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 turn 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, the installation in Hatfield House was carried out by an aristocratic amateur. That the installation was dangerous did not perturb visitors to the house who' when the naked wires on the gallery ceiling broke into flame nonchalantly threw up cushions to put out the fire and then went on with their conversation'

Many names of the early electric pioneers survive today. Julius Sax began to make electric bells in 1855, and later supplied the telephone with which Queen Victoria spoke between Osborne, in the Isle of Wight, and Southampton in 1878. He founded one of the earliest purely electric manufacturing firms, which exists today and still makes bells

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 guarantied that all the components offered for sale were technically suited to each other, were of adequate quality and were offered at an economic price.

Specializing in lighting, Falk Statesman & 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. Glover was originally a designer of textile machinery, but by 1868 he was also making braided steel wires for the then fashionable crinolines. From this type of wire it was a natural step to the production of insulated conductors for electrical purposes. At the Crystal Palace Exhibition in 1885 he showed a great range of cables; he was also responsible for the wiring of the exhibition.

The well-known J. & P. firm (Johnson & Phillips) began with making telegraphic equipment, extended to generators and arc lamps, and then to power supply.

The coverings for the insulation 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.

Siemens 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 Siemens, whose early system was to give a cable a certain length related to a standard resistance of 0.1 ohm. Thus a No.90 cable in their catalogue was a cable of which 90 yards had a resistance of 0.1 ohm. The Standard Wire Gauge also generally knew Cable sizes.

For many years ordinary VRI cables made up about 95 per cent 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 safeguard against the two wires touching and so causing fire. Choosing a cable at the turn 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 insulation: up to 600 V and 600 V/1,000 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 was 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 insulation material came from America to Britain where it formed part of the first wiring system for domestic premises. This was twin lead-sheathed cable. Bases for switches and other accessories associated with the system were of cast solder, to which the cable sheathing was wiped, and then all joints sealed with a compound. The compound was necessary because 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 affected good electrical continuity. The insulation was rubber. It became very popular. Indeed, it proved so easy to install that a lot of unqualified people appeared on the contracting scene as ‘electricians’. When it received the approval of the IEE Rules, it became an established wiring system and is still in use today.

The main competitor to rubber as an insulating material appeared in the late 1930s. This material was PVC (polyvinyl chloride), a synthetic material that came from Germany. The material, though inferior to rubber so far as elastic properties were 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 introduced in 1937. This was tough rubber sheathed cable with a semi-embedded braiding treated with a 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 Argyllshire. Despite the fact that lead and lead-alloy proved to be of great value in the sheathing of cables, aluminium was looked to for a sheath of, in particular, light weight. Many experiments were carried out before a reliable system of aluminium-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 copper-sheathed 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 Pyrotenax Ltd, and later by other firms. Mineral insulation has also been used with conductors and sheathing of aluminium.

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 sleepless 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 Rayland's Library in Manchester in 1886. Aluminium 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 also were 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 earlier material, which required the use of heat for bending.

Accessories for use with wiring systems were the subjects 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 this country 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 electric 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 contacts 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 an 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 forward 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: Verity's, McGeoch, Tucker, and Crabtree. Further developments to produce the semi-recessed, the flush, the ac only, and the 'silent' switch proceeded apace. The switches of today are indeed of long and worthy pedigrees.

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 and 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 1900s, introduced by Dorman & Smith Ltd.

Lord Kelvin, a pioneer of electric wiring systems and wiring accessories brought out 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 curling-tong heaters. Crompton designed shuttered sockets in 1893. The modern shuttered type of socket appeared as a prototype in 1905, introduced by 'Diamond H'. Many sockets were individually fused, a practice, which was later meet the 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 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 'Multi-Contact' and associated with a type of socket outlet, which eventually became the standard design for this accessory. It was Scholes, under the name of 'Wylex', who introduced a revolutionary design of plug-and-socket: a hollow circular earth pin and rectangular current-carrying pins. This was really the first

attempt to 'polarize', or to differentiate between live, earth and neutral pins.

One of the 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-outlets 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 encased 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 in the switchgear field were Bill & Co., Sanders & 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 the motorcar 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 Ottermill.

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, Compton, Swan, Edison, Kelvin and many others, is well worth noting; 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. For those who are interested in details of the evolution and development of electric wiring systems and accessories, good reading can be found in the book by J. Mellanby: The History of Electric Wiring (MacDonald, London).

2.2 Historical Review of Wiring Installation

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 lamp, 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 electrical 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 Institution of Electrical Engineers) 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 laying down a set of principles rather than, as Heaphy did, drawing up a guide or 'Code of Practice'. A second edition of the Society's Rules was issued in 1888. The third edition was issued in 1897 and entitled General Rules recommended for Wiring for the Supply of Electrical Energy.

The Rules have since been revised at fairly regular intervals as new developments and the results of experience can be written in for the considered attention of all those 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 Institution of Electrical Engineers (IEE) was not alone in the insistence of good standards in electrical installation work. In 1905, the Electrical Trades Union, through the London District Committee, in a letter to the Phoenix Assurance Co., said 'they view with alarm the large extent to which bad work is now being carried out by electric light contractors As the carrying out of bad work is attended by fires and other risks, besides injuring the Trade, they respectfully ask you to. . Uphold a higher standard work'.

The legislation embodied in the Factory and Workshop Acts of 1901 and 1907 had a considerable influence on wiring practice. In the latter Act it was recognized for the first time that the generation, distribution and use of electricity in industrial premises could be dangerous. To control electricity in factories and other premises a draft set of Regulations was later to be incorporated into statutory requirements.

While the IEE and the statutory regulations were making their 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 this country is that they form the primary requirements, which must by law be satisfied. The IEE Regulations and Codes of Practice indicate 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 the IEE Regulations, but cannot insist on a standard which is in excess of the IEE requirements.

2.3 INDUSTRIAL INSTALLATION .

1.All cables must be rated at, or above, the current which they will normally be expected to carry (Tables 1M to 31M in the I.E.E. Regulations supply this information) without undue heating or voltage drop (normally 5 per cent of nominal voltage).

2.All conductors, cables and equipment used in the Installation must be of the correct voltage rating, for example, 250V grade switchgear should not be used on 415V 3-phase installations; 500 V switchgear is necessary.

3. The fuse in a circuit must be capable of protecting the smallest conductor in that circuit. For example, a twin flexible cord of 3 A rating should not be used In a circuit fused above 5 A because serious over-heating could occur in the flexible cord under fault conditions.

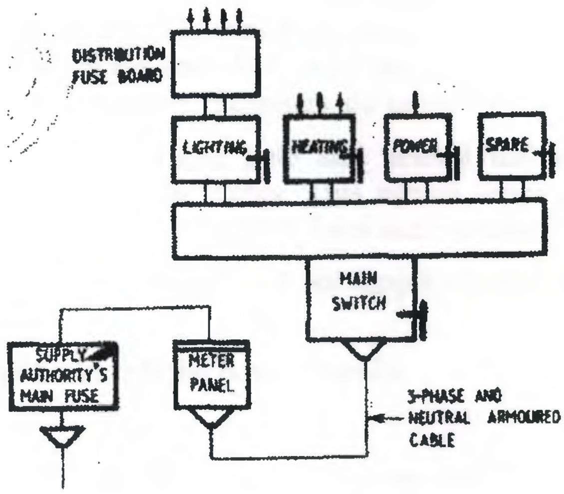

Fig. 2.1 Layout of small engineering works.

4. All conductors and equipment must be properly labelled; this saves time and also minimizes the danger of opening the wrong circuit when Isolating or fault-finding.

Earth wire GREEN and YELLOW

3-Phase wires (non-flexible) RED, YELLOW, and BLUE

Neutral: BLACK

3-Phase wires (flexible) All phase wires BSOWH (identified by sleeves or tabs)

Neutral: BLUE

Single-Phase (3-core) Live: BROWN

Neutral:BLUE

Paper-insulated cables:	0=NEUTRAL	1=RED PHASE
	2=YELLOW	3=BLUE

Mineral–insulated metal sheated Identification sleeves should be used at terminations.

5.All equipment must be protected against:high temperatures, moisture, corrosion and mechanical damage.

6.The main distribution point should be situated, if possible, at the centre of the Installation In order to keep cable runs short.

7.Sufficient capacity should be installed at the outset (In main switches, bus-bar chambers, and cables) to allow for future expansion.

Fig. 2.1 shows a suggested layout for a relatively small engineering works. The supply is fed into the premises by means of an underground cable (3- neutral), through a sealing chamber into the Supply Authority's fuse.Tails are taken from the fuses and neutral block Into the meter panel. An armoured cable supplies the consumer's main switch, which, In this case, is a 500 A triple-pole and neutral linked switch (all poles are switched simultaneously). The conductors are then brought out to the bus-bar chamber. Tappings are taken from the bus-bars as follows:

No. 1 switch is a triple pole and neutral linked switch (all poles are switched simultaneously) for the lights. This switch feeds an 18-way distribution fuse board comprising three sets of six 15A fuses and a neutral block.

No. 2 switch is similar to No. 1 but supplies the heating load, which is balanced over 3 phases.

No. 3 switch controls the power circuits.

Sub-division of Loads. This is considered under lighting, heating, and power circuits

Lighting Circuits: The lighting load will be taken from the distribution board to the final sub-circuits. A final sub-circuit is defined in the I.E.E. Regulations as "an outgoing circuit connected to a distribution board and intended to supply electrical energy direct to current-using apparatus*'. The conductors between the bus-bar chamber and the distribution fuse board are termed the sub-main. The conductors from the lighting distribution fuse board may also feed local switches supplying small distribution fuse boards (for example, 5 A fuses) for offices, stores, etc.

The lighting final sub-circuits comprise a switch-panel and the lights controlled by these switches.

All fuses and switches must be placed in the phase conductor and metal lampholders (used in industrial fittings of 200 W and over) must be earthed and the phase conductor should be terminated at the centre pin of Giant Edison Screw (G.E.S.) lampholders

Heating Circuits. The heating load (Fig. 4.6) is split up over 3 phases to give a balanced load. The heaters, for example, fan heaters, would be controlled a 3-phase isolator or a 3-phase switch fuse. For example, if 240 V tubular heaters (200 W per metre) are used the heating circuits are subdivided into three sections with a seperatephase for each section.

Power Circuits, which consist of, in this instance, a 3-pliase isolator and a starter controlling a milling-machine motor taking a full load current of 8 A. A 1 mm^2 or a 1-5 mm^a cable would be adequate for this circuit, but the fuse should be loaded to three times the full load current of the motor, that is, approximately 25 A (0-75 mm tinned-copper wire).

The main distribution fuse board may also be used to supply smaller distribution fuse boards for smaller lathes, drills, etc.

The 2--meter Rule. In conditions where two separate phases (for example, the red and blue phases) are brought into the same room:

(a) The controlling switch must be clearly marked '415 volts',

b) Switches and socket outlets supplied from different phases must be

placed at least 2 metres apart. This is particularly important where

portable appliances are used .

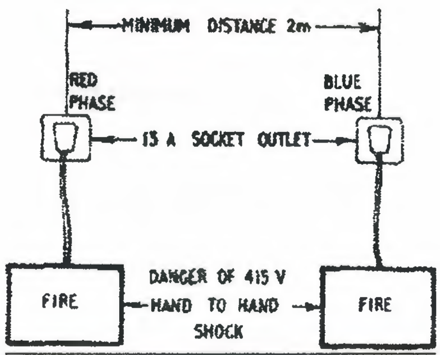

Fig 2.2 The 2-meter rule

This is termed the ‘2-meter rule’.It avoids the danger of a voltage of 415V appearing between appliance or switches which can be touched simultaneously.

2.4 DOMESTIC INSTALLATIONS

2.4.1 General Rules for Domestic Installation

There are two types of installation

I. Surface Installation

II. Under plaster installation

Installation system at costumers place

OPERATOR ➡ DISTRIBUTION BOARD ➡ FUSES ➡ LINES (CABLES)

In both types of installation, same main principle is accepted these are;

1. Lines from metering unit will be applied to the operator (V/O, C/O) or if operator is in distribution board, we put 2-pole isolator into box of metering unit and earth continuity conductor will come from another place, not with line and neutral conductor. If the operator is outside of the operator line neutral earth will be connected together to 2-pole isolator, which is in distribution board. These maybe 3 phase or 1 phase operator or isolator.

2. In distribution board for each type of circuit different cable sizes and fuses or miniature circuit breakers are used.

Domestic installation are usually supplied from a 16mm2 twin armoured cable.

1.The supply Authority's sealingchamber for the termination of the armoured cable.

2.The Supply Authority's fuse and neutral block.

3.The Supply Authority's energy meter (kWh).

4.Consumer's control unit.

NOTE:The Supply Authority's fuses need not be dublicated if the permissionof the Authority is obtained

2.4.2. Under Plaster Installation

Steps do this type of installation as follows;

I. Ceiling installation and stairs.

II. Inside of home and stairs.

2.4.2.1. Ceiling Installation;

Plastic pipes and plastic lamb box do this part of installation. Generally, 5/8 plastic pipes are used for cell lighting. While we are doing these also, pipes of stairs installation is fixed. Pipes and lamb boxes are out be cording to the electric installation project.

NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ELECTRICAL INSTALLATION

Graduation Project

EE- 400

Student: Umut Çağlar Çamoğlu

Supervisor: Dr. Kadri Bürüncük

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ABSTRACT

While human is living, electrical installation is important study. Design and make the installation is to be secure. The basics of genaration, transmmission and distribution are given.Installatıon work is considered. Circuits types is also investigated for insttallation works. Shortly insulators, conductors are given. Also what kind of cable can use for installation their types are investigated. Illumination for a building are consired. Earthing subject is given.

Protection and protection method are trying to be given. Building services are investigated what the necessay for a buildings. Some symbols which are used in the project are given. Cost calculations are considered and how much an enginner takes money is trying to be given.

INTRODUCTION

First important part is drawing in electrical installation project. It has to be carefully designed because it will use in the life. It is not just theoritical. So all the neccasary parts are told in this project.

Firstly electrical generation are considered. When dealing with high voltage everybody has to be carefull.and then in the same chapter distribution and transmission of this voltage is considered. Calculation of the voltage drops has to be good. In the second chapter installation works given. It started firstly historical review of installation and wiring.

In the third chapter circuits are investigated which is necessary for electrical installation. Circuits are very important also if it is not to be good designed, big faults can occur. After that chapter what matterials are using in the electrical installation are given. Insulator, conductor and cables what kind of cable we are using in the electrical installation are important. Choosing cable size has to be economical.In the I.E.E Regulations book gives the tables using in the electrical installation work.

In the sixth chapter, illumination subject are trying to be given and then again to be essential part of insttallation work is earthing are given. It is essential because all the safety for this job is dependent that. Protection and protection methods are investigated and then in the appendix part it showed to us, using some symbols in the electrical installation work and also cost calculations.

The conclusion presents the significant results of that project.

CHAPTER 1

1.1 GENERATION AND TRANSMISSION

The generation of electric is to convert the mechanical energy into the electrical energy. Mechanical energy means that motors which makes the turbine turn.

Electrical energy must be at definite value. And also frequency must be 50Hz or at other countries 60Hz. The voltage which is generated (the output of the generator) is 11KV. After the station the lines which transfer the generated voltage to the costumers at expected value. These can be done in some rules. If the voltage transfers as it is generated up to costumers. There will be voltage drop and looses. So voltage is stepped up. When the voltage is stepped up, current will decrease. That is why the voltage is increased. This is done as it is depending on ohm's law. Actually these mean low current. Used cables will become thin. This will be economic and it will be easy to install transmission lines. If we cannot do this, we will have to use thicker cable.

To transfer the generated voltage these steps will be done. Generated voltage (11KV) is applied to the step-up transformer to have 66KV. This voltage is carried up to a sub-station. In this sub-station the voltage will be stepped-down again to 11KV. At the end the voltage stepped-down to 415V that is used by costumers. As a result the value of the voltage has to be at definite value. These;

a-) line to line – 415V

b-) line to neutral – 240V

c-) line to earth – 240V

d-) earth to neutral – 0V

1.2 DISTRIBUTION AND CONTROL

There are three main sets of regulations to which the electrician must conform in order that an installation shall be safe from excess current, shock, fire, corrosion, mechanical damage, and leakage. These are as follows:

1.Electricity (Factories Act) Special Regulations, 1908 and 1944:

These regulations cover 'the generation , transformation, distribution and use of electrical energy' in factories and workshops. An explanatory leaflet ,*Memorandum by the Senior Electrical Inspector of Factories on the Electricity Regulations*, is issued by H.M. Stationery Office to explain the workkings of these regulations.

2.The Electricity Supply Regulations(1937):

The purpose of the Electricity Supply Regulations is to secure " the safety of the public and for ensuring a proper and sufficient supply of electrical energy ". Under these regulations, the Supply Authority (the Area Board) undertakes to supply the consumer at s stated voltage, phase, and frequency, with permissible variations. The Area Board has the right to withhold connection or disconnect a supply if their regulations are not adhered to.

NOTE :These regulations, or statutes, have the force of law and for an employer , consumer, or electrician to disregard them could lead to legal action being taken against him.

3.Regulations for the Electrical Equipment of Buildings:

These regulations (commonly called the LE.E, Regulations) have been devised by the Wiring Committee of the Institution of Electrical Engineers to " ensure safety in the utilization of electricity in and about buildings". The I.E.E. Regulations are of considerable assistance to electricians as they largely cover the requirements of the Electricity Supply Regulations. The I.E.E. Regulations consist of two parts: Part 1 contains "requirements for safety" and Part 2 contains "means of securing compliance with Part 1"

It should be noted that the LE.E. Regulations are not legally binding but are generally accepted as an efficient standard by Electricity Boards, con- tractors, and industrial and domestic consumers. However, Electricity Boards may have their own particular rules which must be obeyed. Particular industries have their own regulations—for example coal mines and cinemas. These special regulations have the force of law.

Generally, if an installation complies with the I.E.E Regulations it complies both with the Factory Acts and with the Electricity Supply Regulations since the I.E.E

Regulations are based on the requirements of these statutory regulations.

1.3 SUPPLY SYSTEM

The Grid is made up of a series of power stations throughout the country which feed current into a system of conductors at a very high voltage. Overhead conductors, supported by steel towers (pylons), are used to carry the current over long distances.

There are three main types of power station: (1) coal-fired, (2) nuclear, (3) hydro-electric.

The most common type is the coal-fired station. Heat, obtained from the burning of low grade coal, is used to produce high-pressure steam. This high pressure steam is used to drive a turbine which is mechanically connected to a 3-phase a.c. generator (alternator) generating at 11,000V. The voltage is stepped up, by means of a transformer, to 132,000V (or on the super grid). High voltages are used in transmit high power with a cable of small cross-sectional area and also to increase the efficiency of transmission by decreasing copper losses ($(I^2)R$ losses).

1.The 132 kV **(1000 V=** 1 kV) 3-phase supply is terminated at an open air sub-station, containing switchgear and transformers, and stepped down to 11kV or 6.6kV.

2.These voltages (1lkV or 6.6 kV) are used to transmit supplies over shorter distances for bulk supplies to large factories possessing their own sub-stations.

3.These voltages are also used to supply pole transformers for agricultural consumers and isolated installations

4.The supply Authority's sub-stations step down the 3-phase 6.6kV or 11kV to 415 V 3-phase 4-wire(3-phase and neutral).

5.Consumers requiring 240V single phase (i.e phase or live wire and neutral wire), for example, a housing estate, are fed from a 4-core armoured cable (3-phase and neutral conductor).Each house is tapped from a diffirent phase (Fig 4.1) to balance the three phases (red, white, and blue).The underground cable is connected in a series of rings, thus decreasing the voltage drop and cross sectional area required.This interconnection also ensures a continuity of supply.

Fig.1.1 shows an open circuit at point X but all the consumers on the ring receive an uninterrupted supply.

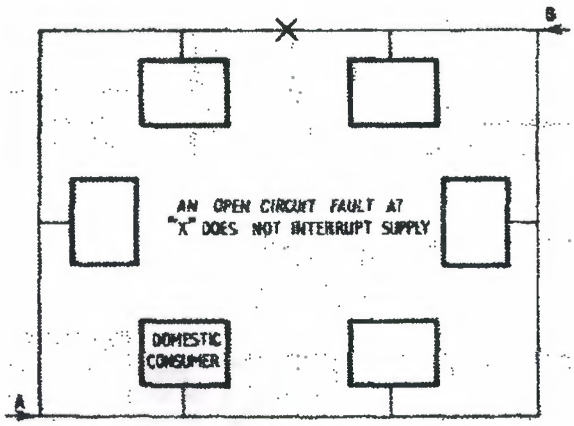


Fig 1.1 Open Circuit fault on ring system supply uninterrupted

1.3.1 Control of Supply at Consumer's premises

It is essential that the consumer's supply should be effectively controlled and also that all switchgear should be accessible.

NOTE:'All conductors and apparatus must be sufficientsize and power for the work they are called upon to do, and so constructed, installed and protected as to prevent danger.'

This quotation from the Electricity Supply Regulations also appears in substance in the Factories Act and the I.E.E Regulations.

The main switchgear in an installation must contain:

(a)Means of isolating the supply.

(b)Protection against excess current.

(c)Means of cutting-off the current if a serious earth fault occurs.

A main switch containing a fuse (or 3 fuses if 3-phase) fulfils these conditions as the switch isolates the supply and the fuse protects the circuit against excess current due to overload or serious earth fault.

Sequence of Control Equipment. Fig.1.2 shows two common methods of controlling the incoming supply.The earth leakage circuit breaker is used where it is difficult to get a good earth path {low-impedance earth return). The earth electrode of the E.L.C.B- must be placed outside the resistance area of any parallel path to earth.

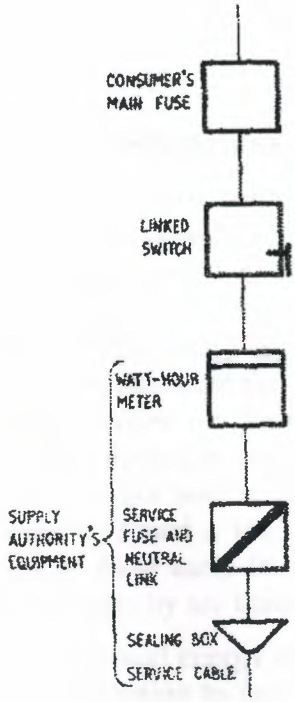


Fig 1.2 sequence of control equipment

1.4 TYPES of INTAKE POSITION

There are two types of intake position;

1.Over-Head Transmission Lines

2.Underground Transmission Lines

1.4.1. Over-Head Transmission Lines

The metal is put on to building, which is near to the transmission lines. We connect the lines, which are coming from pillar, to the "T Point", and, the lines will be gotten into the box of the metering units.

1.4.2. Under-ground Intake:

Lines are taken from pillar but here under-ground cable is used. When the cable put under-ground, it will be done in some rules. These rules are;

1. Earth will be dogged (depth nearly 100 cm)
2. Sand will be separated in channel
3. Plastic pipes will be put into channel
4. Again sand is separated onto pipes
5. And these are covered by cement
6. Cable will be passed through the pipes to the box of metering units.

After these the lines are connected to the HRC (High Rupturing Fuses) fuses. And then, Cutout, metering unit, operator, and distribution board.

CHAPTER 2

INSTALLATION

2.1. 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 was for lighting in houses, shops, and offices. By the 1870s, electric lighting had advanced from being 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 bean 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 ingot and castings. The first all-welded ship was constructed in 1920; and the other ship building processes were operated by electric motor power for punching, shearing, drilling machines and woodworking 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 turn 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, the installation in Hatfield House was carried out by an aristocratic amateur. That the installation was dangerous did not perturb visitors to the house who' when the naked wires on the gallery ceiling broke into flame nonchalantly threw up cushions to put out the fire and then went on with their conversation'

Many names of the early electric pioneers survive today. Julius Sax began to make electric bells in 1855, and later supplied the telephone with which Queen Victoria spoke between Osborne, in the Isle of Wight, and Southampton in 1878. He founded one of the earliest purely electric manufacturing firms, which exists today and still makes bells

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 guarantied that all the components offered for sale were technically suited to each other, were of adequate quality and were offered at an economic price.

Specializing in lighting, Falk Statesman & 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. Glover was originally a designer of textile machinery, but by 1868 he was also making braided steel wires for the then fashionable crinolines. From this type of wire it was a natural step to the production of insulated conductors for electrical purposes. At the Crystal Palace Exhibition in 1885 he showed a great range of cables; he was also responsible for the wiring of the exhibition.

The well-known J. & P. firm (Johnson & Phillips) began with making telegraphic equipment, extended to generators and arc lamps, and then to power supply.

The coverings for the insulation 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.

Siemens 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 Siemens, whose early system was to give a cable a certain length related to a standard resistance of 0.1 ohm. Thus a No.90 cable in their catalogue was a cable of which 90 yards had a resistance of 0.1 ohm. The Standard Wire Gauge also generally knew Cable sizes.

For many years ordinary VRI cables made up about 95 per cent 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 safeguard against the two wires touching and so causing fire. Choosing a cable at the turn 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 insulation: up to 600 V and 600 V/1,000 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 was 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 insulation material came from America to Britain where it formed part of the first wiring system for domestic premises. This was twin lead-sheathed cable. Bases for switches and other accessories associated with the system were of cast solder, to which the cable sheathing was wiped, and then all joints sealed with a compound. The compound was necessary because 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 affected good electrical continuity. The insulation was rubber. It became very popular. Indeed, it proved so easy to install that a lot of unqualified people appeared on the contracting scene as ‘electricians’. When it received the approval of the IEE Rules, it became an established wiring system and is still in use today.

The main competitor to rubber as an insulating material appeared in the late 1930s. This material was PVC (polyvinyl chloride), a synthetic material that came from Germany. The material, though inferior to rubber so far as elastic properties were 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 introduced in 1937. This was tough rubber sheathed cable with a semi-embedded braiding treated with a 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 Argyllshire. Despite the fact that lead and lead-alloy proved to be of great value in the sheathing of cables, aluminium was looked to for a sheath of, in particular, light weight. Many experiments were carried out before a reliable system of aluminium-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 copper-sheathed 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 Pyrotenax Ltd, and later by other firms. Mineral insulation has also been used with conductors and sheathing of aluminium.

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 sleepless 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 Rayland's Library in Manchester in 1886. Aluminium 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 also were 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 earlier material, which required the use of heat for bending.

Accessories for use with wiring systems were the subjects 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 this country 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 electric 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 contacts 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 an 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 forward 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: Verity's, McGeoch, Tucker, and Crabtree. Further developments to produce the semi-recessed, the flush, the ac only, and the 'silent' switch proceeded apace. The switches of today are indeed of long and worthy pedigrees.

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 and 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 1900s, introduced by Dorman & Smith Ltd.

Lord Kelvin, a pioneer of electric wiring systems and wiring accessories brought out 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 curling-tong heaters. Crompton designed shuttered sockets in 1893. The modern shuttered type of socket appeared as a prototype in 1905, introduced by 'Diamond H'. Many sockets were individually fused, a practice, which was later meet the 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 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 'Multi-Contact' and associated with a type of socket outlet, which eventually became the standard design for this accessory. It was Scholes, under the name of 'Wylex', who introduced a revolutionary design of plug-and-socket: a hollow circular earth pin and rectangular current-carrying pins. This was really the first

attempt to 'polarize', or to differentiate between live, earth and neutral pins.

One of the 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-outlets 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 encased 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 in the switchgear field were Bill & Co., Sanders & 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 the motorcar 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 Ottermill.

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, Compton, Swan, Edison, Kelvin and many others, is well worth noting; 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. For those who are interested in details of the evolution and development of electric wiring systems and accessories, good reading can be found in the book by J. Mellanby: The History of Electric Wiring (MacDonald, London).

2.2 Historical Review of Wiring Installation

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 lamp, 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 electrical 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 Institution of Electrical Engineers) 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 laying down a set of principles rather than, as Heaphy did, drawing up a guide or 'Code of Practice'. A second edition of the Society's Rules was issued in 1888. The third edition was issued in 1897 and entitled General Rules recommended for Wiring for the Supply of Electrical Energy.

The Rules have since been revised at fairly regular intervals as new developments and the results of experience can be written in for the considered attention of all those 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 Institution of Electrical Engineers (IEE) was not alone in the insistence of good standards in electrical installation work. In 1905, the Electrical Trades Union, through the London District Committee, in a letter to the Phoenix Assurance Co., said 'they view with alarm the large extent to which bad work is now being carried out by electric light contractors As the carrying out of bad work is attended by fires and other risks, besides injuring the Trade, they respectfully ask you to. . Uphold a higher standard work'.

The legislation embodied in the Factory and Workshop Acts of 1901 and 1907 had a considerable influence on wiring practice. In the latter Act it was recognized for the first time that the generation, distribution and use of electricity in industrial premises could be dangerous. To control electricity in factories and other premises a draft set of Regulations was later to be incorporated into statutory requirements.

While the IEE and the statutory regulations were making their 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 this country is that they form the primary requirements, which must by law be satisfied. The IEE Regulations and Codes of Practice indicate 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 the IEE Regulations, but cannot insist on a standard which is in excess of the IEE requirements.

2.3 INDUSTRIAL INSTALLATION .

1.All cables must be rated at, or above, the current which they will normally be expected to carry (Tables 1M to 31M in the I.E.E. Regulations supply this information) without undue heating or voltage drop (normally 5 per cent of nominal voltage).

2.All conductors, cables and equipment used in the Installation must be of the correct voltage rating, for example, 250V grade switchgear should not be used on 415V 3-phase installations; 500 V switchgear is necessary.

3. The fuse in a circuit must be capable of protecting the smallest conductor in that circuit. For example, a twin flexible cord of 3 A rating should not be used In a circuit fused above 5 A because serious over-heating could occur in the flexible cord under fault conditions.

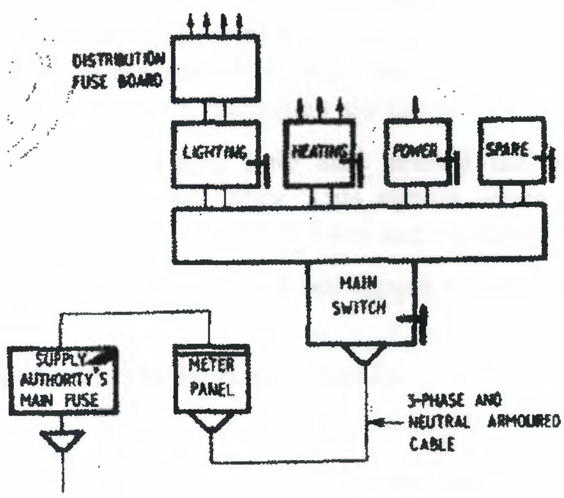


Fig. 2.1 Layout of small engineering works.

4. All conductors and equipment must be properly labelled; this saves time and also minimizes the danger of opening the wrong circuit when Isolating or fault-finding.

Earth wire GREEN and YELLOW

3-Phase wires (non-flexible) RED, YELLOW, and BLUE

Neutral: BLACK

3-Phase wires (flexible) All phase wires BSOWH (identified by sleeves or tabs)

Neutral: BLUE

Single-Phase (3-core) Live: BROWN

Neutral:BLUE

Paper-insulated cables: 0=NEUTRAL 1=RED PHASE

2=YELLOW 3=BLUE

Mineral–insulated metal sheated Identification sleeves should be used at terminations.

5.All equipment must be protected against:high temperatures, moisture, corrosion and mechanical damage.

6.The main distribution point should be situated, if possible, at the centre of the Installation In order to keep cable runs short.

7.Sufficient capacity should be installed at the outset (In main switches, bus-bar chambers, and cables) to allow for future expansion.

Fig. 2.1 shows a suggested layout for a relatively small engineering works. The supply is fed into the premises by means of an underground cable (3- neutral), through a sealing chamber into the Supply Authority's fuse.Tails are taken from the fuses and neutral block Into the meter panel. An armoured cable supplies the consumer's main switch, which, In this case, is a 500 A triple-pole and neutral linked switch (all poles are switched simultaneously). The conductors are then brought out to the bus-bar chamber. Tappings are taken from the bus-bars as follows:

No. 1 switch is a triple pole and neutral linked switch (all poles are switched simultaneously) for the lights. This switch feeds an 18-way distribution fuse board comprising three sets of six 15A fuses and a neutral block.

No. 2 switch is similar to No. 1 but supplies the heating load, which is balanced over 3 phases.

No. 3 switch controls the power circuits.

Sub-division of Loads. This is considered under lighting, heating, and power circuits

Lighting Circuits: The lighting load will be taken from the distribution board to the final sub-circuits. A final sub-circuit is defined in the I.E.E. Regulations as "an outgoing circuit connected to a distribution board and intended to supply electrical energy direct to current-using apparatus*'. The conductors between the bus-bar chamber and the distribution fuse board are termed the sub-main. The conductors from the lighting distribution fuse board may also feed local switches supplying small distribution fuse boards (for example, 5 A fuses) for offices, stores, etc.

The lighting final sub-circuits comprise a switch-panel and the lights controlled by these switches.

All fuses and switches must be placed in the phase conductor and metal lampholders (used in industrial fittings of 200 W and over) must be earthed and the phase conductor should be terminated at the centre pin of Giant Edison Screw (G.E.S.) lampholders

Heating Circuits. The heating load (Fig. 4.6) is split up over 3 phases to give a balanced load. The heaters, for example, fan heaters, would be controlled a 3-phase isolator or a 3-phase switch fuse. For example, if 240 V tubular heaters (200 W per metre) are used the heating circuits are subdivided into three sections with a seperatephase for each section.

Power Circuits, which consist of, in this instance, a 3-pliase isolator and a starter controlling a milling-machine motor taking a full load current of 8 A. A 1 mm^2 or a 1-5 mm^a cable would be adequate for this circuit, but the fuse should be loaded to three times the full load current of the motor, that is, approximately 25 A (0-75 mm tinned-copper wire).

The main distribution fuse board may also be used to supply smaller distribution fuse boards for smaller lathes, drills, etc.

The 2--meter Rule. In conditions where two separate phases (for example, the red and blue phases) are brought into the same room:

(a) The controlling switch must be clearly marked '415 volts',

b) Switches and socket outlets supplied from different phases must be

placed at least 2 metres apart. This is particularly important where

portable appliances are used .

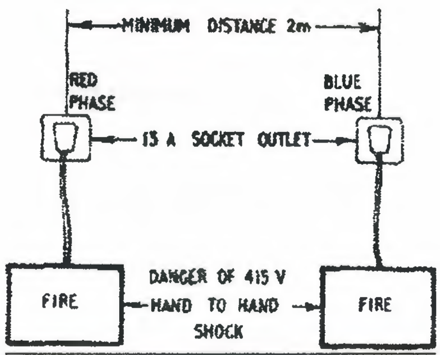


Fig 2.2 The 2-meter rule

This is termed the '2-meter rule'.It avoids the danger of a voltage of 415V appearing between appliance or switches which can be touched simultaneously.

2.4 DOMESTIC INSTALLATIONS

2.4.1 General Rules for Domestic Installation

There are two types of installation

I. Surface Installation

II. Under plaster installation

Installation system at costumers place

OPERATOR ➡ DISTRIBUTION BOARD ➡ FUSES ➡ LINES (CABLES)

In both types of installation, same main principle is accepted these are;

1. Lines from metering unit will be applied to the operator (V/O, C/O) or if operator is in distribution board, we put 2-pole isolator into box of metering unit and earth continuity conductor will come from another place, not with line and neutral conductor. If the operator is outside of the operator line neutral earth will be connected together to 2-pole isolator, which is in distribution board. These maybe 3 phase or 1 phase operator or isolator.

2. In distribution board for each type of circuit different cable sizes and fuses or miniature circuit breakers are used.

Domestic installation are usually supplied from a 16mm2 twin armoured cable.

1.The supply Authority's sealingchamber for the termination of the armoured cable.

2.The Supply Authority's fuse and neutral block.

3.The Supply Authority's energy meter (kWh).

4.Consumer's control unit.

NOTE:The Supply Authority's fuses need not be dublicated if the permissionof the Authority is obtained

2.4.2. Under Plaster Installation

Steps do this type of installation as follows;

I. Ceiling installation and stairs.

II. Inside of home and stairs.

2.4.2.1. Ceiling Installation;

Plastic pipes and plastic lamb box do this part of installation. Generally, 5/8 plastic pipes are used for cell lighting. While we are doing these also, pipes of stairs installation is fixed. Pipes and lamb boxes are out be cording to the electric installation project.

Following steps to do these.

a-)Ceiling installation and stairs. First the lamp boxes are filled by wet papers. Lamps boxes may fill with concrete there fore we fill the inside of lamp boxes with paper not to have problem.

b-) Lamps boxes will be nailed according to the electrical plan. If there is only single lamp in a room. Lamp boxes will be nailed to the center of room. If there is more than one lamp. You have to follow a special ways. For example, in a corridor generally there are two lamps length of corridor will be divided by there and with will be divided two to point the place of lamp.

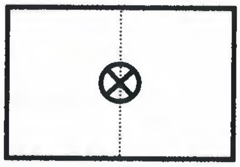
c-) You will take out the pipes from the lamp boxes for switches (to under of the roof). We have to be careful. When we put the pipes inside of the coulomb the pipes, which will be under roof, must not be above doors or windows and also, it should not be behind doors.

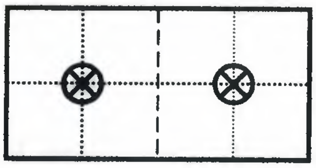
d-) For each circuit, from the lamb boxes, pipes will be taken out up to the distribution board. This is done as same as position of switches.

e-) Pipes will be put for the heater and for the water tank on the roof to the distribution board. (3/4")

f-) For antenna and telephone lines pipes are fixed to the suitable position (1" or ¾"). In apartments extra pipes are put in stairs for main lines and for the lighting of stairs. They are put inside of the coulomb

Figure 2.3. Ceiling installation samples





2.4.2.2 Inside of Home and Stairs.

According to the plan, you paint the positions of sockets, switches, etc. with paint (spray paint). Painted places have to be broken. Metal boxes and plastic pipes that are in different sizes, for each type of circuit.

5/8" pipes for lighting, telephone lines, water pump, and earthing.

3/4" for sockets, antenna, heater circuits.

3/4" or 1" fore cooker control

1 ¼" or thicker is used for main lines,

When the metal boxes are being put they have to have different heights. These heights are;

In bathroom, dinning rooms, and corridor, sockets/Telephone/Antenna sockets 50cm (between floor to metal box)

Switches 150cm (between floor to metal box)

Special lamps on wall 200cm (between floor to metal box)

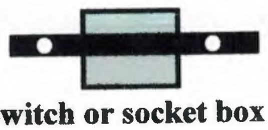


Figure 2.4. Switch or socket box

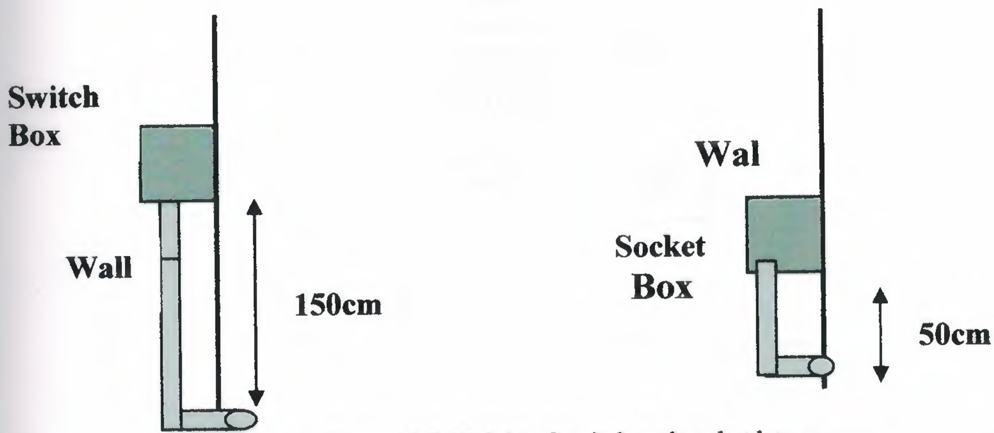


Figure 2.5. Height of switch and socket boxes

In Kitchen;

Here you have to be careful for position of metal boxes. Because cooker, switches, sockets boxes have to be at the same line and you have to measure careful not to put them on the place of the cupboards and this height is generally 125cm.

In Toilet and Bathrooms;

You must not put the metal box of switches inside of toilets or bathrooms. Because you may have risk of electric shock. Lamps must be waterproof. In these wet places, we have to use waterproof components for protection of life. Height of lamp is nearly at 200cm.

The round of the metal boxes must not be plastered because, metal box will have corrosion problem.

Steps

a-) We paint the places of switches, sockets, etc.

b-) Painted paces have to be broken, up to 65cm for sockets, switches 150cm, if the pipes of switch will come from roof, that pipe will come to 150cm painted line.

c-) Metal box will be fixed at painted places, but they have to be flat and good appearance we tie with wire on at piece of flat wood. This wood is nailed to the wall.

d-) We bend the pipes from anywhere of pipes, where it is needed and put them in boxes from hole on box.

e-) After plasterer to fait and the pipes plasters these boxes which are on floor are also plastered to protect the pipes.

After these have been finished, we will pull the cable as connecting to the special stainless wire. What types of cables are suitable for each circuit.

In kitchen, toilets and bathrooms metal place labs will be earthed by special clips which is called earthen clips and also switches, sockets and something like these will be connected and this is called finish.

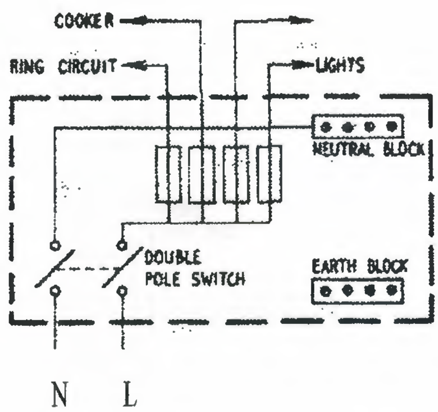


FIG. 2.6. Domestic consumer's control unit

Domestic Consumer's Control Unit (Fig. 2.6).This type of unit is usually made up of the following :

(a) Main switch (60 A) which isolates *both* the phase and the neutral conductors,

(b) One 30 A fuse for the cooker circuit.

(c) One 30 A fuse for the 1 3 A ring circuit (capable of taking two 7/0-85 in cables).

(d) One or two 5 A fuses for lighting circuits.

Loading of Final Sub-circuits. The assumed current demand from points is as follows (Table B, I.E.E. Regulations):

15 A socket outlet	15 A
5A socket outlet	5A
2A socket outlet	at least 1/2A
Lighting outlet	minimum 100W

1.Only one phase of a supply should preferably be brought in to a multi gang switch box. Where more than one phase is used there must be a rigid screen or barrier separating the phases, and a clearly visible notice warning of the maximum voltage present. This notice must be placed outside the switch.

2.All final sub-circuits must be electrically separate (i.e. there must be no 'bunching' of neutral conductors). All neutral conductors must be connected at the distribution board in the same order as the line conductors.

Domestic Ring Circuit (Fig. 2.7). The domestic ring circuit is defined in the I.E.E. Regulations as "a final sub-circuit in which the current-carrying and earth continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution fuse board or its equivalent. A spur of a ring circuit shall be a branch cable having conductors of a cross-sectional area not smaller than that of the conductors forming the ring".

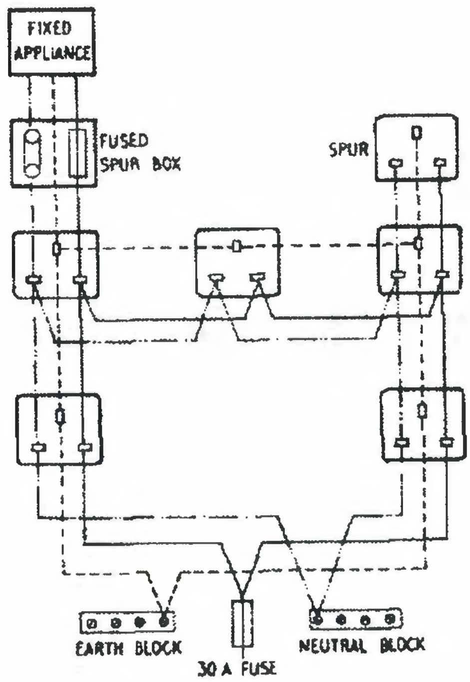


Fig. 2.7. Domestic ring circuit

The main I.E.E. Regulations relating to the ring are as follows:

1.Cable size: minimum twin 2-5 mm^2 and earth p.v.c. or t.r.s.

2.Maximum number of socket outlets allowed: unlimited number in floor area under 100 m^2, but spurs may not number more than half the socket outlets on the ring circuit, including stationary appliances.

3.Fused 13 A plugs to be used at socket outlets supplying portable appliances.

4.Fixed appliances must be protected by a local fuse, for example, 3 fused spur box.

5.A 30 A fuse should be used to protect the ring circuit.

6.All socket outlets in any one room must be connected to the same phase.

7.Apparatus permanently connected to the ring circuit without a fused plug or socket outlet must be protected by a local fuse or circuit-breaker with a rating not exceeding 15 A. The apparatus must have an adjacent con- trolling switch.

The purpose of the ring circuit is:

(a} To minimize trailing flexes.

(b) To take advantage of the fact that all outlets in a domestic installation are not pperated simultaneously .This is known as the diversity in an installation.

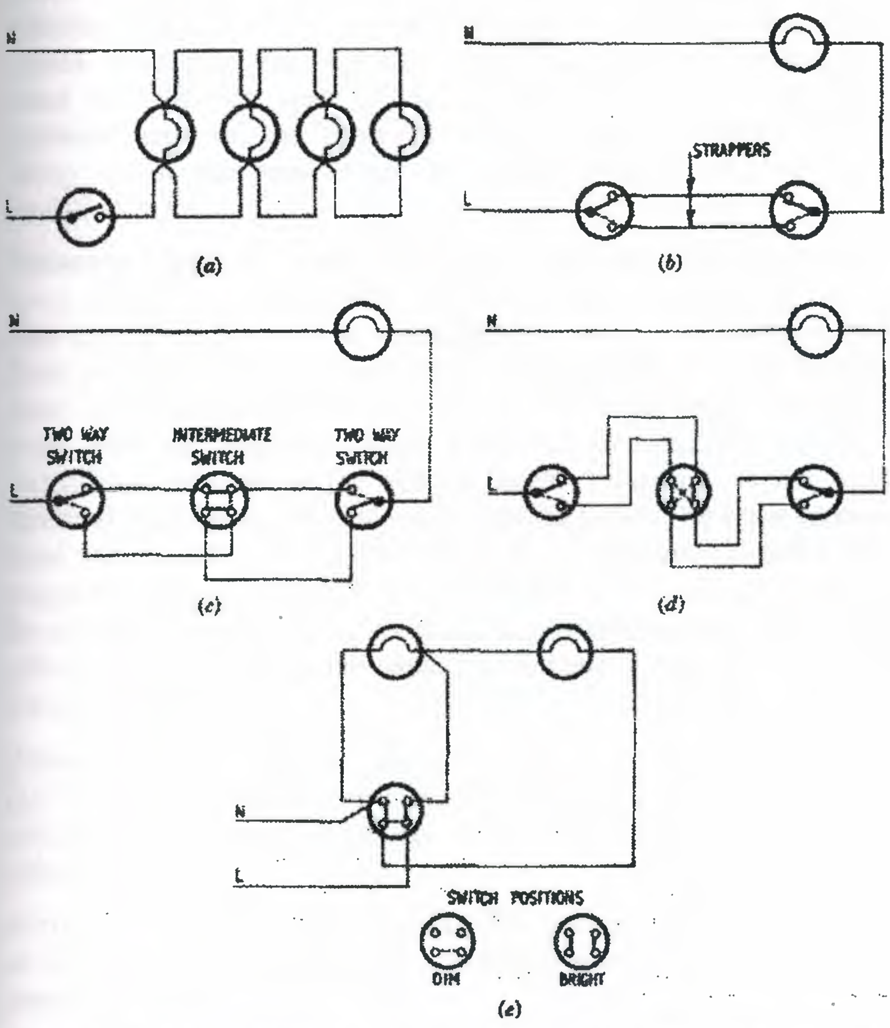


Fig. 2.8 Lighting circuits. (a) One–way switching : one switch serving lights. The conductors are lopped between the lambs. (b) The two-way switching circuit.Used for stairs and corridors. (c) The two-way switch used with an intermediate switch for long corridors in hospitals, schools, etc. (d) Another type of intermediate switching. The internal connections in the switch determine the circuit used. (e) Dim-bright switching. The lamps are connected in series for dim operation and in parallel for bright.

2.5 DIVERSITY FACTOR

The diversity factor in an installation can be calculated as follows:

$$\text{Diversity factor} = \frac{\text{Actual connected load}}{\text{Total Load}} \times 100 \text{ (per cent)}$$

The diversity factor vanes for different types or installations, for example; the diversity factor suggested in the I.E.E. Regulations for the lighting circuits of a block of residential flats is 50 per cent. This means that the cables supplying the lighting load *(not* the final sub-circuits) need only be rated for 50 per cent of the full-load current. This decrease In the cross-sectional area of the cable Is allowed because the likelihood of all the lights being on at the same time is remote, although any one final sub-circuit may be fully loaded.

Domestic Lighting: Domestic lighting circuits are usually wired in I mm- twin t.r.s. or p,v,c. (twin *1-5 (mm^2)* may also be used). The protecting fuse is generally *5* A (20 mm tinned copper wire or cartridge fuse with white body). Conductors in a lighting final sub-circuit (or any final sub-circuit) should never be interconnected with other final sub-circuits. For example, a final sub-circuit neutral should never be used to teed more than one final sub-circuit. Each neutral conductor should be connected to its individual terminal at the neutral block: 'bunching[5] is not permitted. An earthing terminal must be provided at every lighting point. The earth continuity conductor of the final sub-circuit must be connected to this terminal, metallic switches must also be supplied with an. earthing to which the final sub-circuit earth continuity conductor must be connected. The earthing terminal is not required where earthed metal boxes are used which have a fixing for the metal switch plate giving reliable electrical contact between the plate and the metal box.

Fittings: Light switches are usually of the 5 A (a.c.) quick-make-slow-break (Q.M.S.B.) type, flush mounting. Switches used in fluorescent lamp circuits must be capable of carrying twice the normal circuit current in order to withstand the Inductive effect of the choke.

NOTE. An incombustible material, for example, a hard wood block, must be placed at the back of surface-mounted accessories where these are fitted to soft wood or other combustible material.

***Ceiling Roses**:* There are two main types of ceiling rose: *(a)* the three-plate pattern and *(b)* the two-plate pattern.

The three-plate ceiling rose is used to economize in wire and minimize the number of joint boxes used in the installation.A joint must be made as indicated or three wires run to the first switch. All joints must in joint boxes.

NOTE: Ceiling roses must not be used on circuits operating above 250 V and no more than one flexible cord is permitted from any one ceiling rose. The earthing terminal of every ceiling rose must be connected to the earth continuity conductor of the final sub-circuit

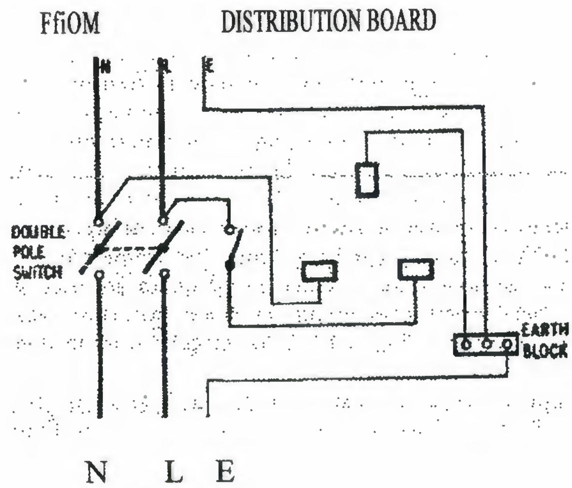


Fig. 2.9. Cooker control unit.

Water Heaters:

Domestic water heaters are generally rated at 3kW and are usually supplied from ring circuit. Asbestos-covered cable should be used to terminate the conductors at the immersion heater since p.v.c. and t.rs cables are normally expected to be used where the surrounding temperature (the ambient temperature) does not exceed 30'C. The temperature age of water heaters is between 43 'C and 82 'C. The thermostat, in common with all other switching devices, must always fitted in the phase conductor.

Bathroom : All lamp holders must be of the Home Office (skirted) type and lamps should be totally enclosed. Only circular flexible cable should be used where necessary and the switch must be of the pull-cord type. No portable appliances should be fitted or used in the bathroom and fixed appliances for example, wall fires, must be placed out of reach of persons in the bath.

Garages:Socket outlets in garages must be placed at a safe distance from floor level.All portable appliances, particularly handlamps, must be earthed and handlamps should be fitted with an earthed shield.

Cooker Control unit: This generally consists of a double-pole switch feeding the cooker and an independent 13A socket outlet. It is essential that the earth continuity conductor supplying the unit should he effectively connected.

The cooker control unit is generally supplied from a separate way in the consumer's control unit and wired with 10 mm^2 twin and earth p.v.c . or t.r.s. cable. It is fused at 30 A which is sufficient to protect a maximum of 9 kW {3-plate cooker). The current demand from a stationary cooking appliance is calculated as follows: 10 A + 30 per cent of the total remaining full load current. Every stationary cooking appliance in domestic premises must have an adjacent control switch fitted within 2 m of the appliance.

*NOTE:*No Diversity factor is allowed with a final sub-circuit supplying a cooker as it is possible that all elements will be in use when the cooker is being fully utilized.

Layout of a Domestic Circuit:The lighting circuits would be connected from two

junction boxes in the attic(one box for each circuit). The cable supplying the cooker would also be run in tha attic and the ring circuit would be run below the floor.Socket outlets are placed 30 cm above the floor level and light switches 1.5m above floor level.

2.6. SPECIAL INSTALLATIONS

Though the bulk of electrical installation work carried out in this country does not involve the consideration of special factors in the context of the wiring systems, accessories and the equipment 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. These sources include BS Codes of Practice and manufacturers' instructions, and IEE Regulations.

2.7. TEMPORARY INSTALLATIONS

A temporary installation is an installation with an expected period of service of three months.A temporary installation used beyond this period must be completely overhauled at three-monthly intervals.

It must be pointed out that the electrician in charge of temporary installation has a legal responsibility and ensure the safety of the installation; this includes its construction maintanance and extension. The particular danger in this type of installation is the work of the amateur electrician who overloads bayonet-cap lighting circuits beyond their 1kW maximum loading , often with unearthed metal fittings, and uses unsheated cable or unprotected cable. Conduit should not be used in the installation unless it complies with the relevant I.E.E Regulations .

Protection: The temporary installation must be protected with an adequate switch which isolates all the poles (including neutral) from the supply.The name of the person in charge and their position should be displayed near the main switch.

NOTE: The greatest care should be taken to protect the temporary installation against mechanical damage and portable appliances(for example drills) should be regularly checked.Low-voltage (e.g 110V) step-down transformers should be used wherever possible , to minimize the danger from shock.

2.8 DAMP SITUATION

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 (particularly from surface leakage over otherwise healthy insulation) and the risks, which attend a gradual deterioration of the metalwork of the installation as the result of corrosion.

The I.EE Regulations require that every cable installed in a 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. Conduit threads should be painted over with a bituminous paint immediately after erection Cables, which are armoured 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, 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 he 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 conduit 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 glanded into totally enclosed lighting fittings and run into the 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 temperatures below $0^{\circ}C$, PVC has a 'cold-shatter' characteristic and may crack if hit sharply. There is also a warning note regarding the use of cables with bituminous-compounded beddings or servings.

2.9 Corrosion

Wherever metal is used there is the attendant problem of corrosion. Two conditions are necessary for corrosion: a susceptible metal and a corrosive environment. Nearly all of the common metals in use today corrode under most natural conditions; the bulk of all anti-corrosive measures have thus been attempts either to isolate the metal from its environment, or to changing the environment chemically to render it less corrosive In installation work, the problems of corrosion tend to be more acute in certain types of installation. Chemical works, salt works, cow byres and other ammonia-affected areas, all require special consideration in their design and the work executed to produce the installation. Corrosion, in a normal installation condition, may affect earth connections.

The corrosion of metals in contact with soil or water is an electrochemical reaction; that is, the corrosion reaction involves both the chemical change (e.g., from iron to rust) and a flow of electric current. It is this principle, which is used in the dry cell, where the corrosion of the zinc case provides the cell's electrical output. The current flows from

the metal into the soil or water (called the electrolyte) at the anode and then from the electrolyte into the metal at the cathode. Corrosion occurs at the point where the current flows from tile metal into tile electrolyte. Every metal develops its own particular electrode potential when placed in an electrolyte or similar medium. If two different metals are coupled together in the same electrolyte, tile difference between their potentials will be sufficient to produce a current of electricity. The metal with the more negative potential will suffer corrosion. It follows that the more compatible the metals are, the less will be the rate of progress of any corrosive action which takes place between them, because the amount of potential difference between them is reduced.

In general there is a 'natural' potential of -0.3 to - 0.6 V between a buried mass of metal and its surrounding soil. This potential is measured by using a very-high-resistance voltmeter and a device called a half-cell, which consists of a copper rod immersed in saturated copper sulphate solution contained in a plastic tube which has a porous plug at the bottom for making contact with the soil as near as possible to the buried mass. Certain areas of the mass surface will act as anodes (where the current leaves the metal) and these will corrode. The areas, which act as cathodes (where the current enters the metal) do not corrode. This sub-division in the areas of the surface of the buried mass is due to the fact that the areas assume the roles of anodes and cathodes depending upon variations in the metal itself, its surface treatment, and the electrolyte.

Reducing the amount of current that flows from it into the surrounding medium or electrolyte can diminish the corrosion of a metal. Painting or otherwise coating the metal will increase the electrical resistance of both anodes and cathodes. But if the coating has flaws or holes in it, then the current concentrates at these points and deep pitting will occur. The corrosion current can also be reduced by lowering the electrical potential difference between the anodes and the cathodes either by controlling the purity of the electrolyte or by adding inhibitors to it.

Because only the anodes corrode, current flowing into them from an introduced external anode so as to cause the whole of the buried structure to become a cathode can prevent corrosion. This is the principle of cathodic protection. The method can be used only where the introduced anode can be accommodated within the electrolyte that surrounds the buried metal, and the soil or water must be present in bulk.

The method is widely employed as a corrosion preventive measure on underground metalwork. Two basic techniques are used to give cathodic protection: (i) the sacrificial anode system; (ii) the impressed current system.

In the first method , a mass of base metal, such as magnesium, is buried in the electrolyte and connected electrically to the structure to be protected. The natural difference in potential between the structure metal, usually steel, and the magnesium causes a current to flow from the magnesium (the new anode) through the electrolyte to the steel, which is the new cathode. The anode gradually corrodes and is thus called a 'sacrificial anode'. In practice a closely controlled magnesium-alloy is used. The main factors which govern the degree of protection, and the current output from the galvanic cell so formed by the protective system, are the surface area, volume and shape of the anodes used, the resistivity of the electrolyte and the surface area of the exposed metal being protected. The sacrificial anode system is common in congested areas since the low potentials generated by the galvanic system virtually eliminate the possibility of corrosion arising on adjacent metal structures on account of stray current. The system also needs no external electrical supply and is to a great extent self regulating in output, which latter will vary according to the resistivity of the surrounding medium (e.g., in

wet or dry weather conditions). The anodes need periodical renewal. In reasonable soil conditions, the life of an anode may be up to 15 years.

The second method of protection, the impressed-current system, uses a conventionally generated direct current from rotating machinery or via a transformer/rectifier unit. The negative side of the supply is connected to the structure to be protected; the positive side is fed to an 'anode ground-bed' usually formed from high-quality graphite impregnated by resin, wax or linseed oil, silicon iron or scrap iron or steel. The buried structure then becomes the cathode. The anode may, but need not, corrode. Silicon-iron and graphite anode ground-beds are semi-inert and have a very long life. Scrap iron or scrap steel beds go into solution quite rapidly and disintegrate at the rate of about 10 kg/Ampere/year.

The metalwork associated with electrical installations, which may require cathodic protection include supporting lattice structures, armoured cables with rotted servings, metal pipes containing cables, and general structural steelwork.

Another aspect of corrosion may not be too familiar to installation installers. This concerns the continuous exposure of PVC-insulated cables to temperatures above 115°C that may cause the formation of corrosive products, which can attack conductors and other metalwork. Generally, the precautions to prevent the occurrence of corrosion in normal installations include:

1. The prevention of contact between two dissimilar metals (e.g. copper and aluminium), particularly where dampness is likely to be present.

2. The protection of cables, wiring Systems and equipment against the corrosive action of water, oil, and dampness, unless they are designed to withstand these conditions.

3. The protection of metal sheaths of cables and metal-conduit fittings where they come into contact with lime, plaster, cement and certain hardwoods such as beech and oak.

4. The use of bituminous paints and PVC over sheathing on metallic surfaces liable to corrosion in service.

CHAPTER 3

3.0 CIRCUITS

3.1Lighting circuits

Most lighting circuits comprise several switching arrangements, such as one-way, two-way and intermediate. A typical domestic circuit is derived from a 5 A way in a consumer unit.In larger installations the rating of the circuit protective device can be either 15 A or 16 A. Domestic light- ing is largely based on the use of filament lamps, with fluorescent luminaires found in kitchen areas. Commercial installations are based on fluorescent lamps.

The simplest lighting circuit is a one-way, comprising one lamp controlled by a one-way switch; multi-lamp chandeliers are also controlled from the one-way switch. The two-way switching arrangement is used when a room has two points of entry and the luminaire is thus controlled from any one of two positions. The intermediate switching arrangement is used where one or more luminaires are required to be controlled from a number of switch positions, such as in long corridors or areas where there are a number of entry points.

One-way switches are rated at both 5 A and 15A. They must always be connected in the phase ('live") side of the supply. When being installed, ihe switches must be positioned so that when the rocker is in the 'down' position, the circuit is energised.Usually the word 'top' is marked on the reverse of the switch plate to ensure the correct mounting position.

The two-way switch has no OFF position. Rather the lamps are switched ON and OFF by the operation of one or other of the switches. Again, these switches are effectively 'single-pole' control devices and so must be connected to the phase side of the supply.

The intermediate switch has two positions and is effectively a change-over switch. It is connected between two two-way switches and so is able to change the direction of the current in the wires which connect the two-way switches together, known as 'strappers', 'strap wires' or 'pass wires'.

Switches are available as one-gang, or multi-gang, the latter being used to allow a number of individual luminaires to be controlled from one location.

In the provision of lighting circuits in a domestic-installation it is usual to split the lighting provision into two, with around ten lamps at the most on each circuit. Each lampholder is assessed at the current equivalent of 100 W. Thus ten lamps would take a total of just over 4 A. The reason for having two lighting circuits is to ensure that part of the house has some light should one circuit fail.

In commercial installations it is essential to ensure that the switches are either rated to carry inductive currents (e.g. 'ac rated') or else are derated to half their normal current rating. This is because fluorescent lamp circuits take more current than the simple rating of the lamp. To calculate the total current taken by fluorescent fittings the lamp wattage is multiplied by a factor of 1.8 and the product divided by the supply voltage:

$$I = \frac{\text{Total lamp watts X 1.8}}{voltage} \quad amps$$

Care should be taken that the correct size of conductor is used for lighting circuits, particularly to prevent excessive voltage drop. Every conductor has a certain value of resistance and when a current flows along it a voltage loss occurs *($V_{d=}$ I X R),* The longer the length of run from its supply point (consumer unit or distribution board) the greater will be the volt drop. If the drop is excessive the lamps (particularly filament lamps) will deliver a reduced light output. This tends to be more a problem in commercial installations than in domestic premises. Usually conductors of 1.5 mm^2 CSA will be found adequate for most circuits.

Most general lighting circuits are wired either using the loop-in' method or by using a joint box. The loop-in method requires a phase terminal in the ceiling rose (which must always be shrouded to prevent inadvertant contact or else a shock will he received). The other terminals in the rose are for the neutral conductor, the switch wire, and the two terminals to which the luminaire is connected. A final terminal (or terminals) is provided for the CPC which must be connected to both the earth terminal in the switch mounting box and the earth terminal in the luminaire accessory. Some lampholders only have two terminals and so the CPC must be terminated in a single block connector and not left loose. The loop-in method using a rose with a phase terminal allows the switches to be fed with two-core cable and also allows other lamps to be looped from the rose.

The joint-box method uses a box made from moulded plastic and can incorporate four terminals or else has a block-connector strip fitted by the electrician. From the box are taken the cables for feeding the switch and the lamp and it also allows other circuits to be taken from the same box.

Note that all CPCs contained in either two- or three-core cables must be sleeved with green/yellow sleeving when being terminated in ceiling roses, joint boxes, switches or lamp accessories.

If one-way switching is involved, the red core must be the switch feed conductor. The other core, coloured black, actually forms the switch wire and, to comply with the Wiring Regulations, must be identified as being on the live' side of the circuit and coloured red, yellow or blue depending on the phase from which the installation is being supplied. This identification of the switch wire is often ignored by practising electricians and while it is general practice it must be recognised that it does contravene the Regulations.

In commercial and industrial installations, the live may be derived from the red. yellow or blue phase and its colour should be consistent throughout the circuit.

In lighting circuits generally, 1 mm^2 cable is used with 5 A fuse because the authority says that in a lamb circuit you will put 10 lamp (100 W), this will be 1 kW=I=1kW/240=4.16 A. 5 A limit must not be passed that's why we use the fife Amp. If we want to put more than10 lamps in a circuit we have to change the cable size to 1.5 mm^2 with a 10 A fuse.

3.2 POWER CIRCUITS

Two types of circuits are used to feed socket-outlet units and fused connection units: radial and ring. The radial circuit is derived from a 20 A way in a distribution board or consumer unit and is intended to serve a floor area not exceeding 20 nf. If the floor area to be served is not more than 50 m^2 the rating of the protective device is 30 A or 32 A. Kitchens in domestic premises {where a large number of socket-outlets are often needed for electrical appliances) are often fed by radial circuits.

The ring circuit is derived from a 30 A or 32 A way and has its conductors terminated at its point of origin in the distribution board or consumer unit. An unlimited number of socket-outlets may be connected us the circuit provided that the floor area served does not exceed 100 m^2 in domestic installations. As most modern domestic premises have a floor area in excess of this figure, two ring circuits are usually provided (or one ring and one radial circuit for the kitchen). When more than one ring circuit is installed in the same premises, the socket-outlets should be reasonably shared between the circuits to balance the loading.

Spurs can be taken off a ring circuit. If they are of the non-fused type, [he number must not exceed the number of socket-outlets (and any stationary equipment) connected directly in the ring. Double or two-gang units are regarded as two separate outlets. Connection units can be either fused or switched and fused, with the latter being used for equipment which has no direct control switch. A fused connection unit can be used to feed devices which take very little current, such as a fan, a clock or a lamp.

When installing a ring circuit, the spurs can be fed from socket-outlets connected directly in the ring, from the origin of the circuit or from a joint box (with terminals rated for 30 A) connected in the ring and left for future extensions to a building (e.g. a conservatory or extra bedroom).

Three types of cable are recognised for use with ring and radial circuits: PVC-sheathed, MI cable and copper-clad aluminium, PVC-insulated. For ring circuits the respective csa involved are 2.5, 1.5 and 4 mm".

3.2.1. POWER CIRCUITS TYPES

1. Sockets

There are two types of sockets.

1.Radial Socket Circuit

2.Ring Socket Circuit

I-) Radial Socket Circuit:

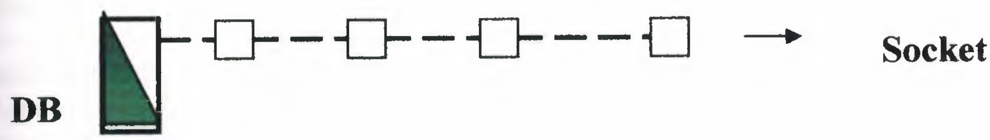
We have some standards.

1-) In a kitchen area two sockets can be put in radial socket circuit with 2.5 mm^2 conductor and 15 amps. fuse.

2-) In an area, which is not in kitchen and less, than 30 $m^{2,}$ 6 sockets can be put in radial circuit with 2.5 mm^2 conductors and 15 Amp. fuse.

3-) If the area is greater than 30 m^2, 6 sockets can be put in a radial socket cct. With 4 mm^2 conductor and 20 Amp. fused.

Figure 3.1. Radial socket circuit



II-) Ring Socket Circuit:

Ring means, you will start from one point and after you went to each point, you will come back to first point.

1-) Any number of socket can be put in a ring socket circuit if the area less than 100 m^2, if area is greater than 100 m^2 in any building. You have to another ring socket circuits.

2-) From any sockets in a ring sockets circuits you can put spur from each sockets.

3-) Only one stationary appliance can be put in a ring socket circuit either include in the ring or taken as a spur. (Washing machine, dish washer, bathroom heater or heater, and water pump)

NOTE: If these are connected to the ring socket circuit as a spur or with any heater switch. The heater switch has to be fused.

For other power circuits cable sizes and value of fuse.

Figure 3.2. Ring socket circuit

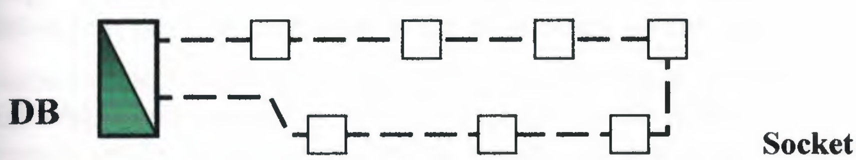


Figure 3.3 Ring socket circuit with spur socket

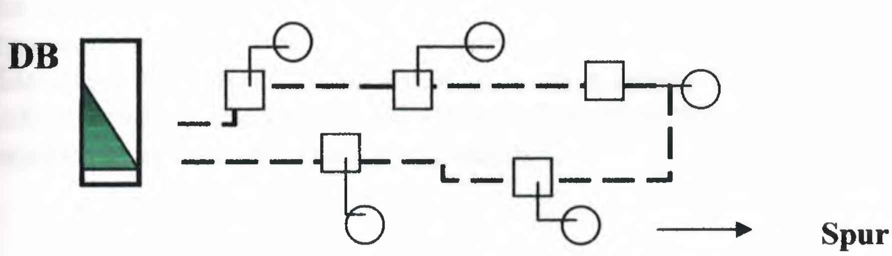


Table 3.1. Circuits cable thickness and fuses			
Circuit	L+N	Earth	Fuses
Cooker Control	6 mm^2	2.5 mm^2	30 A
Heater	2.5 mm^2	1 mm^2	15 A
Dish Washer	2.5 mm^2	1 mm^2	15 A
Washing machine	2.5 mm^2	1 mm^2	15 A
Jacuzzi	2.5 mm^2	1 mm^2	5 A
Instant Heater	4 mm^2	2.5 mm^2	30 A
Air Conditioner	2.5-4 mm^2	1-2.5 mm^2	15-30 A

Regulations summary

Socket-outlets (except for shaver units) are not permitted in bathrooms. Fixed appliances fed from connection units must have an appropriate provision in the unit (either fused or switched and fused). Appliances connected to fused connection units must have a rating of 3 kW maximum. A two-gang socket-outlet unit is regarded as two separate units. Any socket-outlet used for supplying electrical equipment intended for outdoor use must incorporate a residual current device (RCD) with a trip current of 30 mA; the socket-outlet must be next to a warning label reading "For equipment outdoors'. In industrial or commercial premises, adjacent socket-outlets must be connected to the same phase of the supply.

All socket-outlets must be protected by a device (fuse or miniature circuit-breaker, MCB) which will operate within 0.4 second should a fault occur. The cable sizes recommended for both ring and radial circuits assume normal ambient temperatures and that the conductors are not bunched. Higher operating temperatures, bunching, contact with thermal insulation material and the use of a semi-enclosed fuse (BS 3036) may mean an increase in the csa of the conductors.

3.3 Cooker Circuits

These are derived from (usually) a 30 A or 32 A way, but can be higher depending on the kW rating of the cooker. The control units need not have a socket-outlet incorporated in them, but if one is provided the protective device must be able to. disconnect the circuit in the event of a fault within 0.4 second (it would be 5 seconds otherwise). The control unit must be located within 2 m of the appliance (this also applies to 'split-level' cooking appliances).

3.4 Water -Heater Circuits

Generally derived from a 15 A or 16 A way, the circuit must incorporate a double-pole switch (usually of 20 A rating), with an additional switch recommended in close proximity to the immerser unit which should be connected by using heat- resisting flexible cable or cord.

Voltage drop in Circuits

If any conductor carries a current there will be a loss of voltage between both ends of the conductor. This loss or 'volt drop' is $V=IxR$, where V is the volt drop,I is the current in the conductor and R *is* the conductor resistance. The effect of serious volt drop is to reduce the effective performance of lamps, heaters and other electrical devices. To limit volt drop in any circuit, the IEE Regulations impose a maximum drop of 4 per cent of the nominal circuit voltage. Thus, on a 240 V supply, the drop between the consumer's terminals and the farthest end of any circuit in the installation is 9.6 V. It is the concern of the installation designer, and often the electrician, 10 choose a size of circuit conductor for a particular load so that this figure is not exceeded. The Current-rating Tables in the Regulations indicate the volt drop (in millivolts [mV|) when a current of 1 A flows through a 1 metre length of a particular cable. This rnV figure is then multiplied by the actual load current in the cable and also by the length of cable run, to arrive at the total volt drop. If, for a particular size of cable, the total volt drop exceeds 9.6 V (for a 240 V supply), the next size of cable is chosen in turn until the final volt drop is less than 9.6 V. Other factors are, however, required to be taken into account when choosing the initial size of cable, such as the cable's ambient temperature, the cable's installation condition (e.g. bunched with other cables), the circuit protection (e.g. semi-enclosed fuse or MCB), and whether the cable is in contact with thermal insulation material. The IEE Regulations require that the choice of a cable to feed a particular circuit must have regard for a number of factors, and not just the circuit current.

The Regulations require that the method used to choose the correct size of a conductor be based on the rating of the protective overcurrent device. Al! factors which affect the rating of the cable in its installed condition are applied as divisors to the rating of the protective device, as the following examples show. The process involved in working out the correct cable size, and the final volt drop, is as follows:

1.First find the load current of the circuit (I_B).

2.Determine the correction factor for the ambient temperature in which the cable

is to be installed (the highest temperature is always taken).

3.Determine the correction factor for grouping C_a, if the cable is run with others.

4.Determine the correction factor *C*-, if the cable is in contact with, or surrounded by, thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material (e.g. cable clipped to a joist) and 0.5 if the material completely surrounds the cable.

5.Select the rating of the ovcrcurrent device. If this offers what used to be called "close protection', e.g. by an MCB, the factor is 1.0. If, however, the device is a semi-enclosed fuse, the factor is reduced to 0.725. In any case, the rating of the device must equal the circuit load current.

6.Determine the size of the circuit conductor , by calculating desired current rating.

7.Check that the volt drop does not exceed the maximum permissible allowed.

$$I_z = \frac{I_n}{C_g X C_a X C_I X 0.725}$$

where $C\ g$ is the correction factor for grouping. C, is the factor for ambient temperature, C, is the factor for the thermal insulation, if applicable, and 0.725 is the factor for the overcurrent protective device, if applicable.

3.5 FINAL CIRCUITS

A final circuit is defined as "A circuit connected directly to current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such 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 hoard. They also require that the wiring of each final circuit shall be electrically separate from that of 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" 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 No. 27 of the Electricity Supply-Regulations: 'All conductors and apparatus must he 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.

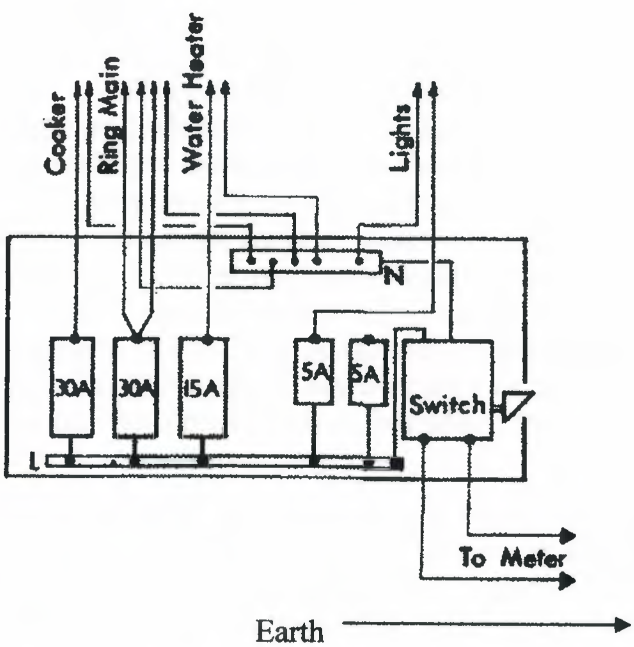
An industrial installation may have all five types; a domestic installation may have only 1, 2 and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at any early stage in the design of an installation.

Before indicating the factors which are involved in the choice of final circuit types, a few brief notes on planning aspects will he relevant.

Installation planning

(a) Domestic installations seem to be the simplest to plan, but there are a number of points which are worth 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 for 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 inter- mediate switching; and a large house should have two or more lighting circuits. A note in an older edition of the IEE Regulations is still relevant: 'In the interests of good planning it is undesirable that the whole of the fixed lighting of an installation should be supplied from one final subcircuit.' The reason for this is not far to seek. If an installation has two lighting circuits and one circuit fails, the house is not plunged into darkness. It is often a good point to consider a slight 'overlap' of Sighting 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 this 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 a purely functional basis. In living rooms and bedrooms, wall-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 over-looked, 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 1363 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switched 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.

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 a single socket-outlet should be provided at each side of a bed; two-gang units can be used to good advantage {e.g. to supply a bedside lamp and an electric blanket). 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 surfaces and two-gang units are recommended.

In the dining 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 fixed 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 (of the enclosed- element type) or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

(b) 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 buildings 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 lighting, wall points, etc. The service lighting is that associated with lifts, corridors, stairs, landings and is usually the responsibility of the landlord. Where a tenant's specific lighting requirements are not known when the building is being erected, the lighting outlets are laid out on a 'grid' system, in which the outlet points are sited at regular intervals usually related to the module of the building (mat is, the basic size, multiples of which are used in the construction of the building). Generally, about 3 m are allowed between outlets. Outlets may be left on the ceiling for 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 (e.g. an office may go over to all-electric typewriters or install a computer or data-processing system), it is often difficult to extend or alter an inflexible installation. Thus, the electrical services provisions should allow for 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.

(c) Industrial premises require lighting installations which cater for the intensity of lighting required for the process to be carried out. In addition, local lighting at reduced voltages is 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.

(d)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.

Circuits rated under 16A

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 (e.g. clocks, bell transformers, electric shaver supply units), provided that their rating is not greater than 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 he taken Into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favourable circuit conditions, but to provide for 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.

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 l0A of [he 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 (46A) would 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 the 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.

Circuits rated for 13A socket-outlets

Final circuits which supply 13A socket-outlets with fused plugs and i3A fused (switched or unswitched) connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maxi- mum floor area of 100 nr derived from a 30A

protective device. Radial circuits serving a maximum area of 50 nr are also protected by a 30A device, while if the area served is no more than 20 m^2 a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

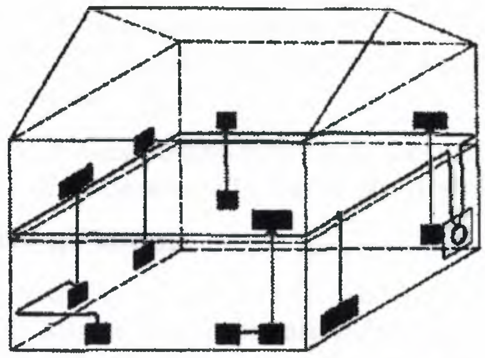


Fig 3.4. typical ring-circuit serving two floors.

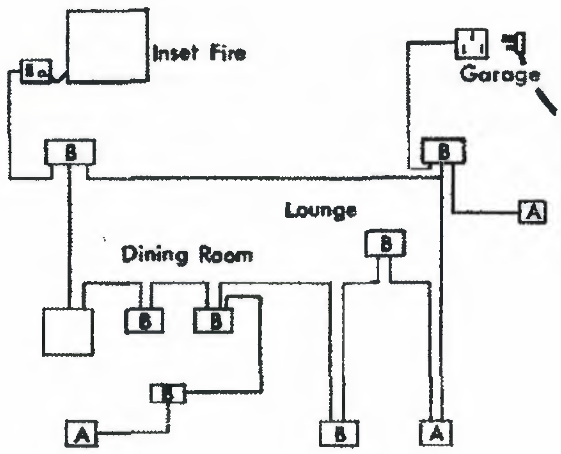


Fig.3.5 Typical ring circuit with spurs to outlying points

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 a circuit-breaker.

It is important to realise that the conductor sixes recommended for ring circuits arc 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 he run in the form of a ring, having both ends connected to earth at the distribution hoard for its equivalent).

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.

Circuits feeding discharge lamps

One of the main requirements is a consideration of the 'rating' of a discharge lamp outlet, for it has a rather different interpretation from that used for other lighting points. The reason for this is that, owing to the losses in the lamp control gear plus the low power factor (about 0.9), it is necessary to multiply the rated lamp watts by 1.8 and divide by the lamp rated voltage to obtain the actual current flowing in the circuit. It should be noted that certain switches may not be suitable for controlling the highly inductive circuits associated with discharge Sighting. If a switch is not specifically designed to break an inductive load (quick-make, slow-break), it should have a current rating of not less than twice the total steady current which it is required to carry.

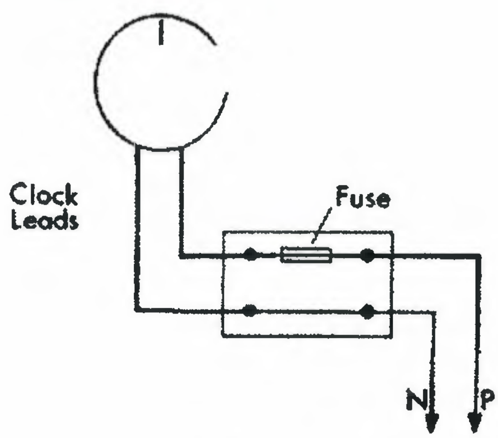


Fig.3.7 electric clock circuit

Circuits feeding motors

Final circuits which supply motors require careful consideration. In particular, cables which carry the starting, accelerating and load currents of a motor must be rated at least to the fail-load current rating of the motor. If, however, the motor is subjected to frequent starting and stopping, the csa of the cables should be increased to cater for the consequent increase in conductor temperature. More than one motor may be connected to a 16A final circuit, provided that the aggregate full-load rating of the motors does not exceed 16A. If a motor lakes more than 16A full-load current, it should be fed from its own final circuit.

Final-Circuit Protection

Protection of final circuits is by means of fuses, circuit-breakers or miniature circuit-breakers located at switchboards and distribution boards. The protection is for over-currents caused by short- circuits between conductors, between conductors and earth, or overloads. The protective gear should be capable of interrupting any short-circuit current that may occur without danger of fire risk and damage to the associated equipment. In large installations, where there are main circuits, sub-mains and final circuits, it is often necessary to introduce a discriminative factor in the provision of protective gear. Where circuit-breakers are used, discrimination is provided by setting sub-circuit-breakers to operate at a lower over-current value and a shorter time-lag than the main circuit- breaker. Thus, if a fault occurs on a final circuit, the associated gear will come into operation, while the main breaker remains closed. However, if the fault persists, or the sub-circuit-breaker fails to operate within its specified time (e.g. 2 seconds), the main breaker will trip out (e.g. 0.5 second later).

Fuses are often used for back-up protection of circuit-breakers. Generally, where cartridge fuses are used the fuse will operate before the circuit-breaker, particularly in the event of a short-circuit current. Where small over-currents occur (e.g. overload) the circuit-breaker is likely to operate before the fuse blows.

Where full use is made of cartridge fuses, their ratings, type and make should be consistent for each circuit protected. The rating of sub-circuit and main fuses should be chosen so that in the event of faults the sub-circuit fuses blow first. Generally, discrimination between the fuses can be obtained if the rating of the sub-circuit fuses does not exceed 50 per cent of the rating of an associated main fuse. If this margin is too large, reference should be made to the data provided by the fuse makers.

Discrimination is very difficult to obtain with any degree of accuracy where cartridge fuses and semi-enclosed rewirable fuses are used together because of the many factors which are involved in the operation of the latter type of fuse. These include the type of element, its size, the ambient temperature, its age and its material.

Choosing cable sizes

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 (grouping). There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when overcurrents 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 situations produces an environment which can quickly lead to the deterioration of the cable insulation (particularly when PVC is involved) and lead to a becomes very soft, so that a conductor can 'migrate" or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, with 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 dependent on the ability of the over-current protection device to operate to disconnect the circuit from its supply. As is probably realised, 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 a 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 recognise the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. The regulations list 20 standard methods of installation (Table 4A of Appendix 4), each of which is identified by "Methods'. These classifications are used in the tables which give the current-carrying capacities of cables. The installation conditions include "enclosed" (e.g. in conduit trunking and ducts); 'open and clipped direct' (e.g. clipped to a wall, to a cable tray, embedded direct in plaster which is not thermally-insulating, and suspended from a catenary wire); 'defined conditions', which include 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 a particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

(a) the ambient temperature in which the cable is installed;

(b) the installation condition, e.g. whether grouped or bunched with other current-carrying cables, enclosed or installed 'open';

(c) whether the cable is surrounded by or in contact with thermal insulating material;

(d) whether the circuit is protected by semi- enclosed (rewirable) fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by the IEE Regulations, is based on the rating of the overcurrent protective device. Ail factors affecting the cable in its installed condition are applied as divisors to the rating of the device, as the following examples show. The requirement of Regulation 525-01-02 must also be considered. In general, the size of every hare conductor or cable conductor shall be such that the 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. Values of volt drop per ampere per meter are given in the current rating tables in Appendix 4 of the Regulations, In this context, it should be noted that conductors of large cross-sectional area have different volt drops per ampere per meter for ac circuits than those operating from dc supplies. This is because of the reactance inherent in conductors carrying ac.

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

1. First find the load current of the circuit (I_B),

2. Determine the correction factor for the ambient temperature which 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 for grouping. Here we refer to Table 4B1 of the Regulations

4.Determine the correction factor if the cable İs in contact with or is surrounded by thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material {e.g. a cable clipped to the side of a joist) and 0.5 if the cable is completely surrounded by the material.

5. Select the rating of the overcurrent 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 in Tables 9D1A to 4L4A in

7. Check that the volt drop does not exceed the maximum permissible allowed by Regulation 525-01-02.

If I_z represents the current rating of the conductor and I_n the rating of the protective device, then

$$I_z = \frac{I_n}{C_g X C_a X C_I X C_f} \quad amperes$$

where C_g is the factor for grouping;

C_a is the factor for ambient temperature;

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

C_f is the factor for the overcurrent device. This factor is 1 for ail devices except semi-enclosed fuses, when the factor is 0.725.

CHAPTER 4

4.0 CONDUCTORS AND CABLES

4.1 Definition of conductors

A conductor is a material which offers a low resistance to a flow of current. Conductors for everyday use must be (a) of low electrical resistance, (b) mechanically strong and flexible, and *(c)* relatively cheap. For example, silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are tin, lead, and iron.

Formation of conductors

Electrical conductors are usually made of copper, although aluminium is being used to a greater extent, particularly as the price of copper increases. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. The copper wire is then dipped into a tank containing molten tin. This is done for two reasons: *(a) to* protect the copper if the wire is to be insulated with vulcanized rubber, as this contains sulphür which attacks the copper; and *(b)* to make the copper conductor easier to solder. Aluminium wire is also drawn from a solid block but is not tinned.

Aluminium

1.Smaller weight for similar resistance and current-carry ing capacity

2.Easier to machine

3.Greater current density because larger heat-radiating surface

4.Resisiivity 2-845 μΩ-cm

5.Temperature coefficient practically similar (0-004 Ω/Ω degC)

Copper

1.Better electrical and thermal conductor, therefore lower C.S-A, required for same voltagedrop
2.Greater mechanical strength

3.Corrosion resistant

4.High scrap value

5.Much easier to joint

6.Lower resistivity: l-78μΩ-cm

The determining factor in the use of one type of metal for conductors is usually that of cost. The future trend in costs will be for the price of aluminium to drop relative to that of copper, as the underdeveloped countries achieve the industrial capacity necessary to work their bauxite (aluminium ore) deposits.

Stranding of Conductors. Conductors were often stranded to make the completed cable more flexible. A set number of strands are used in cables: 1, 3, 7, *19,* 37, 61, 91, and 127. Each layer of strands is spiralled on to the cable in an opposite direction to the previous layer. This system increases the flexibility of the completed cable and also minimizes the danger of 'bird caging', or the opening-up of the strands under a bending or twisting force.

Size of Stranded Conductors. The size of a stranded conductor is given by the number of strands and the diameter of the individual strands. For example. & 7/0-85 mm cable consists of seven strands of wire, each strand having a diameter *(not* cross sectional area) of 0-85 mm. Solid (non- stranded) conductors are now being used in new installations.

Bare Conductors. Copper and aluminium conductors are also formed into a variety of sections, for example, rectangular and circular sections, for bare conductor systems. *Applications,* Extra-low voltage electroplating and sub-station work.

The following precautions must be taken with open bus-bar systems (above extra-low voltage). They must be: *(a)* inaccessible to unauthorized persons, *(b)* free to expand and contract, and *(c)* effectively insulated. Where bare conductors are used in extra-low voltage systems they must be protected against the risk of fire.

4.2 INSULATORS

An insulator is a material which offers a very high resistance to a flow of current. An insulator should have certain electrical, mechanical, physical, and chemical properties.

Electrical Properties: It must have high resistance.

Mechanical Properties: It must be capable of withstanding mechanical stresses, for example, compression.

Physical Properties. The perfect insulator would have the following physical properties: (a) non-absorbent; (&) capable of withstanding high temperatures.

Chemical Properties. An insulator must be capable of withstanding the corrosive effects of chemicals.

No insulator is perfect and each type is picked for a particular application. For example, porcelain and fireclay are relatively good insulators, but could not be used for covering conductors forming a cable because they are not flexible. P.V.C. is also a good insulator, but cannot be used in conditions where the temperature exceeds 45 °C—for example, insulation for electric fires. Other examples of insulators are mica, wood, and paper.

4.3 CABLES

Definition of Cables

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor(solid or stranded), or of two or more such conductors,, each provided with its own insulation, which are laid up together. The insulated conductor or conductors mat or may not be provided with an overall covering for mechanical protection.'' A cable consist of two basic parts:(*a*) the conductor;(*b*) the insulator.

4.3.1 Construction of cables

A cable usually derives its name from the type of insulation used Polyvinyl Chloride (P.V.C.,} Cable. This is termed a 'thermo plastic' cable as the insulation is formed from a synthetic resin which softens when heated. The process of manufacture is as follows:

1.The p.v.c, is extruded on. to the conductors by passing them through & die into which soft p.v.c. is forced.

2.The formed cable is then passed through a trough of cold water t harden the plastic insulation.

Multi-core Cable: This is cable which is made up of two or more insu lated conductors. Multi-core cable is sheathed in a protective covering— for example, tough rubber for tough rubber-sheated cables (_t.r,s.) and p.v.c, for plastic cables.

Tough-Rubber-Sheated (t.r.s) Cable: This is made of specially toughened rubber which is resistant to acids and alkalies. Specially" constructed t.r.s., which has been reinforced with tape and an external braiding; is used to farmyards.

Polychloroprene (p.c.p or neoprene) Cable: An insulation somewhat similar to that of t.r.s but capable of withstanding most weather conditions and particularly direct sunlight.

Heat-resisting, Oil-resisting and Flame-retardant (h.o.f.r) Cables:

These cables are used in conditions damaging to P.V.C. cables such as high temperature and oil. The resistant qualities are developed by a vulcanizing (or curing) process which forms an elastomer capable of withstanding tough conditions and still retaining its flexibility. The following are examples of cables using elastomer material: c.s.p, chlorosulphonated polythene), butyl rubber, silicon rubber, ethylene propylene rubber (e.p.r,).

The maximum operating temparature for both rubber and p.v.c. insulated cables is 45 degrees.

4.3.2 Flexible Cables and Flexible Cords

The I.EE Regulations define a flexible cable as: " A cable consisting of cores, each containing a group of wires, the diameters of the the construction of the cable being such as to afford flexibility'' A flexible cord is defined as; 'A flexible cable in which the cross-sectional of each conductor does not exceed $4mm^2$".

Twisted Twin Flex Cable: This is made up of a multi-strand tinned-copper conductor with silicon rubber insulation. *Application:* lighting flex.

Circular Flex: The rubber-insulated cores are formed into a circular section to cotton worming and contained in a cotton, braiding. *Applications :* connections to household appliances (irons, kettles, etc.).

Circular Flex Rubber Sheathed: This flex is also packed with jute or cotton to form a circular cross-section but an outer sheath of rubber replaces the cotton braiding. *Applications:* vacuum cleaner and portable drill leads (3-core).

Workshop or (industrial) Flex (Fig 2.3): This flex is similar in construction to the above , but has the addition of a compounded braiding. *Application*: connections to industrial lighting.

4.3.3. Outdoor Cable

The I.E.EE Regulations underline the need for adequate mechanical protection when cables are used outdoors and the importance of having sufficient support to avoid mechanical strain. They also supply tables showing the necessary spacing for supports and the minimum allowable radius for bends.

F

Fig. 4.1 House service over-head system(H.S.O.S) cable

H.S.O.S. (House Service Overhead System) Cable (Fig. 4.1): H.S.O.S. cable is constructed as follows: *(a)* hard-drawn copper conductor, *(b)* rubber insulation, *(c)* varnished tape, and *(d)* outer coating of compounding braiding. *Application:* house-to-house overhead supplies.

NOTE :p.v.c insulated copper and aliminium cables are gradually replacing this cable, except in conditions where creosote is present, at this attacks the p.v.c insulation.

4.3.4. Cable Sizes: Use of I.E.E. Tables

The I.E.E. Regulations contain comprehensive information regarding the curret carrying capacity of cables under certain conditions.

These tables supply: *(a)* cross-sectional area, number$_s$ and diameter of conductors; (b) type of insulation; *(c)* length, of run for IV drop; *(d)* current rating (a.c. and d.c.), single and bunched. The following terms are used in the I.E.E. tables:*(a)*ambient temperature and (b} rating factor.

Ambient Temperature: This is the temperature of the air surrounding the conductor. The current rating of a cable is decreased as the temperature of the surrounding air increases, and this changed current-carrying capacity can be calculated by using the relevant rating factor.

Rating Factor: This is a number, without units, which is multiplied with the current to find the new current-carrying capacity as the operating conditions of the cable change. For example, a twin-core 10 mm^s (7/1.35 mm) p.v.c cable will carry a maximum current of 40A at an ambient temperature of 25‘C , but if the ambient temperature is increased to 65’C the maximum current allowed will now be:

40A X 0.44 (rating factor) =17.6 A

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carrying capacity will decrease: a rating factor is therefore supplied for the bunching , or grouping of cables.

Permissible Voltage Drop in Cable: Voltage drop is another essential feature in calculation of cable size, as it is useless installing a cable which is capable of supplying the required current if the voltage at the consumers equipment is too low. Low voltage at the consumer's equipment leads to the Inefficient operation of lighting, power equipment,, and heating appliances. The maximum voltage drop allowed between the consumer's terminals and any point In the installation is 2-5 per cent of the voltage supplied by the Electricity Board, including motor circuits.

Voltage Drop and the I.E.E. Tables: The I.E.E. tables state the voltage- drop across a section of cable when maximum current Is flowing through it. If the current is halved, the voltage drop will also be halved. For example, a 4 mm^2 twin-core cable has a

current rating of 24 A and a voltage drop of 10 mV per ampere per meter. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per ampere per meter.

New Voltage Bands: Extra-low voltage (Band I) now covers voltages not exceeding 50 V a.c. or 100 V d.c. (measured between conductors or to earth). The new low voltage range (Band II) is from extra-low voltage to 1000 V a.c. or 1500 V d.c., measured between conductors, or 600 V a.c. and 900 V d.c. between conductors and earth.

Current Density and Cable Size: The current density of a conductor Is the amount of current which, the conductor can safely carry without undue heating per unit cross-sectional area. For example, If a copper conductor has a current density of 300 A/cm^2 a copper conductor of cross-sectional area 0-5 cm^2 will be capable of carrying one half of 300 A, that is, 150 A.

To calculate the current-carrying capacity of a cable (given cross-sectional area (cm^2) and current density (A/cm^2)):

Current-carrying capacity = current density X cross-sectional area

4.3.5 Resistance of a Conductor

The resistance which a conductor offers to a flow of current is determined by three factors: (a) the length of the conductor ,(b) its cross-sectional area, and (c) type of material used.

Length: If the length of a conductor is doubled , for example, from 100m to 200m , the resistance of that conductor will also double.

Resistance R (in ohms) is *directly* proportional to length l

Cross-sectional Area: If the cross-sectional area a of a conductor is doubled , for example, from 0.1 cm^2 to 0.2 cm^2 ,the resistance of that conductor will be halved.

Resistance R (Ω) is inversely *proportional* to cross-sectional area a

Resistivity (Specific Resistance) : This is the factor which takes into consideration the type of material used. The resistivity of a material is the resistance of a unit cube of that material$_s$ measured across opposite faces of e, If the resistivity of copper is given as 1.7μΩ-cm· Then the resistance measured across opposite faces of a centimetre cube of copper will be 1.7μΩ This may also be written $1.7\times10^{-6}\Omega$-cm or 1-7 microhm-centimetre (uΩ-cm). (1uΩ is one millionth of an ohm.) The symbol of resistivity is ρ (Greek letter rho).

$$R = \frac{\rho l}{a}$$

Where R is resistance (Ω), ρ=resistivity, l=length , and a = cross-sectional area.

*NOTE:*Since resistivity is usually given in ohm-centimeters or microohmcentimeters, the length of the conductor must be changed to centimeters.

NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ELECTRICAL INSTALLATION

Graduation Project
EE- 400

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CONTENTS

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ABSTRACT

While human is living, electrical installation is important study. Design and make the installation is to be secure. The basics of genaration, transmmission and distribution are given.Installatıon work is considered. Circuits types is also investigated for insttallation works. Shortly insulators, conductors are given. Also what kind of cable can use for installation their types are investigated. Illumination for a building are consired. Earthing subject is given.

Protection and protection method are trying to be given. Building services are investigated what the necessay for a buildings. Some symbols which are used in the project are given. Cost calculations are considered and how much an enginner takes money is trying to be given.

INTRODUCTION

First important part is drawing in electrical installation project. It has to be carefully designed because it will use in the life. It is not just theoritical. So all the neccasary parts are told in this project.

Firstly electrical generation are considered. When dealing with high voltage everybody has to be carefull.and then in the same chapter distribution and transmission of this voltage is considered. Calculation of the voltage drops has to be good. In the second chapter installation works given. It started firstly historical review of installation and wiring.

In the third chapter circuits are investigated which is necessary for electrical installation. Circuits are very important also if it is not to be good designed, big faults can occur. After that chapter what matterials are using in the electrical installation are given. Insulator, conductor and cables what kind of cable we are using in the electrical installation are important. Choosing cable size has to be economical.In the I.E.E Regulations book gives the tables using in the electrical installation work.

In the sixth chapter, illumination subject are trying to be given and then again to be essential part of insttallation work is earthing are given. It is essential because all the safety for this job is dependent that. Protection and protection methods are investigated and then in the appendix part it showed to us, using some symbols in the electrical installation work and also cost calculations.

The conclusion presents the significant results of that project.

CHAPTER 1

1.1 GENERATION AND TRANSMISSION

The generation of electric is to convert the mechanical energy into the electrical energy. Mechanical energy means that motors which makes the turbine turn.

Electrical energy must be at definite value. And also frequency must be 50Hz or at other countries 60Hz. The voltage which is generated (the output of the generator) is 11KV. After the station the lines which transfer the generated voltage to the costumers at expected value. These can be done in some rules. If the voltage transfers as it is generated up to costumers. There will be voltage drop and looses. So voltage is stepped up. When the voltage is stepped up, current will decrease. That is why the voltage is increased. This is done as it is depending on ohm's law. Actually these mean low current. Used cables will become thin. This will be economic and it will be easy to install transmission lines. If we cannot do this, we will have to use thicker cable.

To transfer the generated voltage these steps will be done. Generated voltage (11KV) is applied to the step-up transformer to have 66KV. This voltage is carried up to a sub-station. In this sub-station the voltage will be stepped-down again to 11KV. At the end the voltage stepped-down to 415V that is used by costumers. As a result the value of the voltage has to be at definite value. These;

a-) line to line – 415V

b-) line to neutral – 240V

c-) line to earth – 240V

d-) earth to neutral – 0V

1.2 DISTRIBUTION AND CONTROL

There are three main sets of regulations to which the electrician must conform in order that an installation shall be safe from excess current, shock, fire, corrosion, mechanical damage, and leakage. These are as follows:

1.Electricity (Factories Act) Special Regulations, 1908 and 1944:

These regulations cover 'the generation , transformation, distribution and use of electrical energy' in factories and workshops. An explanatory leaflet ,*Memorandum by the Senior Electrical Inspector of Factories on the Electricity Regulations*, is issued by H.M. Stationery Office to explain the workkings of these regulations.

2.The Electricity Supply Regulations(1937):

The purpose of the Electricity Supply Regulations is to secure " the safety of the public and for ensuring a proper and sufficient supply of electrical energy ". Under these regulations, the Supply Authority (the Area Board) undertakes to supply the consumer at s stated voltage, phase, and frequency, with permissible variations. The Area Board has the right to withhold connection or disconnect a supply if their regulations are not adhered to.

*NOTE :*These regulations, or statutes, have the force of law and for an employer , consumer, or electrician to disregard them could lead to legal action being taken against him.

3.Regulations for the Electrical Equipment of Buildings:

These regulations (commonly called the LE.E, Regulations) have been devised by the Wiring Committee of the Institution of Electrical Engineers to " ensure safety in the utilization of electricity in and about buildings". The I.E.E. Regulations are of considerable assistance to electricians as they largely cover the requirements of the Electricity Supply Regulations. The I.E.E. Regulations consist of two parts: Part 1 contains "requirements for safety" and Part 2 contains "means of securing compliance with Part l"

It should be noted that the LE.E. Regulations are not legally binding but are generally accepted as an efficient standard by Electricity Boards, con- tractors, and industrial and domestic consumers. However, Electricity Boards may have their own particular rules which must be obeyed. Particular industries have their own regulations—for example coal mines and cinemas. These special regulations have the force of law.

Generally, if an installation complies with the I.E.E Regulations it complies both with the Factory Acts and with the Electricity Supply Regulations since the I.E.E

Regulations are based on the requirements of these statutory regulations.

1.3 SUPPLY SYSTEM

The Grid is made up of a series of power stations throughout the country which feed current into a system of conductors at a very high voltage. Overhead conductors, supported by steel towers (pylons), are used to carry the current over long distances.

There are three main types of power station: (1) coal-fired, (2) nuclear, (3) hydro-electric.

The most common type is the coal-fired station. Heat, obtained from the burning of low grade coal, is used to produce high-pressure steam. This high pressure steam is used to drive a turbine which is mechanically connected to a 3-phase a.c. generator (alternator) generating at 11,000V. The voltage is stepped up, by means of a transformer, to 132,000V (or on the super grid). High voltages are used in transmit high power with a cable of small cross-sectional area and also to increase the efficiency of transmission by decreasing copper losses (*(I^2)R* losses).

1.The 132 kV **(1000 V=** 1 kV) 3-phase supply is terminated at an open air sub-station, containing switchgear and transformers, and stepped down to 11kV or 6.6kV.

2.These voltages (1lkV or 6.6 kV) are used to transmit supplies over shorter distances for bulk supplies to large factories possessing their own sub-stations.

3.These voltages are also used to supply pole transformers for agricultural consumers and isolated installations

4.The supply Authority's sub-stations step down the 3-phase 6.6kV or 11kV to 415 V 3-phase 4-wire(3-phase and neutral).

5.Consumers requiring 240V single phase (i.e phase or live wire and neutral wire), for example, a housing estate, are fed from a 4-core armoured cable (3-phase and neutral conductor).Each house is tapped from a diffirent phase (Fig 4.1) to balance the three phases (red, white, and blue).The underground cable is connected in a series of rings, thus decreasing the voltage drop and cross sectional area required.This interconnection also ensures a continuity of supply.

Fig.1.1 shows an open circuit at point X but all the consumers on the ring receive an uninterrupted supply.

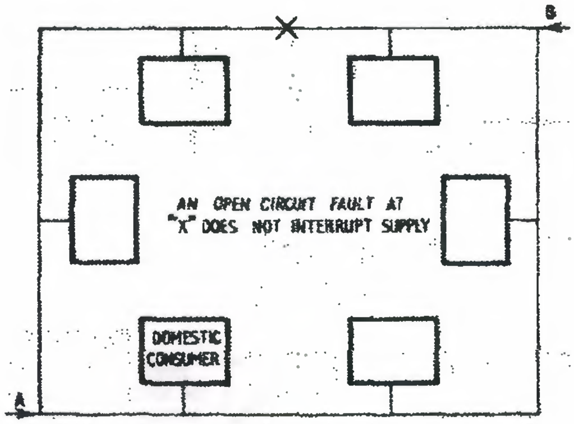


Fig 1.1 Open Circuit fault on ring system supply uninterrupted

1.3.1 Control of Supply at Consumer's premises

It is essential that the consumer's supply should be effectively controlled and also that all switchgear should be accessible.

NOTE:'All conductors and apparatus must be sufficientsize and power for the work they are called upon to do, and so constructed, installed and protected as to prevent danger.'

This quotation from the Electricity Supply Regulations also appears in substance in the Factories Act and the I.E.E Regulations.

The main switchgear in an installation must contain:

(a)Means of isolating the supply.

(b)Protection against excess current.

(c)Means of cutting-off the current if a serious earth fault occurs.

A main switch containing a fuse (or 3 fuses if 3-phase) fulfils these conditions as the switch isolates the supply and the fuse protects the circuit against excess current due to overload or serious earth fault.

Sequence of Control Equipment. Fig.1.2 shows two common methods of controlling the incoming supply.The earth leakage circuit breaker is used where it is difficult to get a good earth path {low-impedance earth return). The earth electrode of the E.L.C.B- must be placed outside the resistance area of any parallel path to earth.

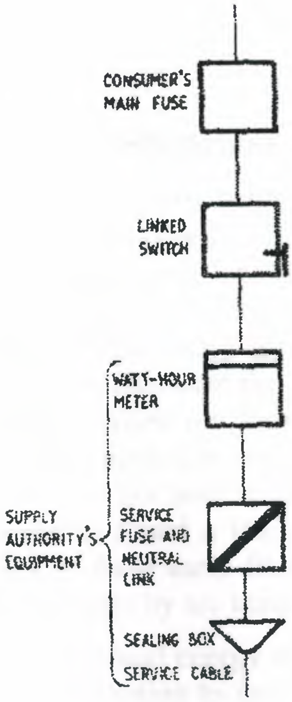


Fig 1.2 sequence of control equipment

1.4 TYPES of INTAKE POSITION

There are two types of intake position;

1.Over-Head Transmission Lines

2.Underground Transmission Lines

1.4.1. Over-Head Transmission Lines

The metal is put on to building, which is near to the transmission lines. We connect the lines, which are coming from pillar, to the "T Point", and, the lines will be gotten into the box of the metering units.

1.4.2. Under-ground Intake:

Lines are taken from pillar but here under-ground cable is used. When the cable put under-ground, it will be done in some rules. These rules are;

1. Earth will be dogged (depth nearly 100 cm)
2. Sand will be separated in channel
3. Plastic pipes will be put into channel
4. Again sand is separated onto pipes
5. And these are covered by cement
6. Cable will be passed through the pipes to the box of metering units.

After these the lines are connected to the HRC (High Rupturing Fuses) fuses. And then, Cutout, metering unit, operator, and distribution board.

CHAPTER 2

INSTALLATION

2.1. 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 was for lighting in houses, shops, and offices. By the 1870s, electric lighting had advanced from being 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 bean 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 ingot and castings. The first all-welded ship was constructed in 1920; and the other ship building processes were operated by electric motor power for punching, shearing, drilling machines and woodworking 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 turn 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, the installation in Hatfield House was carried out by an aristocratic amateur. That the installation was dangerous did not perturb visitors to the house who' when the naked wires on the gallery ceiling broke into flame nonchalantly threw up cushions to put out the fire and then went on with their conversation'

Many names of the early electric pioneers survive today. Julius Sax began to make electric bells in 1855, and later supplied the telephone with which Queen Victoria spoke between Osborne, in the Isle of Wight, and Southampton in 1878. He founded one of the earliest purely electric manufacturing firms, which exists today and still makes bells

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 guarantied that all the components offered for sale were technically suited to each other, were of adequate quality and were offered at an economic price.

Specializing in lighting, Falk Statesman & 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. Glover was originally a designer of textile machinery, but by 1868 he was also making braided steel wires for the then fashionable crinolines. From this type of wire it was a natural step to the production of insulated conductors for electrical purposes. At the Crystal Palace Exhibition in 1885 he showed a great range of cables; he was also responsible for the wiring of the exhibition.

The well-known J. & P. firm (Johnson & Phillips) began with making telegraphic equipment, extended to generators and arc lamps, and then to power supply.

The coverings for the insulation 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.

Siemens 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 Siemens, whose early system was to give a cable a certain length related to a standard resistance of 0.1 ohm. Thus a No.90 cable in their catalogue was a cable of which 90 yards had a resistance of 0.1 ohm. The Standard Wire Gauge also generally knew Cable sizes.

For many years ordinary VRI cables made up about 95 per cent 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 safeguard against the two wires touching and so causing fire. Choosing a cable at the turn 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 insulation: up to 600 V and 600 V/1,000 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 was 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 insulation material came from America to Britain where it formed part of the first wiring system for domestic premises. This was twin lead-sheathed cable. Bases for switches and other accessories associated with the system were of cast solder, to which the cable sheathing was wiped, and then all joints sealed with a compound. The compound was necessary because 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 affected good electrical continuity. The insulation was rubber. It became very popular. Indeed, it proved so easy to install that a lot of unqualified people appeared on the contracting scene as ‘electricians’. When it received the approval of the IEE Rules, it became an established wiring system and is still in use today.

The main competitor to rubber as an insulating material appeared in the late 1930s. This material was PVC (polyvinyl chloride), a synthetic material that came from Germany. The material, though inferior to rubber so far as elastic properties were 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 introduced in 1937. This was tough rubber sheathed cable with a semi-embedded braiding treated with a 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 Argyllshire. Despite the fact that lead and lead-alloy proved to be of great value in the sheathing of cables, aluminium was looked to for a sheath of, in particular, light weight. Many experiments were carried out before a reliable system of aluminium-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 copper-sheathed 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 Pyrotenax Ltd, and later by other firms. Mineral insulation has also been used with conductors and sheathing of aluminium.

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 sleepless 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 Rayland's Library in Manchester in 1886. Aluminium 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 also were 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 earlier material, which required the use of heat for bending.

Accessories for use with wiring systems were the subjects 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 this country 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 electric 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 contacts 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 an 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 forward 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: Verity's, McGeoch, Tucker, and Crabtree. Further developments to produce the semi-recessed, the flush, the ac only, and the 'silent' switch proceeded apace. The switches of today are indeed of long and worthy pedigrees.

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 and 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 1900s, introduced by Dorman & Smith Ltd.

Lord Kelvin, a pioneer of electric wiring systems and wiring accessories brought out 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 curling-tong heaters. Crompton designed shuttered sockets in 1893. The modern shuttered type of socket appeared as a prototype in 1905, introduced by 'Diamond H'. Many sockets were individually fused, a practice, which was later meet the 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 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 'Multi-Contact' and associated with a type of socket outlet, which eventually became the standard design for this accessory. It was Scholes, under the name of 'Wylex', who introduced a revolutionary design of plug-and-socket: a hollow circular earth pin and rectangular current-carrying pins. This was really the first

attempt to 'polarize', or to differentiate between live, earth and neutral pins.

One of the 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-outlets 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 encased 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 in the switchgear field were Bill & Co., Sanders & 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 the motorcar 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 Ottermill.

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, Compton, Swan, Edison, Kelvin and many others, is well worth noting; 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. For those who are interested in details of the evolution and development of electric wiring systems and accessories, good reading can be found in the book by J. Mellanby: The History of Electric Wiring (MacDonald, London).

2.2 Historical Review of Wiring Installation

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 lamp, 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 electrical 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 Institution of Electrical Engineers) 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 laying down a set of principles rather than, as Heaphy did, drawing up a guide or 'Code of Practice'. A second edition of the Society's Rules was issued in 1888. The third edition was issued in 1897 and entitled General Rules recommended for Wiring for the Supply of Electrical Energy.

The Rules have since been revised at fairly regular intervals as new developments and the results of experience can be written in for the considered attention of all those 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 Institution of Electrical Engineers (IEE) was not alone in the insistence of good standards in electrical installation work. In 1905, the Electrical Trades Union, through the London District Committee, in a letter to the Phoenix Assurance Co., said 'they view with alarm the large extent to which bad work is now being carried out by electric light contractors As the carrying out of bad work is attended by fires and other risks, besides injuring the Trade, they respectfully ask you to. . Uphold a higher standard work'.

The legislation embodied in the Factory and Workshop Acts of 1901 and 1907 had a considerable influence on wiring practice. In the latter Act it was recognized for the first time that the generation, distribution and use of electricity in industrial premises could be dangerous. To control electricity in factories and other premises a draft set of Regulations was later to be incorporated into statutory requirements.

While the IEE and the statutory regulations were making their 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 this country is that they form the primary requirements, which must by law be satisfied. The IEE Regulations and Codes of Practice indicate 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 the IEE Regulations, but cannot insist on a standard which is in excess of the IEE requirements.

2.3 INDUSTRIAL INSTALLATION .

1.All cables must be rated at, or above, the current which they will normally be expected to carry (Tables 1M to 31M in the I.E.E. Regulations supply this information) without undue heating or voltage drop (normally 5 per cent of nominal voltage).

2.All conductors, cables and equipment used in the Installation must be of the correct voltage rating, for example, 250V grade switchgear should not be used on 415V 3-phase installations; 500 V switchgear is necessary.

3. The fuse in a circuit must be capable of protecting the smallest conductor in that circuit. For example, a twin flexible cord of 3 A rating should not be used In a circuit fused above 5 A because serious over-heating could occur in the flexible cord under fault conditions.

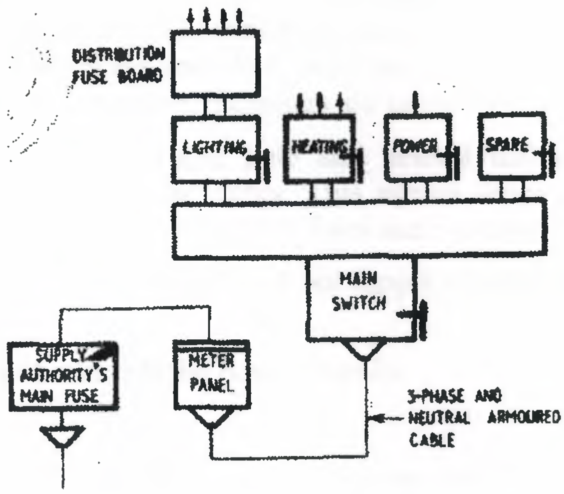


Fig. 2.1 Layout of small engineering works.

4. All conductors and equipment must be properly labelled; this saves time and also minimizes the danger of opening the wrong circuit when Isolating or fault-finding.

Earth wire GREEN and YELLOW

3-Phase wires (non-flexible) RED, YELLOW, and BLUE

Neutral: BLACK

3-Phase wires (flexible) All phase wires BSOWH (identified by sleeves or tabs)

Neutral: BLUE

Single-Phase (3-core) Live: BROWN

Neutral:BLUE

Paper-insulated cables:	0=NEUTRAL	1=RED PHASE
	2=YELLOW	3=BLUE

Mineral–insulated metal sheated Identification sleeves should be used at terminations.

5.All equipment must be protected against:high temperatures, moisture, corrosion and mechanical damage.

6.The main distribution point should be situated, if possible, at the centre of the Installation In order to keep cable runs short.

7.Sufficient capacity should be installed at the outset (In main switches, bus-bar chambers, and cables) to allow for future expansion.

Fig. 2.1 shows a suggested layout for a relatively small engineering works. The supply is fed into the premises by means of an underground cable (3- neutral), through a sealing chamber into the Supply Authority's fuse.Tails are taken from the fuses and neutral block Into the meter panel. An armoured cable supplies the consumer's main switch, which, In this case, is a 500 A triple-pole and neutral linked switch (all poles are switched simultaneously). The conductors are then brought out to the bus-bar chamber. Tappings are taken from the bus-bars as follows:

No. 1 switch is a triple pole and neutral linked switch (all poles are switched simultaneously) for the lights. This switch feeds an 18-way distribution fuse board comprising three sets of six 15A fuses and a neutral block.

No. 2 switch is similar to No. 1 but supplies the heating load, which is balanced over 3 phases.

No. 3 switch controls the power circuits.

Sub-division of Loads. This is considered under lighting, heating, and power circuits

Lighting Circuits: The lighting load will be taken from the distribution board to the final sub-circuits. A final sub-circuit is defined in the I.E.E. Regulations as "an outgoing circuit connected to a distribution board and intended to supply electrical energy direct to current-using apparatus*'. The conductors between the bus-bar chamber and the distribution fuse board are termed the sub-main. The conductors from the lighting distribution fuse board may also feed local switches supplying small distribution fuse boards (for example, 5 A fuses) for offices, stores, etc.

The lighting final sub-circuits comprise a switch-panel and the lights controlled by these switches.

All fuses and switches must be placed in the phase conductor and metal lampholders (used in industrial fittings of 200 W and over) must be earthed and the phase conductor should be terminated at the centre pin of Giant Edison Screw (G.E.S.) lampholders

Heating Circuits. The heating load (Fig. 4.6) is split up over 3 phases to give a balanced load. The heaters, for example, fan heaters, would be controlled a 3-phase isolator or a 3-phase switch fuse. For example, if 240 V tubular heaters (200 W per metre) are used the heating circuits are subdivided into three sections with a seperatephase for each section.

Power Circuits, which consist of, in this instance, a 3-pliase isolator and a starter controlling a milling-machine motor taking a full load current of 8 A. A 1 mm^2 or a 1-5 mm^a cable would be adequate for this circuit, but the fuse should be loaded to three times the full load current of the motor, that is, approximately 25 A (0-75 mm tinned-copper wire).

The main distribution fuse board may also be used to supply smaller distribution fuse boards for smaller lathes, drills, etc.

The 2--meter Rule. In conditions where two separate phases (for example, the red and blue phases) are brought into the same room:

(a) The controlling switch must be clearly marked '415 volts',

b) Switches and socket outlets supplied from different phases must be

placed at least 2 metres apart. This is particularly important where

portable appliances are used .

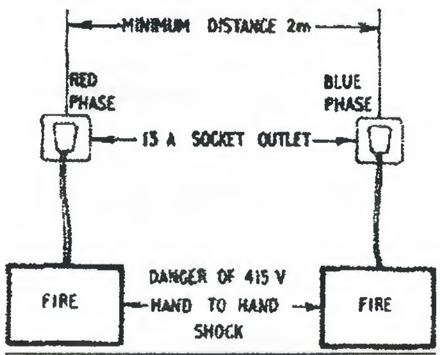


Fig 2.2 The 2-meter rule

This is termed the '2-meter rule'.It avoids the danger of a voltage of 415V appearing between appliance or switches which can be touched simultaneously.

2.4 DOMESTIC INSTALLATIONS

2.4.1 General Rules for Domestic Installation

There are two types of installation

I. Surface Installation

II. Under plaster installation

Installation system at costumers place

OPERATOR ➡ DISTRIBUTION BOARD ➡ FUSES ➡ LINES (CABLES)

In both types of installation, same main principle is accepted these are;

1. Lines from metering unit will be applied to the operator (V/O, C/O) or if operator is in distribution board, we put 2-pole isolator into box of metering unit and earth continuity conductor will come from another place, not with line and neutral conductor. If the operator is outside of the operator line neutral earth will be connected together to 2-pole isolator, which is in distribution board. These maybe 3 phase or 1 phase operator or isolator.

2. In distribution board for each type of circuit different cable sizes and fuses or miniature circuit breakers are used.

Domestic installation are usually supplied from a 16mm2 twin armoured cable.

1.The supply Authority's sealingchamber for the termination of the armoured cable.

2.The Supply Authority's fuse and neutral block.

3.The Supply Authority's energy meter (kWh).

4.Consumer's control unit.

NOTE:The Supply Authority's fuses need not be dublicated if the permissionof the Authority is obtained

2.4.2. Under Plaster Installation

Steps do this type of installation as follows;

I. Ceiling installation and stairs.

II. Inside of home and stairs.

2.4.2.1. Ceiling Installation;

Plastic pipes and plastic lamb box do this part of installation. Generally, 5/8 plastic pipes are used for cell lighting. While we are doing these also, pipes of stairs installation is fixed. Pipes and lamb boxes are out be cording to the electric installation project.

Following steps to do these.

a-)Ceiling installation and stairs. First the lamp boxes are filled by wet papers. Lamps boxes may fill with concrete there fore we fill the inside of lamp boxes with paper not to have problem.

b-) Lamps boxes will be nailed according to the electrical plan. If there is only single lamp in a room. Lamp boxes will be nailed to the center of room. If there is more than one lamp. You have to follow a special ways. For example, in a corridor generally there are two lamps length of corridor will be divided by there and with will be divided two to point the place of lamp.

c-) You will take out the pipes from the lamp boxes for switches (to under of the roof). We have to be careful. When we put the pipes inside of the coulomb the pipes, which will be under roof, must not be above doors or windows and also, it should not be behind doors.

d-) For each circuit, from the lamb boxes, pipes will be taken out up to the distribution board. This is done as same as position of switches.

e-) Pipes will be put for the heater and for the water tank on the roof to the distribution board. (3/4")

f-) For antenna and telephone lines pipes are fixed to the suitable position (1" or ¾"). In apartments extra pipes are put in stairs for main lines and for the lighting of stairs. They are put inside of the coulomb

Figure 2.3. Ceiling installation samples

2.4.2.2 Inside of Home and Stairs.

According to the plan, you paint the positions of sockets, switches, etc. with paint (spray paint). Painted places have to be broken. Metal boxes and plastic pipes that are in different sizes, for each type of circuit.

5/8" pipes for lighting, telephone lines, water pump, and earthing.

3/4" for sockets, antenna, heater circuits.

3/4" or 1" fore cooker control

1 ¼" or thicker is used for main lines,

When the metal boxes are being put they have to have different heights. These heights are;

In bathroom, dinning rooms, and corridor, sockets/Telephone/Antenna sockets 50cm (between floor to metal box)

Switches 150cm (between floor to metal box)

Special lamps on wall 200cm (between floor to metal box)

Switch or socket box

Figure 2.4. Switch or socket box

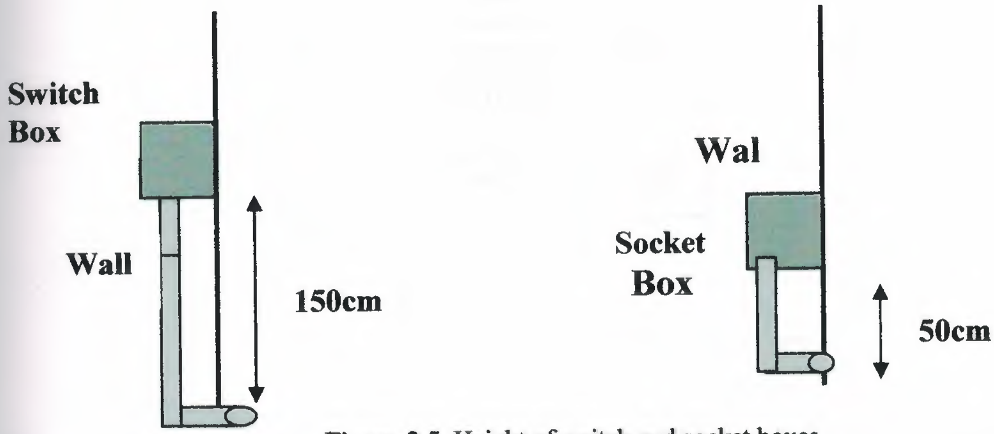


Figure 2.5. Height of switch and socket boxes

In Kitchen;

Here you have to be careful for position of metal boxes. Because cooker, switches, sockets boxes have to be at the same line and you have to measure careful not to put them on the place of the cupboards and this height is generally 125cm.

In Toilet and Bathrooms;

You must not put the metal box of switches inside of toilets or bathrooms. Because you may have risk of electric shock. Lamps must be waterproof. In these wet places, we have to use waterproof components for protection of life. Height of lamp is nearly at 200cm.

The round of the metal boxes must not be plastered because, metal box will have corrosion problem.

Steps

a-) We paint the places of switches, sockets, etc.

b-) Painted paces have to be broken, up to 65cm for sockets, switches 150cm, if the pipes of switch will come from roof, that pipe will come to 150cm painted line.

c-) Metal box will be fixed at painted places, but they have to be flat and good appearance we tie with wire on at piece of flat wood. This wood is nailed to the wall.

d-) We bend the pipes from anywhere of pipes, where it is needed and put them in boxes from hole on box.

e-) After plasterer to fait and the pipes plasters these boxes which are on floor are also plastered to protect the pipes.

After these have been finished, we will pull the cable as connecting to the special stainless wire. What types of cables are suitable for each circuit.

In kitchen, toilets and bathrooms metal place labs will be earthed by special clips which is called earthen clips and also switches, sockets and something like these will be connected and this is called finish.

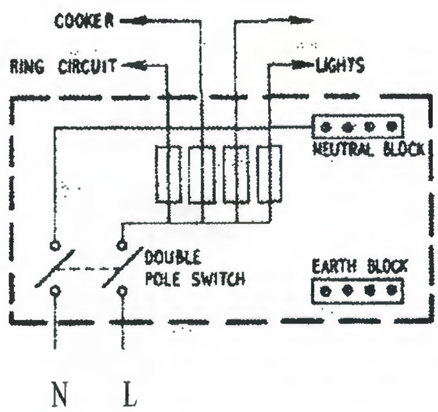


FIG. 2.6. Domestic consumer's control unit

Domestic Consumer's Control Unit (Fig. 2.6).This type of unit is usually made up of the following :

(a) Main switch (60 A) which isolates *both* the phase and the neutral

conductors,

(b) One 30 A fuse for the cooker circuit.

(c) One 30 A fuse for the 1 3 A ring circuit (capable of taking two 7/0-85 in cables).

(d) One or two 5 A fuses for lighting circuits.

Loading of Final Sub-circuits. The assumed current demand from points is as follows (Table B, I.E.E. Regulations):

15 A socket outlet	15 A
5A socket outlet	5A
2A socket outlet	at least 1/2A
Lighting outlet	minimum 100W

1.Only one phase of a supply should preferably be brought in to a multi gang switch box. Where more than one phase is used there must be a rigid screen or barrier separating the phases, and a clearly visible notice warning of the maximum voltage present. This notice must be placed outside the switch.

2.All final sub-circuits must be electrically separate (i.e. there must be no 'bunching' of neutral conductors). All neutral conductors must be connected at the distribution board in the same order as the line conductors.

Domestic Ring Circuit (Fig. 2.7). The domestic ring circuit is defined in the I.E.E. Regulations as "a final sub-circuit in which the current-carrying and earth continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution fuse board or its equivalent. A spur of a ring circuit shall be a branch cable having conductors of a cross-sectional area not smaller than that of the conductors forming the ring".

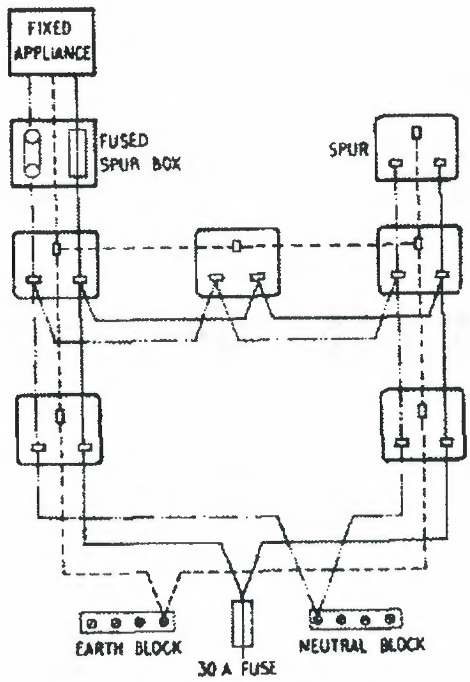


Fig. 2.7. Domestic ring circuit

The main I.E.E. Regulations relating to the ring are as follows:

1.Cable size: minimum twin 2-5 mm^2 and earth p.v.c. or t.r.s.

2.Maximum number of socket outlets allowed: unlimited number in floor area under 100 m^2, but spurs may not number more than half the socket outlets on the ring circuit, including stationary appliances.

3.Fused 13 A plugs to be used at socket outlets supplying portable appliances.

4.Fixed appliances must be protected by a local fuse, for example, 3 fused spur box.

5.A 30 A fuse should be used to protect the ring circuit.

6.All socket outlets in any one room must be connected to the same phase.

7.Apparatus permanently connected to the ring circuit without a fused plug or socket outlet must be protected by a local fuse or circuit-breaker with a rating not exceeding 15 A. The apparatus must have an adjacent con- trolling switch.

The purpose of the ring circuit is:

(a} To minimize trailing flexes.

(b) To take advantage of the fact that all outlets in a domestic installation are not pperated simultaneously .This is known as the diversity in an installation.

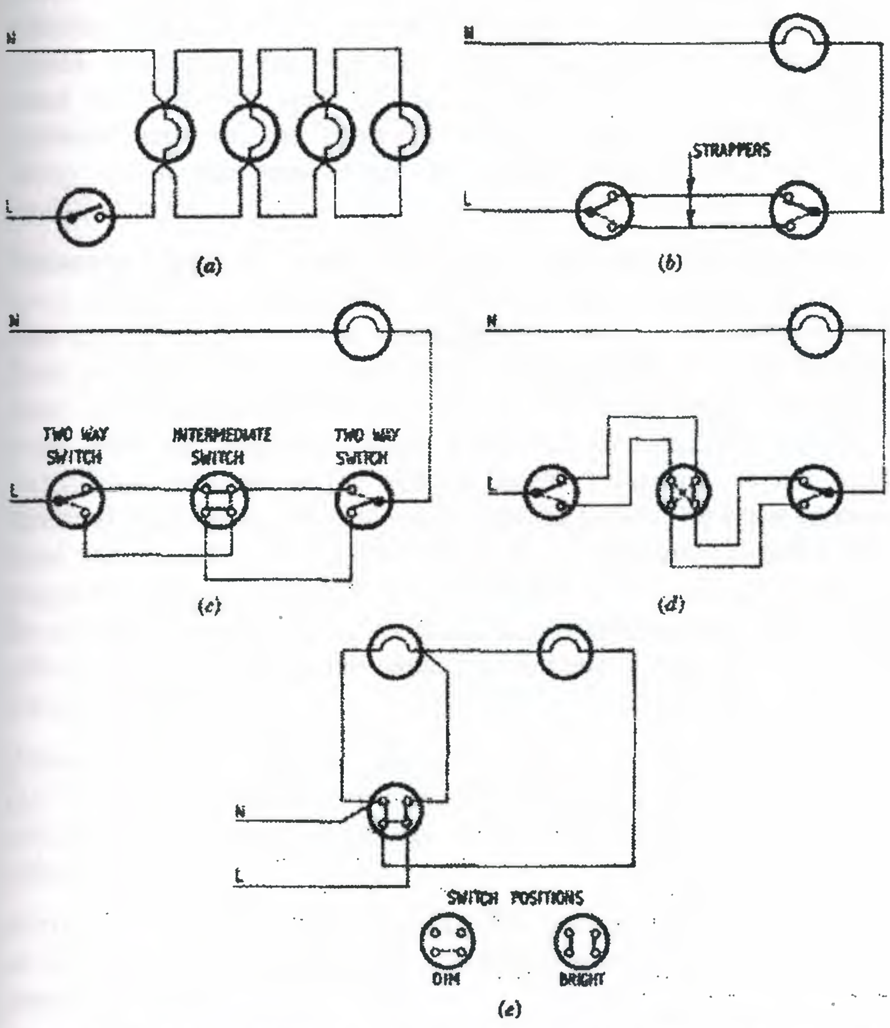


Fig. 2.8 Lighting circuits. (a) One–way switching : one switch serving lights. The conductors are lopped between the lambs. (b) The two-way switching circuit.Used for stairs and corridors. (c) The two-way switch used with an intermediate switch for long corridors in hospitals, schools, etc. (d) Another type of intermediate switching. The internal connections in the switch determine the circuit used. (e) Dim-bright switching. The lamps are connected in series for dim operation and in parallel for bright.

2.5 DIVERSITY FACTOR

The diversity factor in an installation can be calculated as follows:

$$\text{Diversity factor} = \frac{\text{Actual connected load}}{\text{Total Load}} \times 100 \text{ (per cent)}$$

The diversity factor vanes for different types or installations, for example; the diversity factor suggested in the I.E.E. Regulations for the lighting circuits of a block of residential flats is 50 per cent. This means that the cables supplying the lighting load *(not* the final sub-circuits) need only be rated for 50 per cent of the full-load current. This decrease In the cross-sectional area of the cable Is allowed because the likelihood of all the lights being on at the same time is remote, although any one final sub-circuit may be fully loaded.

Domestic Lighting: Domestic lighting circuits are usually wired in I mm- twin t.r.s. or p,v,c. (twin *1-5 (mm^2)* may also be used). The protecting fuse is generally *5* A (20 mm tinned copper wire or cartridge fuse with white body). Conductors in a lighting final sub-circuit (or any final sub-circuit) should never be interconnected with other final sub-circuits. For example, a final sub-circuit neutral should never be used to teed more than one final sub-circuit. Each neutral conductor should be connected to its individual terminal at the neutral block: 'bunching[5] is not permitted. An earthing terminal must be provided at every lighting point. The earth continuity conductor of the final sub-circuit must be connected to this terminal, metallic switches must also be supplied with an. earthing to which the final sub-circuit earth continuity conductor must be connected. The earthing terminal is not required where earthed metal boxes are used which have a fixing for the metal switch plate giving reliable electrical contact between the plate and the metal box.

Fittings: Light switches are usually of the 5 A (a.c.) quick-make-slow-break (Q.M.S.B.) type, flush mounting. Switches used in fluorescent lamp circuits must be capable of carrying twice the normal circuit current in order to withstand the Inductive effect of the choke.

NOTE. An incombustible material, for example, a hard wood block, must be placed at the back of surface-mounted accessories where these are fitted to soft wood or other combustible material.

***Ceiling Roses**:* There are two main types of ceiling rose: *(a)* the three-plate pattern and *(b)* the two-plate pattern.

The three-plate ceiling rose is used to economize in wire and minimize the number of joint boxes used in the installation.A joint must be made as indicated or three wires run to the first switch. All joints must in joint boxes.

NOTE: Ceiling roses must not be used on circuits operating above 250 V and no more than one flexible cord is permitted from any one ceiling rose. The earthing terminal of every ceiling rose must be connected to the earth continuity conductor of the final sub-circuit

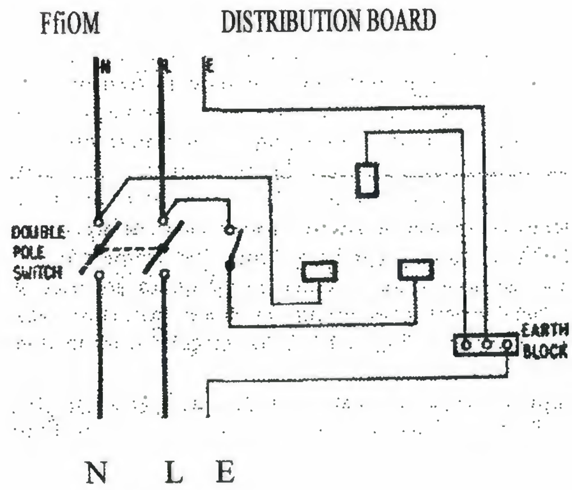


Fig. 2.9. Cooker control unit.

Water Heaters:

Domestic water heaters are generally rated at 3kW and are usually supplied from ring circuit. Asbestos-covered cable should be used to terminate the conductors at the immersion heater since p.v.c. and t.rs cables are normally expected to be used where the surrounding temperature (the ambient temperature) does not exceed 30‘C. The temperature age of water heaters is between 43 'C and 82 'C. The thermostat, in common with all other switching devices, must always fitted in the phase conductor.

Bathroom : All lamp holders must be of the Home Office (skirted) type and lamps should be totally enclosed. Only circular flexible cable should be used where necessary and the switch must be of the pull-cord type. No portable appliances should be fitted or used in the bathroom and fixed appliances for example, wall fires, must be placed out of reach of persons in the bath.

Garages:Socket outlets in garages must be placed at a safe distance from floor level.All portable appliances, particularly handlamps, must be earthed and handlamps should be fitted with an earthed shield.

Cooker Control unit: This generally consists of a double-pole switch feeding the cooker and an independent 13A socket outlet. It is essential that the earth continuity conductor supplying the unit should he effectively connected.

The cooker control unit is generally supplied from a separate way in the consumer’s control unit and wired with 10 mm^2 twin and earth p.v.c . or t.r.s. cable. It is fused at 30 A which is sufficient to protect a maximum of 9 kW {3-plate cooker). The current demand from a stationary cooking appliance is calculated as follows: 10 A + 30 per cent of the total remaining full load current. Every stationary cooking appliance in domestic premises must have an adjacent control switch fitted within 2 m of the appliance.

*NOTE:*No Diversity factor is allowed with a final sub-circuit supplying a cooker as it is possible that all elements will be in use when the cooker is being fully utilized.

Layout of a Domestic Circuit:The lighting circuits would be connected from two

junction boxes in the attic(one box for each circuit). The cable supplying the cooker would also be run in tha attic and the ring circuit would be run below the floor.Socket outlets are placed 30 cm above the floor level and light switches 1.5m above floor level.

2.6. SPECIAL INSTALLATIONS

Though the bulk of electrical installation work carried out in this country does not involve the consideration of special factors in the context of the wiring systems, accessories and the equipment 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. These sources include BS Codes of Practice and manufacturers' instructions, and IEE Regulations.

2.7. TEMPORARY INSTALLATIONS

A temporary installation is an installation with an expected period of service of three months.A temporary installation used beyond this period must be completely overhauled at three-monthly intervals.

It must be pointed out that the electrician in charge of temporary installation has a legal responsibility and ensure the safety of the installation; this includes its construction maintanance and extension. The particular danger in this type of installation is the work of the amateur electrician who overloads bayonet-cap lighting circuits beyond their 1kW maximum loading , often with unearthed metal fittings, and uses unsheated cable or unprotected cable. Conduit should not be used in the installation unless it complies with the relevant I.E.E Regulations .

Protection: The temporary installation must be protected with an adequate switch which isolates all the poles (including neutral) from the supply.The name of the person in charge and their position should be displayed near the main switch.

NOTE: The greatest care should be taken to protect the temporary installation against mechanical damage and portable appliances(for example drills) should be regularly checked.Low-voltage (e.g 110V) step-down transformers should be used wherever possible , to minimize the danger from shock.

2.8 DAMP SITUATION

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 (particularly from surface leakage over otherwise healthy insulation) and the risks, which attend a gradual deterioration of the metalwork of the installation as the result of corrosion.

The I.EE Regulations require that every cable installed in a 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. Conduit threads should be painted over with a bituminous paint immediately after erection Cables, which are armoured 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, 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 he 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 conduit 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 glanded into totally enclosed lighting fittings and run into the 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 temperatures below $0^{\circ}C$, PVC has a 'cold-shatter' characteristic and may crack if hit sharply. There is also a warning note regarding the use of cables with bituminous-compounded beddings or servings.

2.9 Corrosion

Wherever metal is used there is the attendant problem of corrosion. Two conditions are necessary for corrosion: a susceptible metal and a corrosive environment. Nearly all of the common metals in use today corrode under most natural conditions; the bulk of all anti-corrosive measures have thus been attempts either to isolate the metal from its environment, or to changing the environment chemically to render it less corrosive In installation work, the problems of corrosion tend to be more acute in certain types of installation. Chemical works, salt works, cow byres and other ammonia-affected areas, all require special consideration in their design and the work executed to produce the installation. Corrosion, in a normal installation condition, may affect earth connections.

The corrosion of metals in contact with soil or water is an electrochemical reaction; that is, the corrosion reaction involves both the chemical change (e.g., from iron to rust) and a flow of electric current. It is this principle, which is used in the dry cell, where the corrosion of the zinc case provides the cell's electrical output. The current flows from

the metal into the soil or water (called the electrolyte) at the anode and then from the electrolyte into the metal at the cathode. Corrosion occurs at the point where the current flows from tile metal into tile electrolyte. Every metal develops its own particular electrode potential when placed in an electrolyte or similar medium. If two different metals are coupled together in the same electrolyte, tile difference between their potentials will be sufficient to produce a current of electricity. The metal with the more negative potential will suffer corrosion. It follows that the more compatible the metals are, the less will be the rate of progress of any corrosive action which takes place between them, because the amount of potential difference between them is reduced.

In general there is a 'natural' potential of -0.3 to - 0.6 V between a buried mass of metal and its surrounding soil. This potential is measured by using a very-high-resistance voltmeter and a device called a half-cell, which consists of a copper rod immersed in saturated copper sulphate solution contained in a plastic tube which has a porous plug at the bottom for making contact with the soil as near as possible to the buried mass. Certain areas of the mass surface will act as anodes (where the current leaves the metal) and these will corrode. The areas, which act as cathodes (where the current enters the metal) do not corrode. This sub-division in the areas of the surface of the buried mass is due to the fact that the areas assume the roles of anodes and cathodes depending upon variations in the metal itself, its surface treatment, and the electrolyte.

Reducing the amount of current that flows from it into the surrounding medium or electrolyte can diminish the corrosion of a metal. Painting or otherwise coating the metal will increase the electrical resistance of both anodes and cathodes. But if the coating has flaws or holes in it, then the current concentrates at these points and deep pitting will occur. The corrosion current can also be reduced by lowering the electrical potential difference between the anodes and the cathodes either by controlling the purity of the electrolyte or by adding inhibitors to it.

Because only the anodes corrode, current flowing into them from an introduced external anode so as to cause the whole of the buried structure to become a cathode can prevent corrosion. This is the principle of cathodic protection. The method can be used only where the introduced anode can be accommodated within the electrolyte that surrounds the buried metal, and the soil or water must be present in bulk.

The method is widely employed as a corrosion preventive measure on underground metalwork. Two basic techniques are used to give cathodic protection: (i) the sacrificial anode system; (ii) the impressed current system.

In the first method , a mass of base metal, such as magnesium, is buried in the electrolyte and connected electrically to the structure to be protected. The natural difference in potential between the structure metal, usually steel, and the magnesium causes a current to flow from the magnesium (the new anode) through the electrolyte to the steel, which is the new cathode. The anode gradually corrodes and is thus called a 'sacrificial anode'. In practice a closely controlled magnesium-alloy is used. The main factors which govern the degree of protection, and the current output from the galvanic cell so formed by the protective system, are the surface area, volume and shape of the anodes used, the resistivity of the electrolyte and the surface area of the exposed metal being protected. The sacrificial anode system is common in congested areas since the low potentials generated by the galvanic system virtually eliminate the possibility of corrosion arising on adjacent metal structures on account of stray current. The system also needs no external electrical supply and is to a great extent self regulating in output, which latter will vary according to the resistivity of the surrounding medium (e.g., in

wet or dry weather conditions). The anodes need periodical renewal. In reasonable soil conditions, the life of an anode may be up to 15 years.

The second method of protection, the impressed-current system, uses a conventionally generated direct current from rotating machinery or via a transformer/rectifier unit. The negative side of the supply is connected to the structure to be protected; the positive side is fed to an 'anode ground-bed' usually formed from high-quality graphite impregnated by resin, wax or linseed oil, silicon iron or scrap iron or steel. The buried structure then becomes the cathode. The anode may, but need not, corrode. Silicon-iron and graphite anode ground-beds are semi-inert and have a very long life. Scrap iron or scrap steel beds go into solution quite rapidly and disintegrate at the rate of about 10 kg/Ampere/year.

The metalwork associated with electrical installations, which may require cathodic protection include supporting lattice structures, armoured cables with rotted servings, metal pipes containing cables, and general structural steelwork.

Another aspect of corrosion may not be too familiar to installation installers. This concerns the continuous exposure of PVC-insulated cables to temperatures above 115°C that may cause the formation of corrosive products, which can attack conductors and other metalwork. Generally, the precautions to prevent the occurrence of corrosion in normal installations include:

1. The prevention of contact between two dissimilar metals (e.g. copper and aluminium), particularly where dampness is likely to be present.

2. The protection of cables, wiring Systems and equipment against the corrosive action of water, oil, and dampness, unless they are designed to withstand these conditions.

3. The protection of metal sheaths of cables and metal-conduit fittings where they come into contact with lime, plaster, cement and certain hardwoods such as beech and oak.

4. The use of bituminous paints and PVC over sheathing on metallic surfaces liable to corrosion in service.

CHAPTER 3

3.0 CIRCUITS

3.1Lighting circuits

Most lighting circuits comprise several switching arrangements, such as one-way, two-way and intermediate. A typical domestic circuit is derived from a 5 A way in a consumer unit.In larger installations the rating of the circuit protective device can be either 15 A or 16 A. Domestic light- ing is largely based on the use of filament lamps, with fluorescent luminaires found in kitchen areas. Commercial installations are based on fluorescent lamps.

The simplest lighting circuit is a one-way, comprising one lamp controlled by a one-way switch; multi-lamp chandeliers are also controlled from the one-way switch. The two-way switching arrangement is used when a room has two points of entry and the luminaire is thus controlled from any one of two positions. The intermediate switching arrangement is used where one or more luminaires are required to be controlled from a number of switch positions, such as in long corridors or areas where there are a number of entry points.

One-way switches are rated at both 5 A and 15A. They must always be connected in the phase ('live") side of the supply. When being installed, ihe switches must be positioned so that when the rocker is in the 'down' position, the circuit is energised.Usually the word 'top' is marked on the reverse of the switch plate to ensure the correct mounting position.

The two-way switch has no OFF position. Rather the lamps are switched ON and OFF by the operation of one or other of the switches. Again, these switches are effectively 'single-pole' control devices and so must be connected to the phase side of the supply.

The intermediate switch has two positions and is effectively a change-over switch. It is connected between two two-way switches and so is able to change the direction of the current in the wires which connect the two-way switches together, known as 'strappers', 'strap wires' or 'pass wires'.

Switches are available as one-gang, or multi-gang, the latter being used to allow a number of individual luminaires to be controlled from one location.

In the provision of lighting circuits in a domestic-installation it is usual to split the lighting provision into two, with around ten lamps at the most on each circuit. Each lampholder is assessed at the current equivalent of 100 W. Thus ten lamps would take a total of just over 4 A. The reason for having two lighting circuits is to ensure that part of the house has some light should one circuit fail.

In commercial installations it is essential to ensure that the switches are either rated to carry inductive currents (e.g. 'ac rated') or else are derated to half their normal current rating. This is because fluorescent lamp circuits take more current than the simple rating of the lamp. To calculate the total current taken by fluorescent fittings the lamp wattage is multiplied by a factor of 1.8 and the product divided by the supply voltage:

$$I = \frac{\text{Total lamp watts X 1.8}}{\textit{voltage}} \; \textit{amps}$$

Care should be taken that the correct size of conductor is used for lighting circuits, particularly to prevent excessive voltage drop. Every conductor has a certain value of resistance and when a current flows along it a voltage loss occurs $(V_{d}= I \text{ X } R)$, The longer the length of run from its supply point (consumer unit or distribution board) the greater will be the volt drop. If the drop is excessive the lamps (particularly filament lamps) will deliver a reduced light output. This tends to be more a problem in commercial installations than in domestic premises. Usually conductors of 1.5 mm^2 CSA will be found adequate for most circuits.

Most general lighting circuits are wired either using the loop-in' method or by using a joint box. The loop-in method requires a phase terminal in the ceiling rose (which must always be shrouded to prevent inadvertant contact or else a shock will he received). The other terminals in the rose are for the neutral conductor, the switch wire, and the two terminals to which the luminaire is connected. A final terminal (or terminals) is provided for the CPC which must be connected to both the earth terminal in the switch mounting box and the earth terminal in the luminaire accessory. Some lampholders only have two terminals and so the CPC must be terminated in a single block connector and not left loose. The loop-in method using a rose with a phase terminal allows the switches to be fed with two-core cable and also allows other lamps to be looped from the rose.

The joint-box method uses a box made from moulded plastic and can incorporate four terminals or else has a block-connector strip fitted by the electrician. From the box are taken the cables for feeding the switch and the lamp and it also allows other circuits to be taken from the same box.

Note that all CPCs contained in either two- or three-core cables must be sleeved with green/yellow sleeving when being terminated in ceiling roses, joint boxes, switches or lamp accessories.

If one-way switching is involved, the red core must be the switch feed conductor. The other core, coloured black, actually forms the switch wire and, to comply with the Wiring Regulations, must be identified as being on the live' side of the circuit and coloured red, yellow or blue depending on the phase from which the installation is being supplied. This identification of the switch wire is often ignored by practising electricians and while it is general practice it must be recognised that it does contravene the Regulations.

In commercial and industrial installations, the live may be derived from the red. yellow or blue phase and its colour should be consistent throughout the circuit.

In lighting circuits generally, 1 mm^2 cable is used with 5 A fuse because the authority says that in a lamb circuit you will put 10 lamp (100 W), this will be 1 kW=I=1kW/240=4.16 A. 5 A limit must not be passed that's why we use the fife Amp. If we want to put more than10 lamps in a circuit we have to change the cable size to 1.5 mm^2 with a 10 A fuse.

3.2 POWER CIRCUITS

Two types of circuits are used to feed socket-outlet units and fused connection units: radial and ring. The radial circuit is derived from a 20 A way in a distribution board or consumer unit and is intended to serve a floor area not exceeding 20 nf. If the floor area to be served is not more than 50 m^2 the rating of the protective device is 30 A or 32 A. Kitchens in domestic premises {where a large number of socket-outlets are often needed for electrical appliances) are often fed by radial circuits.

The ring circuit is derived from a 30 A or 32 A way and has its conductors terminated at its point of origin in the distribution board or consumer unit. An unlimited number of socket-outlets may be connected us the circuit provided that the floor area served does not exceed 100 m^2 in domestic installations. As most modern domestic premises have a floor area in excess of this figure, two ring circuits are usually provided (or one ring and one radial circuit for the kitchen). When more than one ring circuit is installed in the same premises, the socket-outlets should be reasonably shared between the circuits to balance the loading.

Spurs can be taken off a ring circuit. If they are of the non-fused type, [he number must not exceed the number of socket-outlets (and any stationary equipment) connected directly in the ring. Double or two-gang units are regarded as two separate outlets. Connection units can be either fused or switched and fused, with the latter being used for equipment which has no direct control switch. A fused connection unit can be used to feed devices which take very little current, such as a fan, a clock or a lamp.

When installing a ring circuit, the spurs can be fed from socket-outlets connected directly in the ring, from the origin of the circuit or from a joint box (with terminals rated for 30 A) connected in the ring and left for future extensions to a building (e.g. a conservatory or extra bedroom).

Three types of cable are recognised for use with ring and radial circuits: PVC-sheathed, MI cable and copper-clad aluminium, PVC-insulated. For ring circuits the respective csa involved are 2.5, 1.5 and 4 mm".

3.2.1. POWER CIRCUITS TYPES

1. Sockets

There are two types of sockets.

1.Radial Socket Circuit

2.Ring Socket Circuit

I-) Radial Socket Circuit:

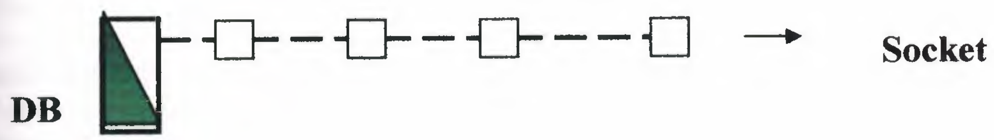
We have some standards.

1-) In a kitchen area two sockets can be put in radial socket circuit with 2.5 mm^2 conductor and 15 amps. fuse.

2-) In an area, which is not in kitchen and less, than 30 $m^{2,}$ 6 sockets can be put in radial circuit with 2.5 mm^2 conductors and 15 Amp. fuse.

3-) If the area is greater than 30 m^2, 6 sockets can be put in a radial socket cct. With 4 mm^2 conductor and 20 Amp. fused.

Figure 3.1. Radial socket circuit



II-) Ring Socket Circuit:

Ring means, you will start from one point and after you went to each point, you will come back to first point.

1-) Any number of socket can be put in a ring socket circuit if the area less than 100 m^2, if area is greater than 100 m^2 in any building. You have to another ring socket circuits.

2-) From any sockets in a ring sockets circuits you can put spur from each sockets.

3-) Only one stationary appliance can be put in a ring socket circuit either include in the ring or taken as a spur. (Washing machine, dish washer, bathroom heater or heater, and water pump)

NOTE: If these are connected to the ring socket circuit as a spur or with any heater switch. The heater switch has to be fused.

For other power circuits cable sizes and value of fuse.

Figure 3.2. Ring socket circuit

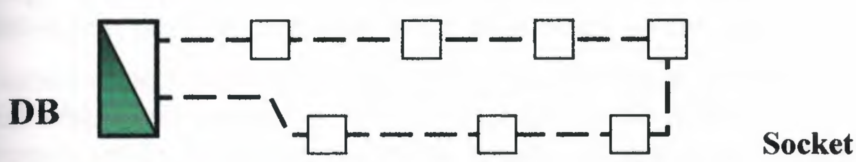


Figure 3.3 Ring socket circuit with spur socket

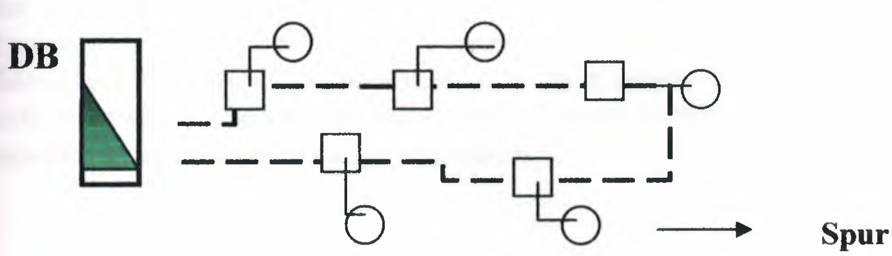


Table 3.1. Circuits cable thickness and fuses

Circuit	L+N	Earth	Fuses
Cooker Control	6 mm^2	2.5 mm^2	30 A
Heater	2.5 mm^2	1 mm^2	15 A
Dish Washer	2.5 mm^2	1 mm^2	15 A
Washing machine	2.5 mm^2	1 mm^2	15 A
Jacuzzi	2.5 mm^2	1 mm^2	5 A
Instant Heater	4 mm^2	2.5 mm^2	30 A
Air Conditioner	2.5-4 mm^2	1-2.5 mm^2	15-30 A

Regulations summary

Socket-outlets (except for shaver units) are not permitted in bathrooms. Fixed appliances fed from connection units must have an appropriate provision in the unit (either fused or switched and fused). Appliances connected to fused connection units must have a rating of 3 kW maximum. A two-gang socket-outlet unit is regarded as two separate units. Any socket-outlet used for supplying electrical equipment intended for outdoor use must incorporate a residual current device (RCD) with a trip current of 30 mA; the socket-outlet must be next to a warning label reading "For equipment outdoors'. In industrial or commercial premises, adjacent socket-outlets must be connected to the same phase of the supply.

All socket-outlets must be protected by a device (fuse or miniature circuit-breaker, MCB) which will operate within 0.4 second should a fault occur. The cable sizes recommended for both ring and radial circuits assume normal ambient temperatures and that the conductors are not bunched. Higher operating temperatures, bunching, contact with thermal insulation material and the use of a semi-enclosed fuse (BS 3036) may mean an increase in the csa of the conductors.

3.3 Cooker Circuits

These are derived from (usually) a 30 A or 32 A way, but can be higher depending on the kW rating of the cooker. The control units need not have a socket-outlet incorporated in them, but if one is provided the protective device must be able to. disconnect the circuit in the event of a fault within 0.4 second (it would be 5 seconds otherwise). The control unit must be located within 2 m of the appliance (this also applies to 'split-level' cooking appliances).

3.4 Water -Heater Circuits

Generally derived from a 15 A or 16 A way, the circuit must incorporate a double-pole switch (usually of 20 A rating), with an additional switch recommended in close proximity to the immerser unit which should be connected by using heat- resisting flexible cable or cord.

Voltage drop in Circuits

If any conductor carries a current there will be a loss of voltage between both ends of the conductor. This loss or 'volt drop' is $V=IxR$, where V is the volt drop,I is the current in the conductor and R *is* the conductor resistance. The effect of serious volt drop is to reduce the effective performance of lamps, heaters and other electrical devices. To limit volt drop in any circuit, the IEE Regulations impose a maximum drop of 4 per cent of the nominal circuit voltage. Thus, on a 240 V supply, the drop between the consumer's terminals and the farthest end of any circuit in the installation is 9.6 V. It is the concern of the installation designer, and often the electrician, 10 choose a size of circuit conductor for a particular load so that this figure is not exceeded. The Current-rating Tables in the Regulations indicate the volt drop (in millivolts [mV|) when a current of 1 A flows through a 1 metre length of a particular cable. This rnV figure is then multiplied by the actual load current in the cable and also by the length of cable run, to arrive at the total volt drop. If, for a particular size of cable, the total volt drop exceeds 9.6 V (for a 240 V supply), the next size of cable is chosen in turn until the final volt drop is less than 9.6 V. Other factors are, however, required to be taken into account when choosing the initial size of cable, such as the cable's ambient temperature, the cable's installation condition (e.g. bunched with other cables), the circuit protection (e.g. semi-enclosed fuse or MCB), and whether the cable is in contact with thermal insulation material. The IEE Regulations require that the choice of a cable to feed a particular circuit must have regard for a number of factors, and not just the circuit current.

The Regulations require that the method used to choose the correct size of a conductor be based on the rating of the protective overcurrent device. Al! factors which affect the rating of the cable in its installed condition are applied as divisors to the rating of the protective device, as the following examples show. The process involved in working out the correct cable size, and the final volt drop, is as follows:

1.First find the load current of the circuit *(I_B)*.

2.Determine the correction factor for the ambient temperature in which the cable

is to be installed (the highest temperature is always taken).

3.Determine the correction factor for grouping C_a, if the cable is run with others.

4.Determine the correction factor *C-*, if the cable is in contact with, or surrounded by, thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material (e.g. cable clipped to a joist) and 0.5 if the material completely surrounds the cable.

5.Select the rating of the ovcrcurrent device. If this offers what used to be called "close protection', e.g. by an MCB, the factor is 1.0. If, however, the device is a semi-enclosed fuse, the factor is reduced to 0.725. In any case, the rating of the device must equal the circuit load current.

6.Determine the size of the circuit conductor , by calculating desired current rating.

7.Check that the volt drop does not exceed the maximum permissible allowed.

$$I_z = \frac{I_n}{C_g X C_a X C_I X 0.725}$$

where $C\ g$ is the correction factor for grouping. C_a is the factor for ambient temperature, C_i is the factor for the thermal insulation, if applicable, and 0.725 is the factor for the overcurrent protective device, if applicable.

3.5 FINAL CIRCUITS

A final circuit is defined as "A circuit connected directly to current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such 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 hoard. They also require that the wiring of each final circuit shall be electrically separate from that of 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" 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 No. 27 of the Electricity Supply-Regulations: 'All conductors and apparatus must he 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.

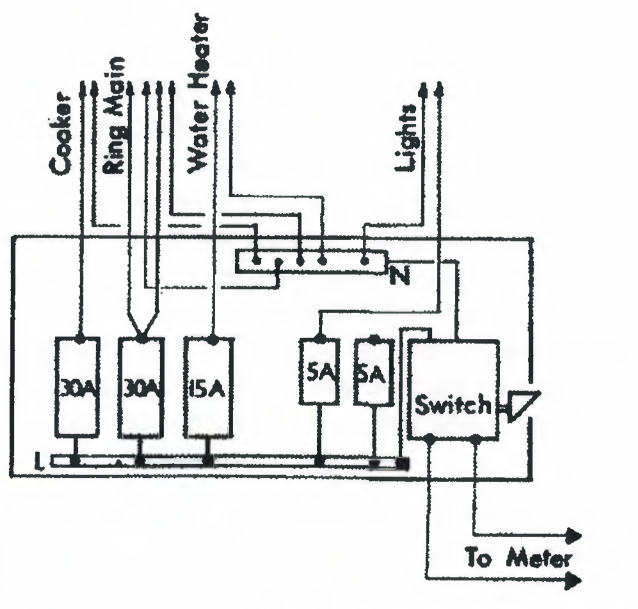
An industrial installation may have all five types; a domestic installation may have only 1, 2 and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at any early stage in the design of an installation.

Before indicating the factors which are involved in the choice of final circuit types, a few brief notes on planning aspects will he relevant.

Installation planning

(a) *Domestic installations* seem to be the simplest to plan, but there are a number of points which are worth 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 for 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 inter- mediate switching; and a large house should have two or more lighting circuits. A note in an older edition of the IEE Regulations is still relevant: 'In the interests of good planning it is undesirable that the whole of the fixed lighting of an installation should be supplied from one final subcircuit.' The reason for this is not far to seek. If an installation has two lighting circuits and one circuit fails, the house is not plunged into darkness. It is often a good point to consider a slight 'overlap' of Sighting 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 this 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 a purely functional basis. In living rooms and bedrooms, wall-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 over-looked, 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 1363 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switched 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.

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 a single socket-outlet should be provided at each side of a bed; two-gang units can be used to good advantage {e.g. to supply a bedside lamp and an electric blanket). 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 surfaces and two-gang units are recommended.

In the dining 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 fixed 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 (of the enclosed- element type) or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

(b) 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 buildings 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 lighting, wall points, etc. The service lighting is that associated with lifts, corridors, stairs, landings and is usually the responsibility of the landlord. Where a tenant's specific lighting requirements are not known when the building is being erected, the lighting outlets are laid out on a 'grid' system, in which the outlet points are sited at regular intervals usually related to the module of the building (mat is, the basic size, multiples of which are used in the construction of the building). Generally, about 3 m are allowed between outlets. Outlets may be left on the ceiling for 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 (e.g. an office may go over to all-electric typewriters or install a computer or data-processing system), it is often difficult to extend or alter an inflexible installation. Thus, the electrical services provisions should allow for 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.

(c) *Industrial premises* require lighting installations which cater for the intensity of lighting required for the process to be carried out. In addition, local lighting at reduced voltages is 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.

(d)*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.

Circuits rated under 16A

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 (e.g. clocks, bell transformers, electric shaver supply units), provided that their rating is not greater than 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 he taken Into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favourable circuit conditions, but to provide for 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.

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 l0A of [he 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 (46A) would 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 the 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.

Circuits rated for 13A socket-outlets

Final circuits which supply 13A socket-outlets with fused plugs and i3A fused (switched or unswitched) connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maxi- mum floor area of 100 nr derived from a 30A

protective device. Radial circuits serving a maximum area of 50 nr are also protected by a 30A device, while if the area served is no more than 20 m^2 a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

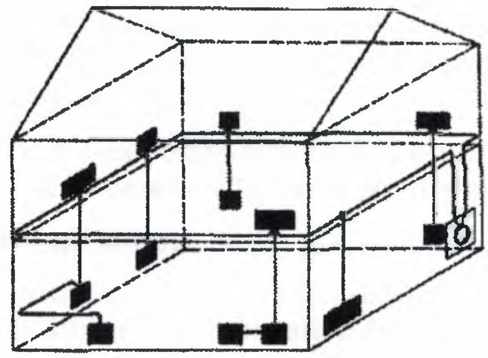


Fig 3.4. typical ring-circuit serving two floors.

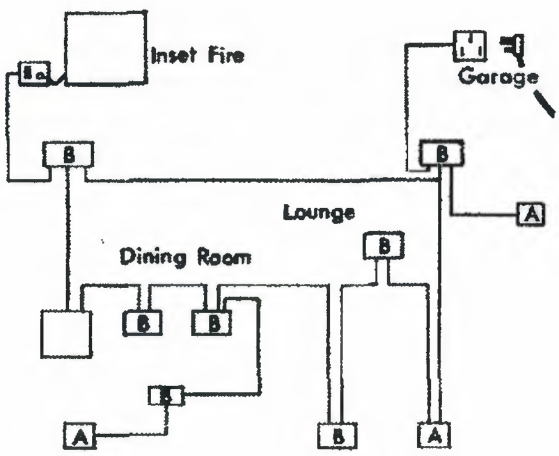


Fig.3.5 Typical ring circuit with spurs to outlying points

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 a circuit-breaker.

It is important to realise that the conductor sixes recommended for ring circuits arc 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 he run in the form of a ring, having both ends connected to earth at the distribution hoard for its equivalent).

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.

Circuits feeding discharge lamps

One of the main requirements is a consideration of the 'rating' of a discharge lamp outlet, for it has a rather different interpretation from that used for other lighting points. The reason for this is that, owing to the losses in the lamp control gear plus the low power factor (about 0.9), it is necessary to multiply the rated lamp watts by 1.8 and divide by the lamp rated voltage to obtain the actual current flowing in the circuit. It should be noted that certain switches may not be suitable for controlling the highly inductive circuits associated with discharge Sighting. If a switch is not specifically designed to break an inductive load (quick-make, slow-break), it should have a current rating of not less than twice the total steady current which it is required to carry.

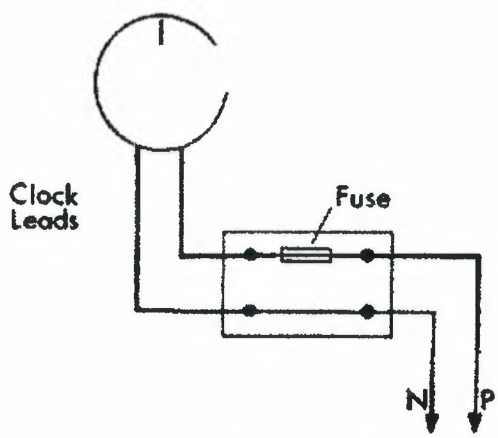


Fig.3.7 electric clock circuit

Circuits feeding motors

Final circuits which supply motors require careful consideration. In particular, cables which carry the starting, accelerating and load currents of a motor must be rated at least to the fail-load current rating of the motor. If, however, the motor is subjected to frequent starting and stopping, the csa of the cables should be increased to cater for the consequent increase in conductor temperature. More than one motor may be connected to a 16A final circuit, provided that the aggregate full-load rating of the motors does not exceed 16A. If a motor lakes more than 16A full-load current, it should be fed from its own final circuit.

Final-Circuit Protection

Protection of final circuits is by means of fuses, circuit-breakers or miniature circuit-breakers located at switchboards and distribution boards. The protection is for over-currents caused by short- circuits between conductors, between conductors and earth, or overloads. The protective gear should be capable of interrupting any short-circuit current that may occur without danger of fire risk and damage to the associated equipment. In large installations, where there are main circuits, sub-mains and final circuits, it is often necessary to introduce a discriminative factor in the provision of protective gear. Where circuit-breakers are used, discrimination is provided by setting sub-circuit-breakers to operate at a lower over-current value and a shorter time-lag than the main circuit- breaker. Thus, if a fault occurs on a final circuit, the associated gear will come into operation, while the main breaker remains closed. However, if the fault persists, or the sub-circuit-breaker fails to operate within its specified time (e.g. 2 seconds), the main breaker will trip out (e.g. 0.5 second later).

Fuses are often used for back-up protection of circuit-breakers. Generally, where cartridge fuses are used the fuse will operate before the circuit-breaker, particularly in the event of a short-circuit current. Where small over-currents occur (e.g. overload) the circuit-breaker is likely to operate before the fuse blows.

Where full use is made of cartridge fuses, their ratings, type and make should be consistent for each circuit protected. The rating of sub-circuit and main fuses should be chosen so that in the event of faults the sub-circuit fuses blow first. Generally, discrimination between the fuses can be obtained if the rating of the sub-circuit fuses does not exceed 50 per cent of the rating of an associated main fuse. If this margin is too large, reference should be made to the data provided by the fuse makers.

Discrimination is very difficult to obtain with any degree of accuracy where cartridge fuses and semi-enclosed rewirable fuses are used together because of the many factors which are involved in the operation of the latter type of fuse. These include the type of element, its size, the ambient temperature, its age and its material.

Choosing cable sizes

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 (grouping). There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when overcurrents 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 situations produces an environment which can quickly lead to the deterioration of the cable insulation (particularly when PVC is involved) and lead to a becomes very soft, so that a conductor can 'migrate" or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, with 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 dependent on the ability of the over-current protection device to operate to disconnect the circuit from its supply. As is probably realised, 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 a 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 recognise the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. The regulations list 20 standard methods of installation (Table 4A of Appendix 4), each of which is identified by "Methods'. These classifications are used in the tables which give the current-carrying capacities of cables. The installation conditions include "enclosed" (e.g. in conduit trunking and ducts); 'open and clipped direct' (e.g. clipped to a wall, to a cable tray, embedded direct in plaster which is not thermally-insulating, and suspended from a catenary wire); 'defined conditions', which include 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 a particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

(a) the ambient temperature in which the cable is installed;

(b) the installation condition, e.g. whether grouped or bunched with other current-carrying cables, enclosed or installed 'open';

(c) whether the cable is surrounded by or in contact with thermal insulating material;

(d) whether the circuit is protected by semi- enclosed (rewirable) fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by the IEE Regulations, is based on the rating of the overcurrent protective device. Ail factors affecting the cable in its installed condition are applied as divisors to the rating of the device, as the following examples show. The requirement of Regulation 525-01-02 must also be considered. In general, the size of every hare conductor or cable conductor shall be such that the 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. Values of volt drop per ampere per meter are given in the current rating tables in Appendix 4 of the Regulations, In this context, it should be noted that conductors of large cross-sectional area have different volt drops per ampere per meter for ac circuits than those operating from dc supplies. This is because of the reactance inherent in conductors carrying ac.

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

1. First find the load current of the circuit (I_B),

2. Determine the correction factor for the ambient temperature which 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 for grouping. Here we refer to Table 4B1 of the Regulations

4. Determine the correction factor if the cable İs in contact with or is surrounded by thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material {e.g. a cable clipped to the side of a joist) and 0.5 if the cable is completely surrounded by the material.

5. Select the rating of the overcurrent 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 in Tables 9D1A to 4L4A in

7. Check that the volt drop does not exceed the maximum permissible allowed by Regulation 525-01-02.

If I_z represents the current rating of the conductor and I_n the rating of the protective device, then

$$I_z = \frac{I_n}{C_g X C_a X C_I X C_f} \quad \textit{amperes}$$

where C_g is the factor for grouping;

C_a is the factor for ambient temperature;

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

C_f is the factor for the overcurrent device. This factor is 1 for ail devices except semi-enclosed fuses, when the factor is 0.725.

CHAPTER 4

4.0 CONDUCTORS AND CABLES

4.1 Definition of conductors

A conductor is a material which offers a low resistance to a flow of current. Conductors for everyday use must be (a) of low electrical resistance, (b) mechanically strong and flexible, and *(c)* relatively cheap. For example, silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are tin, lead, and iron.

Formation of conductors

Electrical conductors are usually made of copper, although aluminium is being used to a greater extent, particularly as the price of copper increases. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. The copper wire is then dipped into a tank containing molten tin. This is done for two reasons: *(a) to* protect the copper if the wire is to be insulated with vulcanized rubber, as this contains sulphür which attacks the copper; and *(b)* to make the copper conductor easier to solder. Aluminium wire is also drawn from a solid block but is not tinned.

Aluminium

1.Smaller weight for similar resistance and current-carry ing capacity

2.Easier to machine

3.Greater current density because larger heat-radiating surface

4.Resisiivity 2-845 μΩ-cm

5.Temperature coefficient practically similar (0-004 Ω/Ω degC)

Copper

1.Better electrical and thermal conductor, therefore lower C.S-A, required for same voltagedrop
2.Greater mechanical strength

3.Corrosion resistant

4.High scrap value

5.Much easier to joint

6.Lower resistivity: l-78μΩ-cm

The determining factor in the use of one type of metal for conductors is usually that of cost. The future trend in costs will be for the price of aluminium to drop relative to that of copper, as the underdeveloped countries achieve the industrial capacity necessary to work their bauxite (aluminium ore) deposits.

Stranding of Conductors. Conductors were often stranded to make the completed cable more flexible. A set number of strands are used in cables: 1, 3, 7, *19,* 37, 61, 91, and 127. Each layer of strands is spiralled on to the cable in an opposite direction to the previous layer. This system increases the flexibility of the completed cable and also minimizes the danger of 'bird caging', or the opening-up of the strands under a bending or twisting force.

Size of Stranded Conductors. The size of a stranded conductor is given by the number of strands and the diameter of the individual strands. For example. & 7/0-85 mm cable consists of seven strands of wire, each strand having a diameter *(not* cross sectional area) of 0-85 mm. Solid (non- stranded) conductors are now being used in new installations.

Bare Conductors. Copper and aluminium conductors are also formed into a variety of sections, for example, rectangular and circular sections, for bare conductor systems. *Applications,* Extra-low voltage electroplating and sub-station work.

The following precautions must be taken with open bus-bar systems (above extra-low voltage). They must be: *(a)* inaccessible to unauthorized persons, *(b)* free to expand and contract, and *(c)* effectively insulated. Where bare conductors are used in extra-low voltage systems they must be protected against the risk of fire.

4.2 INSULATORS

An insulator is a material which offers a very high resistance to a flow of current. An insulator should have certain electrical, mechanical, physical, and chemical properties.

Electrical Properties: It must have high resistance.

Mechanical Properties: It must be capable of withstanding mechanical stresses, for example, compression.

Physical Properties. The perfect insulator would have the following physical properties: (a) non-absorbent; (&) capable of withstanding high temperatures.

Chemical Properties. An insulator must be capable of withstanding the corrosive effects of chemicals.

No insulator is perfect and each type is picked for a particular application. For example, porcelain and fireclay are relatively good insulators, but could not be used for covering conductors forming a cable because they are not flexible. P.V.C. is also a good insulator, but cannot be used in conditions where the temperature exceeds 45 °C—for example, insulation for electric fires. Other examples of insulators are mica, wood, and paper.

4.3 CABLES

Definition of Cables

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor(solid or stranded), or of two or more such conductors,, each provided with its own insulation, which are laid up together. The insulated conductor or conductors mat or may not be provided with an overall covering for mechanical protection.'' A cable consist of two basic parts:(*a*) the conductor;(*b*) the insulator.

4.3.1 Construction of cables

A cable usually derives its name from the type of insulation used Polyvinyl Chloride (P.V.C.,} Cable. This is termed a 'thermo plastic' cable as the insulation is formed from a synthetic resin which softens when heated. The process of manufacture is as follows:

1.The p.v.c, is extruded on. to the conductors by passing them through & die into which soft p.v.c. is forced.

2.The formed cable is then passed through a trough of cold water t harden the plastic insulation.

Multi-core Cable: This is cable which is made up of two or more insu lated conductors. Multi-core cable is sheathed in a protective covering— for example, tough rubber for tough rubber-sheated cables (_t.r,s.) and p.v.c, for plastic cables.

Tough-Rubber-Sheated (t.r.s) Cable: This is made of specially toughened rubber which is resistant to acids and alkalies. Specially" constructed t.r.s., which has been reinforced with tape and an external braiding; is used to farmyards.

Polychloroprene (p.c.p or neoprene) Cable: An insulation somewhat similar to that of t.r.s but capable of withstanding most weather conditions and particularly direct sunlight.

Heat-resisting, Oil-resisting and Flame-retardant (h.o.f.r) Cables:

These cables are used in conditions damaging to P.V.C. cables such as high temperature and oil. The resistant qualities are developed by a vulcanizing (or curing) process which forms an elastomer capable of withstanding tough conditions and still retaining its flexibility. The following are examples of cables using elastomer material: c.s.p, chlorosulphonated polythene), butyl rubber, silicon rubber, ethylene propylene rubber (e.p.r,).

The maximum operating temparature for both rubber and p.v.c. insulated cables is 45 degrees.

4.3.2 Flexible Cables and Flexible Cords

The I.EE Regulations define a flexible cable as: " A cable consisting of cores, each containing a group of wires, the diameters of the the construction of the cable being such as to afford flexibility'' A flexible cord is defined as; 'A flexible cable in which the cross-sectional of each conductor does not exceed $4mm^2$".

Twisted Twin Flex Cable: This is made up of a multi-strand tinned-copper conductor with silicon rubber insulation. *Application:* lighting flex.

Circular Flex: The rubber-insulated cores are formed into a circular section to cotton worming and contained in a cotton, braiding. *Applications :* connections to household appliances (irons, kettles, etc.).

Circular Flex Rubber Sheathed: This flex is also packed with jute or cotton to form a circular cross-section but an outer sheath of rubber replaces the cotton braiding. *Applications:* vacuum cleaner and portable drill leads (3-core).

Workshop or (industrial) Flex (Fig 2.3): This flex is similar in construction to the above , but has the addition of a compounded braiding. *Application*: connections to industrial lighting.

4.3.3. Outdoor Cable

The I.E.EE Regulations underline the need for adequate mechanical protection when cables are used outdoors and the importance of having sufficient support to avoid mechanical strain. They also supply tables showing the necessary spacing for supports and the minimum allowable radius for bends.

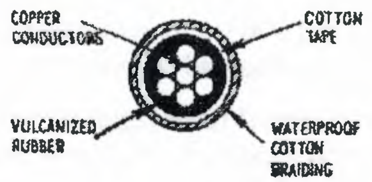


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Fig. 4.1 House service over-head system(H.S.O.S) cable

H.S.O.S. (House Service Overhead System) Cable (Fig. 4.1): H.S.O.S. cable is constructed as follows: *(a)* hard-drawn copper conductor, *(b)* rubber insulation, *(c)* varnished tape, and *(d)* outer coating of compounding braiding. *Application:* house-to-house overhead supplies.

NOTE :p.v.c insulated copper and aliminium cables are gradually replacing this cable, except in conditions where creosote is present, at this attacks the p.v.c insulation.

4.3.4. Cable Sizes: Use of I.E.E. Tables

The I.E.E. Regulations contain comprehensive information regarding the curret carrying capacity of cables under certain conditions.

These tables supply: *(a)* cross-sectional area, number$_s$ and diameter of conductors; (b) type of insulation; *(c)* length, of run for IV drop; *(d)* current rating (a.c. and d,c.), single and bunched. The following terms are used in the I.E.E. tables:*(a)*ambient temperature and (b} rating factor.

Ambient Temperature: This is the temperature of the air surrounding the conductor. The current rating of a cable is decreased as the temperature of the surrounding air increases, and this changed current-carrying capacity can be calculated by using the relevant rating factor.

Rating Factor: This is a number, without units, which is multiplied with the current to find the new current-carrying capacity as the operating conditions of the cable change. For example, a twin-core 10 mm^s (7/1.35 mm) p.v.c cable will carry a maximum current of 40A at an ambient temperature of 25‘C , but if the ambient temperature is increased to 65’C the maximum current allowed will now be:

$$40A \times 0.44 \text{ (rating factor)} = 17.6 \text{ A}$$

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carrying capacity will decrease: a rating factor is therefore supplied for the bunching , or grouping of cables.

Permissible Voltage Drop in Cable: Voltage drop is another essential feature in calculation of cable size, as it is useless installing a cable which is capable of supplying the required current if the voltage at the consumers equipment is too low. Low voltage at the consumer's equipment leads to the Inefficient operation of lighting, power equipment,, and heating appliances. The maximum voltage drop allowed between the consumer's terminals and any point In the installation is 2-5 per cent of the voltage supplied by the Electricity Board, including motor circuits.

Voltage Drop and the I.E.E. Tables: The I.E.E. tables state the voltage- drop across a section of cable when maximum current Is flowing through it. If the current is halved, the voltage drop will also be halved. For example, a 4 mm^2 twin-core cable has a

current rating of 24 A and a voltage drop of 10 mV per ampere per meter. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per ampere per meter.

New Voltage Bands: Extra-low voltage (Band I) now covers voltages not exceeding 50 V a.c. or 100 V d.c. (measured between conductors or to earth). The new low voltage range (Band II) is from extra-low voltage to 1000 V a.c. or 1500 V d.c., measured between conductors, or 600 V a.c. and 900 V d.c. between conductors and earth.

Current Density and Cable Size: The current density of a conductor Is the amount of current which, the conductor can safely carry without undue heating per unit cross-sectional area. For example, If a copper conductor has a current density of 300 A/cm^2 a copper conductor of cross-sectional area 0-5 cm^2 will be capable of carrying one half of 300 A, that is, 150 A.

To calculate the current-carrying capacity of a cable (given cross-sectional area (cm^2) and current density (A/cm^2)):

Current-carrying capacity = current density X cross-sectional area

4.3.5 Resistance of a Conductor

The resistance which a conductor offers to a flow of current is determined by three factors: (a) the length of the conductor ,(b) its cross-sectional area, and (c) type of material used.

Length: If the length of a conductor is doubled , for example, from 100m to 200m , the resistance of that conductor will also double.

Resistance R (in ohms) is *directly* proportional to length l

Cross-sectional Area: If the cross-sectional area a of a conductor is doubled , for example, from 0.1 cm^2 to 0.2 cm^2 ,the resistance of that conductor will be halved.

Resistance R (Ω) is inversely *proportional* to cross-sectional area a

Resistivity (Specific Resistance) : This is the factor which takes into consideration the type of material used. The resistivity of a material is the resistance of a unit cube of that material$_s$ measured across opposite faces of e, If the resistivity of copper is given as 1.7μΩ-cm' Then the resistance measured across opposite faces of a centimetre cube of copper will be 1.7μΩ This may also be written 1.7x10^{-6}Ω-cm or 1-7 microhm-centimetre (uΩ-cm). (1uΩ is one millionth of an ohm.) The symbol of resistivity is ρ (Greek letter rho).

$$R = \frac{\rho l}{a}$$

Where R is resistance (Ω), ρ=resistivity, l=length , and a = cross-sectional area.

*NOTE:*Since resistivity is usually given in ohm-centimeters or microohmcentimeters, the length of the conductor must be changed to centimeters.

4.3.6. Effect of Heat on a conductor

When a current is passed through a conductor the temperature of that conductor rises; an extreme example is the element of an electric fire. The effect of this heat on the resistance of the conductor depends on the composition of the conductor. The resistance of pure metals such as copper and aluminium, increases as temperature increases.The resistance of certain alloys-for example, constantin and manganin-remains relatively constant with increases in temperature. But the resistance of carbon and electrolytes(liquid use in batteries) decreases with increases in temperature.

Temperature Coefficient : The temperature coefficient of a material is the increase in the resistance of a 1Ω resistor of that material when it is subjected to a rise in temperature of 1degC. For example, if copper has a temperature coefficient of 0.004 ohm per ohm per degree celcius (0.004Ω/Ω deg C) a copper resistor of 1 Ω will increase in resistance to 1Ω +0.004Ω if heated through 1deg C. The symbol for temperature coefficient is α (Greek later alpha).

Pure metals, such as copper and aluminium, have a *positive* temperature coefficient, that is, their resistance increases as temperature increases, Carbon and electrolytes have a *negative* temperature coefficient, that is, their resistance decreases as temperature increases.

Calculating Resistance Increase: There are two formula for calculating the increase the resistance of a conductor due to temperature change:(a)temperature increases from 0 deg. C ; (b) temperature increases between two intermediate temperatures.

(a) *Temperature increases from* 0 °C:

$$R_f = R_0(1 + \alpha t)$$

Where R_0 =resistance at 0°C, R_f = final resistance , α = temperature coefficient, and t = rise in temperature.

(b)Temperature increases between two intermediate temperatures:

$$\frac{R_2}{R_1} = \frac{1+\alpha t_2}{1+\alpha t_1}$$

Where R_1 = 1st resistance , R_2 = 2nd resistance , α = temperature coefficient, t_1 = 1st temperature and t_2 = 2nd temperature.

4.3.7. Terminating and Jointing P.V.C Cables

Stripping P.V.C Cables: A single core p.v.c cable should be stripped by holding the cutting knife at an angle to the cable (fig. 2.5), and cutting away from the hand holding the cable. Multi-core cable is stripped by the cutting knife along the center of the cable and then nicking the end of the cable to give two finger grips. This allows the sheathing to be pulled down the cable with the thumb and forefinger of each hand. The sheath is then folded on top of the cable and cut by drawing the knife between the sheathing and the cable

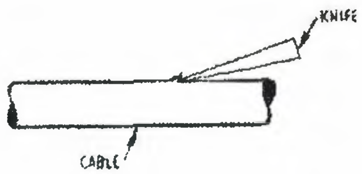


Fig. 4.2 Stripping cable

There are two basic methods of joining electrical conductors: *(a)* mechanical joints; and (b) soldered joints;

Mechanical jointing: This is done by using connector blocks. These consist of one-way or multi-way brass terminal blocks enshrouded with porcelain or plastic insulation. The connector must be capable of containing all the strands of the conductor.

Another method, usually used with larger cables, is mechanical crimping. This is done by placing a sleeve over the conductors to be jointed and crimping (squeezing) the connection with a manual or hydraulically operated crimping jack.

Soldered Joints: Materials required: pliers, sharp knife, soldering bit , flux, blowlamp (or butane gas cylinder), solder, p.v.c tape and black insulating tape.

Soldering Bit : Every joint which is made by twisting strands together must be soldered. Where a lot of single-core jointing is being carried out, it is of convenient to use a heavy bit which has a slot field in it to take cables. The soldering bit should be heated uuntil a green flame appears and must always be kept clean. Always 'tin' the bit with flux and solder before using.

Flux: The purpose of the flux is to remove the oxide film from the surface of the conductor and prevent it from re-forming.

NOTE: Corrosive fluxes, such as 'killed spirits', must not be used when soldering electrical connections.

Blowlamp: This is should be operated as follows:

1. The lamp should not be more than two-thirds full.

2. Leave the valve open when starting.

3. Start lamp with small rag dipped in methylated spirits.

4. When the lamp is hot, the valve should be closed and the pump operated.

5. The pump forces the paraffin through the heated vaporizing tube and out of the nozzle where it is ignited under pressure.

6. The blowlamp should be played against an asbestos sheet until the flame is fully established.

Bottled gas (propane and butane) is displacing the blowlamp as the former is cleaner and quicker.

Solder. Two basic types of solder are used in electrical work: fine solder (tinman's solder), which is 60 parts tin and 40 parts lead, and plumber's metal, which is 30 parts tin and 70 parts lead. Fine solder melts more easily, as tin has a lower melting point than lead, and so it is commonly used for electrical joints. Plumber's metal is used for 'plumbing' joints in armoured cables, as it remains in a plastic state, allowing it to be shaped, longer than fine solder.

Methods of Soldering: There are three different methods used for soldering conductors: *(a)* soldering bit, *(b)* 'stick* method, and (c) (metal) pot and ladle method.

Soldering Bit: The conductors to be jointed are first smeared with a resin- ous flux. The tinned bit is then applied under the joint until the heat penetrates it. The stick of solder is then applied to the joint until the solder flows freely through it.

'Slick' Method: In this method, the joint is first heated with a blowlamp, flux being applied. The solder is then applied by pressing the stick of solder against the heated joint until it penetrates the joint. Care should be taken to protect the insulation against the blowlamp flame.

Pot and Ladle Method. This method is commonly used by jointers when jointing heavy conductors. A solder pot is heated until the solder is running freely. The solder should not be overheated as this will burn the tin and a dross will form on the surface of the solder. When the solder has reached working temperature it is taken from the pot with a ladle. The solder is then poured over the prepared joint and is caught by another ladle placed under the joint. This action is repeated until the solder penetrates the joint.

Soldering Aluminium: The following special points should be noted when soldering aluminium:

1.All surfaces must be scrupulously clean.

2.When making a joint between stranded conductors 'step' the strands to increase the surface area.

3.The surface must be heated *before* the flux is applied as the flux will only take when the temperature is high enough.

4.Apply aluminium solder until the complete surface is bright. Joints in aluminium should be protected from contact with the atmosphere.This can be done by painting, taping, or compounding

Soldering a Socket (or Lug): The method used is as follows:

1.Strip insulation back about 5 cm

2. Tin the socket.

3. Smear both the socket and the bared conductor with. flux.

4. Fit the socket to the conductor. The socket should be a hammer fit.

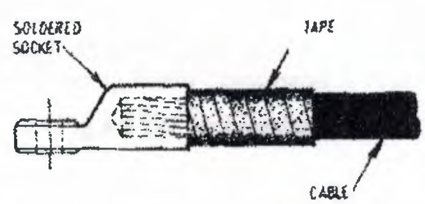


Fig 4.3 Section through soldered socket

If the socket is too large, the conductor can be enlarged with a tinned-wire binding or, better still , by pressing a strand of cable into the center of the conductor.

5. Play the blowlamp in the top of the socket until the heat has penetrated the conductor, and then apply a stick of solder to the lip of the socket. The completed connection should have a rim of solder showing round the lip of the socket; this can be done by applying plumber's metal as the joint is cooling.

6. When the termination is cooled, cut back damaged insulation and apply p.v.c. or cambric tape.

7. Tape is used to replace insulation which has been removed prior to jointing. It should be stretched before being applied, p.v.c. tape is also used for this purpose. Black tape should only be used as a protective outer covering on a joint.

NOTE: Do not attempt to cool a soldered joint by pouring water over it, as this cAN lead to an ineffective soldered connection, often termed a 'dry joint'. Never use a file to smooth or clean-up a soldered connection; the solder should be smoothed by wiping it with a dry rag before it sets.

Through Joint : This type of joint is made by using mechanical connectors,

compression ferrules or grip-type (weak backed) soldered sleeves.

Straight-through Joint using Weak-backed Ferrule: A weak-backed ferrule is a tubular piece of tinned-copper opened along the top and weakened at the bottom by indenting, allowing it to be opened or closed easily. The joint made as follows:

1. Strip Insulation back from the end of both conductors.

2. Clean and tin ferrule.

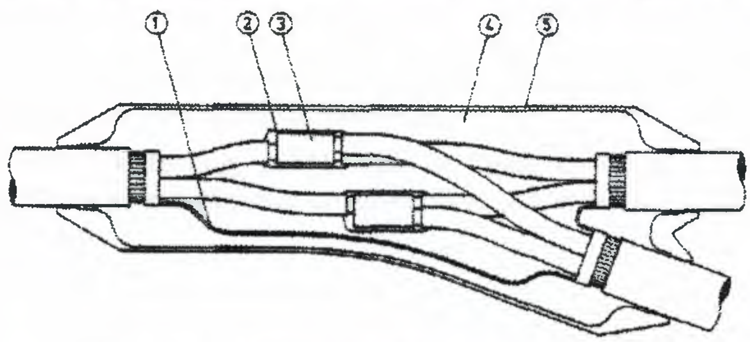
3. 3.Place ferrule on cable. Butt cables together before tightening ferrule.

4.Wind small pieces of rag at each end of ferrule to contain molten metal.

5.Solder connection.

6.Remove damaged insulation and tape.

Tee (or Breeches) Joint (Fig. 4.4). This type of joint is commonly used to tee-off a service from an armoured cable. The weak-backed ferrule is often used but alternative methods are the mechanical connector or the compression ferrule.



1.Armour Bond 2. Primary Insulation 3.Conductor Connection
4. Cold Pouring Resin Compound 5. Plastic Box

Fig 4.4 Tee (or breeches) joint

4.3.8. Types of Armoured cable

This cable is used where there is a likelihood of mechanical damage to conductors or insulation, for example, underground cable runs. There are two main types of armoured cable: *(a]* lead-covered paper-insulated steel wire, or steel tape, armoured cables (shortened to P.I.L.C.S.W.A. and P.I.L.C.S.T.A, respectively) and *(b)* p.v.c. armoured cable.

P.I.L.C.S.W.A. Cable: This consist of the following parts

1.An inner heart of jute used to keep the cable circular.

2.Copper, or aluminium, conductors insulated with mineral oil impregnated paper.

3.A lead sheath which contains the insulation and is also used as an earth continuity conductor.

4.Jute bedding tape impregnated with bitumen,, used to protect the lead against the armouring.

5.Galvanized steel wire (one layer) or steel tape (two layers).

6.Bitumen-impregnated jute serving.

Termination of P.LL.C.S.W.A. Cable: When terminating at the sealing chamber the following procedure should be followed,

1. Place binder 1 m from end of cable,
2. Remove serving to this point (using blowlamp to loosen, if necessary)
3. Bend steel wire armouring back until it is clear of lead sheath.

4.Remove approximately 12cm of lead sheath and clean remainder.

5.Place brass gland on cable, leaving approximately 10cm of lead sheathing. Wedge gland with wood to keep central on cable.

6. Plumb joint, using plumber's metal. Tallow is used as flux.

7.Clean galvanized wire with paraffin rag and shape wire over plumb.

8.Clamp wires to gland and bolt gland to sealing chamber.

9.Cut back paper insulation on conductors and make V.R.I, conductors, using weak-back ferrules.

10. Assemble sealing chamber and pour in hot bitumen to seal oil impregnated paper insulation against moistxire.

P.V.C. Armoured Cable (fig. 2.11). This is made up of p.v.c. insulated cores packed with p.v.c. to give a circular cross-section. An outer p.v.c, sheath covers the galvanized steel wire.

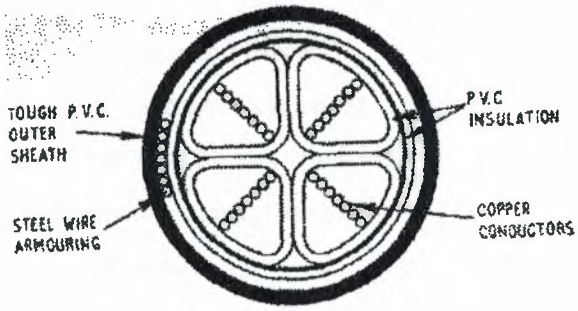


Fig. 4.5 P.V.C armoured cable.

Jointing p.v.c Armoured Cable: p.v.c. armoured cable may be terminated and jointed at the type of cast-iron boxes used for P.I.L.C.S.W.A. armoured cable, although plastic boxes are often used.But the following points require consideration:

1.p.v.c. insulation must be protected against heat (for example with cloth or tape).

2.p.v.c. tapes should be used for insulating the conductors.

3.Particular care must be taken with the cleaning and clamping of the galvanized wire armouring, as it is often the sole earth continuity conductor.

4.Compound Temperature, The temperature of hot pouring compound should be such that it does not melt the p.v.c. insulation of the conductors. This can be checked by dipping a piece of scrap p.v.c. Into the compound before pouring.

NOTE:tables 5M, 6M , and 25M of the I.E.E Regulations give current ratings for p.v.c. armoured cables(copper and aliminium conductors).

4.3.9 Mineral –insulated Metal-sheated (M.I.M.S) Cable

This type of cable is often referred to as M.I.C.C(copper or aliminium covered) cable. M.I.M.S cable consist of three parts:

1.Coppper or Aluminium Conductors. Each core consists of a single copper ar. Common core numbers are: 1, 2, 3, 4, and 7.

2. Insulation: The insulation between the cores is magnesium oxide (magnesia); a material capable of withstanding high temperatures but which is absorbent to moisture.

3. *Outer Sheath.* This is a seamless copper or aluminium tube. The cable is formed by drawing a section through a series of dies, so that the relative distance between the cores and the sheath is constant during the manufacture and use of the cable.

NOTE: Tables 13M to 17B of the I.E.E. Regulations give the current ratings.

Terminating M.I.M.S. Terminations are made at special glands. The procedure for termination is as follows :

1. Slip gland nut, compression ring (sometimes termed 'olive'), and and body on to cable.

2. Strip sheath using stripping tool

3. Screw on sealing pot (forced thread),

4. Slip disc and sleeve assembly on cores.

5. Press compound into sealing pot (making

6. Crimp sealing pot with crimping tool.

Clean off surplus compound.

Outline of Regulations relating to Conductors and Cables

1.correct voltage rating must be used in all cables.*NOTE:*A 250V grade cable is aloowed in 415V 3-phase systems where the neutral is earthed.

2.The voltage drop in a consumer's installation must not be exceed 2.5 per cent of supply voltage.

3.Every conductor must be identified by:colour, sleeves, numbers(paper insulation), or disc.

4.Single-core armoured cable must not be used for a.c.

5.The current ratings given in the J.E.E. Regulations must not be exceeded or overheating will result.

6.All cable terminations must be *(a)* mechanically and electrically sound, *(b)* accessible for inspection (unless buried); *(c)* free of mechanical strain, and *(d)* capable of containing *all* the strands of the conductor. Do *not* nick or cut strands as this decreases the current-carrying capacity of the cable and may lead to overheating at the termination.

7.Joints between two different metals (for example, copper and aluminium) should be protected against corrosion. If it is a clamp connection, the copper should be tinned in order to prevent electrolytic action .

8.Insulation removed from a conductor during the making of a joint should be replaced by a suitable tape,

9.Joints in M.LM.S, must be protected against moisture.

10.Fluxes containing acids must *not* be used for electrical jointing.

11.Terminations in & sheathed-cable system (for example, p.v.c. or t.r.s.) must only be made at enclosed positions. The enclosure containing the termination must be made of an incombustible material (for example, hard-wood block or plastic pattress).

12.Flameproof fittings must be used when cables are terminated under conditions where inflammable materials or gases are present (for example, paint spray shop).

13.t.r.s. must not be installed in direct sunlight without a protective covering.

14.Maximum operating temperature for cables: rubber, 55 ^{C}C and p.v.c., 65 ^{C}C; impregnated paper, 75 ^{C}C.

15.Flexible cable and flexible cord (exceeding 30 V a.c.): Flexible cable of the circular type should only be used for connections to movable equipment. Twisted flex should only be used for fixed lighting fittings, *not* for portable appliances. Ail flexes must be protected from mechanical damage.

16.Cables installed under floors or above ceilings should be positioned so that they are riot damaged by contact with the floor or ceiling or any fixings (e.g. nails or screws). Where cables are run through a wooden joist they should be at least 50 mm from the top or the bottom of the joist, or inserted in securely fixed mechanical protection (e.g. steel conduit).

17.All non-sheathed cable should be mechanically protected e.g. inserted in conduit, trunking or ducting.

18.M.I.M.S. and armoured p.v.c.-insulated cable should be protected with an extruded p.v.c. sheath where they are exposed to the weather or fitted in wet, damp or humid conditions (e.g. concrete ducts).

4.4 PLASTIC PIPES

In past, iron pipes were used but in today's the plastic pipes is used. They can bended however you want. Their life is long and also they do not effect from corrosion. You can work easily with them. They are produced at standard sizes and length, which is 3 meters.

Table 4. 1 Plastic pipes thickness and length

Inch	MM	Length (M)
5/8	16 mm	3
3/4	20 mm	3
1	25 mm	3
1 ¼	32 mm	3
1 ½	38 mm	3
2	50 mm	3

CHAPTER 5

5.0 CONDUIT,TRUNKING AND DUCTING

The wiring systems described in this chapter deal with basic enclosures which are designed to accommodate single insulated non-sheathed conductors. They are, of course, used for sheathed cables where additional protection from mechanical damage is required. Both conduit and trunking are available in steel and PVC. Non-ferrous conduit various alloys) is used for specialized work.Conduit is also available in a flexible form.

5.1Conduit

5.1.1. Steel Conduit

The most common form of conduit used today is screwed steel with a welded seam or solid drawn (used in hazardous areas where there is a high risk of fire and explosion). A light-gauge conduit is also available with its use restricted to providing protection for flush PVC cable installations. Two finishes for conduit are: black enamel (dry situations) and galvanised (for outdoors and situations where dampness is present).

The main advantages of steel conduit include its ability to give conductors good protection against mechanical damage; it allows easy rewiring; fire risks are minimised; and the conduit can be used as a circuit protective conductor (cpc), though it is common practice to run a separate CPC in the conduit.

Steel conduit has a few limitations, including the problem of a build-up of condensation in situations where the temperature tends to fluctuate (this can be avoided by providing drain points in the length of run); it is expensive to erect (it is a labour intensive system having to be measured, cut, threaded and erected before wires are drawn in); and it is liable to corrosion in adverse environmental conditions.

A full range of accessories are used with screwed steel conduit: bends, tees, draw-in boxes and adaptable boxes; all of these give a high degree of flexibility in allowing alterations to be made to an existing conduit system. In fact, once installed in the appropriate conditions a conduit system has a very long life, providing a car cass which can be completely rewired over several periods in the life of a building.

Conduit is available in four sizes (measured on its outside diameter): 16, 20, 25 and 32 mm; the normal length is 3.75 m. The Wiring Regulations restrict the number of conductors that can be drawn into conduit. This is to allow for ventilation of current-carrying cables, to allow for removal and replacement of conductors and, in some cases where the existing conduit capacity is not up to its limit, to allow new circuits to be drawn in. Although manufacturers' conduit bends can be obtained, on site conduit is bent on a bending machine which ensures that the minimum internal radius of the bend is equal to *2½* times the outside diameter. If, however, a bending block (made from a baulk of wood) is used it is essential that the internal radius of the bend complies with the dimension given.

5.1.2. PVC Conduit

Where appropriate, PVC conduit is a popular, and inexpensive, alternative to steel conduit. It is available in both light and heavy grades and does not need to be threaded unless so specified by the job. The conduit is available as rigid, semi-rigid, flexible round (for surface and embedded work) and in an ova! shape (for switch drops). Grades of PVC conduit include super high impact, standard impact, and high temperature (up to 85 *°C)*.

Because the expansion rate for PVC conduit is around five times that of its steel equivalent, expansion couplers are needed in long runs (at every 8 m). Where the conduit IS to be used in damp situations, a special non-setting adhesive ensures a seal which allows for movement as temperatures fluctuate.

Note: The adhesives used with PVC conduit will give off fumes which create a health hazard and thus the electrician is advised to ensure that the working plaee is well ventilated. Contact with the skin should also be avoided.

A wide range of conduit accessories is available, similar to those for steel conduit.

5.1.3. Flexible Conduit

Flexible metallic conduit is often used to make a suitable connection between a rigid conduit system and, for example, a motor which may be required to be moved for belt tensioning, belt removal and replacement. Several types are available. A separate CPC is needed, run either inside the conduit or externally.

5.2. Trunking

Trunking is a fabricated casing for conductors and cables, generally rectangular in shape with a removable lid which allows the conductors to be laid in rather than be drawn in as is the case with conduit. It is used where a large number of conductors are to be carried, or follow the same route. Both steel and PVC trunking are available, with a wide range of such accessories as bends, tees, flanged adaptors, risers and reducers,

The variety of trunking includes plain section, compartmented, skirting, bench, floor trunking, and busbar trunking. Trunking is not necessarily a complete wiring system in itself and is thus associated with conduit and MI cables to allow connection to wiring accessories and their mounting boxes.

Finishes on steel trunking include grey enamel, galvanised and silver enamel on zinc-coated mild steel.

Compartmented trunking allows wiring at different voltages to be segregated but carried within the same unit run. This prevents services at one voltage accidentally becoming live to a higher voltage in the event of a fault.

Skirting trunking is used in offices where the services (socket-outlets, etc.) can be sited on the perimeters of rooms

Beech trunking is commonly found in schools and laboratories where access to a large number of socket-outlets is required. As the name implies, the trunking units are mounted on benches.

Floor trunking is an alternative to skirting trunking. There are three types: underfloor (where the trunking is set in a concrete floor with access only at junction boxes), flushfloor trunking (with the lid mounted flush with the floor surface) and flushduct trunking (where the lid is mounted flush with the screen) and a finish (such as parquet or tiles) is placed directly onto it.

Busbar trunking is basically plain-section trunking containing fixed copper or aluminium bars. Access to the busbars is made by means of tap-off boxes. It is often used in workshops where machinery or equipment may be shifted to different positions in the same area. Down drops are then available from the overhead busbar trunking tap-off boxes, via rigid or flexible conduits.

A variation of busbar trunking is the cable-kip trunking which is plain-section trunking containing cleats which support large csa PVC-insulated cables which form a useful ring-main supply from which fused tap-off boxes provide supplies for smaller circuits.

PVC trunking is made from high-impact PVC and is an inexpensive alternative to the steel equivalent. As with PVC conduit, allowances must be made for expansion of the trunking in high ambient temperatures.

In both steel and PVC trunking, the Wiring Regulations require a limit to ihe number of cables which can be accommodated to allow for adequate ventilation of heat generated by current-carrying cables and to allow for easy withdrawal of circuit conductors. A separate CPC must be run for each circuit run in PVC trunking.

Mini trunking is a small-section high-impact PVC with a clip-on *lid.* Used for surface work it is unobtrusive and is adapted to enter into ceiling roses, socket-outlets and switch boxes. It is popular for use in temporary installations such as Portacabins on building sites hut can also be used effectively in domestic installations where the decoration must not he disturbed.

5.3 Ducting

Ducts are simply passages provided by builders in the structure of a building to allow cables to run from points of supply so their terminations. Ducts can be rectangular channels covered by steel lids, trenches in concrete with covers or simply pipes. All cables run in ducts must be sheathed or armoured.

Cable Tray

Although not quite a wiring system, cable tray is used to carry heavy armoured cables and multiruns of MI cables.It is widely used in industrial installations where normal cable runs may be obstructed by pipework and other structural urcs. The tray is basically a flat metal sheet with perforations and either a simple turned flange or a return flange for greater strength. A range of finishes are provided to meet installation conditions: galvanised, primed with red oxide or yellow chromate, plastic-coated and coated with epoxy resins (resistant to acids and virtually non-flammable). For very heavy cable runs, cable ladders are used.

5.4 Wiring Accessories

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

5.4.1. 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 on inductive circuits, particularly when they are used to control fluorescent lighting. This is because such circuits take 80 per cent more current than the lamps' wattage might suggest. If switches are not rated for inductive circuits, they must be derated by 50 percent.

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 are of the pull-cord type.

Switches water-heaters are of the double-polerated to carry 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 lightingfrom a luminaire.Watertight switches are designed for outdoor use while splashproof switches are found in situations where water is present, such as in shower rooms.

Most switches tend to be made from moulded plastic, but metal-clad versions are available for use. Some switches for domestic installations can be finished in satin chrome or polished brass.

5.4.2. Lambholders

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

5.4.3. Ceiling roses

Ceiling roses are used with cordgrip landholders for pendant luminaires. They must not be used in circuits exceeding 250 V and must not have more than one outgoing flexible cord unless designed for multiple pendants. They are often provided with a loop-in terminal('live') which is required to be insulated against the possibility of receiving a shock from direct contact.

5.4.4. Cooker outlet units

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.

5.4.5. Shaver supply units

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

5.4.6. Cooker-control units

These can be of the double-pole 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 soeket-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.

5.4.7. Socket-outlets

These take 13A 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 appliance has its own switch.

(*Note:* A heating appliance may have thermostatic control, but the thermostat does not act as a 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 round-pin socket-outlets are available for special purposes. Connection units can also be obtained with a cord outlet.

5.4.8. Outlet plates

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

5.4.9. Mounting boxes

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

5.4.10. 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 mourning box. an internally fixed grid which then accepts the switch or switches and a cover plate. The system ranges from one-gang units to twenty-four-gang units. The accessories include switches, bell pushes, indicator lights and key-operated switches.

5.4.11. Industrial socket-outlets and plugs

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

Installation Hints

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

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

Lighting switches. Single-pole switches are to be connected in the phase conductor only which must also be correctly identified by colour. All exposed metalwork (e.g. the metal switch plate) 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 luminaires) it must be derated by 50 per cent.

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 luminaire.

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 earthing tail provided between the 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 or shower. They should be more than 2.5 m away from a shower cubicle in a room other than a bathroom.

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

CHAPTER 6

6.0 ILLUMINATION

6.1 Some Kinds of Lamps

Filament lamps

Filament lamps fall into a group of light-producing devices called 'incandescent'. They give light as a result of heating a filament conductor to a very high temperature. In 1860, Sir Joseph Swan produced the first lamp using carbonized paper strip. Later, carbonized filaments made from silk were used. Until 1900, carbon-filament lamps enjoyed an undisputed field of use. Then the metal-filament lamp appeared and by 1910 it had superseded the carbon lamp. The carbon lamps, which are made today, have a limited application: for lamp resistances (battery-charging), and radiant-heat apparatus. The modern carbon lamp has a filament of Swedish filter paper, which is dissolved in zinc chloride solution. The resultant viscous solution is squirted slowly through a fine die into a jar of acidified alcohol. Tough cellulose threads are the result. They are wound on formers, which are packed into a crucible filled with finely powdered graphite. The crucibles are then baked in a furnace at 1400°C when the cellulose threads become pure carbon. The temperature limit for a carbon filament is about 1800°C. The light output is low, at about 3.6 lumens per watt (lm/W).

The tungsten-filament lamp first appeared about 1910 and has since been the main incandescent lamp in use. It operates at a temperature of about

2300°C and has a light output of about 8 lm/W. The first lamp to use a tungsten filament had the air evacuated from the glass bulb the so called vacuum lamp. Later, the bulb was filled with argon and nitrogen which are inert gases and do not support combustion. This development enabled the filament to be operated at a higher temperature without the undue evaporation of the filament, which tends to take place in a vacuum. The operating temperature of the gas-filled lamp is about 2700°C. The light output is in the region of 12 lm/W. The early lamps had a single-coil filament. Later the coiled-coil lamp was produced, that is, the coiled filament was itself formed into a coil. The light output of this lamp is about 14 lm/W. The main advantages of the coiled-coil lamp are (a) the filament has a more compact formation and (b) the beat losses due to convection currents in the gas are reduced, so giving a higher light output efficiency.

Tungsten has a resistance, which increases with temperature. The resistance when cold is about 6 per cent of that when operating at normal temperature. This means that when the lamp is switched on, a current of about fourteen times the running current flows. The increase in the temperature of the filament is rapid, however, and the current surge does not harm the filament. The resistance of the filament increases as rapidly and has a stabilizing effect on the power consumed.

There are many types of metal-filament lamps available today. Signal lamps are small and are used on indication boards to show the flow of chemicals, the passage of trains past a given point, and the energizing of a circuit in a definite sequence. Spot and flood lamps are made from pressed glass and are internally mirrored to radiate a defined beam of light. The flood lamp has a relatively broad beam and is used for outdoor illumination such as gardens, monuments, parks, and sports grounds. The spot lamp has a narrow beam and is found in shop windows and showcases. They are also used to highlight an object, which has a general illumination. Thermal -radiation lamps are used in piglet and chicken rearing. They are hard-glass bulbs and are internally mirrored for

NEAR EAST UNIVERSITY

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ELECTRICAL INSTALLATION

Graduation Project
EE- 400

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CONTENTS

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ABSTRACT

While human is living, electrical installation is important study. Design and make the installation is to be secure. The basics of genaration, transmmission and distribution are given.Installatıon work is considered. Circuits types is also investigated for insttallation works. Shortly insulators, conductors are given. Also what kind of cable can use for installation their types are investigated. Illumination for a building are consired. Earthing subject is given.

Protection and protection method are trying to be given. Building services are investigated what the necessay for a buildings. Some symbols which are used in the project are given. Cost calculations are considered and how much an enginner takes money is trying to be given.

INTRODUCTION

First important part is drawing in electrical installation project. It has to be carefully designed because it will use in the life. It is not just theoritical. So all the neccasary parts are told in this project.

Firstly electrical generation are considered. When dealing with high voltage everybody has to be carefull.and then in the same chapter distribution and transmission of this voltage is considered. Calculation of the voltage drops has to be good. In the second chapter installation works given. It started firstly historical review of installation and wiring.

In the third chapter circuits are investigated which is necessary for electrical installation. Circuits are very important also if it is not to be good designed, big faults can occur. After that chapter what matterials are using in the electrical installation are given. Insulator, conductor and cables what kind of cable we are using in the electrical installation are important. Choosing cable size has to be economical.In the I.E.E Regulations book gives the tables using in the electrical installation work.

In the sixth chapter, illumination subject are trying to be given and then again to be essential part of insttallation work is earthing are given. It is essential because all the safety for this job is dependent that. Protection and protection methods are investigated and then in the appendix part it showed to us, using some symbols in the electrical installation work and also cost calculations.

The conclusion presents the significant results of that project.

CHAPTER 1

1.1 GENERATION AND TRANSMISSION

The generation of electric is to convert the mechanical energy into the electrical energy. Mechanical energy means that motors which makes the turbine turn.

Electrical energy must be at definite value. And also frequency must be 50Hz or at other countries 60Hz. The voltage which is generated (the output of the generator) is 11KV. After the station the lines which transfer the generated voltage to the costumers at expected value. These can be done in some rules. If the voltage transfers as it is generated up to costumers. There will be voltage drop and looses. So voltage is stepped up. When the voltage is stepped up, current will decrease. That is why the voltage is increased. This is done as it is depending on ohm's law. Actually these mean low current. Used cables will become thin. This will be economic and it will be easy to install transmission lines. If we cannot do this, we will have to use thicker cable.

To transfer the generated voltage these steps will be done. Generated voltage (11KV) is applied to the step-up transformer to have 66KV. This voltage is carried up to a sub-station. In this sub-station the voltage will be stepped-down again to 11KV. At the end the voltage stepped-down to 415V that is used by costumers. As a result the value of the voltage has to be at definite value. These;

a-) line to line – 415V

b-) line to neutral – 240V

c-) line to earth – 240V

d-) earth to neutral – 0V

1.2 DISTRIBUTION AND CONTROL

There are three main sets of regulations to which the electrician must conform in order that an installation shall be safe from excess current, shock, fire, corrosion, mechanical damage, and leakage. These are as follows:

1.Electricity (Factories Act) Special Regulations, 1908 and 1944:

These regulations cover 'the generation , transformation, distribution and use of electrical energy' in factories and workshops. An explanatory leaflet ,*Memorandum by the Senior Electrical Inspector of Factories on the Electricity Regulations*, is issued by H.M. Stationery Office to explain the workkings of these regulations.

2.The Electricity Supply Regulations(1937):

The purpose of the Electricity Supply Regulations is to secure " the safety of the public and for ensuring a proper and sufficient supply of electrical energy ". Under these regulations, the Supply Authority (the Area Board) undertakes to supply the consumer at s stated voltage, phase, and frequency, with permissible variations. The Area Board has the right to withhold connection or disconnect a supply if their regulations are not adhered to.

*NOTE :*These regulations, or statutes, have the force of law and for an employer , consumer, or electrician to disregard them could lead to legal action being taken against him.

3.Regulations for the Electrical Equipment of Buildings:

These regulations (commonly called the LE.E, Regulations) have been devised by the Wiring Committee of the Institution of Electrical Engineers to " ensure safety in the utilization of electricity in and about buildings". The I.E.E. Regulations are of considerable assistance to electricians as they largely cover the requirements of the Electricity Supply Regulations. The I.E.E. Regulations consist of two parts: Part 1 contains "requirements for safety" and Part 2 contains "means of securing compliance with Part 1"

It should be noted that the LE.E. Regulations are not legally binding but are generally accepted as an efficient standard by Electricity Boards, con- tractors, and industrial and domestic consumers. However, Electricity Boards may have their own particular rules which must be obeyed. Particular industries have their own regulations—for example coal mines and cinemas. These special regulations have the force of law.

Generally, if an installation complies with the I.E.E Regulations it complies both with the Factory Acts and with the Electricity Supply Regulations since the I.E.E

Regulations are based on the requirements of these statutory regulations.

1.3 SUPPLY SYSTEM

The Grid is made up of a series of power stations throughout the country which feed current into a system of conductors at a very high voltage. Overhead conductors, supported by steel towers (pylons), are used to carry the current over long distances.

There are three main types of power station: (1) coal-fired, (2) nuclear, (3) hydro-electric.

The most common type is the coal-fired station. Heat, obtained from the burning of low grade coal, is used to produce high-pressure steam. This high pressure steam is used to drive a turbine which is mechanically connected to a 3-phase a.c. generator (alternator) generating at 11,000V. The voltage is stepped up, by means of a transformer, to 132,000V (or on the super grid). High voltages are used in transmit high power with a cable of small cross-sectional area and also to increase the efficiency of transmission by decreasing copper losses ($(I^2)R$ losses).

1.The 132 kV **(1000 V=** 1 kV) 3-phase supply is terminated at an open air sub-station, containing switchgear and transformers, and stepped down to 11kV or 6.6kV.

2.These voltages (1lkV or 6.6 kV) are used to transmit supplies over shorter distances for bulk supplies to large factories possessing their own sub-stations.

3.These voltages are also used to supply pole transformers for agricultural consumers and isolated installations

4.The supply Authority's sub-stations step down the 3-phase 6.6kV or 11kV to 415 V 3-phase 4-wire(3-phase and neutral).

5.Consumers requiring 240V single phase (i.e phase or live wire and neutral wire), for example, a housing estate, are fed from a 4-core armoured cable (3-phase and neutral conductor).Each house is tapped from a diffirent phase (Fig 4.1) to balance the three phases (red, white, and blue).The underground cable is connected in a series of rings, thus decreasing the voltage drop and cross sectional area required.This interconnection also ensures a continuity of supply.

Fig.1.1 shows an open circuit at point X but all the consumers on the ring receive an uninterrupted supply.

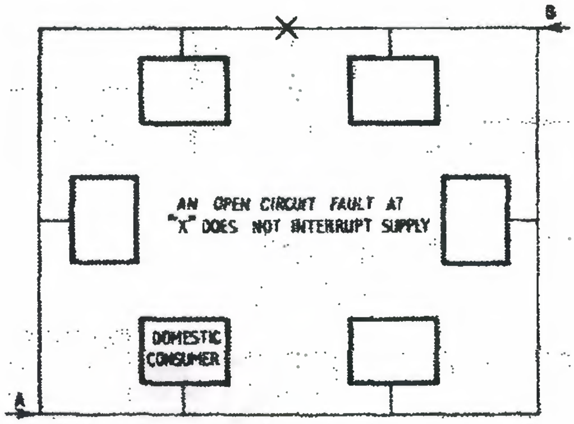


Fig 1.1 Open Circuit fault on ring system supply uninterrupted

1.3.1 Control of Supply at Consumer's premises

It is essential that the consumer's supply should be effectively controlled and also that all switchgear should be accessible.

NOTE:'All conductors and apparatus must be sufficientsize and power for the work they are called upon to do, and so constructed, installed and protected as to prevent danger.'

This quotation from the Electricity Supply Regulations also appears in substance in the Factories Act and the I.E.E Regulations.

The main switchgear in an installation must contain:

(a)Means of isolating the supply.

(b)Protection against excess current.

(c)Means of cutting-off the current if a serious earth fault occurs.

A main switch containing a fuse (or 3 fuses if 3-phase) fulfils these conditions as the switch isolates the supply and the fuse protects the circuit against excess current due to overload or serious earth fault.

Sequence of Control Equipment.Fig.1.2 shows two common methods of controlling the incoming supply.The earth leakage circuit breaker is used where it is difficult to get a good earth path {low-impedance earth return). The earth electrode of the E.L.C.B- must be placed outside the resistance area of any parallel path to earth.

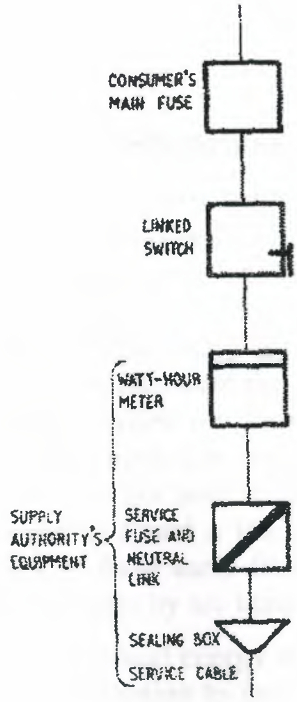


Fig 1.2 sequence of control equipment

1.4 TYPES of INTAKE POSITION

There are two types of intake position;

1.Over-Head Transmission Lines

2.Underground Transmission Lines

1.4.1. Over-Head Transmission Lines

The metal is put on to building, which is near to the transmission lines. We connect the lines, which are coming from pillar, to the "T Point", and, the lines will be gotten into the box of the metering units.

1.4.2. Under-ground Intake:

Lines are taken from pillar but here under-ground cable is used. When the cable put under-ground, it will be done in some rules. These rules are;

1. Earth will be dogged (depth nearly 100 cm)
2. Sand will be separated in channel
3. Plastic pipes will be put into channel
4. Again sand is separated onto pipes
5. And these are covered by cement
6. Cable will be passed through the pipes to the box of metering units.

After these the lines are connected to the HRC (High Rupturing Fuses) fuses. And then, Cutout, metering unit, operator, and distribution board.

CHAPTER 2

INSTALLATION

2.1. 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 was for lighting in houses, shops, and offices. By the 1870s, electric lighting had advanced from being 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 bean 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 ingot and castings. The first all-welded ship was constructed in 1920; and the other ship building processes were operated by electric motor power for punching, shearing, drilling machines and woodworking 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 turn 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, the installation in Hatfield House was carried out by an aristocratic amateur. That the installation was dangerous did not perturb visitors to the house who' when the naked wires on the gallery ceiling broke into flame nonchalantly threw up cushions to put out the fire and then went on with their conversation'

Many names of the early electric pioneers survive today. Julius Sax began to make electric bells in 1855, and later supplied the telephone with which Queen Victoria spoke between Osborne, in the Isle of Wight, and Southampton in 1878. He founded one of the earliest purely electric manufacturing firms, which exists today and still makes bells

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 guarantied that all the components offered for sale were technically suited to each other, were of adequate quality and were offered at an economic price.

Specializing in lighting, Falk Statesman & 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. Glover was originally a designer of textile machinery, but by 1868 he was also making braided steel wires for the then fashionable crinolines. From this type of wire it was a natural step to the production of insulated conductors for electrical purposes. At the Crystal Palace Exhibition in 1885 he showed a great range of cables; he was also responsible for the wiring of the exhibition.

The well-known J. & P. firm (Johnson & Phillips) began with making telegraphic equipment, extended to generators and arc lamps, and then to power supply.

The coverings for the insulation 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.

Siemens 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 Siemens, whose early system was to give a cable a certain length related to a standard resistance of 0.1 ohm. Thus a No.90 cable in their catalogue was a cable of which 90 yards had a resistance of 0.1 ohm. The Standard Wire Gauge also generally knew Cable sizes.

For many years ordinary VRI cables made up about 95 per cent 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 safeguard against the two wires touching and so causing fire. Choosing a cable at the turn 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 insulation: up to 600 V and 600 V/1,000 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 was 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 insulation material came from America to Britain where it formed part of the first wiring system for domestic premises. This was twin lead-sheathed cable. Bases for switches and other accessories associated with the system were of cast solder, to which the cable sheathing was wiped, and then all joints sealed with a compound. The compound was necessary because 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 affected good electrical continuity. The insulation was rubber. It became very popular. Indeed, it proved so easy to install that a lot of unqualified people appeared on the contracting scene as ‘electricians’. When it received the approval of the IEE Rules, it became an established wiring system and is still in use today.

The main competitor to rubber as an insulating material appeared in the late 1930s. This material was PVC (polyvinyl chloride), a synthetic material that came from Germany. The material, though inferior to rubber so far as elastic properties were 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 introduced in 1937. This was tough rubber sheathed cable with a semi-embedded braiding treated with a 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 Argyllshire. Despite the fact that lead and lead-alloy proved to be of great value in the sheathing of cables, aluminium was looked to for a sheath of, in particular, light weight. Many experiments were carried out before a reliable system of aluminium-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 copper-sheathed 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 Pyrotenax Ltd, and later by other firms. Mineral insulation has also been used with conductors and sheathing of aluminium.

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 sleepless 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 Rayland's Library in Manchester in 1886. Aluminium 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 also were 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 earlier material, which required the use of heat for bending.

Accessories for use with wiring systems were the subjects 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 this country 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 electric 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 contacts 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 an 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 forward 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: Verity's, McGeoch, Tucker, and Crabtree. Further developments to produce the semi-recessed, the flush, the ac only, and the 'silent' switch proceeded apace. The switches of today are indeed of long and worthy pedigrees.

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 and 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 1900s, introduced by Dorman & Smith Ltd.

Lord Kelvin, a pioneer of electric wiring systems and wiring accessories brought out 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 curling-tong heaters. Crompton designed shuttered sockets in 1893. The modern shuttered type of socket appeared as a prototype in 1905, introduced by 'Diamond H'. Many sockets were individually fused, a practice, which was later meet the 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 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 'Multi-Contact' and associated with a type of socket outlet, which eventually became the standard design for this accessory. It was Scholes, under the name of 'Wylex', who introduced a revolutionary design of plug-and-socket: a hollow circular earth pin and rectangular current-carrying pins. This was really the first

attempt to 'polarize', or to differentiate between live, earth and neutral pins.

One of the 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-outlets 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 encased 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 in the switchgear field were Bill & Co., Sanders & 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 the motorcar 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 Ottermill.

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, Compton, Swan, Edison, Kelvin and many others, is well worth noting; 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. For those who are interested in details of the evolution and development of electric wiring systems and accessories, good reading can be found in the book by J. Mellanby: The History of Electric Wiring (MacDonald, London).

2.2 Historical Review of Wiring Installation

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 lamp, 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 electrical 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 Institution of Electrical Engineers) 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 laying down a set of principles rather than, as Heaphy did, drawing up a guide or 'Code of Practice'. A second edition of the Society's Rules was issued in 1888. The third edition was issued in 1897 and entitled General Rules recommended for Wiring for the Supply of Electrical Energy.

The Rules have since been revised at fairly regular intervals as new developments and the results of experience can be written in for the considered attention of all those 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 Institution of Electrical Engineers (IEE) was not alone in the insistence of good standards in electrical installation work. In 1905, the Electrical Trades Union, through the London District Committee, in a letter to the Phoenix Assurance Co., said 'they view with alarm the large extent to which bad work is now being carried out by electric light contractors As the carrying out of bad work is attended by fires and other risks, besides injuring the Trade, they respectfully ask you to. . Uphold a higher standard work'.

The legislation embodied in the Factory and Workshop Acts of 1901 and 1907 had a considerable influence on wiring practice. In the latter Act it was recognized for the first time that the generation, distribution and use of electricity in industrial premises could be dangerous. To control electricity in factories and other premises a draft set of Regulations was later to be incorporated into statutory requirements.

While the IEE and the statutory regulations were making their 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 this country is that they form the primary requirements, which must by law be satisfied. The IEE Regulations and Codes of Practice indicate 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 the IEE Regulations, but cannot insist on a standard which is in excess of the IEE requirements.

2.3 INDUSTRIAL INSTALLATION .

1.All cables must be rated at, or above, the current which they will normally be expected to carry (Tables 1M to 31M in the I.E.E. Regulations supply this information) without undue heating or voltage drop (normally 5 per cent of nominal voltage).

2.All conductors, cables and equipment used in the Installation must be of the correct voltage rating, for example, 250V grade switchgear should not be used on 415V 3-phase installations; 500 V switchgear is necessary.

3. The fuse in a circuit must be capable of protecting the smallest conductor in that circuit. For example, a twin flexible cord of 3 A rating should not be used In a circuit fused above 5 A because serious over-heating could occur in the flexible cord under fault conditions.

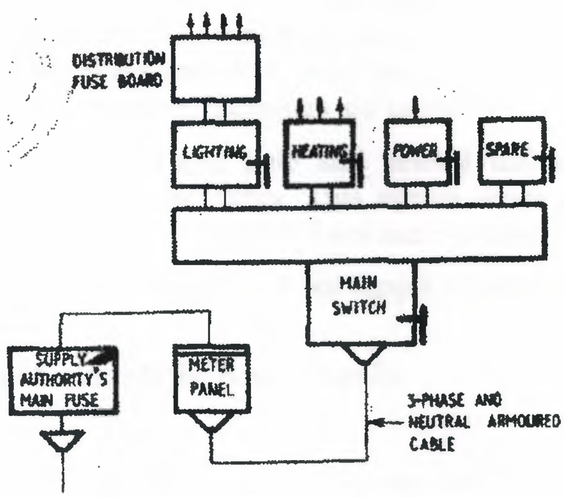


Fig. 2.1 Layout of small engineering works.

4. All conductors and equipment must be properly labelled; this saves time and also minimizes the danger of opening the wrong circuit when Isolating or fault-finding.

Earth wire GREEN and YELLOW

3-Phase wires (non-flexible) RED, YELLOW, and BLUE

Neutral: BLACK

3-Phase wires (flexible) All phase wires BSOWH (identified by sleeves or tabs)

Neutral: BLUE

Single-Phase (3-core) Live: BROWN

Neutral:BLUE

Paper-insulated cables: 0=NEUTRAL 1=RED PHASE

2=YELLOW 3=BLUE

Mineral–insulated metal sheated Identification sleeves should be used at terminations.

5.All equipment must be protected against:high temperatures, moisture, corrosion and mechanical damage.

6.The main distribution point should be situated, if possible, at the centre of the Installation In order to keep cable runs short.

7.Sufficient capacity should be installed at the outset (In main switches, bus-bar chambers, and cables) to allow for future expansion.

Fig. 2.1 shows a suggested layout for a relatively small engineering works. The supply is fed into the premises by means of an underground cable (3- neutral), through a sealing chamber into the Supply Authority's fuse.Tails are taken from the fuses and neutral block Into the meter panel. An armoured cable supplies the consumer's main switch, which, In this case, is a 500 A triple-pole and neutral linked switch (all poles are switched simultaneously). The conductors are then brought out to the bus-bar chamber. Tappings are taken from the bus-bars as follows:

No. 1 switch is a triple pole and neutral linked switch (all poles are switched simultaneously) for the lights. This switch feeds an 18-way distribution fuse board comprising three sets of six 15A fuses and a neutral block.

No. 2 switch is similar to No. 1 but supplies the heating load, which is balanced over 3 phases.

No. 3 switch controls the power circuits.

Sub-division of Loads. This is considered under lighting, heating, and power circuits

Lighting Circuits: The lighting load will be taken from the distribution board to the final sub-circuits. A final sub-circuit is defined in the I.E.E. Regulations as "an outgoing circuit connected to a distribution board and intended to supply electrical energy direct to current-using apparatus*'. The conductors between the bus-bar chamber and the distribution fuse board are termed the sub-main. The conductors from the lighting distribution fuse board may also feed local switches supplying small distribution fuse boards (for example, 5 A fuses) for offices, stores, etc.

The lighting final sub-circuits comprise a switch-panel and the lights controlled by these switches.

All fuses and switches must be placed in the phase conductor and metal lampholders (used in industrial fittings of 200 W and over) must be earthed and the phase conductor should be terminated at the centre pin of Giant Edison Screw (G.E.S.) lampholders

Heating Circuits. The heating load (Fig. 4.6) is split up over 3 phases to give a balanced load. The heaters, for example, fan heaters, would be controlled a 3-phase isolator or a 3-phase switch fuse. For example, if 240 V tubular heaters (200 W per metre) are used the heating circuits are subdivided into three sections with a seperatephase for each section.

Power Circuits, which consist of, in this instance, a 3-pliase isolator and a starter controlling a milling-machine motor taking a full load current of 8 A. A 1 mm^2 or a 1-5 mm^a cable would be adequate for this circuit, but the fuse should be loaded to three times the full load current of the motor, that is, approximately 25 A (0-75 mm tinned-copper wire).

The main distribution fuse board may also be used to supply smaller distribution fuse boards for smaller lathes, drills, etc.

The 2--meter Rule. In conditions where two separate phases (for example, the red and blue phases) are brought into the same room:

(a) The controlling switch must be clearly marked '415 volts',

b) Switches and socket outlets supplied from different phases must be

placed at least 2 metres apart. This is particularly important where

portable appliances are used .

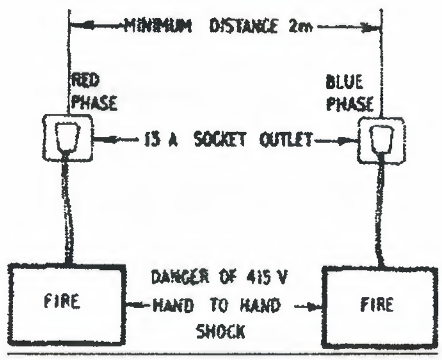


Fig 2.2 The 2-meter rule

This is termed the '2-meter rule'.It avoids the danger of a voltage of 415V appearing between appliance or switches which can be touched simultaneously.

2.4 DOMESTIC INSTALLATIONS

2.4.1 General Rules for Domestic Installation

There are two types of installation

I. Surface Installation

II. Under plaster installation

Installation system at costumers place

OPERATOR ➡ DISTRIBUTION BOARD ➡ FUSES ➡ LINES (CABLES)

In both types of installation, same main principle is accepted these are;

1. Lines from metering unit will be applied to the operator (V/O, C/O) or if operator is in distribution board, we put 2-pole isolator into box of metering unit and earth continuity conductor will come from another place, not with line and neutral conductor. If the operator is outside of the operator line neutral earth will be connected together to 2-pole isolator, which is in distribution board. These maybe 3 phase or 1 phase operator or isolator.

2. In distribution board for each type of circuit different cable sizes and fuses or miniature circuit breakers are used.

Domestic installation are usually supplied from a 16mm2 twin armoured cable.

1.The supply Authority's sealingchamber for the termination of the armoured cable.

2.The Supply Authority's fuse and neutral block.

3.The Supply Authority's energy meter (kWh).

4.Consumer's control unit.

NOTE:The Supply Authority's fuses need not be dublicated if the permissionof the Authority is obtained

2.4.2. Under Plaster Installation

Steps do this type of installation as follows;

I. Ceiling installation and stairs.

II. Inside of home and stairs.

2.4.2.1. Ceiling Installation;

Plastic pipes and plastic lamb box do this part of installation. Generally, 5/8 plastic pipes are used for cell lighting. While we are doing these also, pipes of stairs installation is fixed. Pipes and lamb boxes are out be cording to the electric installation project.

Following steps to do these.

a-)Ceiling installation and stairs. First the lamp boxes are filled by wet papers. Lamps boxes may fill with concrete there fore we fill the inside of lamp boxes with paper not to have problem.

b-) Lamps boxes will be nailed according to the electrical plan. If there is only single lamp in a room. Lamp boxes will be nailed to the center of room. If there is more than one lamp. You have to follow a special ways. For example, in a corridor generally there are two lamps length of corridor will be divided by there and with will be divided two to point the place of lamp.

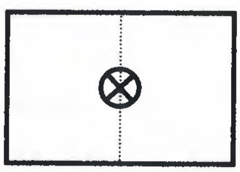
c-) You will take out the pipes from the lamp boxes for switches (to under of the roof). We have to be careful. When we put the pipes inside of the coulomb the pipes, which will be under roof, must not be above doors or windows and also, it should not be behind doors.

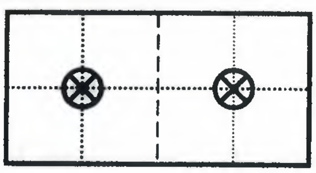
d-) For each circuit, from the lamb boxes, pipes will be taken out up to the distribution board. This is done as same as position of switches.

e-) Pipes will be put for the heater and for the water tank on the roof to the distribution board. (3/4")

f-) For antenna and telephone lines pipes are fixed to the suitable position (1" or ¾"). In apartments extra pipes are put in stairs for main lines and for the lighting of stairs. They are put inside of the coulomb

Figure 2.3. Ceiling installation samples





2.4.2.2 Inside of Home and Stairs.

According to the plan, you paint the positions of sockets, switches, etc. with paint (spray paint). Painted places have to be broken. Metal boxes and plastic pipes that are in different sizes, for each type of circuit.

5/8" pipes for lighting, telephone lines, water pump, and earthing.

3/4" for sockets, antenna, heater circuits.

3/4" or 1" fore cooker control

1 ¼" or thicker is used for main lines,

When the metal boxes are being put they have to have different heights. These heights are;

In bathroom, dinning rooms, and corridor, sockets/Telephone/Antenna sockets 50cm (between floor to metal box)

Switches 150cm (between floor to metal box)

Special lamps on wall 200cm (between floor to metal box)

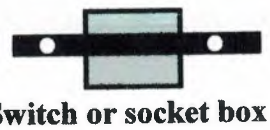


Figure 2.4. Switch or socket box

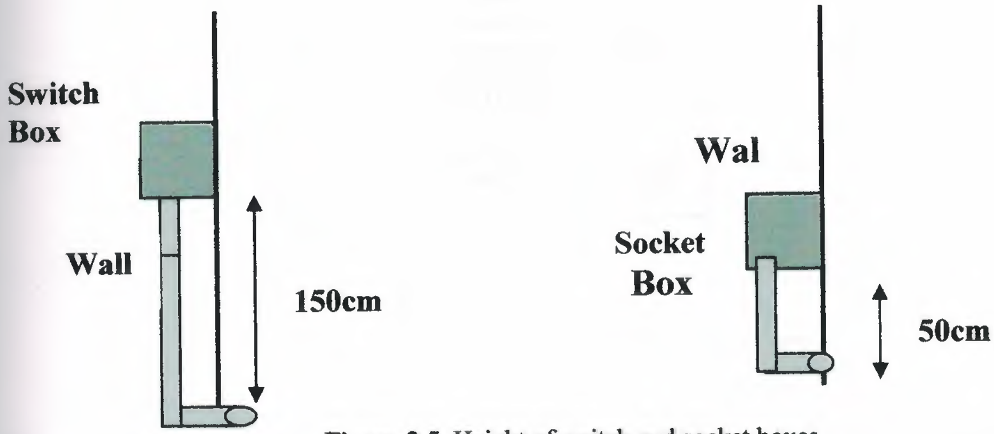


Figure 2.5. Height of switch and socket boxes

In Kitchen;

Here you have to be careful for position of metal boxes. Because cooker, switches, sockets boxes have to be at the same line and you have to measure careful not to put them on the place of the cupboards and this height is generally 125cm.

In Toilet and Bathrooms;

You must not put the metal box of switches inside of toilets or bathrooms. Because you may have risk of electric shock. Lamps must be waterproof. In these wet places, we have to use waterproof components for protection of life. Height of lamp is nearly at 200cm.

The round of the metal boxes must not be plastered because, metal box will have corrosion problem.

Steps

a-) We paint the places of switches, sockets, etc.

b-) Painted paces have to be broken, up to 65cm for sockets, switches 150cm, if the pipes of switch will come from roof, that pipe will come to 150cm painted line.

c-) Metal box will be fixed at painted places, but they have to be flat and good appearance we tie with wire on at piece of flat wood. This wood is nailed to the wall.

d-) We bend the pipes from anywhere of pipes, where it is needed and put them in boxes from hole on box.

e-) After plasterer to fait and the pipes plasters these boxes which are on floor are also plastered to protect the pipes.

After these have been finished, we will pull the cable as connecting to the special stainless wire. What types of cables are suitable for each circuit.

In kitchen, toilets and bathrooms metal place labs will be earthed by special clips which is called earthen clips and also switches, sockets and something like these will be connected and this is called finish.

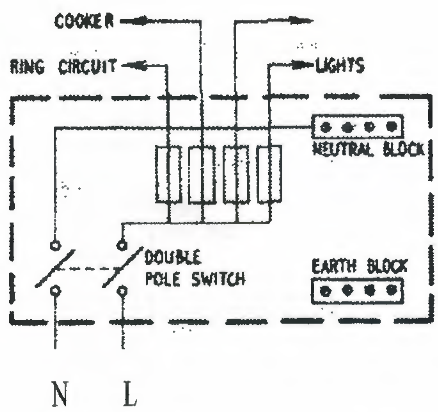


FIG. 2.6. Domestic consumer's control unit

Domestic Consumer's Control Unit (Fig. 2.6).This type of unit is usually made up of the following :

(a) Main switch (60 A) which isolates *both* the phase and the neutral

conductors,

(b) One 30 A fuse for the cooker circuit.

(c) One 30 A fuse for the 1 3 A ring circuit (capable of taking two 7/0-85 in cables).

(d) One or two 5 A fuses for lighting circuits.

Loading of Final Sub-circuits. The assumed current demand from points is as follows (Table B, I.E.E. Regulations):

15 A socket outlet	15 A
5A socket outlet	5A
2A socket outlet	at least 1/2A
Lighting outlet	minimum 100W

1.Only one phase of a supply should preferably be brought in to a multi gang switch box. Where more than one phase is used there must be a rigid screen or barrier separating the phases, and a clearly visible notice warning of the maximum voltage present. This notice must be placed outside the switch.

2.All final sub-circuits must be electrically separate (i.e. there must be no 'bunching' of neutral conductors). All neutral conductors must be connected at the distribution board in the same order as the line conductors.

Domestic Ring Circuit (Fig. 2.7). The domestic ring circuit is defined in the I.E.E. Regulations as "a final sub-circuit in which the current-carrying and earth continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution fuse board or its equivalent. A spur of a ring circuit shall be a branch cable having conductors of a cross-sectional area not smaller than that of the conductors forming the ring".

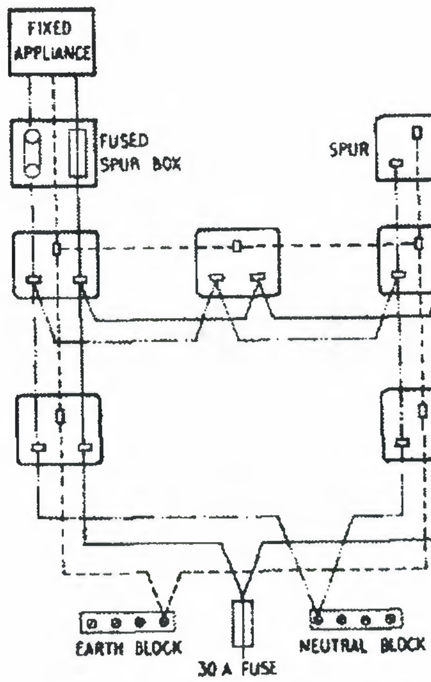


Fig. 2.7. Domestic ring circuit

The main I.E.E. Regulations relating to the ring are as follows:

1.Cable size: minimum twin 2-5 mm^2 and earth p.v.c. or t.r.s.

2.Maximum number of socket outlets allowed: unlimited number in floor area under 100 m^2, but spurs may not number more than half the socket outlets on the ring circuit, including stationary appliances.

3.Fused 13 A plugs to be used at socket outlets supplying portable appliances.

4.Fixed appliances must be protected by a local fuse, for example, 3 fused spur box.

5.A 30 A fuse should be used to protect the ring circuit.

6.All socket outlets in any one room must be connected to the same phase.

7.Apparatus permanently connected to the ring circuit without a fused plug or socket outlet must be protected by a local fuse or circuit-breaker with a rating not exceeding 15 A. The apparatus must have an adjacent con- trolling switch.

The purpose of the ring circuit is:

(a} To minimize trailing flexes.

(b) To take advantage of the fact that all outlets in a domestic installation are not pperated simultaneously .This is known as the diversity in an installation.

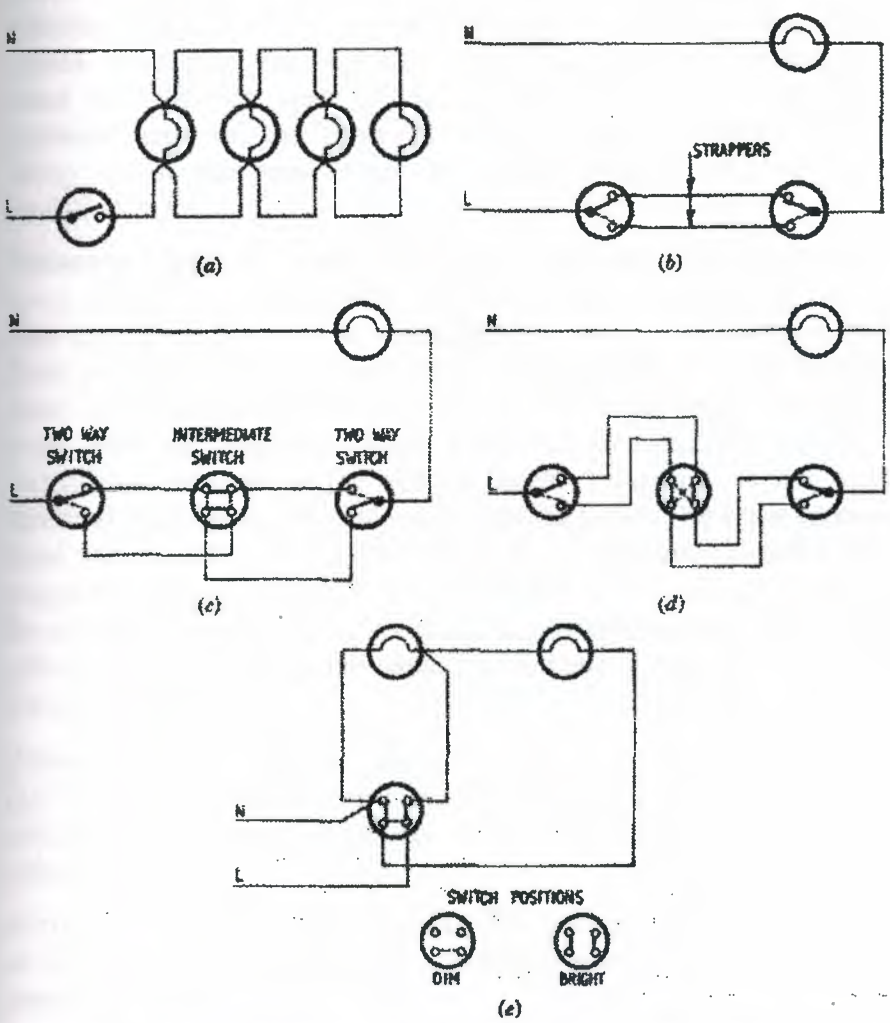


Fig. 2.8 Lighting circuits. (a) One–way switching : one switch serving lights. The conductors are lopped between the lambs. (b) The two-way switching circuit.Used for stairs and corridors. (c) The two-way switch used with an intermediate switch for long corridors in hospitals, schools, etc. (d) Another type of intermediate switching. The internal connections in the switch determine the circuit used. (e) Dim-bright switching. The lamps are connected in series for dim operation and in parallel for bright.

2.5 DIVERSITY FACTOR

The diversity factor in an installation can be calculated as follows:

$$\text{Diversity factor} = \frac{\text{Actual connected load}}{\text{Total Load}} \times 100 \text{ (per cent)}$$

The diversity factor vanes for different types or installations, for example; the diversity factor suggested in the I.E.E. Regulations for the lighting circuits of a block of residential flats is 50 per cent. This means that the cables supplying the lighting load *(not* the final sub-circuits) need only be rated for 50 per cent of the full-load current. This decrease In the cross-sectional area of the cable Is allowed because the likelihood of all the lights being on at the same time is remote, although any one final sub-circuit may be fully loaded.

Domestic Lighting: Domestic lighting circuits are usually wired in I mm- twin t.r.s. or p,v,c. (twin *1-5 (mm^2)* may also be used). The protecting fuse is generally *5* A (20 mm tinned copper wire or cartridge fuse with white body). Conductors in a lighting final sub-circuit (or any final sub-circuit) should never be interconnected with other final sub-circuits. For example, a final sub-circuit neutral should never be used to teed more than one final sub-circuit. Each neutral conductor should be connected to its individual terminal at the neutral block: 'bunching[5] is not permitted. An earthing terminal must be provided at every lighting point. The earth continuity conductor of the final sub-circuit must be connected to this terminal, metallic switches must also be supplied with an. earthing to which the final sub-circuit earth continuity conductor must be connected. The earthing terminal is not required where earthed metal boxes are used which have a fixing for the metal switch plate giving reliable electrical contact between the plate and the metal box.

Fittings: Light switches are usually of the 5 A (a.c.) quick-make-slow-break (Q.M.S.B.) type, flush mounting. Switches used in fluorescent lamp circuits must be capable of carrying twice the normal circuit current in order to withstand the Inductive effect of the choke.

NOTE. An incombustible material, for example, a hard wood block, must be placed at the back of surface-mounted accessories where these are fitted to soft wood or other combustible material.

***Ceiling Roses**:* There are two main types of ceiling rose: *(a)* the three-plate pattern and *(b)* the two-plate pattern.

The three-plate ceiling rose is used to economize in wire and minimize the number of joint boxes used in the installation.A joint must be made as indicated or three wires run to the first switch. All joints must in joint boxes.

NOTE: Ceiling roses must not be used on circuits operating above 250 V and no more than one flexible cord is permitted from any one ceiling rose. The earthing terminal of every ceiling rose must be connected to the earth continuity conductor of the final sub-circuit

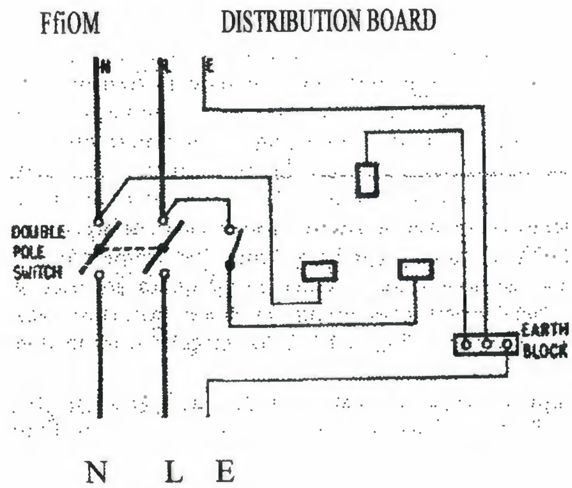


Fig. 2.9. Cooker control unit.

Water Heaters:

Domestic water heaters are generally rated at 3kW and are usually supplied from ring circuit. Asbestos-covered cable should be used to terminate the conductors at the immersion heater since p.v.c. and t.rs cables are normally expected to be used where the surrounding temperature (the ambient temperature) does not exceed 30'C. The temperature age of water heaters is between 43 'C and 82 'C. The thermostat, in common with all other switching devices, must always fitted in the phase conductor.

Bathroom : All lamp holders must be of the Home Office (skirted) type and lamps should be totally enclosed. Only circular flexible cable should be used where necessary and the switch must be of the pull-cord type. No portable appliances should be fitted or used in the bathroom and fixed appliances for example, wall fires, must be placed out of reach of persons in the bath.

Garages:Socket outlets in garages must be placed at a safe distance from floor level.All portable appliances, particularly handlamps, must be earthed and handlamps should be fitted with an earthed shield.

Cooker Control unit: This generally consists of a double-pole switch feeding the cooker and an independent 13A socket outlet. It is essential that the earth continuity conductor supplying the unit should he effectively connected.

The cooker control unit is generally supplied from a separate way in the consumer's control unit and wired with 10 mm^2 twin and earth p.v.c . or t.r.s. cable. It is fused at 30 A which is sufficient to protect a maximum of 9 kW {3-plate cooker). The current demand from a stationary cooking appliance is calculated as follows: 10 A + 30 per cent of the total remaining full load current. Every stationary cooking appliance in domestic premises must have an adjacent control switch fitted within 2 m of the appliance.

*NOTE:*No Diversity factor is allowed with a final sub-circuit supplying a cooker as it is possible that all elements will be in use when the cooker is being fully utilized.

Layout of a Domestic Circuit:The lighting circuits would be connected from two

junction boxes in the attic(one box for each circuit). The cable supplying the cooker would also be run in tha attic and the ring circuit would be run below the floor.Socket outlets are placed 30 cm above the floor level and light switches 1.5m above floor level.

2.6. SPECIAL INSTALLATIONS

Though the bulk of electrical installation work carried out in this country does not involve the consideration of special factors in the context of the wiring systems, accessories and the equipment 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. These sources include BS Codes of Practice and manufacturers' instructions, and IEE Regulations.

2.7. TEMPORARY INSTALLATIONS

A temporary installation is an installation with an expected period of service of three months.A temporary installation used beyond this period must be completely overhauled at three-monthly intervals.

It must be pointed out that the electrician in charge of temporary installation has a legal responsibility and ensure the safety of the installation; this includes its construction maintanance and extension. The particular danger in this type of installation is the work of the amateur electrician who overloads bayonet-cap lighting circuits beyond their 1kW maximum loading , often with unearthed metal fittings, and uses unsheated cable or unprotected cable. Conduit should not be used in the installation unless it complies with the relevant I.E.E Regulations .

Protection: The temporary installation must be protected with an adequate switch which isolates all the poles (including neutral) from the supply.The name of the person in charge and their position should be displayed near the main switch.

NOTE: The greatest care should be taken to protect the temporary installation against mechanical damage and portable appliances(for example drills) should be regularly checked.Low-voltage (e.g 110V) step-down transformers should be used wherever possible , to minimize the danger from shock.

2.8 DAMP SITUATION

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 (particularly from surface leakage over otherwise healthy insulation) and the risks, which attend a gradual deterioration of the metalwork of the installation as the result of corrosion.

The I.EE Regulations require that every cable installed in a 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. Conduit threads should be painted over with a bituminous paint immediately after erection Cables, which are armoured 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, 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 he 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 conduit 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 glanded into totally enclosed lighting fittings and run into the 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 temperatures below $0^{\circ}C$, PVC has a 'cold-shatter' characteristic and may crack if hit sharply. There is also a warning note regarding the use of cables with bituminous-compounded beddings or servings.

2.9 Corrosion

Wherever metal is used there is the attendant problem of corrosion. Two conditions are necessary for corrosion: a susceptible metal and a corrosive environment. Nearly all of the common metals in use today corrode under most natural conditions; the bulk of all anti-corrosive measures have thus been attempts either to isolate the metal from its environment, or to changing the environment chemically to render it less corrosive In installation work, the problems of corrosion tend to be more acute in certain types of installation. Chemical works, salt works, cow byres and other ammonia-affected areas, all require special consideration in their design and the work executed to produce the installation. Corrosion, in a normal installation condition, may affect earth connections.

The corrosion of metals in contact with soil or water is an electrochemical reaction; that is, the corrosion reaction involves both the chemical change (e.g., from iron to rust) and a flow of electric current. It is this principle, which is used in the dry cell, where the corrosion of the zinc case provides the cell's electrical output. The current flows from

the metal into the soil or water (called the electrolyte) at the anode and then from the electrolyte into the metal at the cathode. Corrosion occurs at the point where the current flows from tile metal into tile electrolyte. Every metal develops its own particular electrode potential when placed in an electrolyte or similar medium. If two different metals are coupled together in the same electrolyte, tile difference between their potentials will be sufficient to produce a current of electricity. The metal with the more negative potential will suffer corrosion. It follows that the more compatible the metals are, the less will be the rate of progress of any corrosive action which takes place between them, because the amount of potential difference between them is reduced.

In general there is a 'natural' potential of -0.3 to - 0.6 V between a buried mass of metal and its surrounding soil. This potential is measured by using a very-high-resistance voltmeter and a device called a half-cell, which consists of a copper rod immersed in saturated copper sulphate solution contained in a plastic tube which has a porous plug at the bottom for making contact with the soil as near as possible to the buried mass. Certain areas of the mass surface will act as anodes (where the current leaves the metal) and these will corrode. The areas, which act as cathodes (where the current enters the metal) do not corrode. This sub-division in the areas of the surface of the buried mass is due to the fact that the areas assume the roles of anodes and cathodes depending upon variations in the metal itself, its surface treatment, and the electrolyte.

Reducing the amount of current that flows from it into the surrounding medium or electrolyte can diminish the corrosion of a metal. Painting or otherwise coating the metal will increase the electrical resistance of both anodes and cathodes. But if the coating has flaws or holes in it, then the current concentrates at these points and deep pitting will occur. The corrosion current can also be reduced by lowering the electrical potential difference between the anodes and the cathodes either by controlling the purity of the electrolyte or by adding inhibitors to it.

Because only the anodes corrode, current flowing into them from an introduced external anode so as to cause the whole of the buried structure to become a cathode can prevent corrosion. This is the principle of cathodic protection. The method can be used only where the introduced anode can be accommodated within the electrolyte that surrounds the buried metal, and the soil or water must be present in bulk.

The method is widely employed as a corrosion preventive measure on underground metalwork. Two basic techniques are used to give cathodic protection: (i) the sacrificial anode system; (ii) the impressed current system.

In the first method , a mass of base metal, such as magnesium, is buried in the electrolyte and connected electrically to the structure to be protected. The natural difference in potential between the structure metal, usually steel, and the magnesium causes a current to flow from the magnesium (the new anode) through the electrolyte to the steel, which is the new cathode. The anode gradually corrodes and is thus called a 'sacrificial anode'. In practice a closely controlled magnesium-alloy is used. The main factors which govern the degree of protection, and the current output from the galvanic cell so formed by the protective system, are the surface area, volume and shape of the anodes used, the resistivity of the electrolyte and the surface area of the exposed metal being protected. The sacrificial anode system is common in congested areas since the low potentials generated by the galvanic system virtually eliminate the possibility of corrosion arising on adjacent metal structures on account of stray current. The system also needs no external electrical supply and is to a great extent self regulating in output, which latter will vary according to the resistivity of the surrounding medium (e.g., in

wet or dry weather conditions). The anodes need periodical renewal. In reasonable soil conditions, the life of an anode may be up to 15 years.

The second method of protection, the impressed-current system, uses a conventionally generated direct current from rotating machinery or via a transformer/rectifier unit. The negative side of the supply is connected to the structure to be protected; the positive side is fed to an 'anode ground-bed' usually formed from high-quality graphite impregnated by resin, wax or linseed oil, silicon iron or scrap iron or steel. The buried structure then becomes the cathode. The anode may, but need not, corrode. Silicon-iron and graphite anode ground-beds are semi-inert and have a very long life. Scrap iron or scrap steel beds go into solution quite rapidly and disintegrate at the rate of about 10 kg/Ampere/year.

The metalwork associated with electrical installations, which may require cathodic protection include supporting lattice structures, armoured cables with rotted servings, metal pipes containing cables, and general structural steelwork.

Another aspect of corrosion may not be too familiar to installation installers. This concerns the continuous exposure of PVC-insulated cables to temperatures above $115^{\circ}C$ that may cause the formation of corrosive products, which can attack conductors and other metalwork. Generally, the precautions to prevent the occurrence of corrosion in normal installations include:

1. The prevention of contact between two dissimilar metals (e.g. copper and aluminium), particularly where dampness is likely to be present.

2. The protection of cables, wiring Systems and equipment against the corrosive action of water, oil, and dampness, unless they are designed to withstand these conditions.

3. The protection of metal sheaths of cables and metal-conduit fittings where they come into contact with lime, plaster, cement and certain hardwoods such as beech and oak.

4. The use of bituminous paints and PVC over sheathing on metallic surfaces liable to corrosion in service.

CHAPTER 3

3.0 CIRCUITS

3.1Lighting circuits

Most lighting circuits comprise several switching arrangements, such as one-way, two-way and intermediate. A typical domestic circuit is derived from a 5 A way in a consumer unit.In larger installations the rating of the circuit protective device can be either 15 A or 16 A. Domestic light- ing is largely based on the use of filament lamps, with fluorescent luminaires found in kitchen areas. Commercial installations are based on fluorescent lamps.

The simplest lighting circuit is a one-way, comprising one lamp controlled by a one-way switch; multi-lamp chandeliers are also controlled from the one-way switch. The two-way switching arrangement is used when a room has two points of entry and the luminaire is thus controlled from any one of two positions. The intermediate switching arrangement is used where one or more luminaires are required to be controlled from a number of switch positions, such as in long corridors or areas where there are a number of entry points.

One-way switches are rated at both 5 A and 15A. They must always be connected in the phase ('live") side of the supply. When being installed, ihe switches must be positioned so that when the rocker is in the 'down' position, the circuit is energised.Usually the word 'top' is marked on the reverse of the switch plate to ensure the correct mounting position.

The two-way switch has no OFF position. Rather the lamps are switched ON and OFF by the operation of one or other of the switches. Again, these switches are effectively 'single-pole' control devices and so must be connected to the phase side of the supply.

The intermediate switch has two positions and is effectively a change-over switch. It is connected between two two-way switches and so is able to change the direction of the current in the wires which connect the two-way switches together, known as 'strappers', 'strap wires' or 'pass wires'.

Switches are available as one-gang, or multi-gang, the latter being used to allow a number of individual luminaires to be controlled from one location.

In the provision of lighting circuits in a domestic-installation it is usual to split the lighting provision into two, with around ten lamps at the most on each circuit. Each lampholder is assessed at the current equivalent of 100 W. Thus ten lamps would take a total of just over 4 A. The reason for having two lighting circuits is to ensure that part of the house has some light should one circuit fail.

In commercial installations it is essential to ensure that the switches are either rated to carry inductive currents (e.g. 'ac rated') or else are derated to half their normal current rating. This is because fluorescent lamp circuits take more current than the simple rating of the lamp. To calculate the total current taken by fluorescent fittings the lamp wattage is multiplied by a factor of 1.8 and the product divided by the supply voltage:

$$I = \frac{\text{Total lamp watts X 1.8}}{\textit{voltage}} \quad \textit{amps}$$

Care should be taken that the correct size of conductor is used for lighting circuits, particularly to prevent excessive voltage drop. Every conductor has a certain value of resistance and when a current flows along it a voltage loss occurs *($V_{d=}$ I X R),* The longer the length of run from its supply point (consumer unit or distribution board) the greater will be the volt drop. If the drop is excessive the lamps (particularly filament lamps) will deliver a reduced light output. This tends to be more a problem in commercial installations than in domestic premises. Usually conductors of 1.5 mm^2 CSA will be found adequate for most circuits.

Most general lighting circuits are wired either using the loop-in' method or by using a joint box. The loop-in method requires a phase terminal in the ceiling rose (which must always be shrouded to prevent inadvertant contact or else a shock will he received). The other terminals in the rose are for the neutral conductor, the switch wire, and the two terminals to which the luminaire is connected. A final terminal (or terminals) is provided for the CPC which must be connected to both the earth terminal in the switch mounting box and the earth terminal in the luminaire accessory. Some lampholders only have two terminals and so the CPC must be terminated in a single block connector and not left loose. The loop-in method using a rose with a phase terminal allows the switches to be fed with two-core cable and also allows other lamps to be looped from the rose.

The joint-box method uses a box made from moulded plastic and can incorporate four terminals or else has a block-connector strip fitted by the electrician. From the box are taken the cables for feeding the switch and the lamp and it also allows other circuits to be taken from the same box.

Note that all CPCs contained in either two- or three-core cables must be sleeved with green/yellow sleeving when being terminated in ceiling roses, joint boxes, switches or lamp accessories.

If one-way switching is involved, the red core must be the switch feed conductor. The other core, coloured black, actually forms the switch wire and, to comply with the Wiring Regulations, must be identified as being on the live' side of the circuit and coloured red, yellow or blue depending on the phase from which the installation is being supplied. This identification of the switch wire is often ignored by practising electricians and while it is general practice it must be recognised that it does contravene the Regulations.

In commercial and industrial installations, the live may be derived from the red. yellow or blue phase and its colour should be consistent throughout the circuit.

In lighting circuits generally, 1 mm^2 cable is used with 5 A fuse because the authority says that in a lamb circuit you will put 10 lamp (100 W), this will be 1 kW=I=1kW/240=4.16 A. 5 A limit must not be passed that's why we use the fife Amp. If we want to put more than10 lamps in a circuit we have to change the cable size to 1.5 mm^2 with a 10 A fuse.

3.2 POWER CIRCUITS

Two types of circuits are used to feed socket-outlet units and fused connection units: radial and ring. The radial circuit is derived from a 20 A way in a distribution board or consumer unit and is intended to serve a floor area not exceeding 20 nf. If the floor area to be served is not more than 50 m^2 the rating of the protective device is 30 A or 32 A. Kitchens in domestic premises {where a large number of socket-outlets are often needed for electrical appliances) are often fed by radial circuits.

The ring circuit is derived from a 30 A or 32 A way and has its conductors terminated at its point of origin in the distribution board or consumer unit. An unlimited number of socket-outlets may be connected us the circuit provided that the floor area served does not exceed 100 m^2 in domestic installations. As most modern domestic premises have a floor area in excess of this figure, two ring circuits are usually provided (or one ring and one radial circuit for the kitchen). When more than one ring circuit is installed in the same premises, the socket-outlets should be reasonably shared between the circuits to balance the loading.

Spurs can be taken off a ring circuit. If they are of the non-fused type, [he number must not exceed the number of socket-outlets (and any stationary equipment) connected directly in the ring. Double or two-gang units are regarded as two separate outlets. Connection units can be either fused or switched and fused, with the latter being used for equipment which has no direct control switch. A fused connection unit can be used to feed devices which take very little current, such as a fan, a clock or a lamp.

When installing a ring circuit, the spurs can be fed from socket-outlets connected directly in the ring, from the origin of the circuit or from a joint box (with terminals rated for 30 A) connected in the ring and left for future extensions to a building (e.g. a conservatory or extra bedroom).

Three types of cable are recognised for use with ring and radial circuits: PVC-sheathed, MI cable and copper-clad aluminium, PVC-insulated. For ring circuits the respective csa involved are 2.5, 1.5 and 4 mm".

3.2.1. POWER CIRCUITS TYPES

1. Sockets

There are two types of sockets.

1.Radial Socket Circuit

2.Ring Socket Circuit

I-) Radial Socket Circuit:

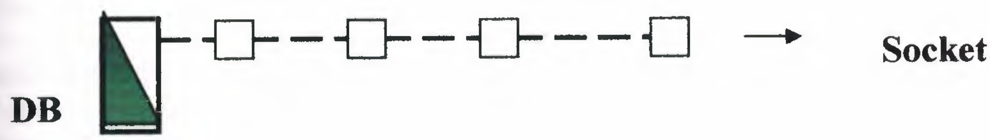
We have some standards.

1-) In a kitchen area two sockets can be put in radial socket circuit with 2.5 mm^2 conductor and 15 amps. fuse.

2-) In an area, which is not in kitchen and less, than 30 $m^{2,}$ 6 sockets can be put in radial circuit with 2.5 mm^2 conductors and 15 Amp. fuse.

3-) If the area is greater than 30 m^2, 6 sockets can be put in a radial socket cct. With 4 mm^2 conductor and 20 Amp. fused.

Figure 3.1. Radial socket circuit



II-) Ring Socket Circuit:

Ring means, you will start from one point and after you went to each point, you will come back to first point.

1-) Any number of socket can be put in a ring socket circuit if the area less than 100 $m^{2,}$ if area is greater than 100 $m^{2\ in}$ any building. You have to another ring socket circuits.

2-) From any sockets in a ring sockets circuits you can put spur from each sockets.

3-) Only one stationary appliance can be put in a ring socket circuit either include in the ring or taken as a spur. (Washing machine, dish washer, bathroom heater or heater, and water pump)

NOTE: If these are connected to the ring socket circuit as a spur or with any heater switch. The heater switch has to be fused.

For other power circuits cable sizes and value of fuse.

Figure 3.2. Ring socket circuit

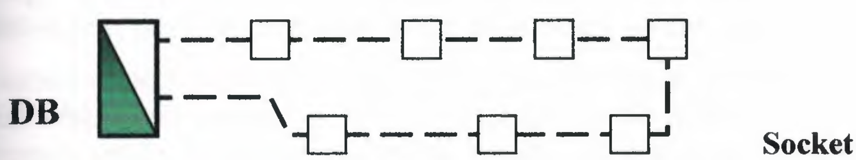


Figure 3.3 Ring socket circuit with spur socket

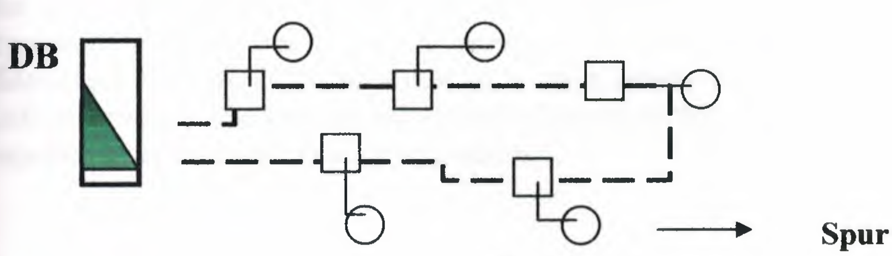


Table 3.1. Circuits cable thickness and fuses			
Circuit	L+N	Earth	Fuses
Cooker Control	6 mm^2	2.5 mm^2	30 A
Heater	2.5 mm^2	1 mm^2	15 A
Dish Washer	2.5 mm^2	1 mm^2	15 A
Washing machine	2.5 mm^2	1 mm^2	15 A
Jacuzzi	2.5 mm^2	1 mm^2	5 A
Instant Heater	4 mm^2	2.5 mm^2	30 A
Air Conditioner	2.5-4 mm^2	1-2.5 mm^2	15-30 A

Regulations summary

Socket-outlets (except for shaver units) are not permitted in bathrooms. Fixed appliances fed from connection units must have an appropriate provision in the unit (either fused or switched and fused). Appliances connected to fused connection units must have a rating of 3 kW maximum. A two-gang socket-outlet unit is regarded as two separate units. Any socket-outlet used for supplying electrical equipment intended for outdoor use must incorporate a residual current device (RCD) with a trip current of 30 mA; the socket-outlet must be next to a warning label reading "For equipment outdoors'. In industrial or commercial premises, adjacent socket-outlets must be connected to the same phase of the supply.

All socket-outlets must be protected by a device (fuse or miniature circuit-breaker, MCB) which will operate within 0.4 second should a fault occur. The cable sizes recommended for both ring and radial circuits assume normal ambient temperatures and that the conductors are not bunched. Higher operating temperatures, bunching, contact with thermal insulation material and the use of a semi-enclosed fuse (BS 3036) may mean an increase in the csa of the conductors.

3.3 Cooker Circuits

These are derived from (usually) a 30 A or 32 A way, but can be higher depending on the kW rating of the cooker. The control units need not have a socket-outlet incorporated in them, but if one is provided the protective device must be able to. disconnect the circuit in the event of a fault within 0.4 second (it would be 5 seconds otherwise). The control unit must be located within 2 m of the appliance (this also applies to 'split-level' cooking appliances).

3.4 Water -Heater Circuits

Generally derived from a 15 A or 16 A way, the circuit must incorporate a double-pole switch (usually of 20 A rating), with an additional switch recommended in close proximity to the immerser unit which should be connected by using heat- resisting flexible cable or cord.

Voltage drop in Circuits

If any conductor carries a current there will be a loss of voltage between both ends of the conductor. This loss or 'volt drop' is $V=IxR$, where V is the volt drop, I is the current in the conductor and R *is* the conductor resistance. The effect of serious volt drop is to reduce the effective performance of lamps, heaters and other electrical devices. To limit volt drop in any circuit, the IEE Regulations impose a maximum drop of 4 per cent of the nominal circuit voltage. Thus, on a 240 V supply, the drop between the consumer's terminals and the farthest end of any circuit in the installation is 9.6 V. It is the concern of the installation designer, and often the electrician, 10 choose a size of circuit conductor for a particular load so that this figure is not exceeded. The Current-rating Tables in the Regulations indicate the volt drop (in millivolts [mV|) when a current of 1 A flows through a 1 metre length of a particular cable. This rnV figure is then multiplied by the actual load current in the cable and also by the length of cable run, to arrive at the total volt drop. If, for a particular size of cable, the total volt drop exceeds 9.6 V (for a 240 V supply), the next size of cable is chosen in turn until the final volt drop is less than 9.6 V. Other factors are, however, required to be taken into account when choosing the initial size of cable, such as the cable's ambient temperature, the cable's installation condition (e.g. bunched with other cables), the circuit protection (e.g. semi-enclosed fuse or MCB), and whether the cable is in contact with thermal insulation material. The IEE Regulations require that the choice of a cable to feed a particular circuit must have regard for a number of factors, and not just the circuit current.

The Regulations require that the method used to choose the correct size of a conductor be based on the rating of the protective overcurrent device. Al! factors which affect the rating of the cable in its installed condition are applied as divisors to the rating of the protective device, as the following examples show. The process involved in working out the correct cable size, and the final volt drop, is as follows:

1.First find the load current of the circuit (I_B).

2.Determine the correction factor for the ambient temperature in which the cable

is to be installed (the highest temperature is always taken).

3.Determine the correction factor for grouping C_a, if the cable is run with others.

4.Determine the correction factor *C-*, if the cable is in contact with, or surrounded by, thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material (e.g. cable clipped to a joist) and 0.5 if the material completely surrounds the cable.

5.Select the rating of the ovcrcurrent device. If this offers what used to be called "close protection', e.g. by an MCB, the factor is 1.0. If, however, the device is a semi-enclosed fuse, the factor is reduced to 0.725. In any case, the rating of the device must equal the circuit load current.

6.Determine the size of the circuit conductor , by calculating desired current rating.

7.Check that the volt drop does not exceed the maximum permissible allowed.

$$I_z = \frac{I_n}{C_g X C_a X C_I X 0.725}$$

where $C\ g$ is the correction factor for grouping. C_a is the factor for ambient temperature, C_i is the factor for the thermal insulation, if applicable, and 0.725 is the factor for the overcurrent protective device, if applicable.

3.5 FINAL CIRCUITS

A final circuit is defined as "A circuit connected directly to current-using equipment, or to a socket-outlet or socket-outlets or other outlet points for the connection of such 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 hoard. They also require that the wiring of each final circuit shall be electrically separate from that of 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" 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 No. 27 of the Electricity Supply-Regulations: 'All conductors and apparatus must he 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.

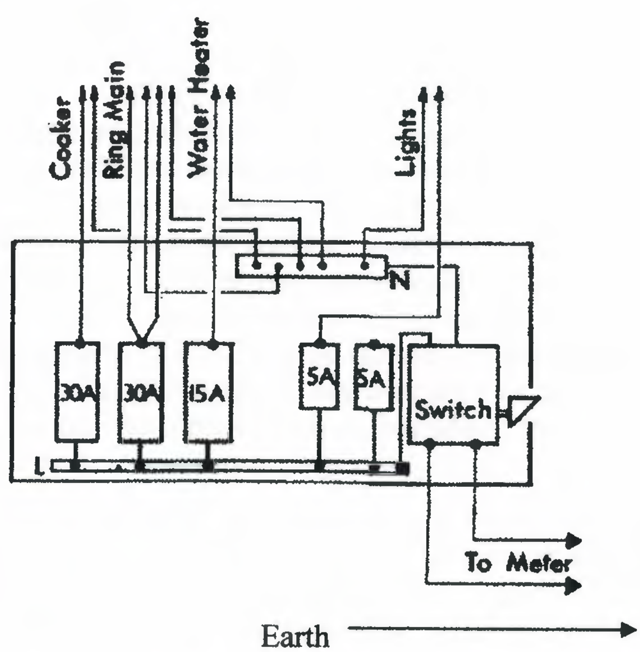
An industrial installation may have all five types; a domestic installation may have only 1, 2 and 3. Whatever the type of installation and the uses to which electrical energy is put, it is essential that some significant element of planning be introduced at any early stage in the design of an installation.

Before indicating the factors which are involved in the choice of final circuit types, a few brief notes on planning aspects will he relevant.

Installation planning

(a) *Domestic installations* seem to be the simplest to plan, but there are a number of points which are worth 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 for 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 inter- mediate switching; and a large house should have two or more lighting circuits. A note in an older edition of the IEE Regulations is still relevant: 'In the interests of good planning it is undesirable that the whole of the fixed lighting of an installation should be supplied from one final subcircuit.' The reason for this is not far to seek. If an installation has two lighting circuits and one circuit fails, the house is not plunged into darkness. It is often a good point to consider a slight 'overlap' of Sighting 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 this 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 a purely functional basis. In living rooms and bedrooms, wall-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 over-looked, 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 1363 should be used exclusively. Where it might be inconvenient to withdraw plugs from the associated socket-outlets when appliances are out of use, switched 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.

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 a single socket-outlet should be provided at each side of a bed; two-gang units can be used to good advantage {e.g. to supply a bedside lamp and an electric blanket). 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 surfaces and two-gang units are recommended.

In the dining 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 fixed 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 (of the enclosed- element type) or towel rail should be permanently connected through a fixed control switch out of reach of the bath or shower position.

(b) 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 buildings 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 lighting, wall points, etc. The service lighting is that associated with lifts, corridors, stairs, landings and is usually the responsibility of the landlord. Where a tenant's specific lighting requirements are not known when the building is being erected, the lighting outlets are laid out on a 'grid' system, in which the outlet points are sited at regular intervals usually related to the module of the building (mat is, the basic size, multiples of which are used in the construction of the building). Generally, about 3 m are allowed between outlets. Outlets may be left on the ceiling for 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 (e.g. an office may go over to all-electric typewriters or install a computer or data-processing system), it is often difficult to extend or alter an inflexible installation. Thus, the electrical services provisions should allow for 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.

(c) Industrial premises require lighting installations which cater for the intensity of lighting required for the process to be carried out. In addition, local lighting at reduced voltages is 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.

(d)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.

Circuits rated under 16A

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 (e.g. clocks, bell transformers, electric shaver supply units), provided that their rating is not greater than 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 he taken Into consideration. The reason for this is that the larger cables are not being chosen for the current that they can carry under favourable circuit conditions, but to provide for 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.

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 l0A of [he 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 (46A) would 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 the 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.

Circuits rated for 13A socket-outlets

Final circuits which supply 13A socket-outlets with fused plugs and i3A fused (switched or unswitched) connection units are provided by two types of circuit: ring and radial. Ring circuits serve a maxi- mum floor area of 100 nr derived from a 30A

protective device. Radial circuits serving a maximum area of 50 nr are also protected by a 30A device, while if the area served is no more than 20 m^2 a 20A device provides the protection. The following is a summary of the requirements relating to 13A socket-outlet circuits:

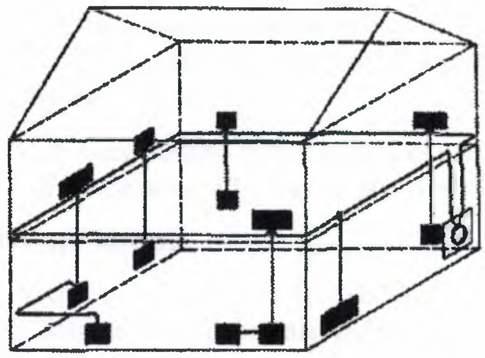


Fig 3.4. typical ring-circuit serving two floors.

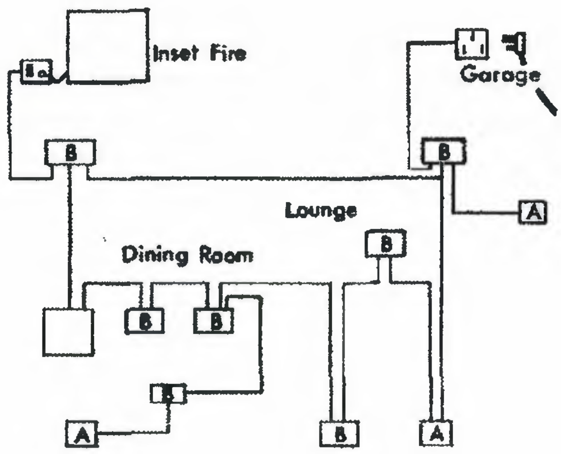


Fig.3.5 Typical ring circuit with spurs to outlying points

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 a circuit-breaker.

It is important to realise that the conductor sixes recommended for ring circuits arc 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 he run in the form of a ring, having both ends connected to earth at the distribution hoard for its equivalent).

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.

Circuits feeding discharge lamps

One of the main requirements is a consideration of the 'rating' of a discharge lamp outlet, for it has a rather different interpretation from that used for other lighting points. The reason for this is that, owing to the losses in the lamp control gear plus the low power factor (about 0.9), it is necessary to multiply the rated lamp watts by 1.8 and divide by the lamp rated voltage to obtain the actual current flowing in the circuit. It should be noted that certain switches may not be suitable for controlling the highly inductive circuits associated with discharge Sighting. If a switch is not specifically designed to break an inductive load (quick-make, slow-break), it should have a current rating of not less than twice the total steady current which it is required to carry.

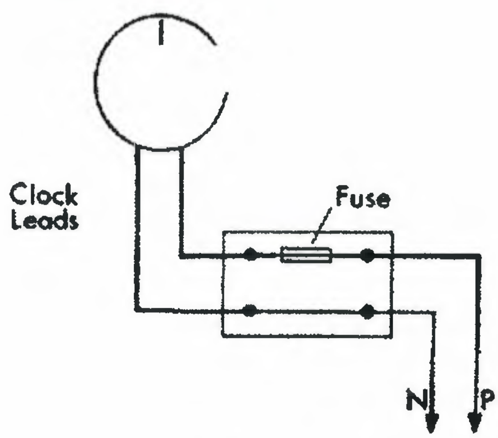


Fig.3.7 electric clock circuit

Circuits feeding motors

Final circuits which supply motors require careful consideration. In particular, cables which carry the starting, accelerating and load currents of a motor must be rated at least to the fail-load current rating of the motor. If, however, the motor is subjected to frequent starting and stopping, the csa of the cables should be increased to cater for the consequent increase in conductor temperature. More than one motor may be connected to a 16A final circuit, provided that the aggregate full-load rating of the motors does not exceed 16A. If a motor lakes more than 16A full-load current, it should be fed from its own final circuit.

Final-Circuit Protection

Protection of final circuits is by means of fuses, circuit-breakers or miniature circuit-breakers located at switchboards and distribution boards. The protection is for over-currents caused by short- circuits between conductors, between conductors and earth, or overloads. The protective gear should be capable of interrupting any short-circuit current that may occur without danger of fire risk and damage to the associated equipment. In large installations, where there are main circuits, sub-mains and final circuits, it is often necessary to introduce a discriminative factor in the provision of protective gear. Where circuit-breakers are used, discrimination is provided by setting sub-circuit-breakers to operate at a lower over-current value and a shorter time-lag than the main circuit- breaker. Thus, if a fault occurs on a final circuit, the associated gear will come into operation, while the main breaker remains closed. However, if the fault persists, or the sub-circuit-breaker fails to operate within its specified time (e.g. 2 seconds), the main breaker will trip out (e.g. 0.5 second later).

Fuses are often used for back-up protection of circuit-breakers. Generally, where cartridge fuses are used the fuse will operate before the circuit-breaker, particularly in the event of a short-circuit current. Where small over-currents occur (e.g. overload) the circuit-breaker is likely to operate before the fuse blows.

Where full use is made of cartridge fuses, their ratings, type and make should be consistent for each circuit protected. The rating of sub-circuit and main fuses should be chosen so that in the event of faults the sub-circuit fuses blow first. Generally, discrimination between the fuses can be obtained if the rating of the sub-circuit fuses does not exceed 50 per cent of the rating of an associated main fuse. If this margin is too large, reference should be made to the data provided by the fuse makers.

Discrimination is very difficult to obtain with any degree of accuracy where cartridge fuses and semi-enclosed rewirable fuses are used together because of the many factors which are involved in the operation of the latter type of fuse. These include the type of element, its size, the ambient temperature, its age and its material.

Choosing cable sizes

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 (grouping). There are many situations in which cables can find themselves being overheated. The more obvious are the conditions set up when overcurrents 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 situations produces an environment which can quickly lead to the deterioration of the cable insulation (particularly when PVC is involved) and lead to a becomes very soft, so that a conductor can 'migrate" or travel through the insulation and eventually make contact with earthed metalwork. This produces a shock-risk situation, with 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 dependent on the ability of the over-current protection device to operate to disconnect the circuit from its supply. As is probably realised, 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 a 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 recognise the fact that, in these circumstances, the ratings of cables have to be reduced quite considerably. The regulations list 20 standard methods of installation (Table 4A of Appendix 4), each of which is identified by "Methods'. These classifications are used in the tables which give the current-carrying capacities of cables. The installation conditions include "enclosed" (e.g. in conduit trunking and ducts); 'open and clipped direct' (e.g. clipped to a wall, to a cable tray, embedded direct in plaster which is not thermally-insulating, and suspended from a catenary wire); 'defined conditions', which include 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 a particular circuit must have due regard for a number of factors, and not just the circuit current. These factors include:

(a) the ambient temperature in which the cable is installed;

(b) the installation condition, e.g. whether grouped or bunched with other current-carrying cables, enclosed or installed 'open';

(c) whether the cable is surrounded by or in contact with thermal insulating material;

(d) whether the circuit is protected by semi- enclosed (rewirable) fuses to BS 3036.

The method of choosing the correct size of conductor for a particular load condition, as recommended by the IEE Regulations, is based on the rating of the overcurrent protective device. Ail factors affecting the cable in its installed condition are applied as divisors to the rating of the device, as the following examples show. The requirement of Regulation 525-01-02 must also be considered. In general, the size of every hare conductor or cable conductor shall be such that the 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. Values of volt drop per ampere per meter are given in the current rating tables in Appendix 4 of the Regulations, In this context, it should be noted that conductors of large cross-sectional area have different volt drops per ampere per meter for ac circuits than those operating from dc supplies. This is because of the reactance inherent in conductors carrying ac.

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

1. First find the load current of the circuit (I_B),

2. Determine the correction factor for the ambient temperature which 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 for grouping. Here we refer to Table 4B1 of the Regulations

4.Determine the correction factor if the cable İs in contact with or is surrounded by thermal insulation material. Two factors are given: 0.75 if only one side of the cable is in contact with the material {e.g. a cable clipped to the side of a joist) and 0.5 if the cable is completely surrounded by the material.

5. Select the rating of the overcurrent 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 in Tables 9D1A to 4L4A in

7. Check that the volt drop does not exceed the maximum permissible allowed by Regulation 525-01-02.

If I_z represents the current rating of the conductor and I_n the rating of the protective device, then

$$I_z = \frac{I_n}{C_g X C_a X C_I X C_f} \quad amperes$$

where C_g is the factor for grouping;

C_a is the factor for ambient temperature;

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

C_f is the factor for the overcurrent device. This factor is 1 for ail devices except semi-enclosed fuses, when the factor is 0.725.

CHAPTER 4

4.0 CONDUCTORS AND CABLES

4.1 Definition of conductors

A conductor is a material which offers a low resistance to a flow of current. Conductors for everyday use must be (a) of low electrical resistance, (b) mechanically strong and flexible, and *(c)* relatively cheap. For example, silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are tin, lead, and iron.

Formation of conductors

Electrical conductors are usually made of copper, although aluminium is being used to a greater extent, particularly as the price of copper increases. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. The copper wire is then dipped into a tank containing molten tin. This is done for two reasons: *(a) to* protect the copper if the wire is to be insulated with vulcanized rubber, as this contains sulphür which attacks the copper; and *(b)* to make the copper conductor easier to solder. Aluminium wire is also drawn from a solid block but is not tinned.

Aluminium

1.Smaller weight for similar resistance and current-carry ing capacity

2.Easier to machine

3.Greater current density because larger heat-radiating surface

4.Resisiivity 2-845 μΩ-cm

5.Temperature coefficient practically similar (0-004 Ω/Ω degC)

Copper

1.Better electrical and thermal conductor, therefore lower C.S-A, required for same voltagedrop
2.Greater mechanical strength

3.Corrosion resistant

4.High scrap value

5.Much easier to joint

6.Lower resistivity: l-78μΩ-cm

The determining factor in the use of one type of metal for conductors is usually that of cost. The future trend in costs will be for the price of aluminium to drop relative to that of copper, as the underdeveloped countries achieve the industrial capacity necessary to work their bauxite (aluminium ore) deposits.

Stranding of Conductors. Conductors were often stranded to make the completed cable more flexible. A set number of strands are used in cables: 1, 3, 7, *19,* 37, 61, 91, and 127. Each layer of strands is spiralled on to the cable in an opposite direction to the previous layer. This system increases the flexibility of the completed cable and also minimizes the danger of 'bird caging', or the opening-up of the strands under a bending or twisting force.

Size of Stranded Conductors. The size of a stranded conductor is given by the number of strands and the diameter of the individual strands. For example. & 7/0-85 mm cable consists of seven strands of wire, each strand having a diameter *(not* cross sectional area) of 0-85 mm. Solid (non- stranded) conductors are now being used in new installations.

Bare Conductors. Copper and aluminium conductors are also formed into a variety of sections, for example, rectangular and circular sections, for bare conductor systems. *Applications,* Extra-low voltage electroplating and sub-station work.

The following precautions must be taken with open bus-bar systems (above extra-low voltage). They must be: *(a)* inaccessible to unauthorized persons, *(b)* free to expand and contract, and *(c)* effectively insulated. Where bare conductors are used in extra-low voltage systems they must be protected against the risk of fire.

4.2 INSULATORS

An insulator is a material which offers a very high resistance to a flow of current. An insulator should have certain electrical, mechanical, physical, and chemical properties.

Electrical Properties: It must have high resistance.

Mechanical Properties: It must be capable of withstanding mechanical stresses, for example, compression.

Physical Properties. The perfect insulator would have the following physical properties: (a) non-absorbent; (&) capable of withstanding high temperatures.

Chemical Properties. An insulator must be capable of withstanding the corrosive effects of chemicals.

No insulator is perfect and each type is picked for a particular application. For example, porcelain and fireclay are relatively good insulators, but could not be used for covering conductors forming a cable because they are not flexible. P.V.C. is also a good insulator, but cannot be used in conditions where the temperature exceeds 45 °C—for example, insulation for electric fires. Other examples of insulators are mica, wood, and paper.

4.3 CABLES

Definition of Cables

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor(solid or stranded), or of two or more such conductors,, each provided with its own insulation, which are laid up together. The insulated conductor or conductors mat or may not be provided with an overall covering for mechanical protection.'' A cable consist of two basic parts:(*a*) the conductor;(*b*) the insulator.

4.3.1 Construction of cables

A cable usually derives its name from the type of insulation used Polyvinyl Chloride (P.V.C.,} Cable. This is termed a 'thermo plastic' cable as the insulation is formed from a synthetic resin which softens when heated. The process of manufacture is as follows:

1.The p.v.c, is extruded on. to the conductors by passing them through & die into which soft p.v.c. is forced.

2.The formed cable is then passed through a trough of cold water t harden the plastic insulation.

Multi-core Cable: This is cable which is made up of two or more insu lated conductors. Multi-core cable is sheathed in a protective covering— for example, tough rubber for tough rubber-sheated cables (_t.r,s.) and p.v.c, for plastic cables.

Tough-Rubber-Sheated (t.r.s) Cable: This is made of specially toughened rubber which is resistant to acids and alkalies. Specially" constructed t.r.s., which has been reinforced with tape and an external braiding; is used to farmyards.

Polychloroprene (p.c.p or neoprene) Cable: An insulation somewhat similar to that of t.r.s but capable of withstanding most weather conditions and particularly direct sunlight.

Heat-resisting, Oil-resisting and Flame-retardant (h.o.f.r) Cables:

These cables are used in conditions damaging to P.V.C. cables such as high temperature and oil. The resistant qualities are developed by a vulcanizing (or curing) process which forms an elastomer capable of withstanding tough conditions and still retaining its flexibility. The following are examples of cables using elastomer material: c.s.p, chlorosulphonated polythene), butyl rubber, silicon rubber, ethylene propylene rubber (e.p.r,).

The maximum operating temparature for both rubber and p.v.c. insulated cables is 45 degrees.

4.3.2 Flexible Cables and Flexible Cords

The I.EE Regulations define a flexible cable as: " A cable consisting of cores, each containing a group of wires, the diameters of the the construction of the cable being such as to afford flexibility'' A flexible cord is defined as; 'A flexible cable in which the cross-sectional of each conductor does not exceed $4mm^2$".

Twisted Twin Flex Cable: This is made up of a multi-strand tinned-copper conductor with silicon rubber insulation. *Application:* lighting flex.

Circular Flex: The rubber-insulated cores are formed into a circular section to cotton worming and contained in a cotton, braiding. *Applications :* connections to household appliances (irons, kettles, etc.).

Circular Flex Rubber Sheathed: This flex is also packed with jute or cotton to form a circular cross-section but an outer sheath of rubber replaces the cotton braiding. *Applications:* vacuum cleaner and portable drill leads (3-core).

Workshop or (industrial) Flex (Fig 2.3): This flex is similar in construction to the above , but has the addition of a compounded braiding. *Application*: connections to industrial lighting.

4.3.3. Outdoor Cable

The I.E.EE Regulations underline the need for adequate mechanical protection when cables are used outdoors and the importance of having sufficient support to avoid mechanical strain. They also supply tables showing the necessary spacing for supports and the minimum allowable radius for bends.

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Fig. 4.1 House service over-head system(H.S.O.S) cable

H.S.O.S. (House Service Overhead System) Cable (Fig. 4.1): H.S.O.S. cable is constructed as follows: *(a)* hard-drawn copper conductor, *(b)* rubber insulation, *(c)* varnished tape, and *(d)* outer coating of compounding braiding. *Application:* house-to-house overhead supplies.

NOTE :p.v.c insulated copper and aliminium cables are gradually replacing this cable, except in conditions where creosote is present, at this attacks the p.v.c insulation.

4.3.4. Cable Sizes: Use of I.E.E. Tables

The I.E.E. Regulations contain comprehensive information regarding the curret carrying capacity of cables under certain conditions.

These tables supply: *{a)* cross-sectional area, number$_s$ and diameter of conductors; (b) type of insulation; *(c)* length, of run for IV drop; *(d)* current rating (a.c. and d,c.), single and bunched. The following terms are used in the I.E.E. tables:*(a)*ambient temperature and (b} rating factor.

Ambient Temperature: This is the temperature of the air surrounding the conductor. The current rating of a cable is decreased as the temperature of the surrounding air increases, and this changed current-carrying capacity can be calculated by using the relevant rating factor.

Rating Factor: This is a number, without units, which is multiplied with the current to find the new current-carrying capacity as the operating conditions of the cable change. For example, a twin-core 10 mm^s (7/1.35 mm) p.v.c cable will carry a maximum current of 40A at an ambient temperature of 25‘C , but if the ambient temperature is increased to 65’C the maximum current allowed will now be:

40A X 0.44 (rating factor) =17.6 A

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carrying capacity will decrease: a rating factor is therefore supplied for the bunching , or grouping of cables.

Permissible Voltage Drop in Cable: Voltage drop is another essential feature in calculation of cable size, as it is useless installing a cable which is capable of supplying the required current if the voltage at the consumers equipment is too low. Low voltage at the consumer's equipment leads to the Inefficient operation of lighting, power equipment,, and heating appliances. The maximum voltage drop allowed between the consumer's terminals and any point In the installation is 2-5 per cent of the voltage supplied by the Electricity Board, including motor circuits.

Voltage Drop and the I.E.E. Tables: The I.E.E. tables state the voltage- drop across a section of cable when maximum current Is flowing through it. If the current is halved, the voltage drop will also be halved. For example, a 4 mm^2 twin-core cable has a

current rating of 24 A and a voltage drop of 10 mV per ampere per meter. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per ampere per meter.

New Voltage Bands: Extra-low voltage (Band I) now covers voltages not exceeding 50 V a.c. or 100 V d.c. (measured between conductors or to earth). The new low voltage range (Band II) is from extra-low voltage to 1000 V a.c. or 1500 V d.c., measured between conductors, or 600 V a.c. and 900 V d.c. between conductors and earth.

Current Density and Cable Size: The current density of a conductor Is the amount of current which, the conductor can safely carry without undue heating per unit cross-sectional area. For example, If a copper conductor has a current density of 300 A/cm^2 a copper conductor of cross-sectional area 0-5 cm^2 will be capable of carrying one half of 300 A, that is, 150 A.

To calculate the current-carrying capacity of a cable (given cross-sectional area (cm^2) and current density (A/cm^2)):

Current-carrying capacity = current density X cross-sectional area

4.3.5 Resistance of a Conductor

The resistance which a conductor offers to a flow of current is determined by three factors: (a) the length of the conductor ,(b) its cross-sectional area, and (c) type of material used.

Length: If the length of a conductor is doubled , for example, from 100m to 200m , the resistance of that conductor will also double.

Resistance R (in ohms) is *directly* proportional to length l

Cross-sectional Area: If the cross-sectional area a of a conductor is doubled , for example, from 0.1 cm^2 to 0.2 cm^2 ,the resistance of that conductor will be halved.

Resistance R (Ω) is inversely *proportional* to cross-sectional area a

Resistivity (Specific Resistance) : This is the factor which takes into consideration the type of material used. The resistivity of a material is the resistance of a unit cube of that material, measured across opposite faces of e, If the resistivity of copper is given as 1.7μΩ-cm Then the resistance measured across opposite faces of a centimetre cube of copper will be 1.7μΩ This may also be written 1.7×10^{-6}Ω-cm or 1-7 microhm-centimetre (uΩ-cm). (1uΩ is one millionth of an ohm.) The symbol of resistivity is ρ (Greek letter rho).

$$R = \frac{\rho l}{a}$$

Where R is resistance (Ω), ρ=resistivity, l=length , and a = cross-sectional area.

*NOTE:*Since resistivity is usually given in ohm-centimeters or microohmcentimeters, the length of the conductor must be changed to centimeters.

4.3.6. Effect of Heat on a conductor

When a current is passed through a conductor the temperature of that conductor rises; an extreme example is the element of an electric fire. The effect of this heat on the resistance of the conductor depends on the composition of the conductor. The resistance of pure metals such as copper and aluminium, increases as temperature increases.The resistance of certain alloys-for example, constantin and manganin-remains relatively constant with increases in temperature. But the resistance of carbon and electrolytes(liquid use in batteries) decreases with increases in temperature.

Temperature Coefficient : The temperature coefficient of a material is the increase in the resistance of a 1Ω resistor of that material when it is subjected to a rise in temperature of 1degC. For example, if copper has a temperature coefficient of 0.004 ohm per ohm per degree celcius (0.004Ω/Ω deg C) a copper resistor of 1 Ω will increase in resistance to 1Ω +0.004Ω if heated through 1deg C. The symbol for temperature coefficient is α (Greek later alpha).

Pure metals, such as copper and aluminium, have a *positive* temperature coefficient, that is, their resistance increases as temperature increases, Carbon and electrolytes have a *negative* temperature coefficient, that is, their resistance decreases as temperature increases.

Calculating Resistance Increase: There are two formula for calculating the increase the resistance of a conductor due to temperature change:(a)temperature increases from 0 deg. C ; (b) temperature increases between two intermediate temperatures.

(a) *Temperature increases from* 0 °C:

$$R_f = R_0(1+\alpha t)$$

Where R_0 =resistance at 0°C, R_f = final resistance , α = temperature coefficient, and t = rise in temperature.

(b)Temperature increases between two intermediate temperatures:

$$\frac{R_2}{R_1} = \frac{1+\alpha t_2}{1+\alpha t_1}$$

Where R_1 = 1^{st} resistance , R_2 = 2^{nd} resistance , α = temperature coefficient, t_1 = 1^{st} temperature and t_2 = 2^{nd} temperature.

4.3.7. Terminating and Jointing P.V.C Cables

Stripping P.V.C Cables: A single core p.v.c cable should be stripped by holding the cutting knife at an angle to the cable (fig. 2.5), and cutting away from the hand holding the cable. Multi-core cable is stripped by the cutting knife along the center of the cable and then nicking the end of the cable to give two finger grips. This allows the sheathing to be pulled down the cable with the thumb and forefinger of each hand. The sheath is then folded on top of the cable and cut by drawing the knife between the sheathing and the cable

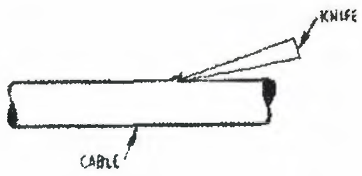


Fig. 4.2 Stripping cable

There are two basic methods of joining electrical conductors: *(a)* mechanical joints; and (b) soldered joints;

Mechanical jointing: This is done by using connector blocks. These consist of one-way or multi-way brass terminal blocks enshrouded with porcelain or plastic insulation. The connector must be capable of containing all the strands of the conductor.

Another method, usually used with larger cables, is mechanical crimping. This is done by placing a sleeve over the conductors to be jointed and crimping (squeezing) the connection with a manual or hydraulically operated crimping jack.

Soldered Joints: Materials required: pliers, sharp knife, soldering bit , flux, blowlamp (or butane gas cylinder), solder, p.v.c tape and black insulating tape.

Soldering Bit : Every joint which is made by twisting strands together must be soldered. Where a lot of single-core jointing is being carried out, it is of convenient to use a heavy bit which has a slot field in it to take cables. The soldering bit should be heated uuntil a green flame appears and must always be kept clean. Always 'tin' the bit with flux and solder before using.

Flux: The purpose of the flux is to remove the oxide film from the surface of the conductor and prevent it from re-forming.

NOTE: Corrosive fluxes, such as 'killed spirits', must not be used when soldering electrical connections.

Blowlamp: This is should be operated as follows:

1. The lamp should not be more than two-thirds full.

2. Leave the valve open when starting.

3. Start lamp with small rag dipped in methylated spirits.

4. When the lamp is hot, the valve should be closed and the pump operated.

5. The pump forces the paraffin through the heated vaporizing tube and out of the nozzle where it is ignited under pressure.

6. The blowlamp should be played against an asbestos sheet until the flame is fully established.

Bottled gas (propane and butane) is displacing the blowlamp as the former is cleaner and quicker.

Solder. Two basic types of solder are used in electrical work: fine solder (tinman's solder), which is 60 parts tin and 40 parts lead, and plumber's metal, which is 30 parts tin and 70 parts lead. Fine solder melts more easily, as tin has a lower melting point than lead, and so it is commonly used for electrical joints. Plumber's metal is used for 'plumbing' joints in armoured cables, as it remains in a plastic state, allowing it to be shaped, longer than fine solder.

Methods of Soldering: There are three different methods used for soldering conductors: *(a)* soldering bit, *(b)* 'stick* method, and (c) (metal) pot and ladle method.

Soldering Bit: The conductors to be jointed are first smeared with a resin- ous flux. The tinned bit is then applied under the joint until the heat penetrates it. The stick of solder is then applied to the joint until the solder flows freely through it.

'Slick' Method: In this method, the joint is first heated with a blowlamp, flux being applied. The solder is then applied by pressing the stick of solder against the heated joint until it penetrates the joint. Care should be taken to protect the insulation against the blowlamp flame.

Pot and Ladle Method. This method is commonly used by jointers when jointing heavy conductors. A solder pot is heated until the solder is running freely. The solder should not be overheated as this will burn the tin and a dross will form on the surface of the solder. When the solder has reached working temperature it is taken from the pot with a ladle. The solder is then poured over the prepared joint and is caught by another ladle placed under the joint. This action is repeated until the solder penetrates the joint.

Soldering Aluminium: The following special points should be noted when soldering aluminium:

1.All surfaces must be scrupulously clean.

2.When making a joint between stranded conductors 'step' the strands to increase the surface area.

3.The surface must be heated *before* the flux is applied as the flux will only take when the temperature is high enough.

4.Apply aluminium solder until the complete surface is bright. Joints in aluminium should be protected from contact with the atmosphere.This can be done by painting, taping, or compounding

Soldering a Socket (or Lug): The method used is as follows:

1.Strip insulation back about 5 cm

2. Tin the socket.

3. Smear both the socket and the bared conductor with. flux.

4. Fit the socket to the conductor. The socket should be a hammer fit.

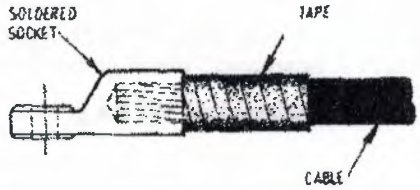


Fig 4.3 Section through soldered socket

If the socket is too large, the conductor can be enlarged with a tinned-wire binding or, better still , by pressing a strand of cable into the center of the conductor.

5. Play the blowlamp in the top of the socket until the heat has penetrated the conductor, and then apply a stick of solder to the lip of the socket. The completed connection should have a rim of solder showing round the lip of the socket; this can be done by applying plumber's metal as the joint is cooling.

6. When the termination is cooled, cut back damaged insulation and apply p.v.c. or cambric tape.

7. Tape is used to replace insulation which has been removed prior to jointing. It should be stretched before being applied, p.v.c. tape is also used for this purpose. Black tape should only be used as a protective outer covering on a joint.

NOTE: Do not attempt to cool a soldered joint by pouring water over it, as this cAN lead to an ineffective soldered connection, often termed a 'dry joint'. Never use a file to smooth or clean-up a soldered connection; the solder should be smoothed by wiping it with a dry rag before it sets.

Through Joint : This type of joint is made by using mechanical connectors,

compression ferrules or grip-type (weak backed) soldered sleeves.

Straight-through Joint using Weak-backed Ferrule: A weak-backed ferrule is a tubular piece of tinned-copper opened along the top and weakened at the bottom by indenting, allowing it to be opened or closed easily. The joint made as follows:

1. Strip Insulation back from the end of both conductors.

2. Clean and tin ferrule.

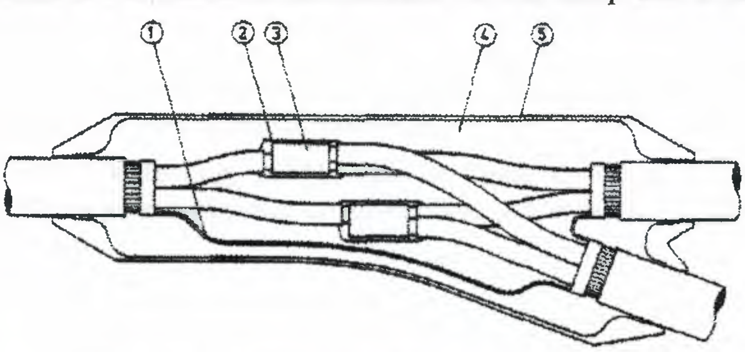
3. 3.Place ferrule on cable. Butt cables together before tightening ferrule.

4.Wind small pieces of rag at each end of ferrule to contain molten metal.

5.Solder connection.

6.Remove damaged insulation and tape.

Tee (or Breeches) Joint (Fig. 4.4). This type of joint is commonly used to tee-off a service from an armoured cable. The weak-backed ferrule is often used but alternative methods are the mechanical connector or the compression ferrule.



1.Armour Bond 2. Primary Insulation 3.Conductor Connection
4. Cold Pouring Resin Compound 5. Plastic Box

Fig 4.4 Tee (or breeches) joint

4.3.8. Types of Armoured cable

This cable is used where there is a likelihood of mechanical damage to conductors or insulation, for example, underground cable runs. There are two main types of armoured cable: *(a]* lead-covered paper-insulated steel wire, or steel tape, armoured cables (shortened to P.I.L.C.S.W.A. and P.I.L.C.S.T.A, respectively) and *(b)* p.v.c. armoured cable.

P.I.L.C.S.W.A. Cable: This consist of the following parts

1.An inner heart of jute used to keep the cable circular.

2.Copper, or aluminium, conductors insulated with mineral oil impregnated paper.

3.A lead sheath which contains the insulation and is also used as an earth continuity conductor.

4.Jute bedding tape impregnated with bitumen,, used to protect the lead against the armouring.

5.Galvanized steel wire (one layer) or steel tape (two layers).

6.Bitumen-impregnated jute serving.

Termination of P.LL.C.S.W.A. Cable: When terminating at the sealing chamber the following procedure should be followed,

1. Place binder 1 m from end of cable,
2. Remove serving to this point (using blowlamp to loosen, if necessary)
3. Bend steel wire armouring back until it is clear of lead sheath.

4.Remove approximately 12cm of lead sheath and clean remainder.

5.Place brass gland on cable, leaving approximately 10cm of lead sheathing. Wedge gland with wood to keep central on cable.

6. Plumb joint, using plumber's metal. Tallow is used as flux.

7.Clean galvanized wire with paraffin rag and shape wire over plumb.

8.Clamp wires to gland and bolt gland to sealing chamber.

9.Cut back paper insulation on conductors and make V.R.I, conductors, using weak-back ferrules.

10. Assemble sealing chamber and pour in hot bitumen to seal oil impregnated paper insulation against moistxire.

P.V.C. Armoured Cable (fig. 2.11). This is made up of p.v.c. insulated cores packed with p.v.c. to give a circular cross-section. An outer p.v.c, sheath covers the galvanized steel wire.

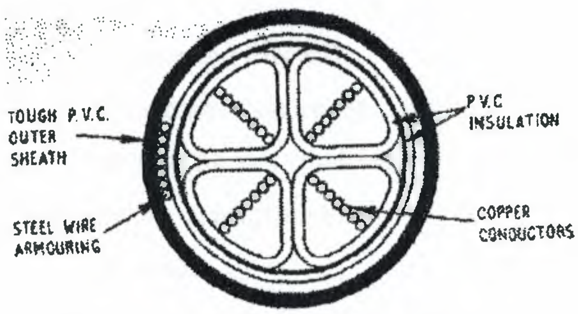


Fig. 4.5 P.V.C armoured cable.

Jointing p.v.c Armoured Cable: p.v.c. armoured cable may be terminated and jointed at the type of cast-iron boxes used for P.I.L.C.S.W.A. armoured cable, although plastic boxes are often used.But the following points require consideration:

1.p.v.c. insulation must be protected against heat (for example with cloth or tape).

2.p.v.c. tapes should be used for insulating the conductors.

3.Particular care must be taken with the cleaning and clamping of the galvanized wire armouring, as it is often the sole earth continuity conductor.

4.Compound Temperature, The temperature of hot pouring compound should be such that it does not melt the p.v.c. insulation of the conductors. This can be checked by dipping a piece of scrap p.v.c. Into the compound before pouring.

NOTE:tables 5M, 6M , and 25M of the I.E.E Regulations give current ratings for p.v.c. armoured cables(copper and aliminium conductors).

4.3.9 Mineral –insulated Metal-sheated (M.I.M.S) Cable

This type of cable is often referred to as M.I.C.C(copper or aliminium covered) cable. M.I.M.S cable consist of three parts:

1.Coppper or Aluminium Conductors. Each core consists of a single copper ar. Common core numbers are: 1, 2, 3, 4, and 7.

2. Insulation: The insulation between the cores is magnesium oxide (magnesia); a material capable of withstanding high temperatures but which is absorbent to moisture.

3. *Outer Sheath.* This is a seamless copper or aluminium tube. The cable is formed by drawing a section through a series of dies, so that the relative distance between the cores and the sheath is constant during the manufacture and use of the cable.

NOTE: Tables 13M to 17B of the I.E.E. Regulations give the current ratings.

Terminating M.I.M.S. Terminations are made at special glands. The procedure for termination is as follows :

1. Slip gland nut, compression ring (sometimes termed 'olive'), and and body on to cable.

2. Strip sheath using stripping tool

3. Screw on sealing pot (forced thread),

4. Slip disc and sleeve assembly on cores.

5. Press compound into sealing pot (making

6. Crimp sealing pot with crimping tool.

Clean off surplus compound.

Outline of Regulations relating to Conductors and Cables

1.correct voltage rating must be used in all cables.*NOTE:*A 250V grade cable is aloowed in 415V 3-phase systems where the neutral is earthed.

2.The voltage drop in a consumer's installation must not be exceed 2.5 per cent of supply voltage.

3.Every conductor must be identified by:colour, sleeves, numbers(paper insulation), or disc.

4.Single-core armoured cable must not be used for a.c.

5.The current ratings given in the J.E.E. Regulations must not be exceeded or overheating will result.

6.All cable terminations must be *(a)* mechanically and electrically sound, *(b)* accessible for inspection (unless buried); *(c)* free of mechanical strain, and *(d)* capable of containing *all* the strands of the conductor. Do *not* nick or cut strands as this decreases the current-carrying capacity of the cable and may lead to overheating at the termination.

7.Joints between two different metals (for example, copper and aluminium) should be protected against corrosion. If it is a clamp connection, the copper should be tinned in order to prevent electrolytic action .

8.Insulation removed from a conductor during the making of a joint should be replaced by a suitable tape,

9.Joints in M.LM.S, must be protected against moisture.

10.Fluxes containing acids must *not* be used for electrical jointing.

11.Terminations in & sheathed-cable system (for example, p.v.c. or t.r.s.) must only be made at enclosed positions. The enclosure containing the termination must be made of an incombustible material (for example, hard-wood block or plastic pattress).

12.Flameproof fittings must be used when cables are terminated under conditions where inflammable materials or gases are present (for example, paint spray shop).

13.t.r.s. must not be installed in direct sunlight without a protective covering.

14.Maximum operating temperature for cables: rubber, 55 ^{C}C and p.v.c., 65 ^{C}C; impregnated paper, 75 ^{C}C.

15.Flexible cable and flexible cord (exceeding 30 V a.c.): Flexible cable of the circular type should only be used for connections to movable equipment. Twisted flex should only be used for fixed lighting fittings, *not* for portable appliances. Ail flexes must be protected from mechanical damage.

16.Cables installed under floors or above ceilings should be positioned so that they are riot damaged by contact with the floor or ceiling or any fixings (e.g. nails or screws). Where cables are run through a wooden joist they should be at least 50 mm from the top or the bottom of the joist, or inserted in securely fixed mechanical protection (e.g. steel conduit).

17.All non-sheathed cable should be mechanically protected e.g. inserted in conduit, trunking or ducting.

18.M.I.M.S. and armoured p.v.c.-insulated cable should be protected with an extruded p.v.c. sheath where they are exposed to the weather or fitted in wet, damp or humid conditions (e.g. concrete ducts).

4.4 PLASTIC PIPES

In past, iron pipes were used but in today's the plastic pipes is used. They can bended however you want. Their life is long and also they do not effect from corrosion. You can work easily with them. They are produced at standard sizes and length, which is 3 meters.

Table 4. 1 Plastic pipes thickness and length

Inch	MM	Length (M)
5/8	16 mm	3
3/4	20 mm	3
1	25 mm	3
1 ¼	32 mm	3
1 ½	38 mm	3
2	50 mm	3

CHAPTER 5

5.0 CONDUIT,TRUNKING AND DUCTING

The wiring systems described in this chapter deal with basic enclosures which are designed to accommodate single insulated non-sheathed conductors. They are, of course, used for sheathed cables where additional protection from mechanical damage is required. Both conduit and trunking are available in steel and PVC. Non-ferrous conduit various alloys) is used for specialized work.Conduit is also available in a flexible form.

5.1Conduit

5.1.1. Steel Conduit

The most common form of conduit used today is screwed steel with a welded seam or solid drawn (used in hazardous areas where there is a high risk of fire and explosion). A light-gauge conduit is also available with its use restricted to providing protection for flush PVC cable installations. Two finishes for conduit are: black enamel (dry situations) and galvanised (for outdoors and situations where dampness is present).

The main advantages of steel conduit include its ability to give conductors good protection against mechanical damage; it allows easy rewiring; fire risks are minimised; and the conduit can be used as a circuit protective conductor (cpc), though it is common practice to run a separate CPC in the conduit.

Steel conduit has a few limitations, including the problem of a build-up of condensation in situations where the temperature tends to fluctuate (this can be avoided by providing drain points in the length of run); it is expensive to erect (it is a labour intensive system having to be measured, cut, threaded and erected before wires are drawn in); and it is liable to corrosion in adverse environmental conditions.

A full range of accessories are used with screwed steel conduit: bends, tees, draw-in boxes and adaptable boxes; all of these give a high degree of flexibility in allowing alterations to be made to an existing conduit system. In fact, once installed in the appropriate conditions a conduit system has a very long life, providing a car cass which can be completely rewired over several periods in the life of a building.

Conduit is available in four sizes (measured on its outside diameter): 16, 20, 25 and 32 mm; the normal length is 3.75 m. The Wiring Regulations restrict the number of conductors that can be drawn into conduit. This is to allow for ventilation of current-carrying cables, to allow for removal and replacement of conductors and, in some cases where the existing conduit capacity is not up to its limit, to allow new circuits to be drawn in. Although manufacturers' conduit bends can be obtained, on site conduit is bent on a bending machine which ensures that the minimum internal radius of the bend is equal to *2½* times the outside diameter. If, however, a bending block (made from a baulk of wood) is used it is essential that the internal radius of the bend complies with the dimension given.

5.1.2. PVC Conduit

Where appropriate, PVC conduit is a popular, and inexpensive, alternative to steel conduit. It is available in both light and heavy grades and does not need to be threaded unless so specified by the job. The conduit is available as rigid, semi-rigid, flexible round (for surface and embedded work) and in an ova! shape (for switch drops). Grades of PVC conduit include super high impact, standard impact, and high temperature (up to 85 *°C).*

Because the expansion rate for PVC conduit is around five times that of its steel equivalent, expansion couplers are needed in long runs (at every 8 m). Where the conduit IS to be used in damp situations, a special non-setting adhesive ensures a seal which allows for movement as temperatures fluctuate.

Note: The adhesives used with PVC conduit will give off fumes which create a health hazard and thus the electrician is advised to ensure that the working plaee is well ventilated. Contact with the skin should also be avoided.

A wide range of conduit accessories is available, similar to those for steel conduit.

5.1.3. Flexible Conduit

Flexible metallic conduit is often used to make a suitable connection between a rigid conduit system and, for example, a motor which may be required to be moved for belt tensioning, belt removal and replacement. Several types are available. A separate CPC is needed, run either inside the conduit or externally.

5.2. Trunking

Trunking is a fabricated casing for conductors and cables, generally rectangular in shape with a removable lid which allows the conductors to be laid in rather than be drawn in as is the case with conduit. It is used where a large number of conductors are to be carried, or follow the same route. Both steel and PVC trunking are available, with a wide range of such accessories as bends, tees, flanged adaptors, risers and reducers,

The variety of trunking includes plain section, compartmented, skirting, bench, floor trunking, and busbar trunking. Trunking is not necessarily a complete wiring system in itself and is thus associated with conduit and MI cables to allow connection to wiring accessories and their mounting boxes.

Finishes on steel trunking include grey enamel, galvanised and silver enamel on zinc-coated mild steel.

Compartmented trunking allows wiring at different voltages to be segregated but carried within the same unit run. This prevents services at one voltage accidentally becoming live to a higher voltage in the event of a fault.

Skirting trunking is used in offices where the services (socket-outlets, etc.) can be sited on the perimeters of rooms

Beech trunking is commonly found in schools and laboratories where access to a large number of socket-outlets is required. As the name implies, the trunking units are mounted on benches.

Floor trunking is an alternative to skirting trunking. There are three types: underfloor (where the trunking is set in a concrete floor with access only at junction boxes), flushfloor trunking (with the lid mounted flush with the floor surface) and flushduct trunking (where the lid is mounted flush with the screen) and a finish (such as parquet or tiles) is placed directly onto it.

Busbar trunking is basically plain-section trunking containing fixed copper or aluminium bars. Access to the busbars is made by means of tap-off boxes. It is often used in workshops where machinery or equipment may be shifted to different positions in the same area. Down drops are then available from the overhead busbar trunking tap-off boxes, via rigid or flexible conduits.

A variation of busbar trunking is the cable-kip trunking which is plain-section trunking containing cleats which support large csa PVC-insulated cables which form a useful ring-main supply from which fused tap-off boxes provide supplies for smaller circuits.

PVC trunking is made from high-impact PVC and is an inexpensive alternative to the steel equivalent. As with PVC conduit, allowances must be made for expansion of the trunking in high ambient temperatures.

In both steel and PVC trunking, the Wiring Regulations require a limit to ihe number of cables which can be accommodated to allow for adequate ventilation of heat generated by current-carrying cables and to allow for easy withdrawal of circuit conductors. A separate CPC must be run for each circuit run in PVC trunking.

Mini trunking is a small-section high-impact PVC with a clip-on *lid.* Used for surface work it is unobtrusive and is adapted to enter into ceiling roses, socket-outlets and switch boxes. It is popular for use in temporary installations such as Portacabins on building sites hut can also be used effectively in domestic installations where the decoration must not he disturbed.

5.3 Ducting

Ducts are simply passages provided by builders in the structure of a building to allow cables to run from points of supply so their terminations. Ducts can be rectangular channels covered by steel lids, trenches in concrete with covers or simply pipes. All cables run in ducts must be sheathed or armoured.

Cable Tray

Although not quite a wiring system, cable tray is used to carry heavy armoured cables and multiruns of MI cables.It is widely used in industrial installations where normal cable runs may be obstructed by pipework and other structural urcs. The tray is basically a flat metal sheet with perforations and either a simple turned flange or a return flange for greater strength. A range of finishes are provided to meet installation conditions: galvanised, primed with red oxide or yellow chromate, plastic-coated and coated with epoxy resins (resistant to acids and virtually non-flammable). For very heavy cable runs, cable ladders are used.

5.4 Wiring Accessories

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

5.4.1. 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 on inductive circuits, particularly when they are used to control fluorescent lighting. This is because such circuits take 80 per cent more current than the lamps' wattage might suggest. If switches are not rated for inductive circuits, they must be derated by 50 percent.

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 are of the pull-cord type.

Switches water-heaters are of the double-polerated to carry 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 lightingfrom a luminaire.Watertight switches are designed for outdoor use while splashproof switches are found in situations where water is present, such as in shower rooms.

Most switches tend to be made from moulded plastic, but metal-clad versions are available for use. Some switches for domestic installations can be finished in satin chrome or polished brass.

5.4.2. Lambholders

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

5.4.3. Ceiling roses

Ceiling roses are used with cordgrip landholders for pendant luminaires. They must not be used in circuits exceeding 250 V and must not have more than one outgoing flexible cord unless designed for multiple pendants. They are often provided with a loop-in terminal('live') which is required to be insulated against the possibility of receiving a shock from direct contact.

5.4.4. Cooker outlet units

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.

5.4.5. Shaver supply units

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

5.4.6. Cooker-control units

These can be of the double-pole 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 soeket-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.

5.4.7. Socket-outlets

These take 13A 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 appliance has its own switch.

(*Note:* A heating appliance may have thermostatic control, but the thermostat does not act as a 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 round-pin socket-outlets are available for special purposes. Connection units can also be obtained with a cord outlet.

5.4.8. Outlet plates

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

5.4.9. Mounting boxes

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

5.4.10. 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 mourning box. an internally fixed grid which then accepts the switch or switches and a cover plate. The system ranges from one-gang units to twenty-four-gang units. The accessories include switches, bell pushes, indicator lights and key-operated switches.

5.4.11. Industrial socket-outlets and plugs

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

Installation Hints

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

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

Lighting switches. Single-pole switches are to be connected in the phase conductor only which must also be correctly identified by colour. All exposed metalwork (e.g. the metal switch plate) 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 luminaires) it must be derated by 50 per cent.

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 luminaire.

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 earthing tail provided between the 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 or shower. They should be more than 2.5 m away from a shower cubicle in a room other than a bathroom.

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

CHAPTER 6

6.0 ILLUMINATION

6.1 Some Kinds of Lamps

Filament lamps

Filament lamps fall into a group of light-producing devices called 'incandescent'. They give light as a result of heating a filament conductor to a very high temperature. In 1860, Sir Joseph Swan produced the first lamp using carbonized paper strip. Later, carbonized filaments made from silk were used. Until 1900, carbon-filament lamps enjoyed an undisputed field of use. Then the metal-filament lamp appeared and by 1910 it had superseded the carbon lamp. The carbon lamps, which are made today, have a limited application: for lamp resistances (battery-charging), and radiant-heat apparatus. The modern carbon lamp has a filament of Swedish filter paper, which is dissolved in zinc chloride solution. The resultant viscous solution is squirted slowly through a fine die into a jar of acidified alcohol. Tough cellulose threads are the result. They are wound on formers, which are packed into a crucible filled with finely powdered graphite. The crucibles are then baked in a furnace at 1400°C when the cellulose threads become pure carbon. The temperature limit for a carbon filament is about 1800°C. The light output is low, at about 3.6 lumens per watt (lm/W).

The tungsten-filament lamp first appeared about 1910 and has since been the main incandescent lamp in use. It operates at a temperature of about

2300°C and has a light output of about 8 lm/W. The first lamp to use a tungsten filament had the air evacuated from the glass bulb the so called vacuum lamp. Later, the bulb was filled with argon and nitrogen which are inert gases and do not support combustion. This development enabled the filament to be operated at a higher temperature without the undue evaporation of the filament, which tends to take place in a vacuum. The operating temperature of the gas-filled lamp is about 2700°C. The light output is in the region of 12 lm/W. The early lamps had a single-coil filament. Later the coiled-coil lamp was produced, that is, the coiled filament was itself formed into a coil. The light output of this lamp is about 14 lm/W. The main advantages of the coiled-coil lamp are (a) the filament has a more compact formation and (b) the beat losses due to convection currents in the gas are reduced, so giving a higher light output efficiency.

Tungsten has a resistance, which increases with temperature. The resistance when cold is about 6 per cent of that when operating at normal temperature. This means that when the lamp is switched on, a current of about fourteen times the running current flows. The increase in the temperature of the filament is rapid, however, and the current surge does not harm the filament. The resistance of the filament increases as rapidly and has a stabilizing effect on the power consumed.

There are many types of metal-filament lamps available today. Signal lamps are small and are used on indication boards to show the flow of chemicals, the passage of trains past a given point, and the energizing of a circuit in a definite sequence. Spot and flood lamps are made from pressed glass and are internally mirrored to radiate a defined beam of light. The flood lamp has a relatively broad beam and is used for outdoor illumination such as gardens, monuments, parks, and sports grounds. The spot lamp has a narrow beam and is found in shop windows and showcases. They are also used to highlight an object, which has a general illumination. Thermal -radiation lamps are used in piglet and chicken rearing. They are hard-glass bulbs and are internally mirrored for use for short-periods at a time. They are also to be found in bathrooms, and in industry for drying processes (e.g. stove enameling).

Discharge lamps

The discharge lamp consists of a glass tube containing a gas. At each end of the tube there is an electrode. If a sufficiently high voltage is applied across these electrodes a discharge takes place between them. The gas now becomes an electrical conductor and light is produced. The color of the light produced by a discharge lamp depends on the gas in the tube: Neon - red; mercury vapor - bluish-white; helium - ivory; sodium vapor - yellow.

There are a number of electric-discharge lamps available today, each of which has a particular application or advantage over another.

Low-pressure mercury-vapor

This lamp is popularly known as the 'fluorescent' lamp. It consists of a glass tube filled with mercury vapor at a low pressure. The electrodes are located at the ends of the tube. When the lamp is switched on, an arc-discharge excites a barely-visible radiation, the greater part of which consists of ultra-violet radiation. The interior wall of the tube is coated with a fluorescent powder, which transforms the ultra-violet radiation into visible radiation or light. The type of light, that is the color range, is determined by the composition of the fluorescent powder. An important aspect of the gas-discharge lamp is that the discharge has a 'negative resistance characteristic'. This means that when the temperature of the gas or vapor rises, its resistance decreases and will thus tend to draw an ever-increasing current from the supply. The current is limited to a predetermined value by the insertion in the circuit, in series with the lamp, of a limiting resistor or choke (inductor).

There are two types of fluorescent lamp: the hot-cathode and the cold-cathode.

The hot-cathode lamp is the more common type, familiar in tube lengths of 2.5, 1.7, 1.3 m and down to 30 cm. In this type, the electrodes are heated and the voltage of operation is low or medium voltage. To assist starting, the mercury vapor is mixed with a small quantity of argon gas. The light produced varies from 30 to 35 lm/W. The colors available from the lamp include a near-daylight and a color-corrected light for use where colors (of wool, paints, etc.) must be seen correctly. The practical application of the lamp includes the lighting of shops, homes, factories, streets, ships, transport ~uses and trains), tunnels, coalmines and caravans. The auxiliary equipment associated with the hot-cathode lamp includes.

1. The choke, which supplies a high initial voltage on starting (caused by the interruption of the lamp's inductive circuit), and also limits the current in the lamp when it is operating.

2. The starter.

3. The capacitor, which is fitted to correct or improve the power factor of the circuit by neutralizing the inductive effect of the choke.

There are a number of methods used to start fluorescent lamp circuits.

The methods fall into two general groups." those which use a switch (sometimes called a 'glow' starter) and those, which do not use a switching arrangement but rely on an autotransformer to produce the high voltage, needed to start the lamps. With the glow-starter, it is important to use the correct type for the size of lamp. Although 'universal' starter switches are available, it must be remembered that they are not in fact suitable for all sizes.

The semi-resonant start circuit has the usual choke or inductor replaced by a specially wound transformer and is used for starting fluorescent lamps in cold temperatures. Current flows through the primary coil to one cathode of the lamp and thence through the secondary coil, which is wound in opposition to it. A large capacitor is connected between the secondary and the second cathode of the lamp. The starting current quickly heats up the cathodes and as the circuit is mainly capacitive; this current leads the mains voltage. Because the primary and secondary windings are in opposition, the voltage across the lamp is increased and causes the lamp to strike.

The glow-start switch consists of two-separated bimetallic contact strips contained in a small glass bulb filled with helium gas. The contacts are connected in series with the lamp electrodes. When the circuit-control switch is closed, the mains voltage appears across the two contacts and results in a small gas discharge. The heat generated by the discharge effects the bimetallic strips, which bend forward to meet each other. When they make contact, current flows through the lamp electrodes to heat them. The gas discharge in the bulb ceases and the strips begin to cool down. When they separate, a high voltage appears between the electrodes and the main gas discharge is started. The voltage, which now appears across the contacts in the bulb, is, during running conditions, insufficient to cause further discharge in the helium gas, and so the contacts remain open while the lamp is burning.

The instant-start or 'quick-start' method of starling fluorescent lamps consists of an autotransformer connected across the tube. Two tapings provide a small current for heating each of the electrodes. When the electrodes become hot (usually in a fraction of a second) the tube strikes. The striking or discharge is caused by the very small currents flowing from the cathodes to an external earthed strip, which runs down the length of the tube, providing a conducting path. A normal choke is used, but only for current-limiting purposes, since there is no interruption of the current on starting.

The cold-cathode lamp uses a high voltage (about 5kV) for its operation. For general lighting purposes, they are familiar as fluorescent tubes of about 2.5 cm in diameter, straight, curved or bent to take a certain form. The power consumption is generally about 24W per meter length. The current taken is of the order of milliamperes.

6.2. Practical aspects of lighting

Though many aspects of lighting or illumination are the special concern of the qualified lighting engineer, there are some, which also affect, either directly or indirectly, the electrician. These aspects are dealt with in the following sections.

6.3. Ambient temperature of lamps

The recent development in lamp sizes and the increase in ratings used in domestic, commercial, and industrial installations have led to problems resulting from the heat generated by these lamps. If a 1000W lamp is operated in an ambient temperature of 25°C, the temperature rise can be greater than 60°C. This means that if the lighting point is a pendant, the flexible cord will be in an ambient temperature of 85°C. It has always been accepted that, owing to such high temperatures near the lamp-holders, embitterment of the insulation of the cord will occur, with consequent shortening of the life of the cord. The trend in recent years has been to manufacture lamps smaller in size than that of the equivalent wattage previously made, so that it has become possible to use a higher wattage lamp in an existing type of fining. For instance, whereas in the past temperatures in enclosed fittings may have been as high as 80°C or so, it is now possible for temperatures to be as high as 130°C and even more where the ambient temperature is also high.

The IEE Regulations have recognized this problem of heat from lamps and now recommend that the choice of a flexible cord for a particular lighting duty should be based, not only on current rating, but on the ambient temperature likely to he encountered at a lighting point. Certain new heat-resisting materials are now available.

Conductors for very high temperatures are now nickel-plated copper, instead of the usual tinned-copper; some conductors are natural copper and are associated with thermoplastic insulating materials such as polythene and polyvinyl chloride (PVC). The greatest advances have been made with insulating materials. Natural rubber is now limited to use where the temperatures do not exceed 65°C. Above this limit the rubber becomes hard and the life of a cord may be as little as a year or so. Inspection of rubber insulation, which has become hard during service, has shown that it may still function as an insulator provided the cable is not fixed.

Polyethylene (polythene) has many electrical properties. But it is a thermoplastic material and deforms seriously under pressure and excessive heat. At about 110°C there is a sharp melting point when severe flow may take place with consequential electrical failure. This type of cable is not used in lamp finings. PVC has excellent age-resisting properties, but has a low maximum operating temperature of 70°C. This type is also not used for lamp fittings, unless the ventilation is adequate.

Butyl-rubber insulation is suitable for lamp fittings where higher ambient temperatures are prevalent. The maximum permitted operating temperature is 85°C. At this temperature, the cable has a long life. At higher temperatures the insulation deteriorates rapidly. Around 130°C it turns to powder. Silicone rubber can be operated continuously at 150°C, and is used for many of the enclosed lamp fittings installed at the present time. The physical properties of this type of insulation are such that a suitable protection is necessary and a heat-resisting braid is normal for this purpose. Glass braiding with a heat-resisting lacquer is an excellent finish, but makes an expensive cable. An alternative is terylene braiding, which is considered ideally suitable for many lamp fittings. Another good heat-resistant type of finish is an impregnated glass lapping with an impregnated glass braid. The temperature of operation of this type of cable may be as high as 180°C. For enclosed lamp fittings, where temperatures of this order are obtained, this cable is a suitable answer. installations, are chlorosulphonated polyethylene (CPS or 'Hypalon') and PVC

Two sheathing materials, which are used widely in /nitrile rubber (NCR/PVC) generally known as HOFR insulants. These materials are both vulcanisable rubbers and besides having good weathering, solvent, and oil resistance, are flame retardant. They may be compounded so as to be used over an insulated conductor operating at 85°C. Another new product, which appears suitable, particularly for insulation, is ethylene propylene rubber. The age-resistance of this material is proving excellent and may well prove to be a common material in the near future.

6.4. The effect of voltage drop

The voltage applied to a lamp is reduced if the actual voltage at the lamp terminals is lower than the rated lamp voltage. Generally, the reduction in light output is more rapid than the reduction of the wattage. It is therefore not economical to run lamps at less than the rated voltage. Another aspect of reduced voltage at the lamp terminals is that financial loss can be experienced in addition to less light being available. Over-volting a lamp by 5 per cent (e.g. a 230V lamp on 242V) halves its life, as the filament is operated at a higher than normal temperature and vaporizes more rapidly. On the other hand, under-volting a lamp lengthens its life but reduces its light output without a corresponding reduction in the wattage consumed. Electricity, in effect, is being run to waste.

Voltage drop can also occur as a result of the lighting cables being too small for the current carried. This situation may arise when old wiring is allowed to supply new lamp fittings, which contain lamps with higher wattage ratings. In fact, in many modern commercial and industrial premises it is often found that with high-wattage lamps being used and long circuit runs, cables larger than the usual 1, 1.5 and 2.5 mm^2 are necessary.

6.5. Faults in discharge lamps

Because of their associated circuitry, containing components such as starters, chokes and capacitors, and transformers, discharge lamps may fail or fault, to show certain symptoms which can be useful in any diagnosis by the electrician sent to investigate the fault. The following is summarized information on different lamp types.

Mercury lamps. One of the first points to note about these lamps is that they require up to 5 minutes to cool before re-ignition can take place. In factory situations lamps are often extinguished because of voltage 'dips'. If a lamp fails to reignite after cooling, the ballast should be checked for over-heating and continuity. If the lamp is nearing the end of its life it will fail to re-strike and should be replaced. If the lamp delivers a poor light output, the choke should be checked for continuity. In some circuits, parallel chokes are used and their currents should be equal. However, one type of 700W circuit uses dissimilar chokes. Some types of lamp may suffer from 'thermal shock' as the result of cold water, e.g. rain, falling onto the hot glass envelopes. Cracked lamps (perhaps the result of damage in transit) will operate until the internal pressure falls to atmospheric when the arc tube will fail. Excessive pressure used when screwing lamps in their holders also produces faults resulting in eventual lamp failure. If the tight output is unstable, a possible cause could be poor contact in the lamp holder (look for signs or arcing on the cap center contact).

6.6. Maintenance

Immediately a lighting installation is put into service it begins to deteriorate. A film of dust or dirt begins to reduce the transparency or reflecting power of all the exposed surfaces of lamps, fittings, and the walls and ceiling of a room. This process, if unchecked, may result in the level of illumination falling very low in a comparatively short time. Only thorough and periodic cleaning of lighting equipment and attention to room decorations can maintain the performance of the installation at a reasonably high average value. Generally, a maintenance factor is applied. The general figure is 0.8. This means that in planning the amount of illumination required for a particular installation, the light in lumens must be divided by 0.8 to allow for a decrease in light output caused by dust, etc. Very dirty situations may have a maintenance factor of 0.6 applied to them.

Maintenance of lighting installations also involves the replacement of lamps, which have either failed or have suffered reductions in their light output.Labour costs generally determine whether such lamps should be replaced individually as they fail, or by group replacement.

6.7. Light control

Most sources radiate light in all directions, and are too brilliant to be viewed comfortably. The light must therefore be controlled to direct it where it is required and to soften its brilliance. All substances absorb some of the light which strikes or passes through them All substance also reflect some of the light falling on them, or transmit it, or both. Reflection of light may be of three kinds:

a) Specular reflection. When light strikes a mirror-like surface it is reflected at the same angle and in the same plane as it strikes. The type of reflection is much used for the precise control of light, e.g. car headlamps, silvered shop-window reflectors. Accidental specular reflection is generally unwanted, e.g. lighting fittings reflected in glossy table tops. A mirror-like surface can took dark even though a great deal of tight is striking it, and vice versa. Its appearance depends only on what is mirrored in its surface from the particular viewpoint concerned. The streakiness sometimes obtained from specular reflection is avoided by breaking up the reflector surface by ripples, flutes or dimples, by giving it a 'satin' finish, by using a pearl (or otherwise obscured) type of lamp, or by using a moulded or lightly frosted glass cover to the lamp fitting.

b) Diffuse reflection. This is the reflection obtained from a perfectly matt surface, the distribution of the reflected tight being independent of the direction of the incident light. The distribution of reflected light follows the cosine law, i.e. the intensity in any direction is proportional to the cosine of the angle between that direction and the perpendicular to the surface. A surface having this characteristic appears equally bright whatever the direction of view. White blotting paper and whitewash are nearly perfect diffuse reflectors. Diffuse reflection is useless for the precise control of light, but it can be used to reflect light in a general direction.

c) Spread reflection. Depolished metals and satin-finished mirrored surfaces have reflection characteristics between secular and diffuse. Vitreous and synthetic enamels are widely used for the reflecting surfaces of lighting fittings. Vitreous enamel is the more hard-wearing.

6.8. Stroboscopic effects.

When discharge lamps operate on alternating current systems, their light output varies in each cycle and this produces certain effects. These are rarely very troublesome, but it is sometimes necessary to take certain precautions to minimize them. The cyclic variation in the light output is not normally perceptible with Lamps operating on a

50 Hz (cycles per second) supply, since it occurs at twice the frequency of the mains. However, it can give rise to stroboscopic effects where the true speed of rotating machinery or other objects is not immediately apparent and they can appear to be, lowed down or even stationary. The means of overcoming this stroboscopic effect are easy to provide in circuitry, and should be used where there is any possibility that accidents may result from misjudgment of machine speed.

Apart from the stroboscopic effect, this flicker from tubular fluorescent lamps may be a source of optical annoyance. This flicker arises from half-wave rectification in the lamps or from the random movement of hot spots on the lamp electrodes. Flicker is also apparent at the extreme ends of fluorescent lamps and is caused by the fact that a small pan of the discharge emits radiation only during one-half of a complete cycle. This fluctuation, which occurs at mains frequency, may be overcome by fitting opaque shields over the lamp ends, or by other methods, which screen the ends of the lamp from direct view.

One method used to eliminate or minimize stroboscopic effect is the connection of every second lamp in a pair of fluorescents in series with a capacitor, to change the phase of the second lamp's circuit. The circuit is usually known as a lead/lag circuit. Another method is to use banks of fluorescent lamps supplied from a three-phase four-wire supply, where each bank of lamps is connected to each phase wire and neutral to give a balanced three-phase lighting load.

CHAPTER 7

7.0 EARTHING

An efficient earthing arrangement is an essential part of every electrical installation and system to guard against the effects of leakage currents, short-circuits, static charges and lightning discharges. The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock, and to reduce the risk of fire hazard. The earthing arrangement provides a low-resistance discharge path for currents, which would otherwise prove injurious or fatal to any person touching the metalwork associated with the faulty circuit. The prevention of electric shock risk in installations is a matter, which has been given close attention in these past few years, particularly since the rapid increase in the use of electricity for an ever-widening range of applications.

7.1. EARTHING TERMS

7.1.1 Earth:

A connection to the general mass of earth by means of an earth electrode.

7.1.2 Earth Electrode:

A metal plate, rod or other conductor band or driven in to the ground and used for earthing metal work.

7.1.3 Earthing Lead:

The final conductor by means of which the connection to the earth electrode is made.

7.1.4 Earth Continuity Conductor (ECC):

The conductor including any lam connecting to the earth or each other those part of an installation which are required to be earthed. The ECC may be in whole or part the metal conduit or the metal sheath of cables or the special continuity conductor of a cable or flexible cord incorporating such a conductor.

7.2 EARTHING SYSTEMS:

In our electricity system, which is same to UK electricity, is an earthed system, which means that star or neutral point of the secondary side of distribution transformer is connected to the general mass of earth.

In this way, the star point is maintained at or about. 0V. Unfortunately, this also means that persons or livestock in contact with a live part and earth is at risk of electric shock.

Lightning protection

Lightning discharges can generate large amounts of heat and release considerable mechanical forces, both due to the large currents involved. The recommendations for the protection of structures against lightning are contained in BS Code of Practice 6651 (Protection of Structures Against Lightning). The object of such a protective system is to lead away the very high transient values of voltage and current into the earth where they are safely dissipated. Thus a protective system, to be effective, should be solid and permanent. Two main factors are considered in determining whether a structure should be given protection against lightning discharges:

1. Whether it is located in an area where lightning is prevalent and whether, because of its height and/or its exposed position, it is most likely to be struck.

2. Whether it is one to which damage is likely to be serious by virtue of its use,

contents, importance, or interest (e.g. explosives factory, church monument, railway station, spire, radio mast, wire fence, etc.).

It is explained in BS Code of Practice 6651 that the 'zone of protection' of a single vertical conductor fixed to a structure is considered to be a cone with an apex at the highest point of the conductor and a base of radius equal to the height. This means that a conductor 30 meters high will protect that part of the structure which comes within a cone extending to 60 meters in diameter at ground level Care is therefore necessary in ensuring that the whole of a structure or building falls within the protective zone; if it does not, two down conductors must be run to provide two protective zones within which the whole structure is contained. All metallic objects and projections, such as metallic vent pipes and guttering, should be bonded to form part of the air-termination network. All down conductors should be cross-bonded.

The use of multiple electrodes is common. Rule 5 of the Phoenix Fire Office Rules states:

Earth connections and number. The earth connection should be made either by means of a copper plate buried in damp earth, or by means of the tubular earth system, or by connection to the water mains (not nowadays recommended). The number of connections should be in proportion to the ground area of the building, and there are few structures where less than two are necessary ... Church spires, high towers, factory chimneys having two down conductors should have two earths which may be interconnected.

All the component parts of a lightning-protective system should be either castings of leaded gunmetal, copper, naval brass or wrought phosphor bronze, or sheet copper or phosphor bronze. Steel, suitably protected from corrosion, may be used in special cases where tensile or compressive strength is needed.

Air terminations constitute that part of dice system, which distributes discharges into, or collects discharges from, the atmosphere. Roof conductors are generally of soft annealed copper strip and interconnect the various air terminations. Down conductors, between earth and the air terminations, are also of soft-annealed copper strip. Test points are joints in down conductors, bonds, earth leads, which allow resistance tests to be made. The earth terminations are those parts of the system designed to collect discharges from, or distribute charges into, the general mass of earth. Down conductors are secured to the face of the structure by 'holdfasts' made from gunmetal The 'building-in type is used for new structures; a caulking type is used for existing structures.

With a lightning protection system, the resistance to earth need not be less than 10 ohms. But in the case of important buildings, seven ohms is the maximum resistance. Because the effectiveness of a lightning conductor is dependent on its connection with moist earth, a poor earth connection may render the whole system useless The 'Hedges' patent tubular earth provides a permanent and efficient earth connection, which is inexpensive, simple in construction and easy to install. These earths, when driven firmly into the soil, do not lose their efficiency by changes in the soil due to drainage; they have a constant resistance by reason of their being kept in contact with moist soil by watering arrangements provided at ground level. In addition, tubular or rod earths are easier to install than plate earths, because the latter require excavation.

Lightning conductors should have as few joints as possible. If these are necessary, other than at the testing-clamp or the earth-electrode clamping points, flat tape should be tinned, soldered, and riveted; rod should be screw-jointed.

All lightning protective systems should he examined and tested by a competent engineer after completion, alteration, and extension. A routine inspection and test should be made once a year and any defects remedied. In the case of a structure containing explosives or other inflammable materials, the inspection and test should be made every six months. The tests should include the resistance to earth and earth continuity. The methods of testing are similar to those described in the IEE Regulations, though tests for earth-resistance of earth electrodes require definite distances to be observed.

Anti-static earthing

'Static', which is a shortened term for 'static electric discharge' has been the subject of increasing concern in recent years partly due to the increasing use of highly insulating materials (various plastics and textile fibres).

Earthing practice

1. Direct Earthing

The term 'direct earthing' means connection to an earth electrode, of some recognized type, and reliance on the effectiveness of over current protective devices for protection against shock and fire hazards in the event of an earth fault. If direct earthing protects non-current-carrying metalwork, under fault conditions a potential difference will exist between the metalwork and the general mass of earth to which the earth electrode is connected. This potential will persist until the protective device comes into operation. The value of this potential difference depends on the line voltage, the substation or supply transformer earth resistance, the line resistance, the fault resistance, and finally, the earth resistance at the installation. Direct earth connections are made with electrodes in the soil at the consumer's premises. A further method of effecting connection to earth is that which makes use of the metallic sheaths of underground cables. But such sheaths are more generally used to provide a direct metallic connection for the return of earth-fault current to the neutral of the supply system rather than as a means of direct connection to earth.

The earth electrode, the means by which a connection with the general mass of earth is made, can take a number of forms, and can appear either as a single connection or as a network of multiple electrodes. Each type of electrode has its own advantages and disadvantages.

The design of an earth electrode system takes into consideration its resistance to ensure that this is of such a value that sufficient current will pass to earth to operate the protective system. It must also be designed to accommodate thermally the maximum fault current during the time it takes for the protective device to clear the fault. In designing for a specific ohmic resistance, the resistivity of the soil is perhaps the most important factor, although it is a variable one.

The current rating or fault-current capacity of earth electrodes must be adequate for the 'fault-current/time-delay' characteristic of the system under the worst possible conditions. Undue heating of the electrode, which would dry out the adjacent soil and increase the earth resistance, must be avoided. Calculated short-time ratings for earth electrodes of various types are available from electrode manufacturers. These ratings are based on the short-time current rating of the associated protective devices and a maximum temperature, which will not cause damage to the earth connections or to the equipment with which they may be in contact.

In general soils have a negative temperature coefficient of resistance. Sustained current loadings result in an initial decrease in electrode resistance and a consequent rise in the earth-fault current for a given applied voltage. However, as the moisture in the soil is driven away from the soil/electrode interface, the resistance rises rapidly and will ultimately approach infinity if the temperature rise is sufficient. This occurs in the region of 100^0C and results in the complete failure of the electrode.

The current density of the electrode is found by:

$$\text{Current density} = \frac{\mathbf{I}}{\mathbf{A}} = \frac{\mathbf{92 \times 10^3}}{\mathbf{\sqrt{t}}}$$

where I = short-circuit fault current; A = area (in cm^2); t = time in seconds (duration of the fault current).

The formula assumes a temperature rise of 120^0C, over an ambient temperature of 25^0C, and the use of high-conductivity copper. The formula does not allow for any dissipation of heat into the ground or into the air.

Under fault conditions, the earth electrode is raised to a potential with respect to the earth surrounding it. This can be calculated from the prospective fault current and the earth resistance of the electrode. It results in the existence of voltages in soil around the electrode, which may harm telephone and pilot cables (whose cores are substantially at earth potential) owing to the voltage to which the sheaths of such cables are raised. The voltage gradient at the surface of the ground may also constitute a danger to life, especially where cattle and livestock are concerned. In rural areas, for instance, it is not uncommon for the earth-path resistance to be such that faults are not cleared within a short period of time and animals which congregate near the areas in which current carrying electrodes are installed are liable to receive fatal shocks. The same trouble occurs on farms where earth electrodes are sometimes used for individual appliances. The maximum voltage gradient over a span of 2 meters to a 25 mm diameter pipe electrode is reduced from 85 per cent of the total electrode potential when the top of the electrode is at ground level to 20 per cent and 5 per cent when the electrode is buried at 30 cm and 100 cm respectively. Thus, in areas where livestock are allowed to roam it is recommended that electrodes be buried with their tops well below the surface of the soil.

Corrosion of electrodes due to oxidation and direct chemical attack is sometimes a problem to be considered. Bare copper acquires a protective oxide film under normal atmospheric conditions which does not result in any progressive wasting away of the metal. It does, however, tend to increase the resistance of joints at contact surfaces. It is thus important to ensure that all contact surfaces in copper work, such as at test links, be carefully prepared so that good electrical connections are made. Test links should be bolted up tightly. Electrodes should not be installed in ground, which is contaminated by corrosive chemicals. If copper conductors must be run in an atmosphere containing hydrogen sulphide, or laid in ground liable to contamination by corrosive chemicals, they should be protected by a covering of PVC adhesive tape or a wrapping of some other suitable material, up to the point of connection with the earth electrode. Electrolytic corrosion will occur in addition to the other forms of attack if dissimilar metals are in contact and exposed to the action of moisture. Bolts and rivets used for making connections in copper work should be of either brass or copper. Annulated copper should not be run in direct contact with ferrous metals. Contact between bare copper and the lead sheath or armouring of cables should be avoided, especially underground. If it is impossible to avoid the connection of dissimilar metals, these should be protected by painting with a moisture-resisting bituminous paint or compound, or by wrapping with PVC tape, to exclude all moisture.

The following are the types of electrodes used to make contact with the general mass of earth:

a) Plates. These are generally made from copper, zinc, steel, or cast iron, and may be solid or the lattice type. Because of their mass, they tend to be costly. With the steel or cast-iron types care must he taken to ensure that the termination of the earthing lead to the plate is water-proofed to prevent cathodic action taking place at the joint, If this happens, the conductor will eventually become detached from the plate and render the electrode practically useless. Plates are usually installed on edge in a hole in the ground about 2-3 meters deep, which is subsequently refilled with soil. Because one plate electrode is seldom sufficient to obtain a low-resistance earth connection, the cost of excavation associated with this type of electrode can be considerable. In addition, due to the plates being installed relatively near the surface of the ground, the resistance value is liable to fluctuate throughout the year due to the seasonal changes in the water content of the soil. To increase the area of contact between the plate and the surrounding ground, a layer of charcoal can be interposed. Coke, which is sometimes used as an alternative to charcoal, often has a high sulphur content, which can lead to serious corrosion and even complete destruction of the copper. The use of hygroscopic salts such as calcium chloride to keep the soil in a moist condition around the electrode can also lead to corrosion.

b) Rods. In general rod electrodes have many advantages over other types of electrode in that they are less costly to install. They do not require much space, are convenient to test and do not create large voltage gradients because the earth-fault current is dissipated vertically. Deeply installed electrodes are not subject to seasonal resistance changes. There are several types of rod electrodes. The solid copper rod gives excellent conductivity and is highly resistant to corrosion. But it tends to be expensive and, being relatively soft, is not ideally suited for driving deep into heavy soils because it is likely to bend if it comes up against a large rock. Rods made from galvanized steel are inexpensive and remain rigid when being installed. However, the life of galvanized steel in acidic soils is short. Another disadvantage is that the copper earthing lead connection to the rod must be protected to prevent the ingress of moisture. Because the conductivity of steel is much less than that of copper, difficulties may arise, particularly under heavy fault current conditions when the temperature of the electrode wilts rise and therefore its inherent resistance. This will tend to dry out the surrounding soil, increasing its resistivity value and resulting in a general increase in the earth resistance of the electrode. In fact, in very severe fault conditions, the resistance of the rod may rise so rapidly and to such an extent that protective equipment may fail to operate.

The bimetallic rod has a steel core and a copper exterior and offers the best alternative to either the copper or steel rod. The steel core gives the necessary rigidity while the copper exterior offers good conductivity and resistance to corrosion. In the extensible type of steel-cored rod, and rods made from bard-drawn copper, steel driving caps are used to avoid splaying the rod end as it is being driven into the soil. The first rod is also provided with a pointed steel tip. The extensible rods are fitted with bronze screwed couplings. Rods should be installed by means of a power driven hammer fitted with a special head. Although rods should be driven vertically into the ground, an angle not exceeding 60° to the vertical is recommended in order to avoid rock or other buried obstruction.

c) Strip. Copper strip is used where the soil is shallow and overlies rock. It should be buried in a trench to a depth of not less than 50 cm and should not be used where there is a possibility of the ground being disturbed (e.g. on farmland). The strip electrode is most effective if buried in ditches under hedgerows where the bacteriological action arising from the decay of vegetation maintains a low soil resistivity.

d) Earths mat. These consist of copper wire buried in trenches up to one meter deep. The mat can be laid out either linearly or in 'star' form and terminated at the down lead from the transformer or other items of equipment to be earthed. The total length of conductor used can often exceed 100 meters. The cost of trenching alone can be expensive. Often scrap overhead line conductor was used but because of the increasing amount of aluminium now being used, scrap copper conductor is scarce. The most common areas where this system is still used are where rock is present near the surface of the soil, making deep excavation impracticable. As with plate electrodes, this method of earthing is subject to seasonal changes in resistance. Also, there is the danger of voltage gradients being created by earth faults along the lengths of buried conductor, causing a risk to livestock.

7.3. Important Points of Earthing:

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

I. To allow current to flow to earth in the event of a fault so that, the protective gears will operate to isolate the faulty circuit.

II. To make sure that in the event of a fault, apparatus "Normally death (0V)" cannot reach a dangerous potential whit respect to earth.

7.4. Electric Shock:

This is the passage of current through the body of such magnitude as to have significant harmful effects these value of currents are;

1mA-2mA	Barely perceptible, no harmful effects
5mA-10mA	Throw off, painful sensation
10mA-15mA	Muscular contraction, cannot let go
20mA-30mA	Impaired breathing
50mA and above	Ventricular fibrillation and earth.

There are two ways in which we can be at risk.

a-) Touching live parts of equipment for systems. That is intended to be live. This is called direct contact.

b-) Touching conductive parts which are not meant to be live, but which have become live due to a fault. This is called indirect contact.

7.5. Earth testing

IEE Regulations requires that tests he made on every installation to ensure that the earthing arrangement provided for that installation is effective and offers the users of the installation a satisfactory degree of protection against earth-leakage currents. The following are the individual tests prescribed by the Regulations.

I. Circuit-protective conductors

Regulation 713-02-01 requires that every circuit-protective conductor (CPC) be tested to verify that it is electrically sound and correctly connected. The IEE Regulations Guidance Notes on inspection and testing give details on the recognized means used to test the CPC. For each final circuit, the CPC forms part of the earth-loop impedance path, its purpose being to connect all exposed conductive parts in the circuit to the main earth terminal. The CPC can take a number of forms. If metallic conduit or trunking is used, the usual figure for ohmic resistance of one-meter length is 5 milliohms/m.

Generally if the total earth-loop impedance (Z_s) for a particular final circuit is within the maximum Z_s limits, the CPC is then regarded as being satisfactory. However, some testing specifications for large installations do require a separate test of each CPC to be carried out. The following descriptions of such tests refer to a.c. installations.

II. Reduced a.c. test.

In certain circumstances, the testing equipment in the a.c. test described above is not always available and it is often necessary to use hand-testers, which deliver a low value of test current at the frequency of the mains supply. After allowing for the resistance of the test lead, a value for impedance of 0.5 ohm maximum should be obtained where the CPC, or part of it, is made from steel conduit. If the CPC is in whole or in part made of copper, copper-alloy, or aluminium, the maximum value is one ohm.

III. Direct current.

Where it is not convenient to use a.c. for the test, D.C. may be used instead. Before the D.C. is applied, an inspection must be made to ensure that no inductor is incorporated in the length of the CPC. Subject to the requirements of the total earth-loop impedance, the maximum values for impedance for the CPC should be 0.5 ohm (if of steel) or one ohm (if of copper, copper-alloy or aluminium).

The resistance of an earth-continuity conductor, which contains imperfect joints, varies with the test current. It is therefore recommended that a D.C. resistance test for quality is made, first at low current, secondly with high current, and finally with low current. The low-current tests should be made with an instrument delivering not more than 200 mA into one ohm; the high-current test should be made at 10 A or such higher current as is practicable. The open-circuit voltage of the test set should be less than 30 V. Any substantial variations in the readings (say 25 per cent) will indicate faulty joints in the conductor; these should be rectified. If the values obtained are within the variation limit, no further test of the CPC is necessary.

IV. Residual current devices

IEE Regulation 713-12-01 requires that where an RCD provides protection against indirect contact, the unit must have its effectiveness tested by the simulation of a fault condition. This test is independent of the unit's own test facility. The consumer who is advised to ensure that the RCD trips when a test current, provided by an internal resistor, is applied to the trip-coil of the unit designs the latter for use. Thus, on pressing the 'Test' button the unit should trip immediately. If it does not it may indicate that a fault exists and the unit should not be used with its associated socket-outlet, particularly if the outlet is to be used for outdoor equipment.

The RCD has a normal tripping current of 30 mA and an operating time not exceeding 40 ms at a test current of 150 mA.

RCD testers are commercially available, which allow a range of tripping currents to be applied to the unit, from 10 mA upwards. In general the lower the tripping current the longer will be the time of disconnection.

It should be noted that a double pole RCD is required for caravans and caravan sites and for agricultural and horticultural installations where socket-outlets are designed for equipment to be used other than 'that essential to the welfare of livestock'.

V. Earth-electrode resistance area

The general mass of earth is used in electrical work to maintain the potential of any part of a system at a definite value with respect to earth (usually taken as zero volts). It also allows a current to flow in the event of a fault to earth, so that protective gear will operate to isolate the faulty circuit. One particular aspect of the earth electrode resistance area is that its resistance is by no means constant. It varies with the amount of moisture in the soil and is therefore subject to seasonal and other changes. As the general mass of earth forms part of the earth-fault loop path, it is essential at times to know its actual value of resistance, and particularly of that area within the vicinity of the earth electrode. The effective resistance area of an earth electrode extends for some distance around the actual electrode; but the surface voltage dies away very rapidly as the distance from the electrode increases . The basic method of measuring the earth-electrode resistance is to pass current into the soil via the electrode and to measure the voltage needed to produce this current. The type of soil largely determines its resistivity. The ability of the soil to conduct currents is essentially electrolytic in nature, and is therefore affected by moisture in the soil and by the chemical composition and concentration of salts dissolved in the contained water. Grain size and distribution, and closeness of packing are also contributory factors, since these control the manner in which moisture is held in the soil. Many of these factors vary locally. The following table shows some typical values of soil resistivity.

Table 7.1.soil-resistivity values

Type of soil	**Approximate value in ohm-cm**
Marshy ground	200 to 350
Loam and clay	400 to 15,000
Chalk	6000 to 40,000
Sand	9000 to 800,000
Peat	5000 to 50,000
Sandy gravel	5000 to 50,000
Rock	100,000 upwards

When the site of an earth electrode is to be considered, the following types of soil are recommended, in order of preference:

1. Wet marshy ground, which is not too well drained.

2. Clay, loamy soil, arable land, clayey soil, and clayey soil mixed with small quantities of sand.

3. Clay and loam mixed with varying proportions of sand, gravel, and stones.

4. Damp and wet sand, peat.

Dry sand, gravel, chalk, limestone, whinstone, granite, and any very stony ground should be avoided, as should all locations where virgin rock is very close to the surface.

Chemical treatment of the soil is sometimes used to improve its conductivity Common salt is very suitable for this purpose. Calcium chloride, sodium carbonate, and other substances are also beneficial, but before any chemical treatment is applied it should be verified that no corrosive actions would be set up, particularly on the earth electrode. Either a hand-operated tester or a mains-energized double-wound transformer can be used, the latter requiring an ammeter and a high-resistance voltmeter. The former method gives a direct reading in ohms on the instrument scale; the latter method requires a calculation in the form:

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

The procedure is the same in each case. An auxiliary electrode is driven into the ground at a distance of about 30 meters away from the electrode under test (the consumer's electrode). A third electrode is driven midway between them. To ensure that the resistance area of the first two electrodes do not overlap, the third electrode is moved 6 meters farther from, and nearer to, the electrode under test. The three tests should give similar results, the average value being taken as the mean resistance of the earth electrode.

One disadvantage of using the simple method of earth electrode resistance measurement is that the effects of emfs (owing to electrolytic action in the soil) have to be taken into account when testing. Also, there is the possibility of stray earth currents being leakages from local distribution systems. Because of this it is usual to use a commercial instrument, the Megger earth tester being a typical example.

VI. Earth-fault loop impedance

Regulation 113-11-01 stipulates that where earth-leakage relies on the operation of over current devices, an earth-loop impedance test should be carried out to prove the effectiveness of the installation's earthing arrangement. Although the supply authority makes its own earth-loop impedance tests, the electrical contractor is still required to carry out his own tests. The tests carried out by a supply authority will not absolve the contractor from his legal responsibilities for the safe and effective operation of protection equipment which he may install as part of a wiring installation. This applies both to new installations and extensions to existing installations. Earth-loop impedance tests must be carried out on all extension work of major importance to ensure that the earth-continuity path right back to the consumer's earthing terminal is effective and will enable the protective equipment to operate under fault conditions.

VII. Phase-earth loop test.

This test closely simulates the condition which would arise should an earth- fault occurs. The instruments used for the test create an artificial fault to earth between the 'me and earth conductors, and the fault current, which is limited by a resistor or some other means, is allowed to flow for a very short period. During this time, there is a voltage drop across the limiting device, the magnitude of which depends on the value of the earth loop. The voltage drop is used to operate an instrument movement, with an associated scale calibrated in ohms. The contribution of the consumer's earthing conductor should be not more than one ohm. This is to ensure that the voltage drop across any two Points on the conductor is kept to a low value and, under fault conditions there will be no danger to any person touching it at the time of the test.

The testers, which are commercially available, include both digital readouts and analogue scales, and incorporate indications of the circuit condition (correct polarity and a proven earth connection). The readings are in ohms and represent the earth-loop impedance (Z_s). Once a reading is obtained, reference must be made to lEE Regulations Tables 41B1 to 41D, which give the maximum values of Z_s which refer to: (a) the type of over current device used to protect the circuit and (b) the rating of the device. Reference should also be made to any previous test reading to see whether any increase in Z_s has occurred in the meantime. Any increase may indicate a deteriorating condition in the CPC or earthing lead and should be investigated immediately. The values of Z_s indicated in the Tables are maximum values, which must not be exceeded if the relevant circuits are to be disconnected within the disconnection times stated.

Before a test is made, the instrument should be 'proved' by using a calibration unit, which will ensure that it reads correctly during the test. It is also recommended that the serial number and type or model used for the test should be recorded, so that future tests made by the same tester will produce readings, which are correlated.

CHAPTER 8

8.0 PROTECTION

The meaning of the word protection, as used in electrical industry, is not different to that in every day used. People protect them selves against personal or financial loss by means of insurance and from injury or discomfort by the use of the correct protective clothing the further protect there property by the installation of security measure such as locks and for alarm systems.

In the same way electrical system need to be protected against mechanical damage the effect of the environment, and electrical over current to be installed in such a fashion that's person and or dive stock are protected from the dangerous that such an electrical installation may create.

8.1. REASONS FOR PROTECTIONS

8.2. Mechanical Damage

Mechanical damage is the term used to describe the physical harm sustains by various parts of electrical sets. Generally by impact hitting cable whit a hammer by obrasing. Cables sheath being rubbed against wall corner or by collision (e.g. sharp object falling to cut a cable prevent damage of cable sheath conduits, ducts tranking and casing)

8.3. Fire Risk:

Electrical fire cawed by;

a-) A fault defect all missing in the firing

b-) Faults or defects in appliances

c-) Mal-operation or abuse the electrical circuit (e.g. overloading)

8.4. Corrosion: Wherever metal is used there is often the attendant problem of corrosion and it's prevented. There is two necessary corrosion for corrosion.

a-) The prevention of contact between two dissimilar metals ex copper & aluminium.

b-) Prohibition of soldering fluxes which remains acidic or corrosive at the compilation of a soldering operation ex cable joint together.

c-)The protection metal sheaths of cables and metal conductions fittings where they come into contact with lime, cement or plaster and certain hard woods ex: corrosion of the metal boxes.

d-)Protection of cables wiring systems and equipment's against the corrosive action of water, oil or dumbness if not they are suitable designed to with these conditions.

8.5. Over current

Over current, excess current the result of either and overload or a short circuit. The 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 overload resistance of the circuit and current increases which causes heating the cables and deteriorate the cable insulation. And the short-circuit. Short circuit is a direct contact between live conductors

a-)Neautral condactor. (Fuse)

b-)Earthed metal work (Operators)

Protectors of overcurrent

a-)Fuses

b-)Circuit Breakers

I. Fuse

A device for opening a circuit by means of a conductor designed to melt when an excesive current flows along it .

There are three types of fuses.

a-)Rewireable

b-)Cartridge

c-)HBC (High Breaking Copacity)

I-)Rewireable Fuse:

A rewireable fuse consists of a fuse, holder, a fuse element and a fuse carrier. The holder and carrier are being made porselain or bakelite. These fuses have designed with color codes, which are marked on the fuse holder as follows;

Table 8.1 Fuse current rating and color codes

Current Rating	**Color Codes**
5A	White
15A	Blue
20A	Yellow
30A	Red
45A	Green
60A	Purple

But, this type of fuse has disadvantages.Putting wrong fuse element can be damaged and spark so fire risk, can open circuit at starting-current surges.

Note: Today's they have not used anymore.

II-)Cartridge Fuse

A cartridge fuse consists of a porcelain tube with metal and caps to which the element is attached. The tube is filled silica. They have the advantage ever the rewirable fuse of not deteriorating, of accuracy in breaking at rated values and of not arcing when interrupting faults. They are however, expensive to replace.

III-)High –Breaking Capacity (HBC)

It is a sophisticated variation of the cartridge fuse and is normally found protecting motor circuits and industrial installations. Porcelain body filled with silica with a silver element and lug type and caps. It is very fast acting and can discriminate between a starting surge and an overload.

I. 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 feed 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 release mechanism of the circuit breaker is operated by hand or automatically by magnetic means. The circuit breaker with magnetic 'tripping' (the term used to indicate the opening of the device) employs a solenoid, which is an 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 (due to an overload or a fault), 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 many installations 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 avoid the need for a circuit breaker to disconnect not only the faulty circuit, but also other healthy circuits, which may be 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-breaker contacts separate either in air or in 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 for modern electrical installations is the miniature circuit-breaker (MCB). It is used as an alternative to the fuse, and has certain advantages: it can be reset or reclosed easily; it gives a close degree of small over current protection (the tripping factor is 1.1); it will trip on a small sustained over current, but not on a harmless transient over current such as a switching surge. For all applications the MCB tends to give much better overall protection against both fire and shock risks than 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 tendency for the tripping mechanism to stick or become sluggish in operation after long periods of inaction It is recommended that the 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.

Values of fuses;

6A, 10A, 16A, 32A, 45A, 60A,, 100A.

3.6. Earth Leakages:

Protection for Earth Leakages:

Using ELCB, which stands for Earth Leakage Circuit Breaker, does this type of protection. There are two types of earth leakage circuit breaker.

1. Current Operated ELCB (C/O ELCB)

Current flowing through the live conductor and back through the neutral conductor and there will be opposite magnetic area in the iron ring, so that the trip coils does not operate If a live to earth fault or a neutral to earth fault happens the incoming and returning current will not be same and magnetic field will circulate in the iron ring to operate the trip coil. This type of operators is used in today.

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.

ne following are the requirements for electrical safety:

Ensuring that all conductors are sufficient in csa for the design load current of rcuits.

All equipment, wiring systems, and accessories must be appropriate to the working nditions.

All circuits are protected against over current using devices, which have ratings propriate to the current-carrying capacity of the conductors

All exposed conductive pans are connected together by means of CPCs.

All extraneous conductive parts are bonded together by means of main bonding nductors and supplementary bonding conductors are taken to the installation main rth terminal.

All control and over current protective devices are installed in the phase conductor.

All electrical equipment has the means for their control and isolation.

All joints and connections must be mechanically secure and electrically continuous d be accessible at all times.

No additions to existing installations should be made unless the existing conductors sufficient in size to carry the extra loading.

) All electrical conductors have to be installed with adequate protection against ysical damage and be suitably insulated for the circuit voltage at which they are to erate.

) In situations where a fault current to earth is not sufficient to operate an over current vice, an RCD must be installed.

) All electrical equipment intended for use outside equipotent zone must be fed from ket-outlets incorporating an RCD.

) The detailed inspection and testing of installation before they are connected to a ins supply, and at regular intervals there after.

CHAPTER 9

9.0 BUILDING SERVICES

9.1. Sound Distribution Systems

Sound-distribution Systems consist essentially of loudspeakers permanently installed in suitable positions in buildings or in open spaces associated with buildings - They are essentially part of the telecommunications Systems of buildings. The currents, which operate such systems, are derived from a microphone, gramophone, radio receiver, or other device, or from a wire broadcasting service. These currents are of a very small order and so require to be amplified to values suitable for the operation of loudspeakers. Sound-distribution systems are found in schools, theatres and cinemas, churches, meeting halls, factories, offices and department stores, hotels and clubs, hospitals, railway stations and sports grounds. Though these systems generally operate from mains supplies, some systems, or parts thereof, operate from batteries or from mains-supplied rectified current, producing low voltages.

9.2. 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 caller calls a person to a particular position. 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 must be either objectionable or useless, 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 the 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 a 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 period (e.g., break, class change, etc.). These systems usually have one or two pushes or other switches connected in parallel and a number of bells throughout the building, which are also 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 energies the bell circuit. In the closed circuit type, all contacts are closed. A circulating current energizes a series relay ith normally open contacts. When a contact set is opened, this current ceases to flow, -energizes the relay, and closes the relay contacts to ring an alarm bell. Some alarm stems operate from photoelectric cells, which work when an invisible light beam is oken. The large plate-glass windows of jewelers' shops often have a series length of ry thin wire, which, if broken when the window is smashed in or a hole cut in it, will ing the relay into operation to ring a bell. In certain systems today, no bell rings, but a zzer and light indication circuit is wired from the protected building and terminated at nearby police station. Thus the intruder is not warned, and the police have the portunity of catching the burglar red-handed.

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

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

minous call systems are used instead of bells. These Systems use color lights, which mmon staff to fulfill a service duty. They are largely used in hospitals and hotels. hen the bell push is pressed in any position in the building, a small lamp lights in a ty room to indicate the general area from which the call has come. Alternatively, a np outside the call room lights and remains so until an attendant extinguishes it by erating a reset push located just outside the room. Some systems incorporate a single-oke bell. Call and indicating circuitry is also incorporated in lift systems.

3. Fire-Alarm Circuits

fire-alarm is defined as 'an arrangement of call points, detectors, sounders and other uipment for the transmission and indication of alarm and supervisory signals, for the ting of circuits, and where required, for the operation of auxiliary services' Section (7) of the Factories Act of 1937 states: where in any factory… more than 20 persons employed… effective provision shall be made for giving warning in case of fire, ich shall be clearly audible throughout the building.

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

e closed-circuit type of system is used so that circuit failure or breakage will at once be indicated by an audible alarm. Manual call-points consist of a pair 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 (e.g., 'Fire Alarm: in case of fire, break glass') must be clearly indicated either on the point itself or on a label beside it.

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 a predetermined temperature (e.g., 80°C).

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 a 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 a diaphragm.

5. Thermocouples.

Some detectors ate 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:

a) Heat detectors. False alarms may be caused by abnormal increases in temperature due to space heating equipment, industrial processes, and sunshine.

b) Smoke detectors. Smoke and other fumes, dusts, fibers may cause false alarms, 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, 1963. 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 (enunciator board) 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 the 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. With some systems, faults are indicated automatically.

Varning devices included bells, sirens, hooters, or whistles; they may be arranged to ;ive either local or general alarms. In either case, the warning should sound :ontinuously once a detector has operated, until the Fire Brigade arrives. An external ıudible warning device is recommended for mounting near to the visual indicating ›anel. The device should indicate which building is involved, this being particularly ıecessary for premises, which comprise several buildings. In hospitals, department tores and other places where a general internal alarm is not thought desirable, an alarm ıay be given at a manned central point only and warning passed by telephone or light ignal to other parts of the premises.

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

ome methods use an auto-dialing unit at the protected premises, which connects alarm alls in the form of a pre-recorded message, either via the public '911' emergency call ervice to the appropriate fire-control room, or direct via the automatic telephone ystem to a pre-selected telephone number. This method is cheaper than the direct-line ıethod, but is less reliable. It for some reason, connection to the appropriate fire-ontrol point is not achieved at the first attempt, it is possible for an alarm call to be ›st. Also, this system cannot be continuously monitored for faults because it is not ermanently connected to the point where the alarm calls are received.

ecommendations on wiring and equipment used are set out in BS Code of Practice BS 339, which also includes recommendations on suitable power supplies.

he following bibliography contains information on fire alarm systems:

ules for Automatic Fire Alarms - Fire Offices' Committee

S 3116 - Heat Sensitive Detectors for Automatic Fire Alarm Systems in Buildings utomatic Fire Detection and Alarm Systems -Fire Protection Association. Fixed Fire xtinguishing Equipment in Buildings - Fire Protection Association

ıe IEE Regulations recognize fire-alarm circuits as 'Category 3' circuits, in that fire-arm circuits, for reasons of security, should be segregated from each other as well as mpletely separated from any other wiring. Mains-voltage circuits (Category 1) for unders, battery-charging and other auxiliary circuits in a fire-alarm system should so be completely separated from other (Category 2) circuits in the same fire-alarm stem. If Category 3 (fire-alarm) circuits are wired in MIC's cable, the cable may be d in a common trunking or channel, but must not be drawn into a common duct or nduit.

. Radio and TV

e erection of aerials for the reception of radio and TV broadcasts is usually dertaken by the specialist. In buildings, which consist of blocks of flats, communal :k-up services are provided, being fed from a communal pre-amplifier. This unit is talled as near as possible to the aerial site so that any interference picked up by the ervening feeder is reduced to a minimum. The contractor's interest in these Services mainly confined to the provision of conduit or socket-outlet facilities. In a multi-point evision installation, Up to twenty receiver points may be connected to one cable, ich is looped through the socket-outlets.

9.5. 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 outlets. 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 this system, which usually 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 Brigade 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. When a call is transferred to an extension it disappears from the switchboard and is then under the full control of the extension; this is a feature not available with the older approved system known as PABX 3.

CONCLUSION

hen preapering an electrical project most important part is the drawing.Because it ntains the imagine something which is not seen.The project has the be well defined d has to be safe.Because small mistakes can create huge damages.Also making tallation is very important.An engineer has to be known all the regulations and rules this job.In this project all regulation standards of I.E.E and British standards have en applied very carefully.

is project is not enough to be an engineer but everybody can see that ;A person who n find easily, quickly , cheaply and permanent answers for problems, is an engineer.

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] Thompson F. G., *Electrical Installation and Workshop Technology*, Volume Three, 4th ed., Longman Groub U.K. Ltd., 1992.

] Theraja B. L., *Electrical Technology in S.I. Systems of Units*, 22nd ed., Niraja Construction & Development Co. (P) Ltd., New Delhi, 1987.

] E.L. Donnely *Electrical Installation Theory and Practise* 3th ed. Nelson.

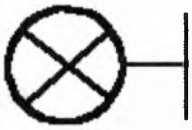
] Chamber of Electrical Engineers. Project Drawing Principles and Help Information's book 5th ed. Nicosia, 2002

PPENDIX A

(MBOLS

re are some symbols that we are using in installation

ILING LAMP



WALL LAMP

2 GANG 1 WAY SWITCH

1 GANG 1WAY SWITCH

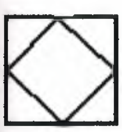
1 GANG 2 WAY SWITCH

2 GANG 2WAY SWITCH

INTERMEDIATE SWITCH

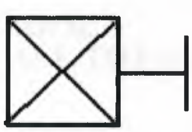
SOCKET OUTLET

2 POLE SOCKET OUTLET



HEATER SWITCH (WITH FUSE)

HEATER SWITCH (WHITHOUT FUSE)



COOKER CONTROL UNIT

'PENDIX B

COST CALCULATIONS

INVESTIGATION COST OF HOUSES

TALLATIONS	items count	mimimum wages of one item	Turkish liras(T.L)
k-lamp	8	36.800.000T.L	294.400.000
ng Glob	9	44.000.000T.L	396.000.000
Glob	3	44.000.000T.L	132.000.000
Light	27	85.700.000T.L	2.313.900.000
len Decoration Lamp	5	85.700.000T.L	428.500.000
rescent	2	79.800.000T.L	159.600.000
3Amp Socket Outlet	24	53.800.000T.L	1.291.200.000
phone Socket-Outlet	8	49.100.000T.L	392.800.000
Antenna Socket Outlet	6	60.300.000T.L	361.800.000
ker	1	98.000.000T.L	98.000.000
er	1	110.000.000T.L	110.000.000
hing Machine	1	73.500.000T.L	73.500.000
Washer	1	73.500.000T.L	73.500.000
er Motor	1	135.000.000T.L	135.000.000
' Door Bell	1	68.300.000T.L	68.300.000
Ways MCCB	1	1.500.000.000T.L	1.500.000.000
Ways MCCB	1	1.200.000.000T.L	1.200.000.000
hing		200.000.000T.L	200.000.000
luit Line	120 meter	16.500.000T.L	1.980.000.000
		TOTAL	11.208.500.000T.L
		TOTALX2	22.417.000.000T.L

INVESTIGATION COST OF GARDEN

L Contactor	2	144.000.000T.L	288.000.000
V Mercury-Vapor lamp	13	199.300.000T.L	2.590.000.000
en Decoration Lamp	4	87.300.000T.L	349.200.000
Lamp	6	412.500.000T.L	2.475.000.000
Ways Consumer Unit	1	520.000.000T.L	520.000.000
Ways MCCB	1	1.200.000.000T.L	1.200.000.000
luit Line	80 meter	16.500.000T.L	1.320.000.000
		TOTAL	8.743.700.000T.L
		ALL TOTAL	31.160.700.000T.L

ngineer has to take %6 of all total cost

31.160.700.000T.L X %6 = 1,900,000,000T.L

) of 1,900,000,000 = 1,330,000,000T.L Cost of project

) of 1,900,000,000 = 570,000,000T.L Cost of controlling.

APPENDIX C

Voltage Drops

Voltage drops between consumer unit houses and garden:

g=voltage drops value(mV/A.m)
L=length(m)
I=Current(A)
ΔU=g.L.I(mV)

Voltage drop does not much than %2.5 of nominal voltage
For single phase ΔU_{max} = 6 V (%2.5 of 240 V)
For three phase ΔU_{max} = 10.375 V ((%2.5 of 415V)

For first house;
g=2.2 (mV/A.m) (from I.E.E Wiring Regulations book)
L=70m
I=60A

$$\Delta U = g.L.I = 2.2 \text{ X } 70 \text{ X } 60 = 9240 \text{ mV} < 10.375 \text{ V}$$

For garden;
g=2.2(mV/A.m)
L=80m
I=40A

$$\Delta U = g.L.I = 2.2 \text{ X } 80 \text{ X } 40 = 7040 \text{ mV} < 10.375 \text{ V}$$

For second house;
g=1(mV/A.m)
L=140m
I=60A

$$\Delta U = g.L.I = 1 \text{ X } 140 \text{ X } 60 = 8400 \text{ mV} < 10.375 \text{ V}$$