NEAR EAST UNIVERSI

Facultv of Engineering

Department of Electrical and Electronic Engineering

# ELECTRICAL INSTALLATIONS IN A HOTEL

Graduation Project
EE-400

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# ABSTRACT

The electrical installations are an application of the theories and rules in Electrical Engineering.

This project is an important study of the electrical installations made in a hotel, it is based on the I.E.E. regulations. It talks about different installations, installation methods and regulations used to choose and install the different objects.

The wiring and cabling are the important part in this project to continue the installation correctly.

illumination is also an important part to achieve the correct illumination for each purpose.

Different kinds of lighting?fixtures were used in the installation and were selected according to the purpose used *lni*

Power circuits, distribution panels and protection and safety and prevention of accidents were also discussed and studied inmyproject.

Testing and measurements for the felectrical installations took a major part of the project.

The main objective of this thesis iğler study and give an outlook about the electrical installations and· how it is worked/\and done under a specific regulation, in order to accomplish a desired objective.

# INTRODUCTION

The electrical installations is an important subject to be studied due to that it gives the idea about applied side of electrical engineering and the ability to use the electrical and mathematical theories behind the electrical practical side.

This thesis is aimed to provide a convenient way to study the electrical installations done in a hotel.

The thesis consists of an introduction, six chapters and conclusion.

The first chapter gives an idea about the historical background of the electrical industry and how it started.

The types and sizes of conductors used in the electrical installations a discussed, as well as, the types of insulators.

Chapter two is devoted to the regulations followed in the electrical installations and the distribution of electrical power and the I.E.E. regulations (Institute of Electrical Engineering).

The subdivision ofloads as lighting,heating and power circuits are also discussed.

The rules that must be followed inthe layout of different loads as the 2-meter rule or spacing between the power sockets in the same room feed by two different phases (out of phase).

Chapter three talks about the illumination and the factors affecting illumination, as well as, giving examples of the types of lamps used in electrical installations, and their principle of operation and faults in the connecting circuits.

The photometer, the instrument usedtomeasure the illumination is also discussed.

Chapter four is devoted to the earthing and protection of electrical installations, the purpose of earthing and the principle of operation of circuit breakers and fuses.

Different installations as the principle of operation of telephones and other systems used in the electrical installations.

Alarm circuits and their main constituents and operation are also presented.

The building services and the systems used.

In chapter five the verification of the different tests and measurements done for the electrical installations and the different measurements.

Chapter six is devoted to talk about the main causes of accidents occurring through work especially those related to the electrical installations, and the necessary actions to prevent accidents.

Chapter seven is the last chapter devoted to describe the work done and the in which the electrical installation were placed in the drawings of the hotel.

The drawings are put at the end of the project.

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# CHAPTER ONE

## CABLES AND CONDUCTORS [4]

### Background

In the early beginnings of the industıy of electricity, the applications, and the methods of applications electricity for lighting, heating and motive power was primitive. The first wide use of it was for lighting in houses, shops and offices. By the 1970s, electric lighting had widely advanced. iArc lamps were the first form of lighting, and were used in the illumination of main streets. After that the incandescent-filament lamp appeared on the scene, then the cheap metal-filament lamps was produced and every home was able to use it.

The electrical installations in general were primitive in the early days. In 1881, the electrical installations in Hatfield House were done by an aristocratic amateur, and were exclusively dangerous; arcs took pfaôehefe and there.

At that time many electrical companies appear as General Electric Company in 1880s, that· was able supply every single iteı:ri that went to complete electrical installation. These items were guaranteed to sfüteach 'to each ()'ther, with adequate quality at an economıc pnce.

Steel was used as the conductor material for wires. 'Ihe insulation material included textiles and gutta-percha. Vulcanizedfııbber was introduced, and it is still used today.

The first application of a lead sheath to rubber-insulated cables was made by Siemens Brothers. The early system was to give a cable with a certain length a resistance of 0. I ohm. Thus a number 90 cable is a90:.yard cable with a resistance of 0. I ohm and so on.

In the 1930s, during polymer revôhıtion, the material PVC (polyvinyl chloride) was introduced as an insulating. Although it was inferior to rubber in elastic properties, it could withstand the effects.of both oilahd sunlight.

Aluminium and copper were used as the conductor instead of steel.

For conduits steel was made in 1883, but never used except 1895. Aluminium conduits were made in 1920s, and were used during the Second World War when steel became a valuable material. Then PVC conduits were made and used until today, which is cheap, elastic and easily bend.

Steel conduits are still used now a day to meet some requirements and purposes.

When lighting became popular, the need for the individual control of each lamp from its own control point. At the beginning 'branch switch ' was used for this purpose. These were made of wood with no ON or OFF position. Usually it made an inefficient contact to produce an arc or to 'dim' the light.

Later on slate, marble and porcelain were used with definite ON and OFF position. Further development lead to the flush and the 'silent' switch made of plastic material.

In order that the lamp could be held, the lamps were fitted with a wire tails for joining to terminal screws. Then the screw-cap lamp holder was made by Thomas Edison in 1880, the bayonet-cap type of lampholders was introduced by Edison & Swan Company and improved to what we know today.

The first plug-and-socket brought Lord Kelvin, it could bear small currents, so used for lighting purposes.

Shuttered sockets that carry heavier currents appeared, and developed to what we know today.

Many sockets were individually fused, which was a small piece of wire between two terminals which caused a lot of troubles, until in 1911 the Institution of Electrical Engineers banned their use.

Scholes introduced a revolutionary design of plug-and-socket; it was a hollow circular earth pin and rectangular current-carrying pins. It was the first attempt to differentiate between live, earth and neutral pins.

Early fuses consisted of lead wires (lead being used due to its low melting point), and devices which contained fuses were called 'cutouts', a term that is used until today.

To provide protection for circuits fuses and fusegears were designed to isolate the circuits in case of arcs.

In 1930s, the distribution of electricity in buildings by means of busbars came into fashion; they used trunks to envelop the busbars and electricity needed from any point.

From that we can see that the development of wiring systems and wiring accessories are very fast not only in the design and appearance, but in the ability to meet the demands made on them of modem electrical installations.

## 1.2 Conductors **and** Cables

A conductor is a material, which offers a low resistance to a flow of current. Conductors for eveıyday 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, andiron.

Materials Used. Electrical conductors are usually made of copper, although aluminum 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 though 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 sulphur which attacks the copper; and (b) to make the coppetaconductor easier to solder. Aluminum wire is also drawn from a solid block but is not tinned.

The determining factor in the use ofiôhe type of metal for conductors is usually that of cost The future trend in costs will<be>for.theprice of aluminum to drop relative to that of copper, as the underdevelopedccüdfries achieve the industrial capacity .necessary to work their bauxite (aluminum ore) deposits.

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 spiraled on to the cable in an opposite direction to the previous.slayer, 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.

The size of a stranded conductor is .given by the number of strands and the diameter of the individual strands. For example, a 7/Q.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.

Copper and aluminum conductors are also formed into a variety of sections, for example, rectangular and circular sections, for bare conductor systems which are used in extra-low voltage electroplating and sub-station work.

## 1.3 Insulators

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

For electrical properties it must have a high resistance.

For mechanical properties it must be capable of withstanding mechanical stresses, for example, compression.

The perfect insulator would have the following physical properties:

Non-absorbent.

Capable of withstanding high temperatures.

The chemical properties of 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 the)' are nof 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.

## 1.4 Definition and Construction of Cables

A cable is defined in the I.E.E.. :Reg;ulations as: "A length of insulated single conductor (solid or stranded), or of two or lll.ore such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall covering for mechanical protection.

A cable consists of two basic parts: (a) the conductor; and (b) the insulator.

It is usually derives its name from the type of insulation used.

The Polyvinyl Chloride (P.V.C.) cable 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 a-die into which soft p.v.c. is forced.

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

The Multi-core cable is the cable, which is made up of two or more insulated conductors. Multi-core cable is sheathed in a protective covering, for example, tough rubber for tough rubber-sheathed cables (t.r.s.) and p.v.c. for plastic cables.

The Tough-Rubber-Sheathed.Itr.s.) cable 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, isused in farmyards.

The Polychloroprene (p.c.p. or neoprene) cable, in which its insulation somewhat similar to that of t.r.s. but capable of withstanding most weather conditions and particularly direct sunlight.

The Heat-resisting, Oil-resisting and(Flarrie--retardant (h.o.fr.) cables are used in conditions damaging to p.v.c. cables such as highJempefature and oil. The resistant qualities are developed by a vulcamsing (ôf curing) prôcess, which forms an elastomer capable of withstanding tough conditions and stillretainingits :flexibility.

The following are examples of cables using elastomer material: c.s.p. (chlorosulphonated polyethylene), butyl rubber, silicon rubber, ethylene propylene rubber (e.p.r.).

Flexible Cables and Flexible Cords. The I.E.E. Regulations define a :flexible cable as: ' cable consisting of one or more cores, each containing a group of wires, the diameters of the wires and the construction of the cable being such as to afford :flexibility.' A :flexible cord is defi:ned as: "A :flexible cable in which the cross-sectional area of each conductor does not exceed 4 mnr".

The Twisted Twin Flex Cable (Figure 1.1) is made up of a tinned-copper

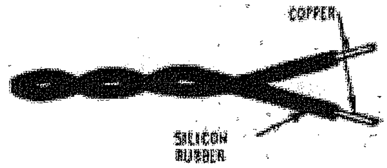



Figure 1.1 Twisted twin flex.

conductor with silicon rubber insulation.

The Circular flex where the rubber-insulated cores flex are formed into a circular section with cotton worming and contained in a cotton braiding.

Applications: connections to household appliances (irons, kettles, etc.).

Circular Flex, Rubber Sheathed (Figure 1.2). 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, as that used in vacuum cleaner and portable drill leads (3-core).

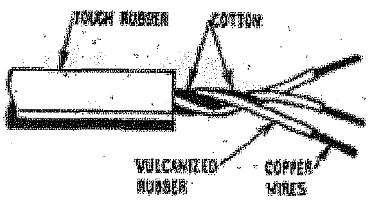



Figure 1.2. Circular flex, rubber sheathed.

Outdoor Cable. The I.E.E. 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.

COITON

COPPER TAPE
CONDUCTORS

VULCANIZED
RUBBER.

WAIERPROOF
COITONBRADING

Figure 1.3 House service overhead system (H.S.O.S.) cable.

H.S.O.S. (House Service Overhead System) cable shown in Figure 1.3 HS.O.S. cable is constructed as follows:

Hard-drawn copper conductor.

Rubber insulation.

Varnished tape.

Outer coating of compoiiiiding braiding.

It is used in house-to-house overhead supplies.

The p.v.c. insulated copper and aluminum cables are gradually replacing this cable, except in conditions where creosote is present, as this attacks the p.v.c. insulation.

## 1.5 Cable Sizes: Use ofLE.E. Tables

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

These tables supply:

Cross-sectional area, number, and diameter of conductors.

Type of insulation.

Length ofrun for 1V drop.

Current rating (a.c. and d.p.);:singlf and bunched.

The following terms ate used in the I.E.E. tables:

Ambient temperature.

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.

The **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 $mm^2$ (7/1.35 mm) p.v.c. cable will carry a maximum current of 40 A at an ambient temperature of 25 $^{\circ}C$, but if the ambient temperature is increased to 65 $^{\circ}C$ the maximum current allowed will now be:

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

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carryingeapacity will decrease:

A rating factor is therefore supplied for the bunching, or grouping, of cables.

The permissible voltage drop in cables is another essential feature in the calculation of cable size, as it is useless installing a cable which is capable of supplying the required current if the voltage at the consumer's 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.

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 metre.

Extra-low voltage (Band I) now covers voltages not exceeding 50 V ac. or 100 V d.c. (measured between conductors or to earth). The new low voltage range (Band II) is from extra-tow 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.

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 cnr' will be capable of carrying one half of 300 A, that is, 150 A.

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

Current-carıying capacity= current density x cross-sectional area. (I. I)

## 1.6 **ResistanceofGonductors**

The resistance which a conductor'ôffers to a flow of current is determined by three factors:

The length of the conductor.

Its cross-sectional area.

(C) Type of material,used.

If the length of a conductor is doubled, for example, from I00 m to 200 m, the resistance of that conductor will also double. Resistance R (in ohms) is directly proportional to length *l*.

If the cross-sectional area of a conductor is doubled, for example, from O.lcm$^2$ to 0.2 cnr', the resistance of that conductor will be halved. The Resistance is inversely proportional to cross-sectional area *a.*

Resistivity (Specific Resistance) is the factor that 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 the cube. For example, if the resistivity of copper is given as I.7 µQ-cm, then the resistance measured across opposite faces of a centimeter cube of copper will be l.7µQ. The symbol of resistivity is p (Greek letter rho). Equation (1.2) represents the relation of resistance with resistivity, length and cross-

Sectional area of the conductor.

$$R=\rho l/a \quad (1.2)$$

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 aluminum, 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 electro-lytes (liquid used in batteries) decreases with increases in temperature.

The temperature coefficient of a material is the increase in the resistance of a 1Ω resistor of that material.when itis subjected to a rise in temperature of 1 degC. For example, if copper has a.Jeıııpe:rature coefficient of 0.004 ohm per ohm per degree Celsius (0.004 Ω / Ω degC) a copper resistor of 1 Ω will increase in resistance to 1 Ω + 0.004 Ω if heated through 1 degC. 'Ille symbol for temperature coefficient is $\alpha$ (Greek letter alpha). Pure metals such as cc>pper and aluminum, have a positive temperature coefficient, that is, their resistance increases as temperature increases.

On the other hand, carbon and electrolytes have .a negative temperature coefficient, where their resistance decreases as temperature increases.

To calculate the increase of resistance of a conductor due.to temperature change, there are two conditions:

Temperature increases from 0 °C.

$$R_1=R_0\,(1+\alpha t) \quad (1.3)$$

Where, Rt is the final resistance, $R_0$ is the resistance at 0 °C, $\alpha$ is the temperature coefficient and t is rise in temperature.

Temperature increases between two immediate temperatures

$$R_2/R_1=(1+\alpha t_2)/(1+\alpha t_1) \quad (1.4)$$

$R_1$ is the first resistance, $R_2$ is the second resistance, $\alpha$ temperature coefficient, $t_1$ is the first temperature and $t_2$ is the second temperature.

# CHAPTER TWO

## DISTRIBUTION AND CONTROL [4]

### 2.1 Overview

There are three main sets of regulations that must be conformed 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 co•"·T? ";~~. generation, transformation, distribution and use of electrical energy"-iti factories and workshops. An explanatoıy leaflet, Memorandum by thT.\~7nior Electrical Inspector of Factories on the Electricity Regulations, isissued by HM. Stationery Office to explain the workings of these regulatiOtı.s.
2. The Electricity Supply Regtı.latiôns (1937). The purpose of the Electricity Supply Regulations is to secure "theisafety 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 a stated voltage, phase, and frequency, with permissible variations. The Area Board has the right to withhold connection, or disconnect a supply if these regulations are not adhered to.

   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 I.E.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 Pan 2 contains "means of securing compliance with Part 1",

It should be noted that the I.E.E. Regulations are not legally binding but are generally accepted as an efficient standard by Electricity Boards, contractors, 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.

## 2.2 Control ()fSuppJy at Consumers Premises

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

"All conductors and apparatus must be of sufficient size and power for the work they are called upon to do, and se-censenıcted, insfaUed 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 supply the fuse protects the circuit against excess current due to overload or serious earth fault.

The sequence of control equipment is shown in Figure 2.1, which 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 patlı (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.

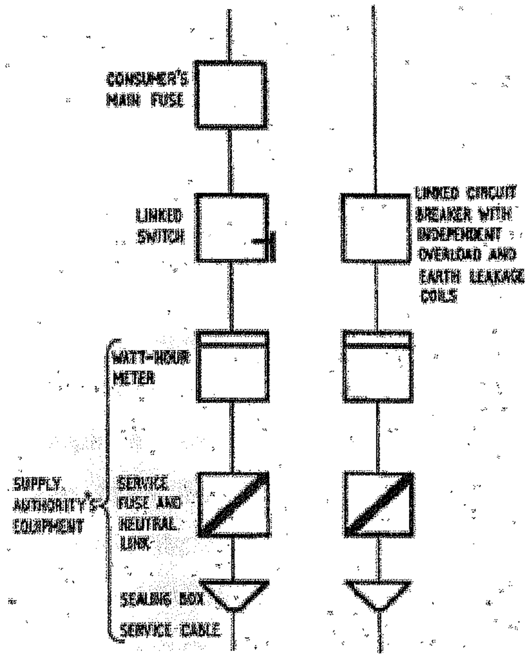



Figure 2.1. Sequence of control equipment.

## 2.3 Industrial Installations

The following points are considered in the industrial installations:

1. All cables must be rated at, or above, the current, which they will normally be, expected to carry without undue heating or voltage drop (normally 25 per cent ofnominal voltage).
2. All conductors, cables and equipment used in the installation must be of the correct voltage rating, for example, 250 V grade switchgear should not be used on 415 V 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 of3 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.

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

Figure 2.2 shows a suggested layout for a relatively small engineering works. The supply is fed into the premises by means of an underground cable (3-phase and neutral), th:roüğh. a> sealing chamber into the Supply Authority's main fuse. Tails are taken ifrôm>.Ythe· fuses and neutral block into the meter - panel. An, armoured cable supplies\the consumer's main switch, which, in this case is a 500k triple-pole and neutral linked}switch.(alLpoles are switched simultaneously). The conductors are then broughtoütiföthebus-bar chamber.

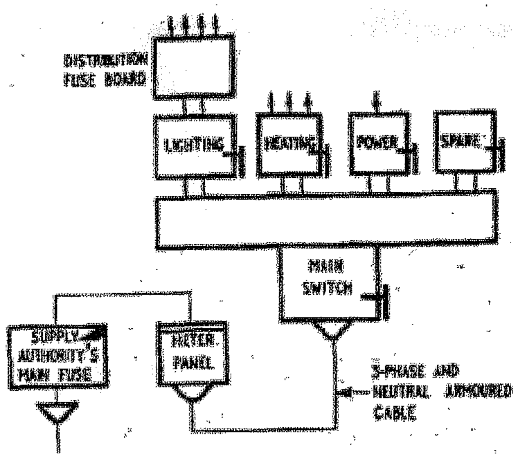



Figure 2.2 Layout of small engineering work.

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 15 A 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.

The sub-division of loads is considered under lighting, heating, and power circuits.

(a) Lighting Circuits (Figure 2.3): The lighting load will be taken from the distribution board to the final·sub-circuits. A final sub-circuit is defined in the LEE. Regulations as "an outgoing circuit connected to a distribution board and intended to supply electrical energy direct to current-using apparatus". The conductors betweea the bus-bar chamber and the distribution fuse board are termed the sub-main: The Côtıductors 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 comptiseaswitch--panel and the lights controlled by these switches.

All fuses and switches must be plaCed in the .phaS¢/conductor and metal lampholders (used in industrial fittings of 200W.a:rı.d over) rtııstbe earthed and-the phase conductor should be terminated at the centrepinof Giant Edison Screw (G.E.S.) Iampholders.

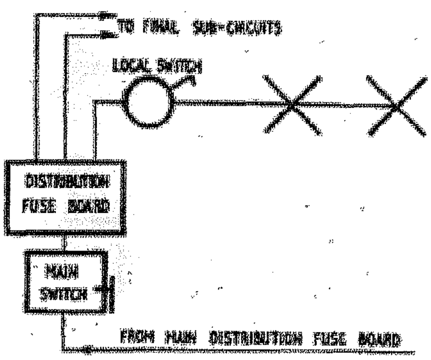



Figure 3.3 Lighting circuit.

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

(b) Power Circuits: the sub-division for power circuits which consist of, in this instance, a 3-phase isolator and a starter controlling a milling-machine motor taking a full load current of8A. A 1 mm2 or a 1.5 mm2 cable would be adequate for this circuit, but the fuse should be loaded to three times the full load current of the motor, tlıat is, approximately 25 A (0. 75 mm tinned-copper wire). The main distribution fuse board may also be used to supply smaller distribution fuse boardSfôfsınaller lathes, drills, etc.

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

(1) The controlling switchnıust be clearly marked '415 volts'.

(2) Switches and sockefôutlets suppliEicFfrom different phases must be placed at least 2 metres apart. This is particularly important where portable appliances are used (Figure 2.4).

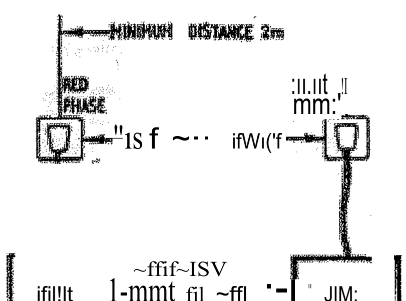



Figure 2.4 the 2-meter rule.

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

## 2.4 Domestic Installations

Domestic installations are usually supplied from a 16 mrrr twirı armoured cable.

The sequence of supply controls for domestic installations is as follows:

1. Supply Authority's sealing chamber for the termination of the armoured cable.
2. The Supply Authority's fuse and neutral block.
3. The supply Authority's energy meter (kWh meter).
4. Consumer's control unit.

The Supply Authority's fuses need not be duplicated if the permission the Authority is obtained.

The domestic consumer's control unit (Figure 2.5). 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 30A fuse for the cooker circuit.

(c)One 30 A fuse for the 13 A ring circuit (capable of taking two 7/0.85 in cables).

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

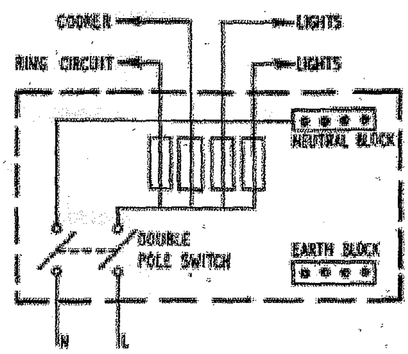



Figure 2.5 Domestic consumer's control unit.

Loading of the final sub-circuits in which the assumed current demand from points is as follows:

(Table 2.1, shows some I.E.E. Regulations)

Table 2.1 Current demand for socket outlets.

| Socket outlet | Current demand |
|---|---|
| 15 A socket outlet | 15 A |
| 5 A socket outlet | 5 A |
| 2 A socket outlet | At least 0.5 A |
| Lighting outlet | Minimum 100 W |

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

The domestic ring circuit (Figure 2'16) 'I'heTcltimestiαiij,ğcii:cuitis defined in theT.E.E. Regulations as "a final sub-circuit in which the curterit--canyinğ and eafth1cȏntinuity conductors are connected in the förnı of a loop, both ends of which are connected to a single way in a distribution fusebôard 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";

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

I. 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, a 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

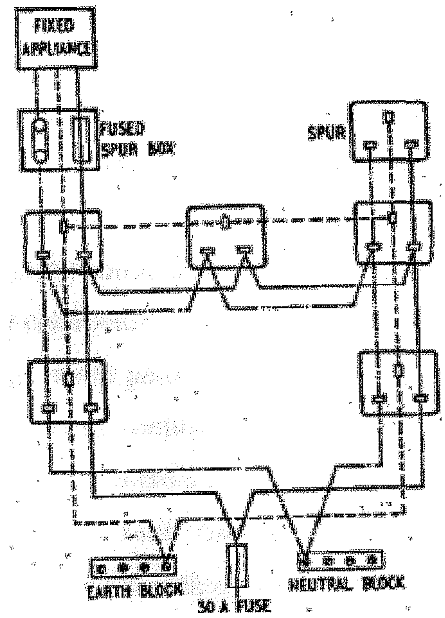



Figure 2.6 Domestic Ring Circuit.

8. outlet must be protected .l>yn/alocal fuse orci:rcl.lİt.,l)re~err-with.aı-ating not exceeding 15 A The appararas'must have an adjacent controlling switch.

The purpose of the ring circuitds;

(a) To minimize trailing flexes.

(b) To take advantage ofthe fact that all outlets in a domestic installation are not operated simultaneou.slyj;'I'hisis known as the diversity in an installation.

The diversity factor in an instalfation. can be calculated as follows:

$$Diversity\ Factor = \frac{Actual\ connected\ load}{Total\ load} \times 100\% \tag{2.1}$$

The diversity factor varies for different types of 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.

The domestic lighting circuits are usually wired in I $mm^2$ 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 sµ.b-cirçµ.it neutral should never be used to feed more than one final sub-circuit. Each ıieutralcônductor should be connected to its individual terminal at the neutral block: 'bunching' is nôtpetınitted. An earthing tetıninal must be provided at every lighting point. The earth cohtinuity conductor of the final sub-circuit must be connected to this terminal. Nonmetallic switches must also be supplied with an earthing to which the final sub-circuit earth: continuity conductor must be connected. The conductors are looped between thelrun.ps. (b) The two-way switching circuit.

Used for stairs and corridors. (c)'1;1ı'e)two--way switch used with an intermediate switch for long corridors in hospitals, schOOls, etc.n(d) Anotheftype of intermediate switching. The internal connections in the switchdetefıınıiethecircuitused.

(e) Dim-bright switching. The lamps are connected in series for dim operation and in parallel for bright.

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.

Figure 2.7 shows, circuits used in domestic installation.

The light switches are usually Ofthe 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.

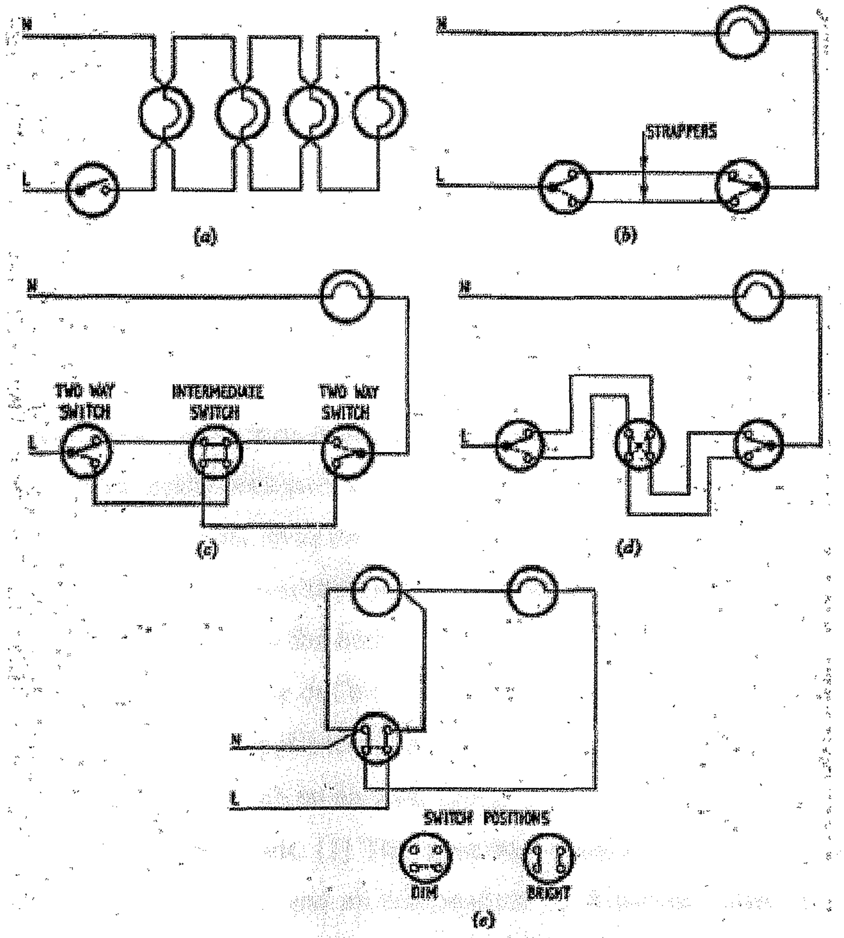



Figure 2.7 Lighting circuits. (a) One way switching: one switch serving four lights.

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, [1]'Fhere are two main types of ceiling rose:

(a) The three-plate pattern.

(b) The two-plate pattern.

The three-plate ceiling rose is used to economize in wire mid minimize the number of joint boxes used in the installation.

Ceiling roses must not be used on circuits operating above 250 V and no more than one :flexiblecord 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.

Water Heaters. [1] Domestic water heaters are generally rated at 3 kW and are usually supplied from the ring circuit. Asbestos-covered cable should be used to terminate the conductors at the immersion heater since p.v.c. and t.r.s. cables are normally expected to be used where the surrounding temper-attire (the ambient temperature) does not exceed 30 °C. The temperature range of water heaters is between 43 °C and 82 °C.

The thermostat, in common with all other switching devices, must always be fitted in the phase conductor.

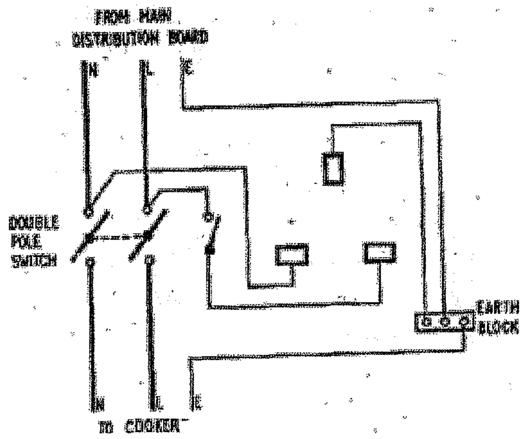
Bathroom. [lJAll lampholders must be of the Horne Office (skirted) type and lamps should be totallfenclôsed. Only circular flexible cable should be used where necessary and the switch musfbeôfthe pull-cord type. No portable appliances should be fitted or used in the bath- rôôn:iaııdfixed appliances, for example, wall fires, must be placed out of reachof persons iritheibath.

Garages. [1] Socketôutlets in garages must be placed at a safe distance from floor level. All portable a~~~\~~;§,tarticularly handlamps, must be earthed and hand lamps should be fitted with an~arthed shield.

Cooker Control Unit.[T]This generally consists of a double-pole switch (Figure 2.8) feeding the cooker .a.tı'gyaıı}iı:i<:l.¢p¢ndehtl3 A socket outlet. It is essential that the earth continuity conductor supplying the uııitshôuld be effectively connected. The cooker control unit is gener~~ır;~~pplied 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 su:ffi.cierıtto protect a maximum of 9 kW (3-plate cooker).
The current demand from a sta-tiôrıary cooking appliance is calculated as follows:

10 A+ 30 per cetıtôfthe total remaining full load current.

Every stationary cooking appliance in domestic premises must have an adjacent control switch fitted within 2 in of the appliance.
Note tliat 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.




Figµ:re 2.8 cooker control units.

**Layout of a DonıestiC€ifcuit.** [I] Figure 2.9 shows a suggested layout for a two-bedroom bungalow. Theliğlı"ti.ng circuits would be connected from two junction boxes in the attic (one box for eaçhqjrcuit). The cable supplyingthe cooker would also be run in the attic and the ringqtrcwtwould be run below the floor. Socket outlets are placed 30 cm above the floor leveFaıidlight switches 1.5 m above floor level.

## 2.5 Temporary Installations

A temporary installation is an ipst~Jlationwith an expected period of service of three months. A temporaıy instaıı,r311/}Usedbeyond this period must be completely overhauled at three-monthlyirıt~rvals.

It must be. pointed out thll{~~~}eftrician in charge of a temporaıy installation has a legal responsibility to ensure the safety of the installation; I this includes its construction, maintenance and ex.tension. The particular danger in this type of installation is the work of the amateıı.relectrician who overloads bayonet-cap lighting circuits beyo;1ld their I kW maximum loading, often with unearthed metal :fittings, and uses unsheathed cable or unprotected cable. Conduit should not be used in the installation unless it complies with the relevant I.E.E. Regulations.

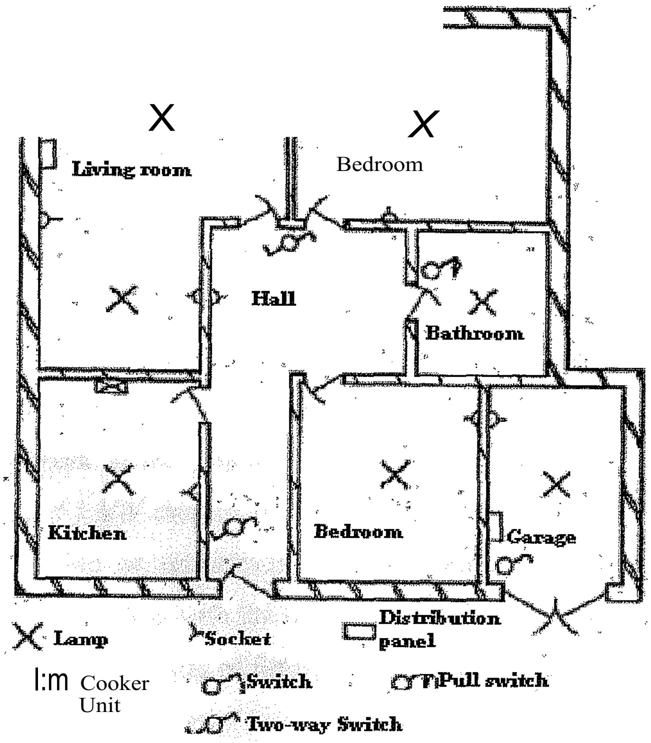



Figure 2.9 Layout of bungalow.

Protection: The ternnontrv ui,:ı,u;ı.ııaLJLVıı 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.

Notes, that the greatest care should>be taken to protect the temporary installation against mechanical damage aı:ıdJ>.()rtable appliances (for example, drills) should be regularly checked. Low-voltage-(e.g. 110 V) step-down transformers should be used wherever possible, to minimi.z~JJ:ı.~.dangefrom shock.

## 2.6 Conduit, Trunking, and Ducting

There are two main types of conduit: (a) light gauge and (b) heavy gauge.

(a) Light Gauge Conduit:

Light gauge conduit is produced from strip steel which is formed into a tube. This type of conduit has an open seam and is only used for small installations at, or below,230 V. The light construction of the tube makes it unsuitable for bending, although it can be set.

## 2.5 Temporary Installations

A temporaıy 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 a temporaıy installation has a legal responsibility to ensure the safety of the installation; I this includes its construction, maintenance and extension. The particular danger in this type of installation is the work pf the amateur electrician who overloads bayonet-cap lighting circuits beyond their I J(~ aj~jJ:J?cum loading, often with unearthed metal fittings, and uses unsheathed cable of.tıı1.pt(.)t~çted cable. Conduit should not be used in the installation unless it complies witJ:].j;]:ı.~televant I.E.E. Regulations.

**Fittings.** Two types>;pf:fittingare supplied for use with this type of conduit: lug grip (Figure 2.1 0) and pin gr~p.

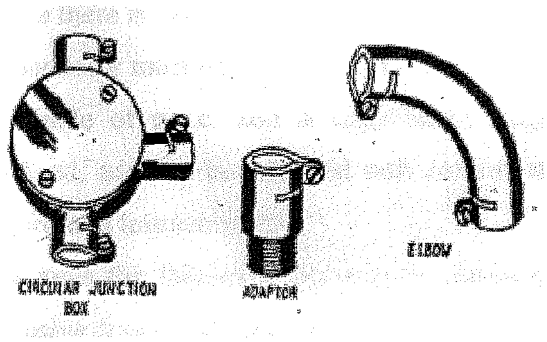



Figure 2. 10 Lug grip conduit fitting.

The paint in lug grip is cleaned ôff the end of the conduit, to ensure electrical continuity, and the fitting is cômı.ected to the conduit by tightening two brass screws.

Continuity in the Pin Grip is obtallied in this type by tightening a hardened-steel screw into the cleaned conduit at each fitting. Pin grip sockets are not acceptable/under section B.98 of the I.E.E. Regulations.

Applications: Slip conduit is ofily used in small installations where there is no danger of moisture affecting the cable. Ifis also used in p.v.c. sheathedsystems to provide mechanical protection for switch drops. Slip conduit is a cheap form of protection but tends to be unsightly and is open to misuse in installation.

(b) Heavy Gauge Conduit:

There are two types of heavy gauge conduit: heavy gauge welded conduit and solid drawn conduit.

The heavy gauge welded conduit is formed from strips of heavy gauge sheet steel and is welded at the seam. This is the most common type of conduit and is supplied in sizes from 16mm to 32mm (outer diameter).

The solid drawn conduit is produced by drawing a heated bar over a ram, forming a heavy-gauge seamless tube. This type of conduit is more expensive than welded steel conduit and is only usedföl"flafüeprôofinstallations (for example, garages).

Metallic conduit has two typesô:ffinish: enamel paint (black or gray)-and galvanized (zinc coated for wet or humid cônditiôııs).

Other types of conduits includingtlıe?flexible metallic conduit. This type of conduit is formed from a pressed-steel spiral and is used to terminate conduit at electrical machinery or in situations where tfıereis likely to be movement or vibration.

A separate earth continuity concii.ictô:tfüustbe run when this type of conduit is used.

The non-metallic conduit is macle'.d:fp.v.c. and is supplied in lengths. It has the appearance of conduit when fixe~0~~~/~!e ~ieacıed with Coıiduitstdcks aıicl dies. p.v.c. boxes are used at junctions aiıdterminations.

Non-metallic conduit systems lıa\te tlıe fôllôwiıig advantages: absence of condensed moisture in the tube, non-corrôsive(rrist-free), and non-inflammable. For capacities of steel and p.v.c. conduits.

**Installing Conduit** 'I'lie standard of an electrician's workmanship can often be judged by the fiı:ıi.slı Ön a &ö:ndfüt installation. Good conduit work can only be achieved by a systematic approach, constant practice, and a regard for detail. The following points are made to assist the electrician in this field.

Planning the Layout. The following points should be considered before starting the actual layout.

(a) The pipe runs of other trades should be studied (for example gas and water).

(b) To be sure that the consumefhas all his requirements clearly marked on the architect's drawing, this saves time (and temper!).

(c) To make allowances for future extensions.

(d) Conduit runs (with number and sizes of cables) should be marked on the drawing.

When marking out, follow the procedure given below:

1. Position of switches, outlets, etc., should be clearly marked, particular care being taken with the positioning and layout of the main board.
2. Individual conduit runs can now be 'struck'. This is done with a chalk-line as follows. String is chalked and held tightly against the surface of the run. The string is then 'twanged' in the centre..leaving a chalk line on the surface. A chalked plumb line should be used to strike vertical runs.

The first job after the marking out is the making of 'ways': cutting and channeling brick and concrete.

To fix the conduit the I.E.E. Regulations state that conduit must be securely fixed. There are six basic methods of fixing conduit (Figure 1.4).

1. Crampets: or pipe hooks, are mainly used to secure conduit n conditions where the conduit is to be covered (for example, in concrete or plaster).
2. Clips: the most common type is the saddle, this is simply a clip with a fixing holes.
3. Spacer Bar Saddles. This consists of two parts: a saddle and 3 mm hick base plate." The base plate has a slot in the centre which is handy hen conduit is being lined up. The saddle is fixed to the base plate by means of brass screws. These saddles are used to hold the conduit away from damp plaster, concrete, etc.
4. Distance Saddles: these saddles, sometimes termed hospital saddles, are used to keep dust from collecting between the conduit and the wall.

The distance saddle holds the conduit 1 cm from the wall. The use of distance saddles also obviates the need for setting conduits at surface boxes.

5. Multiple Saddles: multiple Saddles are used to fasten multiple conduit runs. The multiple saddle consists of either a flat bar drilled to support several saddles or one large saddle capable of clamping several conduits at once.
6. Girder Clips: the basic part of the girder clip is the J-bolt. The J-bolt supports the girder dip without any need for drilling the conduit.

The Girders and building supports should not be drilled as this may decrease their bearing capacity.

Drawing Cables into a Conduit System. The conduit installation must be completed before cables are drawn in.

When drawing-in large runs, start at the centre of the run and draw in to both sides separately.

When drawing-in long lengths of cable, or a bunch of very small cables, a reel stand should be used. The simplest reel stand consists of a short piece of conduit fixed in a pıpe vıce.

French chalk (powder) may be used to ease the drawing-in of cables at difficult points but tallow (grease) must not be used for this purpose.

The draw tape consists of a long strip of glass fibre or spring-steel which has a ball-point at one end anda.<;l()s¢dJqop.at the other end. It should only be used for pulling in the actual draw-in wire (fo(ex.ıı.ı:rıple, p.v.c. cable). It should not be used for drawing·· cables as it is very brittle and S(j()ıf1J¢comes distorted or broken if misused.

The followings are the advantages of111etallic conduits:

1. Provides protection againstı:rı¢chanical damage.
2. Provides earth return path.
3. Durability. Conduit, if prop¢tlY!i.ıızstalled,lasts for years without maintenance.
4. Can be easily extended.
5. Low fire risk.

The disadvantages of metallic condtıits:

1. Liable to corrosion (chemicals.and condensation).
2. More expensive than t.r.s. and/p.v.c. sheathed systems.
3. Difficult to conceal.

Points from the I.E.E. Regulafü,ms:

1. The conduit installationınust be completed before cables are drawn-in and boxes of ample capacity should he. provided for this purpose. All such boxes must be accessible. A space factor of 40 per çent is allowed in conduit systems, this space factor is based on a maximum of two 90° bends per draw-in length.
2. The radius of a bend in conduit should not be greater than 2.5 times the outside diameter of the conduit.
3. The ends of conduit must be filed or reamed to prevent damage to the cable.

3. Conduit installed in damp and humid situations must have a water-resistant finish (for example, galvanized).
5. Conduit must be securely fixed and protected from mechanical damage.
6. Extra-low-voltage and low-voltage cables must not be run in the same conduit.
7. Metal conduit should be kept separate from gas and water services. Conduit which is likely to come into contact with other services should be bonded to those servıces.
8. All metal conduits must be effectively earthed and all joints must be technically and electrically continuous.
9. Drainage points should be provided at the lowest point in a conduit installation and in conditions.where.co:n.derısedmoisture is likely to collect. Drainage points are not made in a gas-tight system.
10. Cables installed in an explosiVea.tn:ıI,sphere must be enclosed in solid drawn conduit, unless they are metal sheathed.
11. Metal conduits not requiring earthing; (a.)<short isolated lengths used for mechanical protection; (b) short unex.pğs~d isolated lengths used for the mechanical protection of cleated wiring. ·
12. Bunching of Cables: Outgoingfiiidıretum cables ınustJpeYrı.uı in the me conduit
13. Substantial boxes must be supplied at every junctiön' where a cable inflection is required in metallic and non-metallic conduirsystems, A11:tı.nusedconduitentries must be blanked off and removable covers secured.

**Trunking.** Is used in conciitions where a considerable number of cables are required in an installation, or where cables are too large for drawing into a conduit. It is manufactured from plastic or sheet steel and is supplied with a large range of terminations and connections.

The I.E.E. RegulationsforTrtı.nking and Ducting:

1. Ducts and trunking mustbe securely fixed and adequately protected against corrosion and mechanical damage.
2. All joint outlets in a duct system must be mechanically sound and free of abrasive surfaces.
3. Entries to ducts and trunking must be protected against the inflow of water.

All covers must be securely fixed on the completion of wiring.

4. A maximum space factor of 45 per cent is required in trunking and channels.
5. Where ducts or trunking pass through floors, ceilings or partitions the hold should be plugged with cement or a :fire-resisting substance to the thickness of the building material. Internal :flame-resisting barriers must also be fitted inside the trunking or ducting in these conditions to prevent the spread of fire.
6. Armoured or M.I.M.S. cable used in concrete ducts must have an overall extruded covering ofp.v.c.
7. A continuous partition must be used in conditions where low voltage and mains voltage are run in the. same channel or trunking.

The following factors ar~)ôf particular importance in installations where cables and conductors are used in conditions ôfhumidity (high moisture content in atmosphere) or where equipment is exposed to directsuıılığhtp:rhightemperatures.

(a) The temperature rating of conductors and cables nuıstbe.carefully adhered to in the calculation of conductor cross-sectional area.

(b) It is essential that care is taken in the jointing of dissimilar metals to guard against the effects of electrolysis.

(c) Ordinary p. v.c. cables will quickly deteriorate when exposed to direct sunlight. It ıs essential that special cables be used. Non-metal sheathed cables used in these situations should preferably have-a.special blackp.v.c. sheath or oil-resistant and :flame-retardant or h.o.fr. sheath.

(d) Metallic conduit must be of the galvanized type and spacer saddles should be used to permit the free flow of moisture on surfaces.

(e) The extensive use of aiı.' conditioning in hot countries tends to increase the temperature range which eqtci.pınentmust be able to withstand.

(t) There should be adequate breather holes in metallic trunking and conduit installations to minimise condensation and allow moisture to escape.

(g) P.V.C. conduit or trunking should be used where rust is likely to affect the installation. -A separate earth-continuity conductor must be run in the p.v.c. conduit or trunking.

# CHAPTER THREE

# ILLUMINATION [4]

## 3.1 Inverse Square Law

The distinction between terms used in illumination often presents difficulties.
The illumination falling on a working plane varies inversely as the square of the distance of that surface from the light source. For example, when the distance from source A in Figure 3.1 is dôµbled {moving from D to 2D) the illumination falling on the working plane is quartered.
Note that it is assumed that thewô'r:kij'ı.ğplane.isat right angle to the light source.

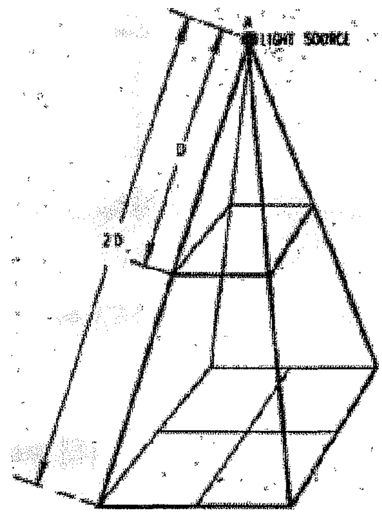



Figure 3.1 Inverse square laws.

The illumination (in lumens per square metre) at a point below a light source on a horizontal work plane (Figure 3.2) is calculated as follows:
Where $E$ = illumination in lumens per square metre, $I$= luminous intensity in candelas, and $d$ = distance from light source in metres.

For example ifwe want to calculate the illumination on a working plane ata point A, as in figure 3.2, 2 m vertically below a lamp emitting 720 ed. The surface is at right angles to the light Source.

Since $$E = \frac{I}{d^2} \quad (3.1)$$

$$E = \frac{720}{2^2}$$

E=l80 *lm l m?*

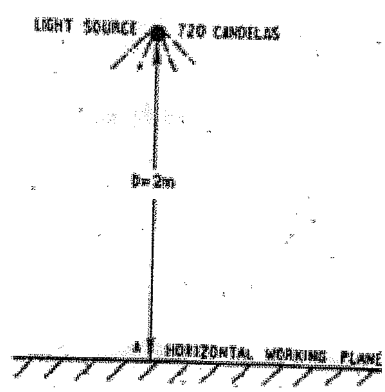



Figure 3.2 Calculating illuminations.

## 3.2 **Cosine Law [3]**

The illumination at a point öna.hôrizontal working plane which is at an angle to the light source (Figure 3.3) is calculated as follows:

$$E = \frac{I}{d^2} \times \cos() \quad (3.2)$$

where cos $\theta$ = cosine of angle between vertical line AC and diagonal line BC in Fig. 3.3.

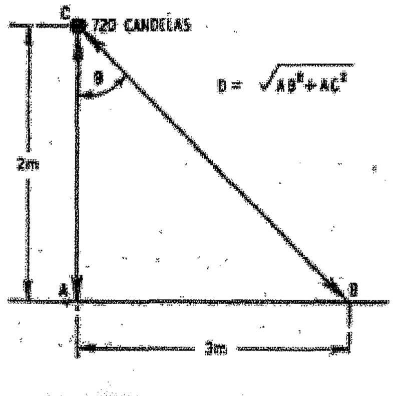



Figure 3.3 Calculating illumination.

## 3.3 Other Factors in Illumina.tifö:ı

### 3.3.1 Maintenance Factor

This factor (a number without units) takes into consideration losses in light output due to (a) ageing of lamps and (b) dirt collectingonlamps and fittings.

The maintenance factor recommended by the Illuminating Engineering Society is 0.8, for fittings cleaned every six weeks,

### 3.3.2 Coefficient of Utilization

The level of illumination in a factory or office is affected by:

(a) Light output oflamp (lumens).

(b) The type of reflector used.

(c) Height and spacing of fittings.

(d) The colouring ofthe walls, ceiling, and floor.

These factors are taken into consideration in the coefficient of utilization (a number without units).

$$\textit{Coefecient of Utilization} = \frac{\textit{Light received on working plane}}{\textit{light output of lamps}} \quad (3.3)$$

The calculation of total lumens required in an installation

$$\textit{Limmous flux (Lumene)} = \frac{\textit{Jllumninaifon required } Vm!m^2 \times \textit{area } (m^2)}{\textit{maintenance factor} \times \textit{coeffeciea of utilizatioı}} \quad (3.4)$$

For example: A yard 25ri:ılorıgby6m wide isto be illuminated to a level of20 lm/m2.

Assuming the average lumen output of the lamps is35lm/W. the maintenance factor 0.8, and the coefficient of utilization 0.5, calculate the total lamp power required.

Using equation 3.4

$$\Phi(lm) = \frac{20 \times 25 \times 6}{0.8 \times 0.5}$$

$$= 7500 \text{ lm.}$$

Since each watt used supplies 35 lm:

$$\textit{Total Watts Required} = \frac{7500 \ lm}{35 \ lm/W} - 214.3 \ W$$

Note. If 80 W :fluorescent lamps are used, number required= 214.3/80 = 3 lamps.

## 3.4 Types of Lamps Used

There many types of lamps used for illumination purposes.

### 3.4.1 Incandescent Lamps

The principle of operation (Figure 3.4), the Light energy is produced by passing a current through a conductor (usually tungsten) enclosed in an evacuated glass bulb. The operating temperature is over 2000 °C.

The efficiency of the lamp is further increased by the following methods:

1. Filling the bulb with an inert gas, usually argon. The gas increased operating temperature (about 2500 °C) giving increased light, as it minimizes the losses from the filament due to evaporation. The life of the lamp is also incfeased(rriinirrı:tim 1000 hours).

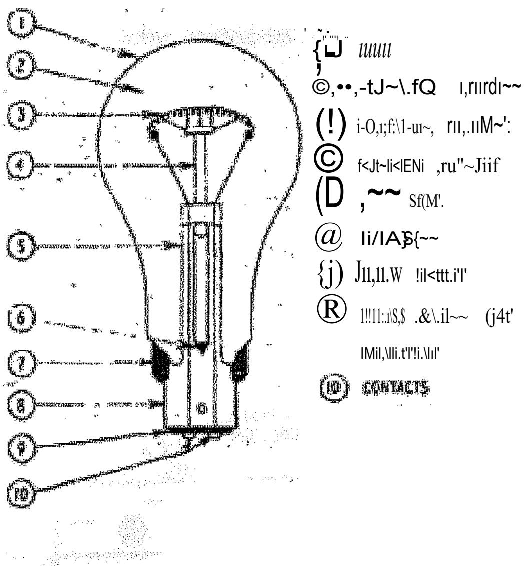


Figure 3.4 Incandescent lamp.

2. Double-coiling the filament (the coiled-coil lamp). This reduces the heat losses due to convection currents in the gas. The filament is operated at the same temperature.

The efficiency of the lamp is approximately 12 lm/W.

The efficiency of a lamp is dependent on:

(a) The rating of the lamp (efficiency increases with lamp size).

(b) The age of the lamp.

(c) The operating voltage Efficiency is decreased when run at values less than rated voltage.

### 3.4.2 Discharge Lamp

The discharge lamp is shown in figure 3.5.

The principle of operation of this lamp is when an electrical pressure is applied across A glass tube containing a certain gas (e.g. neon) an electrical discharge takes place and energy in the .form of light is given off The gas under these conditions is said to be ionized. The electrical connections inside the tube are called electrodes.

Ionization is caused by theri:ıôvement of electrons in the gas. These electrons 'bombard' the atoms of gas and free ôthe:felectrôns.I ..iğh.tis given off during this Bombardment. The flow of current through the tube increa.ses -with .ionization as a' chain reaction' takes place:

1. Increased ionization.
2. Decreased resistance of the discharge path.
3. Increased current.
4. The cycle is repeated.

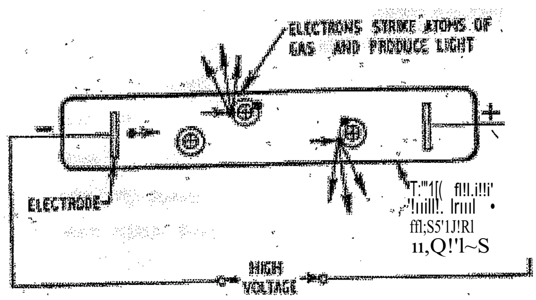



Figure 3.5. Discharge lamp: principle of operation.

This process of ionization is started off by:

(a) A high voltage being.applied across the tube; or (b) the use of heated filaments in the lamp.

The filaments are heated at the moment of starting and are coated with a special oxide, which emits electrons. This type of lamp is termed a hot cathode lamp. A current-limiting device (e.g., a choke) must be fitted in the lamp circuit or the tube will disintegrate.

### 3.4.3 Low-Pressure Mercury Vapour Lamp

The L.P.M.V. (or fluorescent) lamp is the most common type of discharge lamp.
The lamp circµ.itcqnsiṣts pf the following (Figure 3.6):

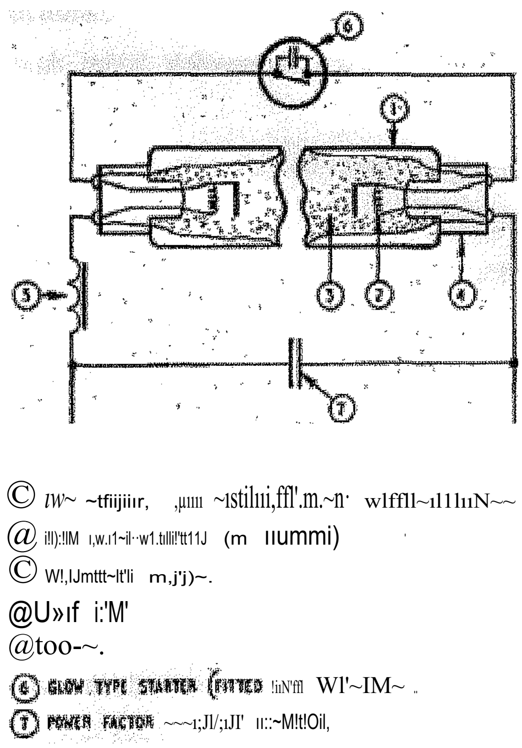



Figure 3.6 Low-presstire mercury vapour (fluorescent) lamp.

1. A glass tube containing low-pressure mercury vapour and argon gas. The argon gas is used to assist in starting.
2. Two oxide-coated filaments (the electrodes). The filaments are heated on starting to assistiri'ioriization (this lamp is called a hot cathode lamp).

Two small plates are fitted to the :filaments to increase the effective cross- sectional area of the electrode.

3. The fluorescent coat. The tube is coated internally with a fluorescent powder as a large part of the light given off by the low-pressure mercury vapour (ultra-violet rays) is not visible to the human eye. The powder converts these invisible rays into visible light rays, with an efficiency of 35-45 lm/W over a life of 3000 hours.

4. Lamp caps. The connecting caps on the lamps are either bayonet caps or bi-pın.

**Ancillary Equipınent.** This comprises (1) the choke and (2) the starter. The choke has two functfön.s:<.

(a) It supplies a.highinitial.'vôltağe <>nistarting, caused by the breaking of an inductive circuit.

(b) It limits the current in the lamp whenthelaırı.pis/running.

There are two types of starters, the glow starter andifl1Jfthermalstarter. The glow starter is the most common type, and consists of two contacts sealed inside a helium-filled glass tube. When the lamp is switched on, a discharge takes place between the starter contacts, one of which is a bimetallic strip. This discharge heats the bi-metallic strip and causes the contacts to come together. A current now flows through the lamp filaments, heating them and starting the process of iôn.izı:1tj.<:>llin the lamp. The starter contacts open as the temperature decreases in theis@::te:t a.n.da high starting voltage is applied across the lamp. The voltage across<tlıe tube.•under running conditions is insufficient to operate the starter and the starter contacts remain open.

The thermal starter has two distiı:ıcfsections (i) the filament and (ii) a bimetallic contact. The contacts are closed wherithedan:ıp is started but the heat of the filament opens them after several seconds and they reınaiı:ı open during the operation of the lamp.

The capacitor (usually about 8 μF)is fitted to correct the power-factor by neutralizing the inductive effect of the choke.

**Principle of Operation.** When a voltage is supplied across the circuit the following occurs.

1. The filaments glow and emit electrons, which assJst in ionizing the gas.
2. The starter switch opens and breaks the inductive circuit of the choke, thus

applying a high starting voltage across the lamp.

3. The main discharge commences in the mercury vapour and the starter contacts remaın open. The argon gas in the lamp assists in establishing this initial discharge.
4. The choke limits the current flowing when the lamp is operating.

This lamp is termed a hot cathode lamp as heated filaments are used to start the discharge.

Faults in Circuits. The flickering Lamp, check

(a)Ends oflamp. If blackened at filaments renew lamp.

(b) Starter. advisable to carry a spare starter to plug in before replacing tube.

(c) Supply voltage. Çhecktlıatsupply voltage is sufficient as voltage is critical.

(d) Draughts. A low ambieııf(surtöunding) temperature may cause flickering, particularly in a draughty.cörriclor.

Slow Flashing ofLamp. This generally occurs whenthela.ın.prequires it renewal.

No Flicker but Filament Glows. Check (a) starter for welded contacts or (b) radio suppressor capacitor (fitted across starter contacts) for short circuit.

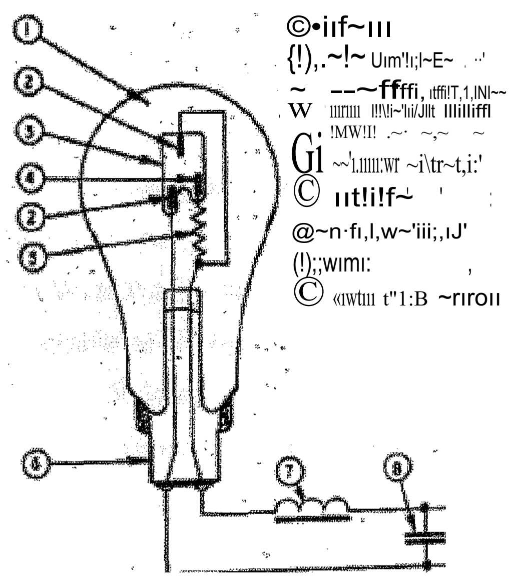


Figure 3.7 High..pressure mercury vapour lamp.

### 3.4.4 High-Pressure Mercury Vapour Lamp

The H.P.M.V. lamp (Figure 3.7) consists of two tubes:

1. The inner tube, containing (i) high-pressure mercury vapour and argon gas (used to help starting); (ii) two main electrodes in the form of a spiral; and (iii) an auxiliary electrode connected through a 50,0000 resistor to one side of the supply.
The inner tube is made of boro-silicate glass or quartz to withstand the high operating temperature (600 °C).
2. The outer tube. This is simply an evacuated case used to minimize heat losses. It also acts as iishielcl against harmful ultra-violet rays.

Ancillary Equipment. The choke is used to limit the current in the circuit.

Principle of,Qperation. This is as follows:

1. The initial discharge takes place between one electrode and the auxiliary electrode and then between the two main electrodes. This initial discharge takes place in the argon gas.
2. As the mercury vapour becomes ionized the column of gas shorts the auxiliary electrode and the~!in dischar~.:.ı~e~R1;!~0.

The H.P.M.V. lamp is a cold cathodelamp. It attains full brilliance after\ıbout five minutes. The colour is greenish-blue.
Th~ low-wattage (80-125 W)H.P.M.V. lamp looks similar to a pearl incandescent lamp but has a 3-pin B.C. larnpholdefto prevent wrong connections.
The applications of the H.P.M.V. lamp is generally used for factory lighting and street lighting as it has a very high luminous efficiency (about 40 lm/W).

### 3.4.5 Sodium Discharge Lamp

The sodium discharge lamp is made up of the following:

1. AU-shaped 2-ply glass tube (the inner ply consisting of a heat-resisting low-silica glass) containing globules of solid sodium and low-pressure neon gas. Oxide-coated electrodes are fitted at both ends of the tube.
2. An outer vacuum jacket, used to minimize heat losses as the lamp runs at a low temperature (300 °C). Both tubes are supported by a porcelain base, which has a two-contact bayonet cap.

The ancillary Equipment. This is as follows:

1. High-reactance transformer. This transformer is used to give a high voltage (480V) on starting and acts as a choke, limiting the current, when the lamp is running.
2. Capacitor. The power factôf ofthe circuit is low due to the transformer. The capacitor is ijsed to cortectiffrom 0.3 to 0.9.

The principle of operation is giveilbeföw:

(a)When a voltage of240 Vis applied acfossfüeicfrcuitthe transformer supplies 480 V across the lamp electrodes.

(b) This high voltage causes the neon gas to glow red.

(c) The heat from the neon gas vaporizes the metallic sodium and assists in ionizing the sodium vapour.

(d) The increasing current in the circuit, due to the ionization of the Sodium vapour, causes a voltage drôp in the transformer.

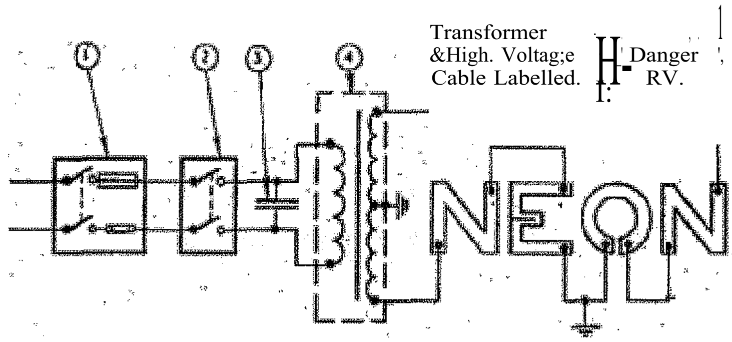
(e) The lamp runs at normaFvôltağe füıd thecurrenfthrôughthelaı:npis liı:nifedby the choking action of the transformer.

The uses of the sodium dischargefaı:np are limited by its yellow colour but it is used for road lighting as it is highly efficient(70 lm/W).

Note that the U-shaped lamp .tub~ should be handled with care, owing to the danger of fire if the sodium comes into contact with moisture.

### 3.4.6 Neon Discharge Lamp

The neon lamp (Figure 3.8)js made up of a tube (generally




© Main Switch

@Firemmı. !nritch.

@Power Factor Correction Capacitor

(1)Hig]ı. Voltae Transformer Maxim.um:S000V To Earth.

Figure 3.8 Neon discharge lamp.

General Points on Discharge Lamps.

I.All cables must be capable of carrying the circuit curre:tıtand, in the last of high Voltage lamps, should be of the correct voltage rating. Cables in high-voltage circuit should be labeled and marked DANGER.

2.Chokes and ancillary equipment should be placed as near as possible to the lamp.

3. Switches must be capable of breaking an inductive load (e.g., a circuit containing a choke or transformer).

4.All live parts must be effectively screened (earthed metal or a strong ~sulating material) and, in the case of high-voltage installations, must be labelled: DANGER IDGHVOLTAGE.

No discharge lamp circuit shoulduse an open-circuit voltage exceeding 5000 V to earth.

## 3.5 The Photometer [3,4]

The photometer is used to measure illumination (in lumens per square metre) falling on a surface.

The photometer cell (figure 3.9) consists of three layers of metal:

1. A transparent film of gold.
2. A selenium film.

3. A steel plate.

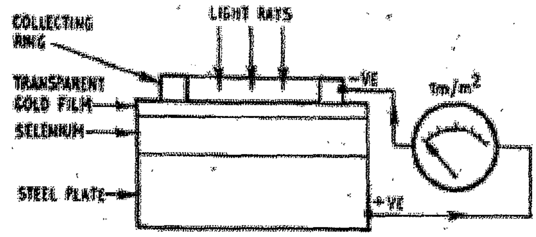



Figure 3.9 Photometer cell.

A connecting.ringıı:ıakesc9rı.tact'Yiththe transparent film; the other connection is taken from the steelplate,.ijQtlı çtjnı:ı.§lctiorı.s(aı-e take:q.to a very sensitive moving-coil instrument which has a scale sub-divided into Iumen.sper square metre.

**Principle, of Operation.** When light rays strike the surface between the transparent film and the selenium film, electrons are freed and a current flows through the moving-coil instrument.

**Stroboscopic Effect.** This is the effect, which the flickering ofa discharge lamp has on moving machinery. Theflick:ering takes place every 1/1()0 second on the zero part of the supply cycle. Th§' strobosq9ptcief-f~cf..Can.\giveJll.e.i.µp~ion that the moving machinery is stationary.

This may be overcome by (a) using a special retention powder in the lamp, which retains the light over the zero pan of the cycle or (b) by splitting the lamps between different phases.

# CHAPTER FOUR

# EARTIDNG AND PROTECTION [4]

## 4.1 Purpose of Earthing

The purpose of earthing is to insure that no person operating an electrical installation can receive an electric shock, which could cause injuıy or a fatality.

It involves the contıectiôfr of all metalwork associated with the electrical installation (the exposed conductive parts) with the circuitpr9tyc:tive conductors (CPC's) which are terminated at a common point, the main earth terminal. This terminal is further connected to a proven earth connection that can be the supply authoOrity's wire-armoured supply cable, an overhead line conductor or an earth electrode driven directly into the soil.

The availability of one or other of these connections depends on the type of electrical system used to supply electricity.

The metal works that is not related to the electrical installations that is the hot-and cold water pipes, radiators, structural steelwork, metal-topped sink units and metallic ducting used for ventilation. These parts are connected by the ıneans of:

(a) Main 'bonding conductors: used it hon together metallic services at their points of entry into a building.

(b) Supplementary bonding côndUctors: used to bond together metallic pipes and the like within the installation.

These bonding conductors are also taken to installation's main earth terminal.

Thus all metallic work within the building is at earth potential.

Once all CPC' s and bonding conductors are taken to the main earth terminal, the building is known as an 'equipotential zone' and acts as a safety cage for any person from serious electric shocks.

Equipotential means that every single piece of metal in the building is at earth potential.

Most soils and rocks when completely dry are considered non-conductors, but when water or moisture are present their resistivity drops to such a low value that they become conductors.

This means that the resistivity of soil is determined by the quantity of water present in it.

### 4.2 **Regulations and Requirements**

The I.E.E. regulations deals with the.requirements which all earthing arrangements must satisfy if an electrical installatiônis to be deemed .safe.

The main basic requirements ate:

1. The complete insulatiôns ôf.paitsCofan electrical.
2. The of appliances with double insulation confirming to the British Standard institute Specifications.
3. The earthing of exposed metal parts (with some exceptions).
4. The isolation of metal work in such a manner that it is not liable to come into contact with any live parts or with earthed metalwork.

The earthing arrangement should be such that the maximum sustained voltage developed .under.fault conditions between exposed metal required.'to be earthed and the consumer's earth should not exceed.SON.

The earth conductor lead·shouldôfniliiimumsi.ze: 6Jnm?,.except2.5 $mm^2$ is accepted for connection to an earth leakage circuit-breaker.

It must also be protected>against mechanical damage and corrosion, and not less than halfofthe conductortobeptotected;butneednotnormally exceed 70 $mm^2$.

There are a number of methôds used to achieve the earthing of an installation:

1. Connection to the metal sheath and armouring of a supply authority's under ground cable.
2. Connection to the continuous earth wire (CEW) provided by the supply authority, in overhead lines energy distribution.
3. Connection to an earth electrode sunk in the ground for this purpose.
4. Installation of protective-multiple earthing system.

5. Installation of automatic fault protection.

### 4.3 Types of Earth Electrodes

There are many types of earthing electrodes:

(a) Cast-iron, or Copper, Plate: This type of earth electrode is used where space is restricted It has the advantage of being capable of carrying large currents. The conductivity of the surrounding earth is often increased by using salt or coke round the electrod.e. It should be noted that salt might have a corrosive effect on the electrodt:ı, The. saltmuşt he. renewed periodically. Plate electrodes are often drilled to .m~¢.cpıιta,çt Sllı-f~.SY· Çopper conductors should be tinned before being connected to an irotı plate to ,pr¢yent çlıernical action corroding the connection.

(b) Copper Earth Rods: copper rods of 20mm or 25 mm diameter are used where there are high-resistance earth conditions (e.g., shingle). It is possible to obtain copper rods with end-on connections where a length (usually about 1.5 m) may be driven in, the removable hard-steel tip unscrewed, and a further length ofrod screwed on.

(c) Copper Tape: this is buried in a trench or stream -ı.vhereJOCky şqil predominates. Low earth resistance can. be obtainycl. by ll~ing tly.§ı;ıı;¢th.9çl,.,Rllt it is costly and requires a long trench, 1]ıeJyngth remftrM dypeı;:ıclsJ.ı.poı;:ı the soil conditions.

(d) Supply Authority'.§ :E:a.rth. ,'fhiş is the, connection taken from the lead sheath of the incoming supply cable ofthe fifth wire of an overhead system. It can only be used as an earthJ¢flTliııaŀı.vith the permission ofthe Supply Authority.

The termination to the earth electrode should be available for inspection and testing. The resistance areas of separate electrodes should not overlap as this decreases the effectiveness pf the system by increasing the overall resistance of the earth path.

(e) Protective Multiple Earthing (p.rn.e.). This is a system of earthing used m conditions where soil resistivity is high (e.g. rock, sand). In this system the neutral line is earthed at a series of points along the distribution system to ensure that earth leakage currents flow back to the source of supply. Permission to use this system can only be granted by the Area Electricity Board.

## 4.4 Circuit Breakers

The LE.E. Regulations define a circuit-breaker as: "a mechanical device for making and breaking a circuit both under normal conditions and under abnormal conditions, such as those of a short circuit, the circuit being broken automatically".

The circuit-breaker is generally opened and closed by hand (manually) but is automatically opened under fault conditions by an over-current release.

The over-curreit telease is öpe:ra-ted by the magnetic effect of the line current flowing in the circuit. This current flows through a current coil consisting of a few turns of heavy-gauge copper wire or copper. tape. When a cô:ritimial overload is placed on the protected circuit the electromagnetic field, due to the current flowing in the coil, draws up a plunger, which operates a mechanical trip, thus isolating the circuit from the supply.

The operation of an electromagnetically operated over-current release. When an overload current flows through the coil, the soft-iron plunger is lifted high enough to open the control circuit.

The time lag over-current release uses a piston fitted in an ôil-filleddashpot to retard the movement of the soft-iron plunger'. thus providing a n:riiellag ôh the operation of the over-current release. The Operattrıg, b:r trippirt,ğ, ttırteht cAff>He Varied by screwing the dashpot up or down; it is generally seftô operate afl.5 times (150 per cent) full load current.

The Over-current releases are côriın:ıo:rily used in motor starter circuits where very high starting currents (about the full load current) are encountered. The time-lag action of the dashpot allows sudden surges of current in the circuit without tripping, although a continuous overload current would operate the trip.

Figure 4.1 shows the circuit of a manually operated 3-phase circuit breaker, which is fitted with electromagnetic overload releases. The circuit breaker is dosed by hand and the operation of any of the over-current releases trips the switch mechanism and opens all the phases.

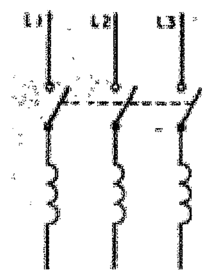


Figure4.T]V[atnıallyoperated 3-phase circuit breaker.

(b) Earth Leakage Circuit-breakef:J'I'he earth.leakage circuit-breaker also uses the magnetic effect of an electric current.

Figure 4.2 shows the simplified circuit of a voltage-opetatecl./earth leakage circuit breaker. The basic circuit consists of a coil connected between the metal framework of the installation and the general mass of earth.

The operation of the earth leakage circuit breaker:

1. Under earth-fault conditions a voltage appears between the metal framework of the insta,llationand the general mass.of earth.
2. Since the coil of the. EL.C .B. is co1111~ctecl .l>c,t\yyyh .tlıese tw-o points . a voltage is applied across itl:ınd. a. Cllff~rtt flows thtough it.
3. An electromagnetis fo®ed <round the coil, which operates the trip mechanism, pp¢ıµııgalltlıe poles of the supply.

Figure 4.2 shows a completeiE.L.C.B. circuit. A two-way switch has been connected in the frame lead to operate a test circuit. When the test push-that is, the two-way switch is operated, the E.L.C.B. coil is connected between the phase conductor of the supply and the earth terminal. A high resistance is also connected in the circuit to limit the test current. The coil becomes energized if the earth fault path is effective, and the trip mechanism operates.

(c) Current-operated EL.Ç.B.: This type ofE.L.C.R.opyrates on the principle of the double wound transformer. The magnetic field round the operating coil is energized when the current flowing through the line and neutral (or phase conductors in a three phase system) is out of balance. For example, an out of balance current caused by an earth leakage induces a current into the fault detector coil, which energises a trip coil.

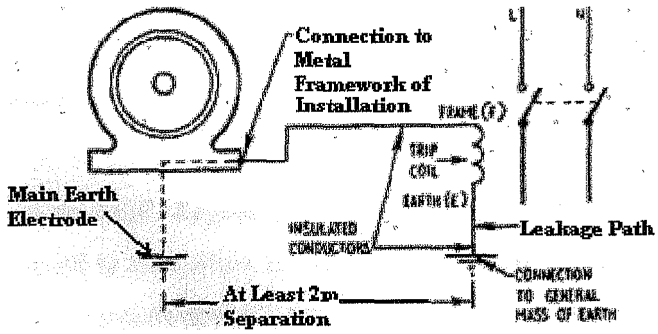



Figure 4.2 Simplified circuitôfyôltage-operated earth leakage circuit breaker.

Its advantages is that it is not affected by parallel earths.

It is essential for the correct operation of the E.L.C.B. that the earth and frame connections are not reversed. A reversal of c~11t1ec~~irplacesJavoltage between the frame and the general mass of earth whenthetestbuttonis·pressed.

The voltage-operated E.L.C.B. is gerierall)'llsedwhere there are poor earthing conditions (for example, rockyôfdıystıb-'-soil).

Advantages of Earthleakağe circuifb:teaker:

1. The E.L.C.B. proviqes.):ı>•cheapand. efficient form of earth-leakage protection, particularly in situatiğriswhere it is difficult to obtain a good earth connection.
2. All poles of the supply aJ"~isolatedwhen an earth fault occurs.

Disadvantages:

1. The earth continuity conductor to the trip. coil may become disconnected.
2. The voltage operated E.L.C.B. can be rendered ineffective (through the shorting of the operating coil) if ground resistance area of the metalwork in the installation overlaps that of the trip earth electrode.
3. The earth continuity conductor serving the E.L.C.B. must be connected to an

earth electrode, which is outside the resistance area of othermetal work.

4. The complete supply is completely disconnected when a fault occurs in any part of the installation.
5. The switch mechanism of the E.L.C.B. can be wedged in the ON position, thus allowing dangerous earth-fault conditions to arise.

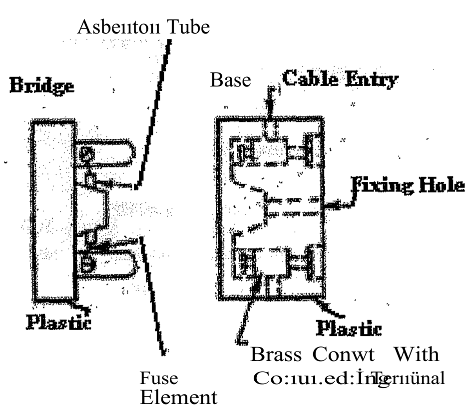
Note: E.L.C.B.'s must be tested at least every three months.

## 4.5 Fuses

A fuse is defined in the I.E.E. Regulations as: "A device for opening a circuit by means of a conductor designed to(111~l!\wheti an excessive current flows. The fuse comprises all the parts.that form the complete clevice,,,tlı.ere>arethreeJypesof fuses:

1. Re-wirable fuse.
2. Cartridge fuse.
3. High breaking capacity (N.B.C.) fuse, formerly termed the high rupturing capacity(N.RC.) fuse.

Re-wirable Fuse. This consists .(Figure 4.4). of a. plastic .bridge and base. The bridge has two sets of copper contacts, which fit into contacts in. the base.




F'igure4.4. Re-wirablefuse.

The fuse element; for example, tinned copper wire, is connected between the terminals of the bridge. An asbestos tube, or pad, is generally fitted in the fuse to minimize the effect of arcing when the fuse element melts.

This type of fuse is termed a 'semi-enclosed fuse' to distinguish it from the older type of fuse which consisted simply of a piece of wire connected between two terminals.

The current rating is the current, which the fuse element will carry continuously without deterioration.

The fusing current is the current at width the fuse element will melt, this is approximately twice the current rating of the fuse element (fusing factor =2).

Advantages:

L'Cheap.

2. Easy to replace fuse elen:ı,~ntş.

Note: The fuse must be capable ôf.cpfQtectingthesrnall~stcônductor in the circuit.

Disadvantages:

1. Fuse elements deteriorate in use.
2. Any size of fuse wire can be fitted, defeating the purpose of the fuse.
3. Lacking in discriminaıion- -lt- is· -possible that a 15 A fuse element may melt before a 10-A fuse element, depending largely on the condition of the wire. Further, the re-wirable fuse is not capable of discriminating between a rıiôtnenta:ry high starting current and a continuous fault current.
3. Easily damaged, particularly with short-circuit currents.

Cartridge Fuses. This type (Figure 4.5) has come into common use with

FU8e Element

Enıl. ~-- Cap ...._, """"" - Enıl Cap

Pıırceb:in Tube

Figure 4.5 Cartridge fuse.

fused 13 A plug used on the domestic ring circuit. Figure 4.5 shows the construction of a cartridge fuse. The fuse element is contained in a porcelain tube fitted with two connecting caps, and has a fusing factor of 1.5.

The colour code for these fuses is as follows:

| | | |
|---|---|---|
| 5 A-White | 13 A-Brown | 15 A-Blue. |
| 30A-Red | 60 A-Purple | |

**High Breaking** Capacity Fuse (H.B.C.). This type of fuse is designed protect circuits against heavy overloads and is capable of opening a circuit under short-circuit conditions without damaging surrounding equipment.

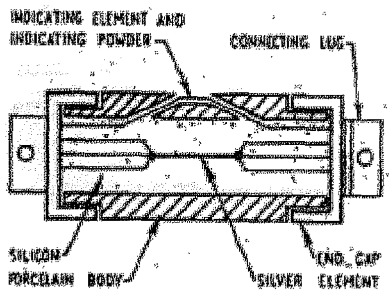



Figure 4.6 High Breaking Capacity Fuse

Figure 4.6 shows the construction of a high breaking capacity fuse. This consists of the following:

1. Porcelain tube.
2. Silver element.
3. Indicating element which·ignites powder under the label to show when the fuse element has opened.
4. End caps.
5. Silica (fine sand) filling used to quench the arc.

Note: The fuse must always be placed in the phase or non-earthed conductor of the installation, stun in the neutral (earthed) conductor.

## 4.6 Thermal Trip

The thermal trip (Figure 4.7) is operated by using the heating effect of an

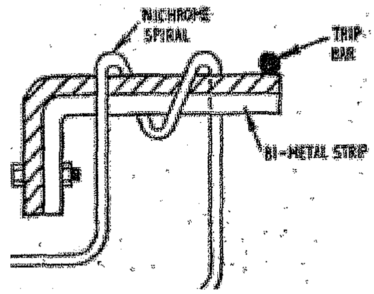



Figure4.7 Thermal trips.

electric current. Two :flat pieces of dissimilar metals are joined together and placed inside a nichrome spiral, which carries the line current of the protected equipment.

When the line current reaches a certain pre-determined level, the heat from the spiral distorts the hi-metallic strip causing it to operate a push-bar mechanism, which opens the switch.

This type of protection is generally used on low-current circuits (for K example, fractional horsepower starters) because the hi-metallic strip tends to distort permanently if heavily overloaded.

All fuses and single pole control devices (e.g.. circuit-breakers, thermostats) must be fitted in the line conductor in a 2-wire installation where one pole is connected to earth.

## 4.7 The Telephone

Principle of Operation (Figure 4.8)

(a) If the resistance of the variable-resistor is varied, the current :flowing in the circuit will vary (Ohm's Law).

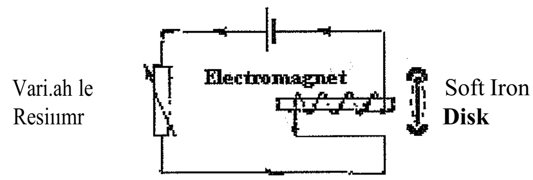



Figure 4.8 Telephone Principle of operation.

(b) These variations in current will cause variations in the strength of the electromagnet.

(c) Variations illthe strength.ofthe magnetic field will vary the 'pull' on the soft-iron diaphfağ)l).<(ötdisc).Thedisc can be made to vibrate by varying the resistance in the circuit.

Simple Telephone Circuit. In the simplest telephôıie circuit (Figure 4. 9)

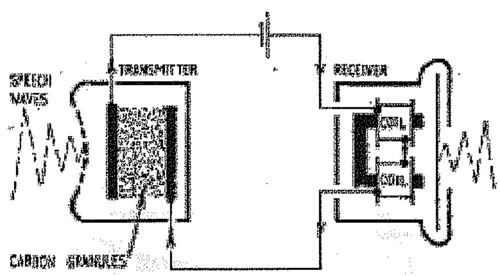



Figure 4.9 Simple telephone circuit

a transmitter (or microphone) takes the place of the variable resistor. Variations· in resistance ate caused by the pressure of sound waves from the voice acting on a layer of carbon granules, thus varying the current in the circuit. The electromagnet of the receiver changes these variations in cur-rent back into sound waves by attracting and repelling the soft-iron diaphragm. Soft iron is used because it does not retain magnetism.

Construction ofTransmitter and Receiver. The traıışpıitter (Figure 4. 10) consists of a sealed chamber containing carbon granules (powdered carbon). The tone-shaped diaphragm presses on the granules, which are placed between two electrodes.

The receiver (Fig. 4. 11) contains the following:

1. A soft-iron diaphragm.
2. Two coils (connected in series) which are wound round a U-shaped permanent magnet.

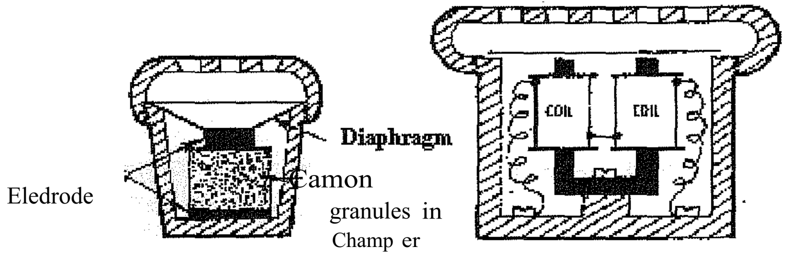



Figure 4.10 The Transmitter. Figure 4.11 The Receiver.

Two-Position Telephone Circuit. Figure 4.12 shows the circuit of a simple circuit used for communicating over short distances.

It consists of a d.c. supply a transmitter and a receiver.

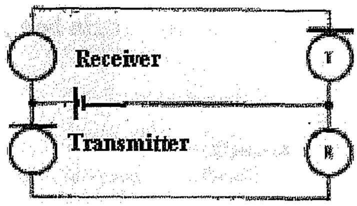



Figure 4.12 Two-position telephone circuit.

## 4.8 The Relay

The relay Figure 4.13 consist of coil of insulated wire.wound around a soft iron core, when the coil is energized the hinged armature is attached

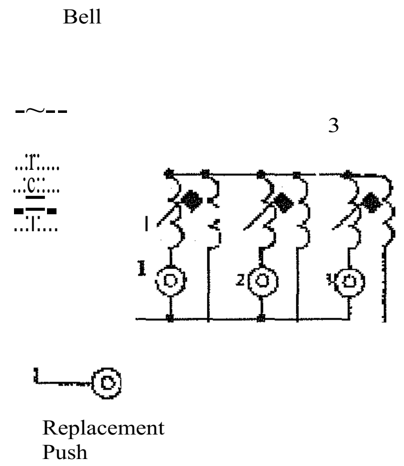


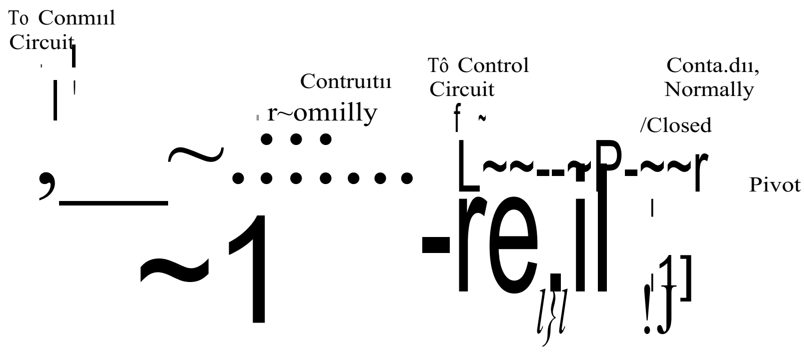

Figure 4.13 Indicator circuit using electrical replacement-type elements.

to the electromagnet and presses two contacts together. The relay in Figure 4.14 is a normally open (N.O.) type. The contacts are open until the coil is energized.

The relay in Figure 4.15 is a normally closed (NC.) relay. The contacts remain open while the coil is energized. When the coil is de-energized, the contacts close.

Applications. The relay is generally used in industry to control heavy currents from a distance so that the power losses ($I^2R$) in the cables will be minimized. The operating current in a relay is usually a fraction of an ampere.

Examples are: control of circuits in power stations, control panels for industrial machines, the car starter circuit, and alarm circuits.




(Left) Figure 4.14. Construction of Relay. (Right)Figure. 4.15. Normally closed (N.C.) relay.

## 4.9 Alarm Circuit

There are two types of alarm circuit a) the closed circuit; and (b) the open circuit.
Both types are made up of two distinct sections:

1. The battery-operated coil circuit.

(d) The mains-operated bell circuit, which is operated by the relay contacts.

Figure 4.16 shows a closed burglar alarm system.

Circuit (1) is a series circuit which is operated when one of the special switches (Figure 4.16) fitted on doors and windows is opened. All switches are connected in series.

Note. The relay coil in this circuit is normally energized: any break in this circuit (for example, the cutting of a wire) will:

(e) Open the circuit.

(f) Demagnetize the coil.

(g) Cause the contacts to come together, thus operating the alarm bell.

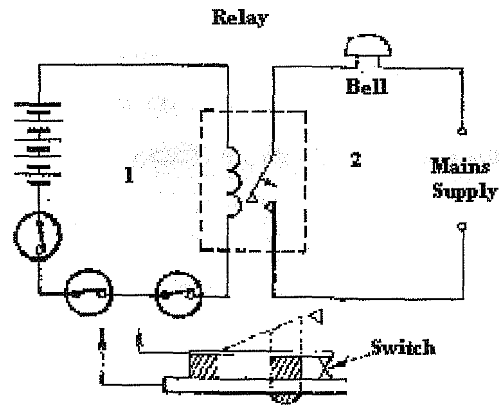



Figure 4.16 Burglar alarm circuit.

Figure 4.17 shows an open alarm circuit, the relay coil is only energized when one of the switches is closed. All the switches are connected in parallel.

The drawback with this circuit is that it becomes ineffective if any wire is cut (the opposite from a closed circuit system or if bad connection occurs in the dosed circuit.

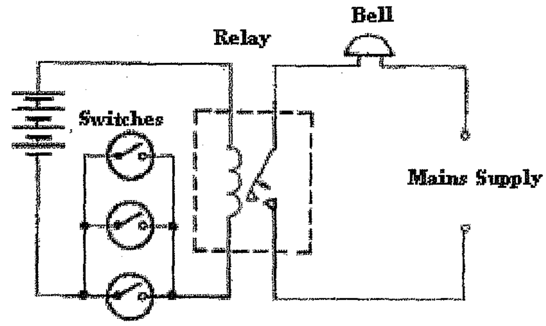



Figure 4.17 Fire alarm circuit.

## 4.10 Fire Alarm Circuit

The open alarm circuit (Figure 4.17) is generally used, .forJP:1"~>.~~ms. The only difference is the use of special heat-operated switches, usually ofone pfthe following types:

1. A metal strip distorts with heat and causes contacts to close.
2. The expansion of a column of mercury acts as a switch.
3. The expansion of air ina cylinder, due to a rise in temperature, pushes two contacts together.

## 4.11 Building Services

While the electrical contractor's interest in a contract tends to be centered on the provision of a power-fed electrical installation which meets the requirements of the client's specification; there are other services with which he may be involved; these are outlined in general in this chapter. The extent to which these services are part of the overall electrical provision of a client's premises depends on function of the building or buildings.

When new buildings are being considered, the client or owner considers the extent to which additional services (e.g. radio and TV aerials, telephones) are required. There is of course the difficulty and cost incurred if these are installed after the main building is completed. The disturbance to decorations is an expected result of inadequate planning and adds further expense, which can be avoided in the initial stages of the electrical provisions.

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

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

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

### 4.11.1 Clock systems

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

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

slave clocks have movements, which accept these impulses and alter their clock hands accordingly.

The mechanism of one type of master clock consists of a pendulum of half-seconds beat operated by an electrically wound spring through a dead-beat escapement. At each one-minute interval, while a small synchronous motor is rewinding the main spring, an impulse is transmitted to the subsidiary clocks. The mains a.c. supply is transformed to 48 V for operating the synchronous motor and gain reduced and rectified to provide 24 Vd.c for the transmitted impulses. Should the mains supply be interrupted for any reason, the main supply has a sufficient reserve to operate the escapement movement and hands for about 10 hours, though no impulses will be transmitted to the subsidiary clocks. The movement of a subsidiary clock is a one-minute polarized movement with a rotating armature, and incorporates a flywheel to render the hands 'dead-beat'. The usual master-and-slave installation can cater for up to 60 clocks. To add clocks to the system, it is only necessary to connect a clock in parallel with the remainder.

The clock load and the connecting cables should total a certain value of resistance so that the farthest-away clock has sufficient voltage at its terminals. The impulse current is around 220 mA. In a series-impulse clock systems, the voltage required for the installation is calculated at the total resistance multiplied by the impulse current of 220 mA. Sixty volts is the required maximum. Should the required operating voltage be above this, the installation should be sub-divided. As it is occasionally required to remove a clock from a series system, shorting-blocks' are provided.

### 4.11.2 Personnel Call Systems

These systems are used in private dwellings, hotels, schools, factories and other premises where it is required to attract the attention of individuals to a situation or circumstance.

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

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

Multiple-call systems are .µsı:ıcl ip. y~ryJarğe hQtelsivırlıere call points are too many to be indicated conveniently on a,Single;~~c2tôr>bo3fdpt)paııel. Pushes are fitted at each call point, but the circuits are group~d>tQ $enr~.CQ:QJdQt;(.QrsflQor. Each.group gives the indication in a central service room. In. these sYstems, art~ğe~eıı~ must. be made to have .attendants on duty in corridors or floors to deal vvith.xthe 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 theiheğinning or end of a time or a period. These systems have usually. one or two.pushes ot.other switches connected in parallel. The bells can be controlled from a clock system, to eliminate the human element required W,ithbellpüshes.

The burglar-alarm system is also a call system. The switches in. this .case are sets of contacts mounted at doors and windows.

As discussed previously there are two circuit types: open-circuit and closed circuit. The first type requires contacts to close to close to energies the bell circuit. In the closed-circuit type, all contacts are closed. A series relay with normally open contacts is energized by a circulating current.

When a contact set is opened, this current ceases to flow, d.c. energizes the relay and close the relay contacts to ring an alarm bell. Some alarm systems operate from photoelectric cells, which work when an invisible light beam is broken, The large plate-glass windows ofjewelers' shops often have a series length of very thin wire, which, if broken when the window is smashed in or a hole cut in it, will bring the relay into operation to ring a bell. In certain systems today, no bell rings, but a buzzer and light indication circuit is wired from the protected building and terminated at a nearby police station. Thus the intruder is not warned, and the police have the opportunity of catching the burglar red-handed.

The open-circuit system is seldom used because it can be interfered with. For instance a cut in the ring will render the complete system inoperative, whereas such a break in a series circuit of a circulating-current system will immediately set an alarm bell ringing.

Supplies are sometimes from the mains but in this instance standby-battery supply is provided in the event ôf a j:fowe:r failıte. Alarm bells are often installed in a place inaccessible to unauthôrize~~~rsf~~|~~~~tsi~~~: ~~~~~-

Another type of call alarm syst:m;is ~ji ;"~t:~:ı's< s~pervisory service. It is designed to provide a recorded indication of the>visits)of watchmen or guards to different pans of a building in the course of the·· düty tôun.d. The system uses a clock movement of the impulse, synchronies-time controlled a.c. ôr &2day'Cföckwork type installed at each contact station throughout the building. Each statiöıı has a box with a .bell push operated by the insertion of a special key. Operation of the contact e:rıerğizes an electromagnetically-operated marker which records the time of the visit on a-paper marked off in hours. In some systems, an alarm is given after a predetermined time if the watchman fails to 'clock in 'at a:ny constant station.

Luminous call systems are used instead of bells. Theses systems use colored lights, which summon staff to ful:fi1l a service duty. They are largely used in hospitals and hotels. When the bell push is pressed in any position in the building, a small light lamp lights in a duty room to indicate the general area froth, which the call has come. Alternatively, a lamp outside the call room lights and remains so until an attendant extinguishes it by operating a reset push located just outside the room. Some systems incorporate a single-stroke bell. Call and indicating circuitry is also incorporated in life systems.

### 4.11.3 **Telephone** systems

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

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

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

# TESTING AND MEASURING [4]

## 5.1 Simple Supply Circuit

A circuit is described in the I.E.E. Regulations as "an arrangement of conductors for the purpose of carrying current". The purpose of any circuit is to supply a means for carrying electric current through a complete set of conductors from phase to neutral or between phases. The simplest electric circuit is that containing a switch and a lamp, which are co:ı:ınectedin series between phase and neutral. For the purpose of this section oil testing I will trace this simple circuit back to the Supply Authority's cable in the street.

In Figure 5.1, the path of the current!:isfollowed from the Supply Authority's

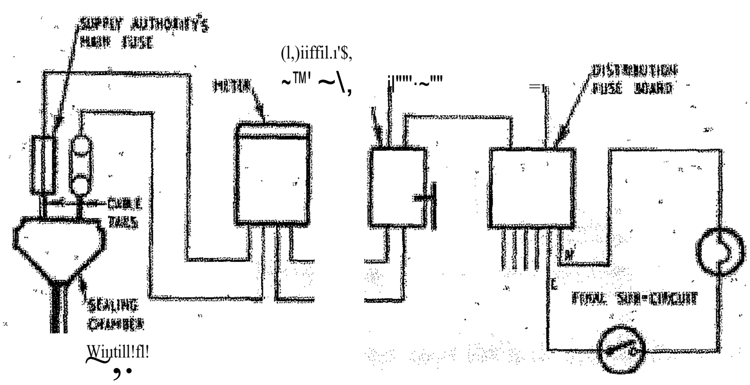



Figure 5. LSupply Authority's connections.

cable to the sealing chamber (a bitumen-filled container used to seal the armoured cable against moisture). Cable 'tails' are then taken from the sealing chamber in the Supply Authority's fuse. The neutral is taken to a solid connecting block and the phase is brought into the bottom of a fuse.

Another set of 'tails' are connected from the Supply Authority's fuse to the meter.

The point of connection of the consumer's conductors to the Supply Authority's meter is called the consumer's terminals. All the equipment before this point (meter, Supply Authority's main fuse, sealing chamber, armoured cable, etc.) belongs to the Supply Authority. The equipment beyond the consumer's terminals belongs to the consumer. The consumer's terminals are defined in the I.E.E. Regulations as "the termination of the electric conductors situated upon any consumer's premises and belonging to him, at which- the supply of energy is delivered from the service lines".

Every consumer's installation [2] must be controlled and protected by the following readily-accessible switchgear means of isolation (e.g. linked switch), excess current protection (e.g. fuse or circuit- breaker) and earth leakage protection Figure 5.2 which shows a typical consu.mer's unit. Each switch must be clearly labelled, where necessary for identification.

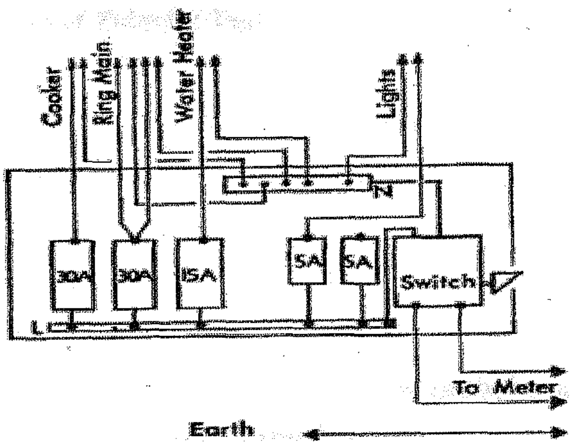



Figure 5.2 Arrangement of typical consumer unit for a domestic installation.

## 5.2 Purpose of Testing an Installation

The main purpose in testing an installation is to detect faults before (dangerous situations arise. The main factors against which an installation must be protected are as follows: earth leakage and danger of electric shock, excess current, moisture and corrosion.

The point should be made at this stage that the I.E.E. Regulations are not a set of rules drawn up to make the electrician's life difficult of a text book to be learnt parrotfashion. The regulations were compiled by a body of qualified electrical engineers and "designed to ensure safety in the use electricity in and about buildings". The Electrical Inspector, like the football referee, is not always a popular personality but he fulfils an essential function; by ensuring the application of the regulations, he safeguards the standard of workmanship in our craft.

The main tests carried out on an electrical installation are as follows:

(a) Verification of polarity.

(b) Insulation resistance tests.

(c) Test ofring circuit continuity.

Tests should be carried out (a) on new installations, (b) on additions to existing installations, arıd<{c) peri()dic;ally9µ ı:ı~isting installations.

### 5.2.1 Verification of Polarity Test

The purpose of the verification of polarity test is to check that the phase conductor is taken through the fuse and the switch to the appliance. The reason for this is that the neutral 'wire is earthed at the Supply Authority's sub-station. But the neutral is not necessarily 'dead'; in a system in which the load is unevenly distributed between the three phases (an 'unbalanced' system), it is possible to get a shock from the neutral. The neutral must never be broken by a fuse or switch. If the fuse opened upunderthese conditions, then the circuit would still be 'live'.Thisis illustrated in Figure 5.3.

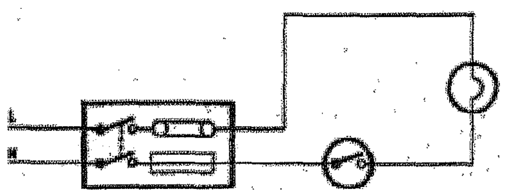


Figure 5.3 Incorrect connection of main switch.

In Fig. 5.4 the main switch has been correctly wired, but the lamp switch

Figure 5.4 Incorrect connection of lamp switch.

is on the wrong pole. An operator changing the lamp could receive a fatal shock, even with the switch off, ifhe accidentally touched the pins of the lampholder.

A case was reported where a man received a serious electric shock while

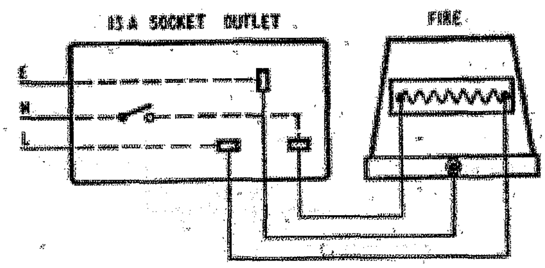



Figure 5.5 Reversal of connections at socket outlet.

cleaning the reflector ofan. electric fire with a damp cloth. The fire had been switched off but the plug was not removed. The man received a hand-to-hand shock between the earthed framework and the element. The phase and neutral conductors to the socket outlet had been reversed. The main danger from this situation lies in the fact that the electric fire (or the lamp in figure 5.4) functions normally.

This is illustrated in Figure 5.5.

The preparations for verification of polarity test is done by:

1. Supply ()FF.

2. Lamps and appliances OUT.
3. All switches OFF; neutral links IN; fuses OUT.

Test İnstrument. Ohmmeter or Bell set.

Method. This is illustrated in Figure 5.6. Test for continuity between: A and B; C and D; E and F.

Reading. Zero on ohmmeter or continuity with Bell set.

Note. This test should not be carried out on a 'live' installation with a neon-tester as a neutral may give a 'live' or phase indication. The insulation tester (e.g., megger) should not be used as the smallest reading is about 10,000 .Q.

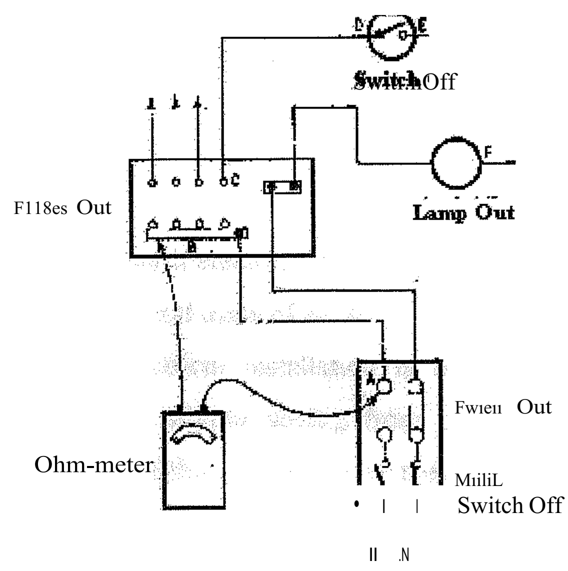



Figure 5.6 Verification of polarity test.

## 5.3 Tests ofEffectiveness ofEarthing

The reasons for carrying out earthing tests are as follows.

(a) To measure the resistance ofthe earth continuity conductor (the metal

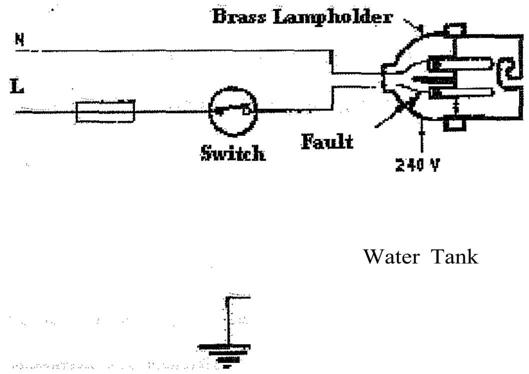



Figure 5.*1* Dangerous non-earthed metal lampholder.

conduit, trunking, and metal sheath or the special coııtinuity conductor, which connects the earthing lead to those parts of an installation which require to be earthed).

(b) To check that the earth continuity conductor is capable of carrying heavy leakage currents.

(c) To ensure that the earth electrode (e.g., buried copper plate) is effectively connected to the general mass of earth.

The earth connection is an electrical installatiô:tı is the essential safety link; the numerous cases of. fatal.electric shocks arising from the Use of two-pin plugs or appliances, particufatly portable appliances, underlinetheıı.eed fora good earth path for leakage currents.

Note. The consumers earthing terminal must be bonded to the metal-work of public services (e.g. gas and water pipes) on the consumer's premises at the nearest point of entry on the consumer's side.

The illustration (Figure 5.7) shows how a man was electrocuted white using a non-earthed portable lamp in a loft. The brass lampholder became 'live' and he received a hand-to-hand shock when he touched a water tank This accident could have been other, those parts of an installation which are required to be earthed. It may be in whole or in part the metal conduit, trunking, or duct, or the metal and/or armouring of a cable, or the special earth-continuity conductor of a cable or flexible cord incorporating such a conductor.

(b) Gas and water pipes must not be used. as earth continuity conductors but they may be bonded to the earth continuity conductor.

(c) Where a separate earth continuity conductor is used, the .minimum .allowable size is mnr'.

(d) It is essential that alhthe-:-joints in an earth-continuity conductor are mechanically and electrically sptırid.(metal--to-metaljoints). The earth-continuity conductor must also rl)eproteQtedaga:instcorrosion.

### 5.3.3 Current InjectionMea.surement of Earth-continuity Conductor Resistance.

In this method (Figure 5.8) an-altemating current of 1.5 times final sub-circuit current, or a maximum of 25 A, is injected through the earth continuity conductor. The impedance (total opposition to a.c:)shôuld not be greater than 1 n.

Apparatus. Double-wound transformer (240 V to maximum of 40 V) Ammeter (0-30 A); variable resistance voltmeter (0-50 V).

Method.

1. Disconnect main supply.
2. Conned current injection tester between one cable of installation (of known resistanc~~.~ıth~ eartfrcontinuity conductor.
3. Inject current (If times final sub-circuit, or maximum of25A) at maximum voltage of 40V.

avoided if an effective earth wire had been connected to the metal casing surrounding the lamp, as is the case in a properly protected portable lamp. The accidental connection of the phase to earth would cause the fuse element to melt and thus open the faulty phase conductor because the earth wire would provide a low-resistance return path for the leakage current.

### 5.3.1 Testing of current-operated Earth-leakage Circuit-breaker

This is done (Figure 5. 8) by applyin.ga maximum voltage of 45 V across the neutral and earth terminals and injecfüıg acınrentith:fough the fault detector coil. The circuit breaker should trip instantaneously. Thistestshôuld be carried out at least every three months.

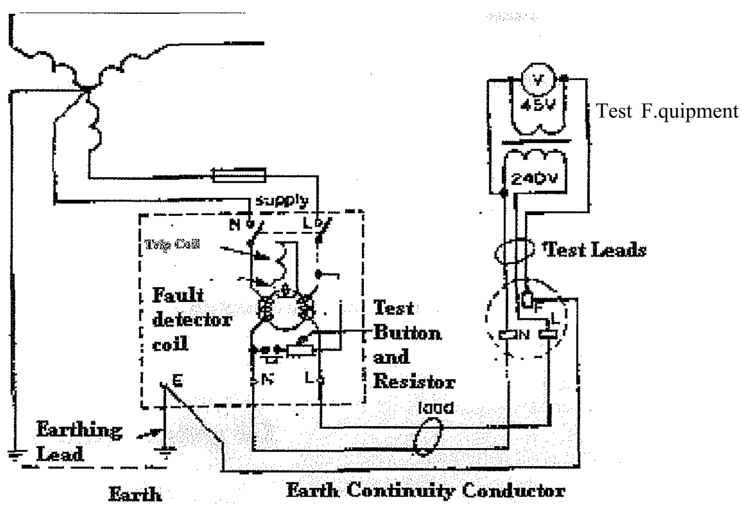



Figure 5.8. Testing current-operated E.L.C.B.

### 5.3.2 Earth-Continuity Conductor

(a) The I.E.E. Regulations define an Earth-continuity conductor as: 'The conductor, including any clamp, connecting to the consumer's earthing terminal, or to the Frame terminal of a voltage-operated earth-leakage circuit-breaker, or to each

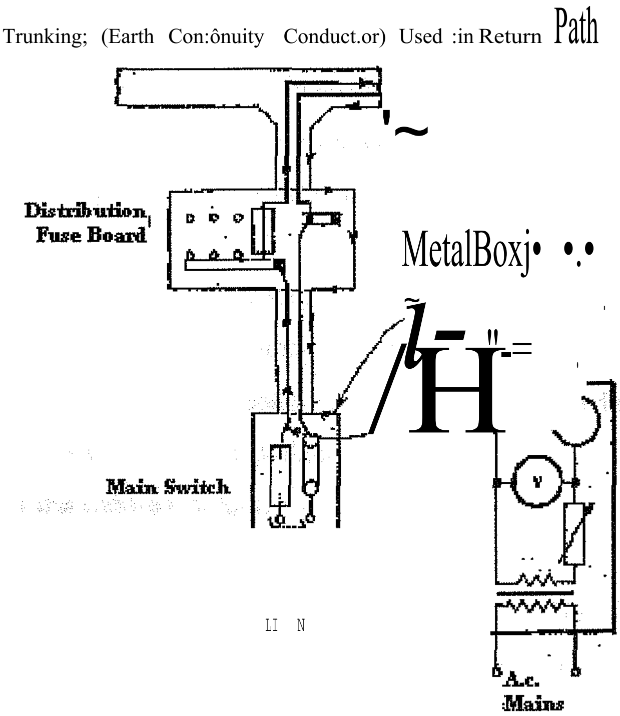



Figure 5.9 Current injection method of measuring the resistance of an earth continuity conductor.

Readings is found by:

$$\frac{Voltage}{Current}(impedance\ in\ ohms) \qquad (5.1)$$

**Maximum allowable reading 1Ω**

### 5.3.4 Earth Fault Loop Impedance Test.

The earth fault loop is the path, which the leakage current will take back to the supply transformer when there is an earth-leakage in an installation. This path is illustrated in Figure 5.10.

This test must be carded out on new or largely modified where earth-leakage protection relies on the operation of fuses or excess current circuit-breakers.

1. The leakage current flows from the faulty conductor into the earth continuity conductor.

2. It then flows along the earth continuity conductor to the earthing lead.
3. The earthing lead (the lead from the earth electrode to the earth continuity conductor) carries the currentto the earth electrode.
4. The leakage current now takes the shortest path back to the earthed neutral of the supply transformer.

The purpose of the earth fault loop impedance test is to show that the earth fault loop is capable of carrying heavy leakage currents so that protective gear (e.g., fuses) will operate when leakages occur between the line conductor and the earthed metalwork of the installation.

Apparatus istheLine-'earthloop tester.

MethodrTh.e:line ..ea.:rtl11ôbptestet7bperating on full mains voltage, passes a short duration current· of appi"ôxiinatelyf20iA fröin!.the line conductor through the consumer's earth continuity and the return path to the neutral of the supply transformer. This instrument measures the value of the loop in ohms. (Figure 5.11 shows the circuit of the megger line-earth loop tester.)

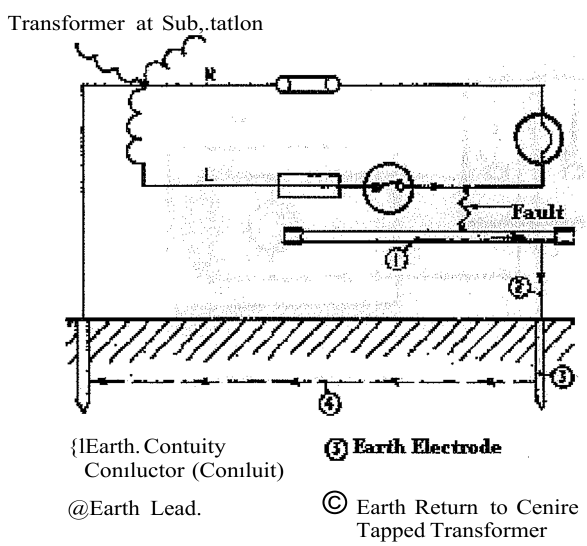



Figure 5.1 0 Earth fault loop impedance test.

The minimum permissible reading depends on the operation but the two main factors are:

1. Operating current of fuse or circuit breaker protecting circuit.
2. Supply voltage.

Example. If the circuit fuse operated at 50 A and the supply voltage is 240 V then the resistance of the earth fault loop must not be more than 250V / 50 A= 4.8 n.
If the resistance is higher than this value the fuse will not open under serious fault conditions.

Factors determining resistance of earth fault loop are as follows.

1. The. cdntinui.ty of. .the!metallic circuit up to the earth electrode (the earth contintıity'.cönducfôf,atıcl:.thev.earthing• ·:Iead)i
2. The· resistance ôf.the:l)ôd.y of':~artlf'sı4Frôfüıdinğtheearth electrode.

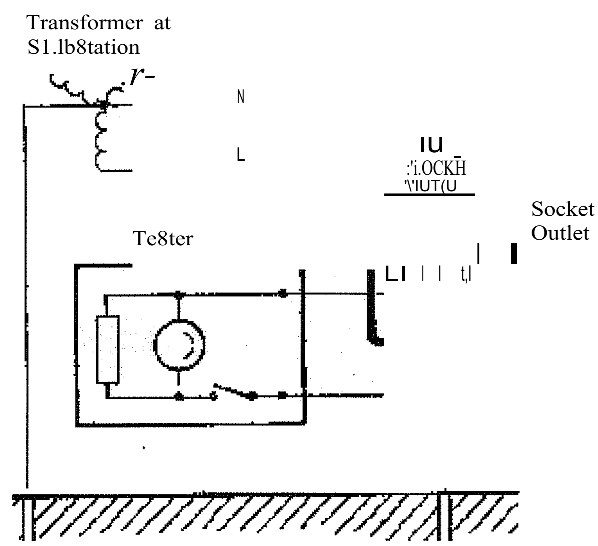



Figure 5.11 Circuit of megger line-earth loop tester.

Earthing Lead. The minimum size of a copper earthing lead is 1 mnr'. The earthing lead connecting an earth-leakage circuit-breaker to an earth electrode need not exceed 2.5 mm2. The earthing lead should be protected against mechanical damage and corrosion and the clamp used for connecting the earth lead to the earth electrode should be non-ferrous and should be accessible for inspection.

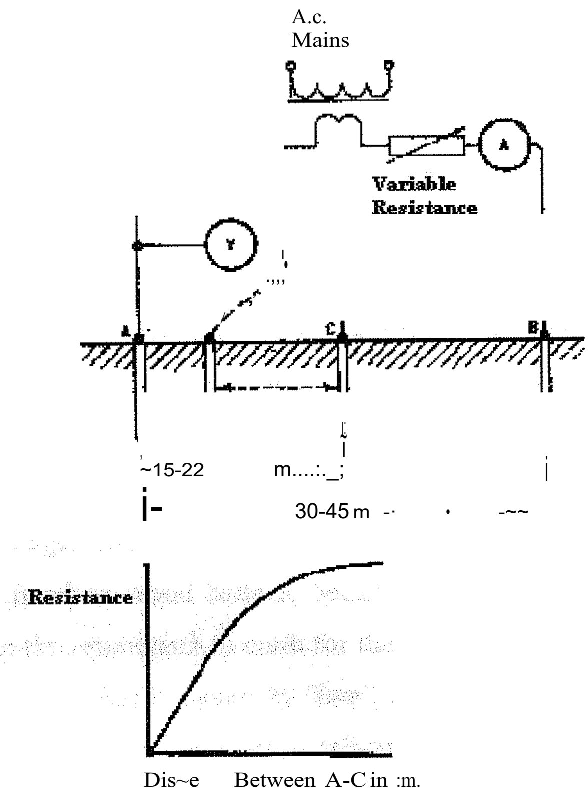
The resistance area is the name given to the resistance of the body of earth surrounding the earth electrode.

The resistance area is measured as follows (Figure 5.12).

1. An alternating current (at a maximum pressure of 40 V) is connected between the main earth electrode A artd an auxiliary electrode B, placed about 30 m from A An ammeter is placed in series with the supply to measure the current through the circuit.
2. A second auxiliary electrode C is placed between A and B and the voltage (potential difference) is measured between A and C. The resistance of the resistance area is found by taking various readings from point A towards point B

$$R = \frac{Voltage \quad between \quad A \quad and \quad C}{Current} \tag{5.2}$$

Outside the resistance area the resistance is constant (giving a horizontal line when Traced graphically.)



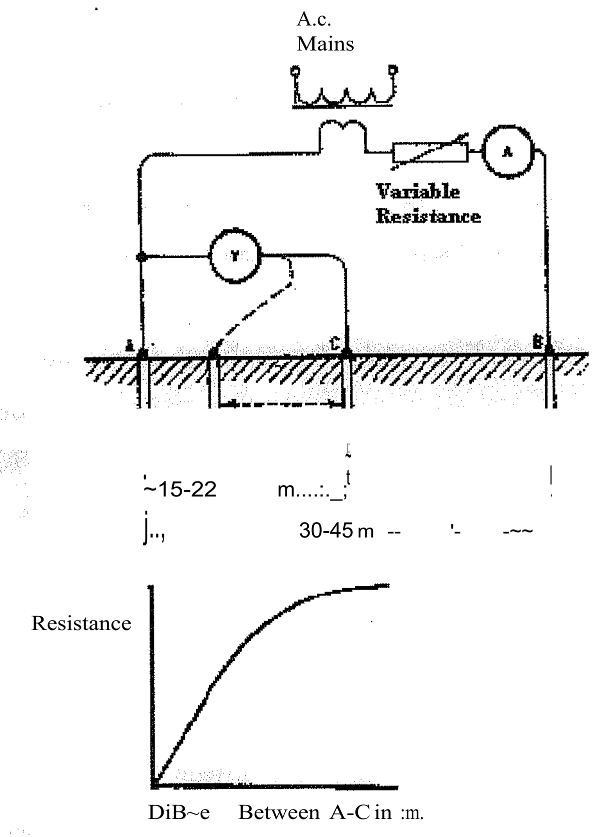




Figure 5. 12 Measuring resistance area.

## 5.3.5 Earth Leakage

Testing for earth leakage is a very important test as a leakage from a live conductor to the frame of an appliance or machine pan cause serious injury to operators if the frame of the equipment is not properly earthed. It only takes approximately 0.05 A to electrocute a person and much less for farm animals. The phase conductor to the equipment became frayed at the entry bushing and shorted to the metal framework. The earth wire carrying leakage current back to the general mass of earth had been disconnected during repairs.

The earth wire.nc>ilongercarried fault currentback to earth and the metal framework of the .equiprnerıt;'.fi:ked. e>U-wôod battens, became 'live'. The operator touched the frame·and made Up!theiretumt.-path/1:ô{earthfor,theleakagecurrent.

It is important to know whatis füea:rıtibyiftliye'.\Ai:rnetalcasing is said to be 'live' when there exists a difference in voltage (electrical pressure) between it and the general mass of earth.

## 5.3.6 Earth Insulation Resistance Test

The purpose of the earth insulation resistance test is to warn of the existence of possible leakages to earth and tor pinpoint the actual leakage.

Preparations for Earth Insulation ResiştancefT~st The preparation for this test includes the following:

1. Supply OFF.
2. Fuses IN, neutral links IN.
3. All switches ON.
4. All lamps IN.
5. Connect all poles together.

Test Instrument. The mstnımenı used for insulation resistance testing is a hand-driven d.c. generator, wh.i.ch sh()tıld be capable of supplying a d.c. voltage not less than twice the voltage normally supplied to the circuit.

The voltage needınct exceed 500 V for low-voltage circuits (low-voltage range: 50 V to 1000 V).

The test should be carried out at the nearest possible point to the Supply Authority's equipment.

**Method.**

1. Connect one wire of insulation tester to earthed metalwork (case of main switch, trunking, conduit, etc.).
2. Connect other wire to phase (or phases) and neutral in tum (see Figure 6.14).

**Rea.ding.** The accepted reading will depend upon the size of the installation but should not be less th.an one megohm.

An outlet, in this instance, in.eludes points and switches but a switch combined with a socket outlet appliance, or light fitting, is regarded as one outlet. These are the readings when an installation is complete.

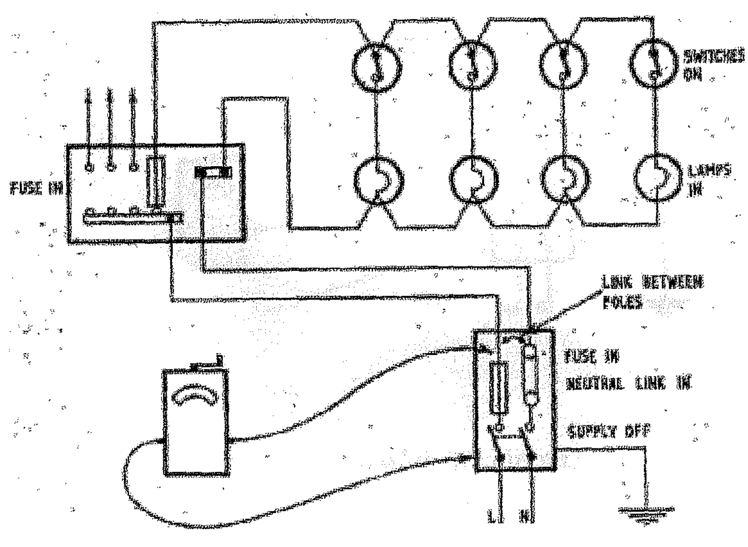



Figure 5.14. Testing insulation resistance.

minimum reading of 1 MQ is allowed, or 0.5 MQ where apparatus is connected.

If.the reading obtained is less than the minimum allowed, then the installation must be sub-divided to. ~s<>lateJlıe faulty circuit. In Figure 5.9 cirpııit 1, 2, and 3 would be completely isolated in turn until the circuit (3) causing the faulty reading was found.

## 5.4 Between Poles Test

The purpose of the between poles test is sure that there are no short circuit or low-resistance connections the 'live' conductors in the installation.

### Preparation for Test

1. Supply OFF.
2. Lamps OUT; appliances OFF.
3. All switches ON; all fuses and neutral links IN.

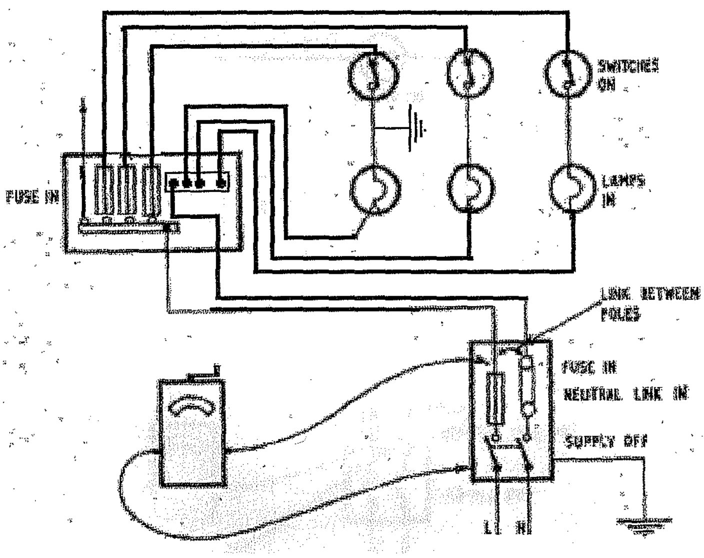



Figure 5.15. Isolation of faulty circuit.

Test Instrument. Insulation resistance tester (e.g., megger). The test should be carried out at the nearest possible point to the Supply Authority's equipment.

Method. Connect insulation resistance tester between phase and neutral (Figure 5.15).

Readings. The minimum readings required are similar to those for the earth insulation resistance test on the same installation.

## 5.5 Test of Ring Circuit Continuity.

On completion of a ring circuit installation a test, similar to that carried out to check the verification of polarity, must be carried out to ensure the continuity of all line, neutral and earth continuity conductors throughout the ring circuit. This test is carried at the point of connection in the distribution fuseboard prior to the completion and connection of the ring circuit conductors.

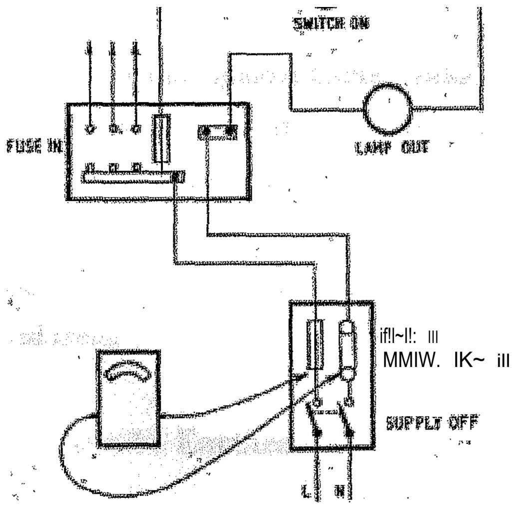



Figure 5. 16 Between poles test.

Tests to be carried out are given below.

1. Verification of polarity: Used to check that phase wire is switched and fused. Reading-on ohmmeter or bell set-zero or continuity.

2. Earthing tests: To ensure that the metalwork of the installation is 'effectively connected to the general mass of earth':

(a) Testing earth continuity conductor. Maximum reading.

(b) Testing earth fault loop impedance by current injection. Reading determined by setting of protective equipment.

(c) Testing effectiveness of earth electrode. Reading determined by setting of protective equipment.

3. Insulation tests: (a) between poles, (b) earth insulation resistance (between all conductors and earth).

Minimum permissible values for both tests: 1 M Q or 0.5 M Q (where appliances are connected).

4.Ring circuit should be tested with ohmmeter or bell set for continuity ring.

Requiremeııtssfor.Banaing. The earth fault loop should be capable of carrying three times the rating><>f the(fu~e orJf times the setting .of the overload circuit-breaker. Maximum allowable vôltağe betw-¢efü eatth~d ımetal,work and the consumer's earth terminal 40 V.

**Methods of Protection against Earth Leakage.**

(a)' All-insulated' construction (e.g., plastic-covered consumer's control unit).

(b) Double-insulation. A protective insulation used over the normal insulation.

(c) Earthing of all exposed metalwork.

(d) Isolation of metalwork so that there is no danger ofit 'coming into contact with live parts or with earthed metal'.

## 5.6 Metalwork to be Earthed

(a) All metalwork not carrying current; this includes cable sheaths and armouring, ducts, boxes, and catenary wire. The purpose of this regulation is to ensure that there is no likelihood of a voltage appearing between the metalwork of the installation and the general mass of earth.

(c) The secondary winding and the metal core of transformers used in consumer's installations must be earthed. If this winding was not earthed a current leakage between the low voltage primary and the extra-low voltage of the secondary winding could cause a voltage of240 V between the conductors of the extra-low bell circuit and earth.

**Metalwork Exempt from Ranking**

(a) Short, isolated lengths of conduit which are used for the mechanical protection of cables (e.g., conduit switch drops in a P.V.C. sheathed system). Short, unexposed lengths of conduit used for mechanical protection in cleated wiring systems.

(b) Screened metal boxes used in T.R.S. and P.V.C. sheathed systems.

**Bathrooms.** Bathrooms are one of the main sources of electrical accidents in domestic installations.

Main points to note are as follows.

(a)No socket outlets should be installed for portable appliances, particularly electric fires (a common cause of· accidents), and tile control of lights should be by pull-cord orby switches fitted outside the bathroom.

(b)Wiring systems should be run separate from other services (e.g., water pipes). If this is not possible then the service metal pipes should be bonded to the earth continuity conductor. The wire used for bonding purposes is called the equipotential bonder (minimum size 2.5 $mm^2$ tinned copper wire). The purpose of the equipotential bonder is to ensure that no difference in potential can exist between any two parts of the metalwork.

(c)A totally ·enclosed light fitting should be used, if possible, or .a Home Office (skirted) type.

CHAPTER SIX

# SAFETY AND PREVENTION OF ACCIDENTS [4]

## 6.1 Overview

About one hundred and thirty people are killed in electrical accidents in Britain each year. There are over 11,000 accidents to people in industıy in one year.

These two sets öf figures underline the importance of safety in industıy and the essential place of ~cfideııtprevehti.ö:tı. ili füıy systern of industrial training.

## 6.2 Main Causes of Accidents

The Factory Inspector's Report (Memorandum of Her Majesty's Chief Inspector of Factories) and the booklet Electrical Accidents and their Causes supply annual statistics and analyses of accidents in factories an.d workshops.

The following are sonie ôfthetecurring points, which appear in these documents:

Carelessness. When any job is done often enough, it tends to become boring and boredom easily leads to careless wô:rk. F'ôf!exainple, a. niailitenarice electrician may continually check control equipment when it. is 'live' and become unconscious of the danger. Don't let fatniliarity breed côritefilpt.

Ignorance. Accidents often occur in industıy due to the ignoııat10er or inexperience of workers. Remember that most tasks look easy when done by an expert. Do not attempt a difficultjob unless under supervision.

Skylarking. Many young people work in industrial premises without a full realization of the hazards present. Skylarking may 'be a legitimate way of letting off steams in a school playground, but it can often lead to serious and, sometimes, fatal accidents in a factory or workshop. Sensible people often do things they would never otherwise do when they are ' dared'.

## 6.3 Sources of Danger

Portable equipment is one of the greatest single causes of serious accidents ın an electrical installation.

Particular points to note are:

(a) Effectiveness .of earth contınuıty conductor. This should be regularly checked, :Danger signs .Jıre .:frayyd .cable at plugs and lead-ins and faulty or incorrect jointing oü cable. Low voltage equipment should be used wherever possible.

(b) Water and chemicals. Moisture imptegn.ates insulation and is often the cause of breakdown. Portable tools should be handled with great care in atmospheres containing inflammable chemicals, For example, fire may result from sparks at the commutator of a pistol drill in a garage. Portable lamps should not be used in garage pits, even if an earthed shield is used, as mechanical damage to the lamp may lead to the ignition of petrol vapour.

Temporary Installations. .'-Fp.~s~;tend to be .. fruitful sources of electrical accidents. Common causes are as/follows:

(a) Use of cable without mechanical protection (for example, p.v.c.).

(b) Lack of protective covering on switches, boxes, etc.

(c) Cable run over sharp edges.

(d) Use of unearthed brass, or unskirted, lampholders.

(e)Unauthorized additions to circuits resulting in overloading with a consequent fire risk

(f) Circuits over-fused.

Other Sources of Danger. These are as follows:

(a) Unprotected electric heaters.

(b)Over-loaded or over-fused cables, particularly flexes.

(c) Unguarded crane trolley wires or bare overhead conductors, particularly

(d) Where non-electrical workers are in the vicinity.

(e) Unprotected or unearthed socket outlets.

(f) Poor or broken earth connections leading to live metalwork under fault conditions.

Points of Danger for the Electrician. These are as follows:

1. Burns. Electrical burns are generally more dangerous (and more painful) than normal burns, as they are usually caused by an arc containing molten metal.

2. Falls. A very large percentage of industrial accidents are caused by falls, either froma height or by workers-tripping over equipment left lying about.

3. Ladders. Points to note:

(a) Ladders should always be placed at a reasonable angle to the vertical.

(b) Ladders should be anchored on a non- slip surface or effectively wedged.

(c) Aluminum ladders should be used with great caution, particularly near bare conductors.

(d) Do not attempt to lift heavy, or unwieldy, equipment (for example, conduit lengths) up or down a ladder unaided.

(e) Do not attempt 'acrobatic feats' you may endanger your life and the lives of others and undermine your right to compensation.

4. Strains. Strains occur through attempts to lift over-heavy· weights or by lifting, weights incorrectly. To lift heavy objects from ground.level:
place the feet apart, get a good grip withithe fingers, keep .the back straight, and lift by straightening the knees.

5. Electric shock: This is one of the main hazards in our craft. It is not always possible to work on 'dead' conductors but certain precautions may be taken:

(a) Never assume that an installation is 'dead': check thoroughly before openıng equipment, and do not check by touching conductors with fingertips.

(b) Check circuit thoroughly before replacing a re-loaded fuse in a 'live' D.F.B. and, if still in doubt, replace with gloves; always keep your face clear.

(c) If working on an installation to which other people have access (for example, a crane), remove fuses and keep them beside you.

6. Moving machinery. Great care should be taken when working on movıng machinery; oil rags and ties should be kept well clear. Do not remove guards and, if it becomes necessary to remove a guard, do so when the machinery is stationary. Replace all guards before leaving a machine.

Goggles should always be worn when operating a grinder and particular care should be taken when drilling and grinding soft metals (for example, brass and copper).

## 6.4 First Aid

Note: First aid is only meant to be a temporary measure until skilled assistance can be obtained.

First-Aid Box. Every factory and workshop is legally bound to possess a first-aid box. Industrial first-aid kits should contain: sterilized dressings, cotton wool, adhesive plaster, roller bandages (25mm and 50mm), sal volatile, and eye drops.

Treatment for Cuts. Do not wash the wound, although the skin round it may be cleansed with soap and water. Apply a sterilized dressing, or an adhesive wound dressing, as quickly as possible.

Treatment for Bums. If serious, send for a doctor or ambulance. Cover the wound with a sterilized dressing, do not apply adhesive dressing or ointments.

Chemical burns. Flush with cold Water immediately and apply sterilized dressing. Use antidote if available (solution of bicarbonate of soda for acids and dilute vinegar for alkalies or buffered phosphate solution for both types of burns). Alkaline burns are more serıous than acid burns and should receive medical attention as quickly as possible.

Treatment for Electric Shock. An electric shock is caused by the pass age of current through the body (generally hand to hand or hand to feet) causing a paralysis of the muscles, particularly the heart muscles. Currents as low as 0.020 A have been known to be fatal. The severity of the.shock will depend on: (a) voltage between 'live' metal and earth, (b) moisture content of skin, (c) proximity of body to effective earth, and (d) length of time of contact.

Speed is essential in treatment for electric shock.

1. Switch off current removing the casualty.
2. Remove any obstruction to breath.
3. Comence artificial respiration.

# CHAPTER SEVEN

## DISCUSSION OF THE PRESENT WORK

This project is about the electrical installation done in a hotel, which consists of three floors in the first stage and may expand to more than that in the future.

The three floors are under ground floor under the level of the street floor with a height of 4.5 m, a first floor with a height with a height of 3 .42 m at the level of the street and a second floor with the same height as the previous floor.

The power distributi()I},Şt~ :fronı tl:J.e3maj()r panel.at the first floor from MDB-1 that is feed by 4 x 240 $mm^2$ cable and Controls the distribution of power at that floor as well as controlling the main panel in the uppetflöor (MDB..3)and the lower floor (MDB-2).

The under ground floor (drawing 1/3) contains the service offices as the technique rooms, the kitchen, the manager of the hotel office, theater, a saloon, casino, restaurant and other services.

It is divided into three areas left hand area that is controlled by a panel SDB-1 that controls the half of that area with a circuit breaker to control SDB-2 that Controls the second half

The middle area is controlled by SDB-3 that controls SDB-4 and the right hand area is divide into two parts controlled by SDB-5 that controls a part of it as well as controlling two other panels and SDB-6.

A main panel MDB-2 feeds those panels and takes its supply from MDB-1 immediately above it.

The first floor (drawing 2/3), which contains the main panel MDB-1, contains customers rooms, the entrance, a big trace and a restaurant.

It is divided into three areas the left hand area SDB-9 controlling SDB-7 and SDB-8.

The middle area is controlled by SDB-10.

The right hand area is controlled by SDB-13 controlling SDB-12 and SDB-11.

The second floor (drawing 3/3) contains customers rooms and a Gallery.

Divide as well into three parts; the left hand part is controlled by SDB-16 controlling SDB-14 and SDB-15.

A main panel MDB-3 feeds those panels and takes its supply from MDB-1 immediately in the floor under it.

The illumination distribution and the number of lamps were done according to the purpose required from each area and by referring to the equation present in chapter three.

Each area requires certain illumination e.g. corridors require 60 lux and so on.

The distribution panels and the power sockets are distributed in accordance to chapter two devoted for this purpose.

The 2-meter rule and the ring circuits and radial power circuits were used in the distribution

The drawings were done according to the previous rules and basis.

# CONCLUSION

The importance of electrical installations is shown in our daily life, where there are no building or house, in the cities, that are free from electrical installations.

It is something essential in our life, and we cannot manage without it.

Industry, agriculture and transportation, all depend on electricity and electrical installations directly or indirectly.

Without the electricity invention, our lives would become very hard and late, because the development of countries depends on electricity.

The disadvantage of electricityis harmful to human and to the environment.

The power generation has a bad effect on the environment, so it is necessary to find new or alternative energy resources safe totheenvirotımentto generate electrical power.

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