## TABLE OF CONTENTS

# ACKNOWLEDGMENTS

Firstly I wish to thank my supervisor, Özgür Özerdem for intellectual support, encaurangement, enthusiasm which made this thesis possible, and for he explained my questions patiently.

I also wish to thank who helped to me about my thesis and my teachers in the faculty of engineering for giving us lectures.

Finally I also wish to thank my friend especially Fatma İkbal Temiz in the faculty of engineering.

## ABSTRACT

The electrical installation is one of the most impotant subject of an electrical gineering. According to this, the thesis is about an electrical installation of a hospital.

The main objective of this thesis is to provide an electrical installation with AutoCAD. For this thesis AutoCAD is very important. Also, with the help of AutoCAD, you can easily draw the part of you installation project.

According to this thesis you can learn to use AutoCAD and also learn to make especially cost calculation and lighting calculation for electrical installation as well.

# INTRODUCTION

The thesis is about an electrical installation, The electrical installation is one of the most impotant subject of an electrical engineering. So I decided to choose this subject, because I believed, it will help me in my future carrier as well.

My thesis is about electrical installation of hospital. In this thesis firstly I research how I can design an electrical installation of the building .After I designed this thesis with an autocad. In this thesis I considered to many application for electrical installation. There are installation type(e.g ring for socets), earthing, protection, illumination, cables and conductors, weak current installation, generation and transmission, cost calculation , etc...

This thesis consist of introduction, 9 chapter and conclusion.

Chapter 1 is about history of electricity.

Chapter 2 is about weak current installation.

Chapter 3 is about conductors and cables.

Chapter 4 is about  electrical safety, protection and earthing.

Chapter 5 is about illumination.

Chapter 6 is about circuit control devices.

Chapter 7 is about domestic installation.

# CHAPTER 1 :THE HİSTORY OF ELECTRICITY

Today's scientific question is: What in the world is electricity? And where does it go after it leaves the toaster?

Here is a simple experiment that will teach you an important electrical lesson: On a cool, dry day, scuff your feet along a carpet, then reach into a friend's mouth and touch one of his dental fillings. Did you notice how your friend twitched violently and cried out in pain? This teaches us that electricity can be a very powerful force, but we must never use it to hurt others unless we need to learn an important electrical lesson. It also teaches us how an electrical circuit works. When you scuffed your feet, you picked up small batches of "electrons," which are very small objects that carpet manufacturers weave into carpets so they will attract dirt. (That will cause the carpet to wear out faster so you will need to buy a new one sooner, but that's another story.) The electrons travel through your blood stream and collect in your finger, where they form a spark that leaps to your friend's filling, then travels down to his feet and back into the carpet, thus completing the circuit. Amazing Electronic Fact: If you scuffed your feet long enough without touching anything, you would build up so many electrons that your finger would explode! But this is nothing to worry about unless you have carpeting.

Although we modern persons tend to take our electric lights, radios, mixers, etc for granted, hundreds of years ago people did not have any of these things,which is just as well because there was no place to plug them in. Then came along the first Electrical Pioneer, Benjamin Franklin, who flew a kite in a lightning storm and electrical shock. This proved that lightning was powered by the same force as carpets, but it also damaged Franklin's brain so badly that he started speaking in maxims, such as "a penny saved is a penny earned." (Eventually he got so bad he had to be given a job running the post office, but that's another story.)

After Franklin came a herd of Electrical Pioneers whose names have become part of our electrical terminology: Myron Volt, Mary Louise Amp, James Watt, Bob Transformer, etc. These pioneers conducted many important electrical experiments. For example, in 1780 Luigi Galvani discovered this is the truth by the way) when he attached two different kinds of metal to the leg of a frog, an electrical current developed and the frog's leg kicked, even though it was no longer attached to the frog, which was dead anyway. Galvani's discovery led to enormous advances in the field of amphibian medicine. Today skilled veterinary surgeons can take a frog that has been seriously injured or killed, implant pieces of metal in its muscles, nd watch it hop back into the pond just like a normal frog, except for the fact that it sinks like stone. But the greatest Electrical Pioneer of them all was Thomas Edison, who was a brilliant inventor despite the fact that he had little formal training and lived in New Jersey. Edison's first major invention in 1877, was the phonograph, which could be found in thousands of American homes, where it basically sat until 1923 when the record was invented. But Edison's greatest achievement came in 1879, when he invented the electric company. Edison's design was a brilliant adaptation of the simple electric circuit: The electric company sends electricity through a wire to a customer, then immediately gets the electricity back through another wire, then (this is the brilliant part) sends it right back to the customer again. This means the electric company can sell a customer the same batch of electricity thousands of times a day and never get caught, since very few customers take the time to examine their electricity closely. In fact the last year any new electricity was generated in the United States was 1937; the electric companies have merely been reselling it ever since, which is why they have so much free time to apply for rate increases. Today, thanks to men like Edison and Franklin, and frog's like Galvani's, we receive unlimited benefits from electricity. For example, in the past decade scientists developed the laser, an electronic appliance so powerful that it can vaporize a bulldozer 2,000 yards away, yet so precise that doctors can use it to perform delicate operations on the human eye, provided they remember to change the power setting from "Vaporize Bulldozer" to "Delicate."

## 1.1Generation And Transmission

In north cyprus elecrical enerjy is generate by Teknecik Power plant and Kalecik power plant. The generation of electric is to convert the mechanical energy into the electrical energy. Mechanical energy means that motors which makes the turbine turn. Electrical energy must be at definite value. And also frequency must be 50Hz or at other countries 60Hz. The voltage which is generated (the output of the generator) is 11KV. After the station the lines which transfer the generated voltage to the costumers at expected value. These can be done in some rules. If the voltage transfers as it is generated up to costumers. There will be voltage drop and looses. So voltage is stepped up. When the voltage is stepped up, current will decrease. That is why the voltage is increased. This is done as it is depending on ohm's law. Actually these mean low current. Used cables will become thin. This will be economic and it will be easy to install transmission lines. If we cannot do this, we will have to use thicker cable.

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

a-) line to line – 415V

b-) line to neutral – 240V

c-) line to earth – 240V

d-) earth to neutral – 0V

# CHAPTER 2: WEAK CURRENT INSTALLATION

In generally, we call the weak current installation as an installation which has less than 65v. Voltage inside and outside of building. The values of voltage are 3v-5v-8v-12v-24v and 48v. The choosen voltage value within weak current subject to the capacity of installation and operating voltage of installation.

Most important one of the weak current installation is the notification installation which has produced for diverse and variant reason. Notification installation; it is the installation which has which has produced notify the any kind of news, event or danger through the faraway place by the sound notify tools or luminous notify tools. Especially installations which are necessary to have every time electricity such as fire alarm, burglar alarm and timing alarm. Such that reason it is necessary to have storage battery which must be continuously charge the battery to feed the installation.

Principal weak current installations which of them placed inside and outside of building are;

1- Bell Installation
2- Door Check (Door lock) Installation
3- Numerator Installation
4- Sound, Luminous Call installation
5- Burglar Notification Installation
6- Fire Notification Installation
7- Electricity clock Installation
8- Diaphone Installation
9- Telephone Installation
10- Radio Antenna Installation
11- Television Antenna Installation
12- Postsynching Installation

## 2.1 Bell Installation

Bell notification installations are one of the most operating tools. Notification installations come about with such conducter as notification tools (bells), button and energy sources.

Bell as a structure separate into two groups which are mechanic and electronic. There is one or two electromagnet, flipper, beetle, bell and base plate at the mechanic bell. But there not beetle and bell at the buzz bell which benefits from the mechanic sound in which come ut of the continuous movement of the track and the name of other mechanic bell is melody ell.

Electronic bells sound with the condenser, circuit in transistor and the other tools. 20 / 3-5-8v, 220 / 15v, 220 / 24v transformer can be used in the bells, if there is not lectricity energy in the installation, we can benefit the battery with 4,5 and 9 volt as an lternative current (AC). Neuter is directly given to bells.

### 2.2 Door Check

Door check occur by lock bolt or a coil which moves the slide rod. Door check can be control with control with one or more button.

### 2.3 Numerator Installations

Such this installations produced to call one person from more than one place and notify the place of calling. Numerators sell in blocks with 3 and 5. we may combine the blocks whether make a call from more than one place and we may use transformer (220/8.12v) as aenergy source.

Numerator shows the calling place with ıts numbers and warns the caller person with buzz sounds.

### 2.4 Luminous, Sound, Calling Installation

Luminous buzz installations uses to prevent distrupting bell sounds at such a place, hospital, hotel, official buildings... etc. and it uses to faciliate the determination of calling place. It uses 220/24 volt transformer as a energy source.

### 2.5 Burglar Notification Installation

On the cause of burglar has apportunity to enter inside the door and window so it is necessary to secure such a place with a strained back layer of conductor. By breaking conductor away, the power of relay circuit will cut so it may provide the notification by operation of bell or lumination of lamp.

The other kind of installation is that, the system which produced over the door-crate. It also used relay in this system the bell and lamp use a vehicle of notification.

Fire Notification Installation

This installation produced to secure the buildings against fire. There are two method in s installation. First; fire notification button placed into rooms, corridors to notify the fire by person who see the condition. When the button is pushed, the alarm circuit will get off and alarm will begin to ring by passing energy across on the relay circuit.

The second kind of notification installation is that; Bimetal termic tools replaced to tton. We may use the termic tools on the place in which there is posibility to have fire. e tools close the switch notify the fire automatically when the heat get high. To reach fire ace in short time we do installation with numarator link.

**7 Electric Clock Installations**

Electric clock installation can be changeable according to company which produces ectric clock.

**.8 Diaphone Installation**

It is the kind of installations which provides mutual conversation. It used for ommunal announcement or mutual dialog with desired place from one center. There re mutual conversation buttons, amplification and laudspeakers.

**.9 Telephone Installations**

It is the vehicle for mutual conversation. It connects the people in two different place place by telephone instrument and telephone installation. Telephone instrument has a pushing and turning switch to transform the sounds into electric current by a microphone and earphone which transform electric current into sound and ring bell.

**2.10 Radio Antenna Installations**

Antenna is a conductive which receive the electromagnetic waves. In todays world, it is loosing its importance to use a roof antenna (permanent antenna) for radio receiver. In todays, the instrument include radio as an antenna mission. We use generally $1.5mm^2$ - $2.5mm^2$ copper conductor as an antenna conductor.

## .11 Television Antenna Installations

It is a installation between antenna and television instrument, television antennas divides into two group according to its production properties such as cone antenna and yogi antennas. It has three section;

1- Dipsle

2- Reflector

3- Director

## 2.12 Sounds Installations

Such installations produced to announce from certain place or to listen music.

# CHAPTER 3 : CONDUCTORS AND CABLES

## 3.1 Conductors

### 3.1.1 Definition of Conductors

A conductor is a material which offers a low resistance to a flow of current. Conductors for everyday use must be;

(a) of low electrical resistance,

(b) mechanically strong and flexible,

(c) relatively cheap.

For example, silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are tin, lead, and iron.

### 3.1.2 Conductor Identification

The wiring regulations require that all conductors have to be identified by some meaning to indicate their functions i.e. phase conductors of a 3 phase system are colored by red, yellow, blue with neutral colored by black, protective conductors are identified by green or yellow/green. In British Standard;

| | |
|---|---|
| Red | Phase |
| Black | Neutral |
| Green | Earth |

We have some methods to identify the conductors.

1.Colouring of the conductor insulation

2.Printed numbers on the conductor

3.Coloraed adhesive cases at the termination of the conductor

4.Colored see levels types at the termination of the conductors

5.Numbered paint for bare conductors

6.Colored discs fixed to the termination of conductors' e.g. on a distribution board.

### 3.1.3 Formation of Conductors

Electrical conductors are usually made of copper, although aluminium is being used to a greater extent, particularly as the price of copper increases. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. The copper wire is then dipped into a tank containing molten tin.

is is done for two reasons:

(a) to protect the copper if the wire is to be insulated with vulcanized rubber, as this ntains sulphur which attacks the copper;

(b) to make the copper conductor easier to solder. Aluminium wire is also drawn from solid block but is not tinned.

## 1.4 Comparision of Alluminium and Copper As Conductor

### .1.4.1 Alluminium

Smaller weight for similar resistance and current-carrying capacity

Easier to machine

Greater current density because larger heat-radiating surface .

Resistivity 2.845 μΩ-cm

Temperature coefficient practically similar (0.004Ω/Ω degC)

### .1.4.2 Copper

Better electrical and thermal conductor, therefore lower C.S.A. required for same voltage drop.

-Greater mechanical strength

-Corrosion resistant

-High scrap value

-Much easier to joint

-Lower resistivity: 1.78 μΩ-cm

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

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

The size of a stranded conductor is given by the number of strands and the diameter of the individual strands. For example, a 7/0.85 mm cable consists of seven strands of wire, each trand having a diameter (not cross-sectional area) of 0.85 rom. Solid (nonstranded) onductors are now being used in new installations.

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

The following precautions must be taken with open bus-bar systems (above extra-low voltage). They must be:

(a) inaccessible to unauthorized persons,

(b) free to expand and contract,

(c) effectively insulated. Where bare conductors are used in extra-low voltage systems they must be protected against the risk of fire.

## 3.2 Cables

### 3.2.1 Definition of Cables

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor (solid or stranded), or of two or more such conduetors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors mayor 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.

### 3.2.2 Types of Cables

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

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

**Single Core Cable**

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

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

**2 Two-Core**

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

**3 Three-Core**

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

**.4 Composite Cables**

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

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

**2.5 Power Cables**

Heavy cables, generally lead sheathed and annored; control cables for electrical ipment. Both copper and aluminum conductors.

**2.2.6 Wiring Cables**

vitchboard wiring; domestic at workshop flexible cables and cords. Mainly copper nductors.

## .7 Mining Cables

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

## 2.8 Ship-Wiring Cables

These cables are generally lead-sheathed and annored, and mineral-insulated, metal-thed. Cables must comply with Lloyd's Rules and regulations and with Admiralty irements.

## 2.9 Overhead Cables

Bare, lightly insulated and insulated conductors of copper, copper vadmiuim and ninum generally. Sometimes with steel core for added strength. For overhead distribution les are PVC and in most cases comply with British Telecom requirements.

## 2.10 Coaxiel Cable (antenna cable)

Antenna cables is a special cable which is used to transfer high frequancy. This cable a type of flexible cables. We use this cale for TV. We are using this type of cable between vision sockets and from television to antenna.

## .2.11 Telephone Cable

Telephone cable is special cable. We use telephone circuit in the buildings and also intercom circuits. This cables are very slim. Telephone cables are not same as electric bles. There are a lot of size the telephone cables. Telephone cables are 0.5mm and erytime one cable is extra near this cables.

## .2.12 Welding Cables

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

## .2.13 Electric-Sign Cables

PVC and rubber insulated cables foe high voltage discharge lamps able to withstand e high voltages.

## 14 Equipment Wires

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

## .15 Appliance Wiring Cables

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

## .16 Heating Cables

Cables for floor warming, road heating, soil warming, ceiling heating and similar ications.

## 2.17 Flexible Cords

A flexible cord is defined as a flexible cable in which the csa of each conductor does exceed 4 mm squared. The most common types of flexible cords are used in domestic and t industrial work. The diameter of each strand or wire varies from 0.21 to 0.31 mm. ible cord come in many sizes and types; for convenience they are groups as follows:

**Twin-Twisted**

These consist of one single insulated stranded conductors twisted together to form a e-cable. Insulation used is vulcanized rubber and PVC. Color identification in red and ck is often provided. The rubber is protected by a braiding of cotton, glazed-cotton, and on barding and artificial silk. The PVC insulated conductors are not provided with litional protection.

**Three-Core (twisted)**

Generally as two twisted cords but with a third conductor colored green, for eating hting fittings.

**Three-Core (circular)**

Generally as twin-core circular except that the third conductorcolored green and llow for earthling purposes.

**Four-Core (circular)**

Generally as twin-core circular. Colors are brown and blue.

**Parallel Twin**

These are two stranded conductors laid together in parallel and insulatedto form a niform cable with rubber or PVC.

**f) Twin-Core (flat)**

This consists of two stranded conductors insulated with rubber, colored red and black. Lay side-by-side and braided with artificial silk.

**g) High Temperature Lighting, Flexible Cord**

With the increasing use of filament lamps which produce very high temperatures, the temperature at the terminals of a lamp holder can reach 71 centigrade or more. In most instances the usual flexible insulators (rubber and PVC) are quite unsuitable and special flexible cords for lighting are now available. Conductors are generally of nickel-plated copper wires, each conductor being provided with two lapping of glass fiber. The braiding is also varnished with silicon. Cord is made in the twisted form (two and three-core).

**h) Flexible Cables**

These cables are made with stranded conductors, the diameters being 0.3, 0.4, 0.5 and 0.6 mm. they are generally used for trailing cables and similar applications where heavy currents up to 630 A are to be carried, for instance, to welding plant.

### 3.2.3 Cable Sizes ( Use of I.E.E. Tables)

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

These tables supply:

(a) cross-sectional area, number, and diameter of conductors;

(b) type of insulation;

(c) length of run for I V drop;

(d) current rating (a.c. and d.c.), single and bunched.

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

(a) ambient temperature

(b) rating factor

### 3.2.4 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.

### 3.2.5 Rating Factor

This is a number, without units, which is multiplied with the current to find the new nt-carrying capacity as the operating conditions of the cable change.

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

### 6 Permissible Voltage Drop in Cable

Voltage drop is another essential feature in the calculation of cable size, as it is useless lling a cable which is capable of supplying the required current if the voltage at the umer's equipment is too low. Low voltage at the consumer's equipment leads to the ficient operation of lighting, power equipment, and heating appliances. The maximum age drop allowed between the consumer's terminals and any point in the installation is 2.5 cent of the voltage supplied by the Electricity Board, including motor circuits.

### 7 Voltage Drop and the I.E.E. Tables

I.E.E. tables state the voltage drop across a section of cable when maximum current is ving through it. If the current is halved, the voltage drop will also be halved. For example, mm2 twin-core cable has a current rating of 24 A and a voltage drop of 10m V per ampere metre. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per pere per metre.

### .8 New Voltage Bands

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

### .9 Current Density and Cable Size

The current density of a conductor is the amount of current which the conductor can fely carry without undue heating per unit cross-sectional area. For example, if a copper nductor has a current density of 300 A/cm2 a copper conductor of cross-sectional area 0,5 n2 will be capable of carrying one half of 300 A, that is, 150 A.

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

**Current-carrying capacity = current density x cross-sectional area**

**Resistance of a Conductor**

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

(a) the length of the conductor,

(b) its cross-sectional area,

(c) type of material used.

## 3.3 Insulators

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

### 3.3.1 Electrical Properties

It must have a high resistance.

### 3.3.2 Mechanical Properties

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

### 3.3.3 Physical Properties

The perfect insulator would have the following physical properties:

(a) non-absorbent;

(b) capable of withstanding high temperatures.

### 3.3.4 Chemical Properties

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

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

# CHAPTER 4: ELECTRICAL SAFETY-PROTECTION-EARTHING

## .1 Electrical safety

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

) The use of insulation (screening live parts, and keeping live parts out of reach).

) Ensuring, by means of earthling that any metal in electrical installation other than the conductor, is prevented from becoming electrically charged. Earthing basically provides a path of low resistance to earth for any current, which results from a fault between a live conductor and earthed metal.

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

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

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

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

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

t is a recommendation of the IEE regulations that every domestic installation be tasted vals of five years or less. The completion and inspection certificates in the IEE ons show the details required in every inspection. And not only should the electrical ion be tested, but all current-using appliances and apparatus used by the consumer.

llowing are some of the points, which the inspecting electrician should look for: 1)

cables not secure at plugs

d cables

s without mechanical protection

f unearthed metalwork

its over-fused

or broken earth connections, and especially sign of corrosion

ıarded elements of the radiant fires.

thorized additions to final circuits resulting in overloaded circuit cables.

otected or unearthed socket-outlets.

oliances with earthing requirements being supplied from two-pin BC adaptors.

ire used to carry mains voltages.

' portable heating appliances in bathrooms.

n connectors, such as plugs.

of heating at socket-outlet contacts.

ving are the requirements for electrical safety:

ing that all conductors are sufficient in csa for the design load current of

ll equipment, wiring systems and accessories must be appropriate to the conditions.

rcuits are protected against over current using devices, which have ratings iate to the current-carrying capacity of the conductors

ll exposed conductive pans are connected together by means of CPCs.

l extraneous conductive parts are bonded together by means of main bonding rs and supplementary bonding conductors are taken to the installation main earth

ll control and over current protective devices are installed in the phase or.

All electrical equipment has the means for their control and isolation.

llljoints and connections must be mechanically secure and electrically continuous and sible at all times.

o additions to existing installations should be made unless the existing ors are sufficient in size to carry the extra loading.

All electrical conductors have to be installed with adequate protection against physical and be suitably insulated for the circuit voltage at which they are to operate.

In situations where a fault current to earth is not sufficient to operate an over device, an RCD must be installed.

All electrical equipment intended for use outside equipotent zone must be n socket-outlets incorporating an RCD.

The detailed inspection and testing of installation before they are connected nains supply, and at regular intervals there after.

**arthing**

An efficient eartling arrangement is an essential part of every electrical tion and system to guard against the effects of leakage currents, short-circuits, static s and lightning discharges. The basic reason for earthing is to prevent or minimize the f shock to human beings and livestock, and to reduce the risk of fire hazard. The g arrangement provides a low-resistance discharge path for currents, which would ise prove injurious or fatal to any person touching the metalwork associated with the circuit. The prevention of electric shock risk in installations is a matter, which has been close attention in these past few years, particularly since the rapid increase in the use of city for an ever-widening range of applications.

**ric shock**

An electric shock is dangerous only when the current through the body reaches a n minimum value. The degree of danger is dependent not only on the current but also on me for which it flows. A low current for a long time can easily prove just as dangerous igh current for a relatively brief period. The applied voltage is in itself only important in ucing this minimum current through the resistance of the body. In human beings, the ance between band and hand, or between band and foot, can be as low as 500 ohms. If ody is immersed in a conducting liquid (e.g. as in a bath) the resistance may be as low as ohms. In the case of a person with a body resistance of 500 ohms, with a 240 V supply esulting current would be
mA, or 1.2 A in the more extreme case. However, much smaller currents are lethal, It has estimated that about 3 mA is sufficient for a shock to be felt, with a tingling sensation. veen 10 mA and 15 mA, a tightening of the muscles is experienced and mere is difficulty leasing any object being gripped. Acute discomfort is felt at this current level. Between nA and 30mA the dangerous level is reached, with the extension of muscular tightening, icularly to the thoracic muscles. An over 50 mA result in fibrillation of the heart which is erally lethal if immediate specialist anention is not given. Fibrillation of the heart is due to gular contraction of the heart muscles.

The object of earthing, as understood by the IEE Regulations, is, so far as is possible, educe the amount of current available for passage through the human body in the event of he occurrence of an earth-leakage current in an installation.

It has been proved that more than 25 per cent of alt electrical deaths are the result of a failure or lack of earthing.

### 4.2.1 Lightning Protection

Lightning discharges can generate large amounts of heat and release considerable mechanical forces, both due to the large currents involved. The recommendations for the protection of structures against lightning are contained in BS Code of Practice 6651 (Protection of Structures Against Lightning). The object of such a protective system is to lead away the very high transient values of voltage and current into the earth where they are safely dissipated. Thus a protective system, to be effective, should be solid and permanent. Two main factors are considered in determining whether a structure should be given protection against lightning discharges:

1. Whether it is located in an area where lightning is prevalent and whether, because of its height and/or its exposed position, it is most likely to be struck.

2. Whether it is one to which damage is likely to be serious by virtue of its use, contents, importance or interest (e.g. explosives factory, church monument, railway station, spire, radio mast, wire fence, etc.).

It is explained in BS Code of Practice 6651 that the 'zone of protection' of a single vertical conductor fixed to a structure is considered to be a cone with an apex at the highest point of the conductor and a base of radius equal to the height. This means that a conductor 30 meters high will protect that part of the structure which comes within a cone extending to 60 meters in diameter at ground level Care is therefore necessary in ensuring that the whole of a structure or building falls within the protective zone; if it does not, two down conductors must be run to provide two protective zones within which the whole structure is contained. All metallic objects and projections, such as metallic vent pipes and guttering, should be bonded to form part of the alrtermination network. All down conductors should be cross-bonded.

The use of multiple electrodes is common. Rule 5 of the Phoenix Fire Office Rules states:

Earth connections and number. The earth connection should be made either by means of a copper plate buried in damp earth, or by means of the tubular earth system, or by connection to the water mains (not nowadays recommended). The number of connections should be in proportion to the ground area of the building, and there are few where less than two are necessary Church spires, high towers, factory chimneys down conductors should have two earths which may be interconnected.

the component parts of a lightning-protective system should be either castings of nmetal, copper, naval brass or wrought phosphor bronze, or sheet copper or ronze. Steel, suitably protected from corrosion, may be used in special cases where compressive strength is needed.

r terminations constitute that part of dice system which distributes discharges into, s discharges from, the atmosphere. Roof conductors are generally of soft annealed rip and interconnect the various air terminations. Down conductors, between earth r terminations are also of soft-annealed copper strip. Test points are joints in down rs, bonds, earth leads, which allow resistance tests to be made. The earth ons are those parts of the system designed to collect discharges from, or distribute nto, the general mass of earth. Down conductors are secured to the face of the by 'holdfasts' made from gunmetal The 'building in' type is used for new structures; a type is used for existing structures.

Vith a lightning protection system, the resistance to earth need not be less than 10 ut in the case of important buildings, seven ohms is the maximum resistance. Because ctiveness of a lightning conductor is dependent on its connection with moist earth, a th connection may render the whole system useless The 'Hedges' patent tubular earth s a permanent and efficient earth connection, which is inexpensive, simple in ction and easy to install These earths, when driven firmly into the soil, do not lose ficiency by changes in the soil due to drainage; they have a constant resistance by of their being kept in contact with moist soil by watering arrangements provided at level. In addition, tubular or rod earths are easier to install than plate earths, because er require excavation.

Lightning conductors should have as few joints as possible. If these are necessary, han at the testing-clamp or the earth-electrode clamping points, flat tape should be soldered and riveted; rod should be screw-jointed.

htning protective systems should he examined and tested by a competent engineer after etion, alteration and extension. A routine inspection and test should be made once a nd any defects remedied. In the case of a structure containing explosives or other mable materials, the inspection and test should be made every six months. The tests d include the resistance to earth and earth continuity. The methods of testing are similar o those described in the IEE Regulations, though tests for earth-resistance of earth electrodes equire definite distances to be observed.

**.2.2 Anti-Static Earthing**

'Static', which is a shortened term for 'static electric discharge' has been the subject of ncreasing concern in recent years partly due to the increasing use of highly insulating naterials (various plastics and textile fibbers).

**5.2.3 Earthing Practice 1. Direct Earthing**

The term 'direct earthing' means connection to an earth electrode, of some recognized type, and reliance on the effectiveness of over current protective devices for protection against shock and fire hazards in the event of an earth fault. If non-currentcarrying metalwork is protected by direct earthing, under fault conditions a potential difference will exist between the metalwork and the general mass of earth to which the earth electrode is connected. This potential will persist until the protective device comes into operation. The value of this potential difference depends on the line voltage, the substation or supply transformer earth resistance, the line resistance, the fault resistance and finally, the earth resistance at the installation. Direct earth connections are made with electrodes in the soil at the consumer's premised A further method of effecting connection to earth is that which makes use of the metallic sheaths of underground cables. But such sheaths are more generally used to provide a direct metallic connection for the return of earth-fault current to the neutral of the supply system rather than as a means of direct connection to earth.

The earth electrode, the means by which a connection with the general mass of earth is made, can take a number of forms, and can appear either as a single connection or as a network of multiple electrodes. Each type of electrode has its own advantages and disadvantages.

The design of an earth electrode system takes into consideration its resistance to ensure that this is of such a value that sufficient current will pass to earth to operate the protective system. It must also be designed to accommodate thermally the maximum fault current during the time it takes for the protective device to clear the fault. In designing for a specific ohmic resistance, the resistivity of the soil is perhaps the most important factor, although it is a variable one.

The current rating or fault-current capacity of earth electrodes must be adequate for the 'fault-currentftime-delay' characteristic of the system under the worst possible conditions.

Undue heating of the electrode, which would dry out the adjacent soil and increase the earth resistance, must be avoided. Calculated short-time ratings for earth electrodes of various types are available from electrode manufacturers. These ratings are based on the short-time current rating of the associated protective devices and a maximum temperature, which will not cause damage to the earth connections or to the equipment with which they may be in contact.

In general soils have a negative temperature coefficient of resistance. Sustained current loadings result in an initial decrease in electrode resistance and a consequent rise in the earth-fault current for a given applied voltage. However, as the moisture in the soil is driven away from the soil/electrode interface, the resistance rises rapidly and will ultimately approach infinity if the temperature rise is sufficient. This occurs in the region of 100°C and results in the complete failure of the electrode.

The current density of the electrode is found by:

$$\text{Current density} = \frac{I}{A}$$

where I = short-circuit fault current; A = area (in cm2); t time in seconds (duration of the fault current).

The formula assumes a temperature rise of 120°C, over an ambient temperature of 25°C, and the use of high-conductivity copper. The formula does pot allow for any dissipation of heat into the ground or into the air.

Under fault conditions, the earth electrode is raised to a potential with respect to the earth surrounding it. This can be calculated from the prospective fault current and the earth resistance of the electrode. It results in the existence of voltages in soil around the electrode, which may harm telephone and pilot cables (whose cores are substantially at earth potential) owing to the voltage to which the sheaths of such cables are raised. The voltage gradient at the surface of the ground may also constitute a danger to life, especially where cattle and livestock are concerned. In rural areas, for instance, it is not uncommon for the earth-path resistance to be such that faults are not cleared within a short period of time and animals which congregate near the areas in which current carrying electrodes are installed are liable to e fatal shocks. The same trouble occurs on farms where earth electrodes are sometimes or individual appliances.

The maximum voltage gradient over a span of 2 meters to a 25 mm diameter lectrode is reduced from 85 per cent of the total electrode potential when the top of the ode is at ground level to 20 per cent and 5 per cent when the electrode is buried at 30 cm 100 cm respectively. Thus, in areas where livestock are allowed to roam it is nmended that electrodes be buried with their tops well below the surface of the soil.

Corrosion of electrodes due to oxidation and direct chemical attack is sometimes a em to be considered. Bare copper acquires a protective oxide film under normal spheric conditions which does not result in any progressive wasting away of the metal. It , however, tend to increase the resistance of joints at contact surfaces. It is thus important sure that all contact surfaces in copper work, such as at test links, be carefully prepared hat good electrical connections are made. Test links should be bolted up tightly. trodes should not be installed in ground, which is contaminated by corrosive chemicals. If per conductors must be run in an atmosphere containing hydrogen sulphide, or laid in nd liable to contamination by corrosive chemicals, iliey should be protected by a ering of PVC adhesive tape or a wrapping of some other suitable material, up to the point connection with the earth electrode. Electrolytic corrosion will occur in addition to the er forms of attack if dissimilar metals are in contact and exposed to the action of moisture. ts and rivets used for making connections in copper work should be of either brass or per. Uninsulated copper should not be run in direct contact with ferrous metals. Contact ween bare copper and the lead sheath or armoring of cables should be avoided, especially lerground. If it is impossible to avoid the connection of dissimilar metals, these should be tected by painting with a moisture-resisting bituminous paint or compound, or by apping with PVC tape, to exclude all moisture.

e following are the types of electrodes used to make contact with the general mass of earth:

**a) Plates**. These are generally made from copper, zinc, steel or cast iron, and dlay be lid or the lattice type. Because of their mass, they tend to be costly. With the Steel or cast-on types care must he taken to ensure that the termination of the earthing
d to the plate is water-proofed to prevent cathodic action taking place at the joint, If this ppens, the conductor will eventually become detached from the plate and render ilie ectrode practically useless. Plates are usually installed on edge in a hole in the ground about 3 meters deep, which is subsequently refilled with soil. Because one plate electrode is ldom sufficient to obtain a low-resistance earth connection, the cost of excavation

:ed with this type of electrode can be considerable. In addition, due to the plates being d relatively near the surface of the ground, the resistance value is liable to fluctuate ıout the year due to the seasonal changes in the water content of the soil. To increase a of contact between the plate and the surrounding ground, a layer of charcoal can be sed. Coke, which is sometimes used as an alternative to charcoal, often has a high r content, which can lead to serious corrosion and even complete destruction of the . The use of hygroscopic salts such as calcium chloride to keep the soil in a moist ion around the electrode can also lead to corrosion.

**b) Rods** In general rod electrodes have many advantages over other types of ode in that they are less costly to install. They do not require much space, are convenient and do not create large voltage gradients because the earth-fault current is dissipated ılly. Deeply installed .electrodes is not subject to seasonal resistance changes. There are l types of rod electrodes. The solid copper rod gives e-xcellent conductivity and is resistant to corrosion. But it tends to be expensive and, being relatively soft, is not y suited for driving deep into heavy soils because It is likely to bend if it comes up st a large rock. Rods made from galvanized steel a.re inexpensive and remain rigid when installed. However, the life of galvanized steel in acidic soils is short. Another vantage is that the copper earthing lead connection to the rod must be protected to ent the ingress of moisture. Because the inductivity of steel is much less than that of er, difficulties may arise, particularly under heavy fault current conditions when the erature of the electrode wilt rise and therefore its inherent resistance. This will tend to out the sunrounding soil, icreasing its resistivity value and resulting in a general increase e earth resistance of the electrode. In fact, in very severe fault conditions, the resistance ne rod may rise so rapidly and to such an extent that protective equipment may fail to rate.

bimetallic rod has a steel core and a copper exterior and offers the best alternative to er the copper or steel rod. The steel core gives the necessary rigidity while the copper erior offers good conductivity and resistance to corrosion. In the extensible type of steel-ed rod, and rods made from bard-drawn copper, steel driving caps are used to avoid ying the rod end as it is being driven into the soil. The first rod is also provided with a nted steel tip. The extensible rods are fitted with bronze screwed couplings. Rods should installed by means of a power driven hammer fitted with a special head. Although rods ould be driven vertically into the ground, an angle not exceeding 600 to the vertical is ommended in order to avoid rock or other buried obstruction.

**c) Strip**. Copper strip is used where the soil is shallow and overlies rock. It should be uried in a trench to a depth of not less than 50 cm and should not be used where there is a ossibility of the ground being disturbed (e.g. on farmland). The strip electrode is most effective if buried in ditches under hedgerows where the bacteriological action arising from he decay of vegetation maintains a low soil resistivity.

**d) Earths mat**. These consist of copper wire buried in trenches up to one meter deep. The mat can be laid out either linearly or in 'star' form and terminated at the down lead from the transformer or other items of equipment to be earthed. The total length of conductor used can often exceed 100 meters. The cost of trenching alone can be expensive. Often scrap overhead line conductor was used but because of the increasing amount of aluminum now being used, scrap copper conductor is scarce. The most common areas where this system is still used are where rock is present near the surface of the soil, making deep excavation impracticable. As with plate electrodes, this method of earthing is subject to seasonal changes in resistance. Also, there is the danger of voltage gradients being created by earth faults along the lengths of buried conductor, causing a risk to livestock.

**e) Cable sheaths**. These form a metallic return path and are provided by the supply undertaking. They are particularly useful where an extensive underground cable system is available; the combination of sheath and armoring forms a most effective earth electrode. In most cases the resistance to earth of such a system is less than one ohm. Cable sheaths are, however, more used to provide a direct metallic connection for the return of fault current to the neutral of a supply system rather than as a means of direct connection with earth this ,even though such cables are served with the gradual deterioration of the final jute or Hessian serving.

In rural areas with overhead distribution, there is a problem, for any direct metallic return path must consist of an additional conductor. This, when provided, is known as a continuous earth wire. The disadvantage, apart from the cost of the extra conductor and its installation, is that an open-circuited earth wire could remam undetected for a long time. The earth wire is connected at the source of supply to the neutral and to the low-voltage distribution earth electrode.

### 4.2.4 Protective Multiple Earthing

This form of earthing is popularly known by the abbreviation PME. It is an extremely reliable system and is being used increasingly in this country. Basically the system uses the neutral of the incoming supply as the earth point. In this way all circuit protective ictors connect all the protected metalwork in an installation to this common point: the earthing terminal. Allline-to-earth faults are convened to lineto-neutral faults, the ion being to ensure that sufficient current flows under the fault conditions to bring over nt protective devices into operation.

There are two main hazards associated with PME. The first is that owing to the ased earth-fault currents, which are encouraged to flow, there is an enhanced fire risk g the time it takes for the protective device to operate. Also, with this method of earthing essential to ensure that the neutral conductor cannot rise to a dangerous potential relative arth. This is because the interconnection of neutral and protected metalwork would natically extend the resultant shock risk to all the protected metalwork on every llation connected to this particular supply distribution network. As a result of these rds, stringent requirements are laid down to cover the use of PME on any particular ibution system. In accordance with the new system of carting arrangements identified by EE Regulations, PME is officially known as TNC-S. Three points of interest might be tioned here. First, the neutral conductor must be earthed at a number of points on the em, and the maximum resistance from neutral to earth must not exceed 10 ohms. In tion, an earth electrode at each consumer's installation is recommended, Secondly, so fir e consumer is concerned, there must be no fusible cutout, single-pole switch, removable or automatic circuitbreaker in any neutral conductor in the installation. Thirdly, the ral conductor at any point must be made of the same material and be at least of equal s-sectional area as the phase conductor at that point.

PME can he applied to a consumer's installation only if the supply authority's feeder is tiple earthed. This restricts PME to new distribution networks, though conversions from systems can be made at a certain cost, which varies according to the type of consumer. supply authority has to obtain permission in accordance with

e provisions laid down by the Minister of Energy and Secretary of State for Scotland ish Telecom approval must also be obtained for each and every PME installation, and is uired since it was once thought that the flow of currents from PME neutrals to the general ss of earth could cause interference with and/or corrosion of their equipment. In practice, vever, no such problems have occurred although the board still retains its right to approve otherwise a proposed PME installation.

Should a break occur in a neutral conductor of a PME system, the conductor will come live with respect to earth on both sides of the break, the actual voltage distribution pending on the relative values of the load and the earth electrode resistances of the two ons of the neutral distributor. All earthed metalwork on every installation supplied from particular distribution system would become live. Highresistance joints on the neutral can have a similar effect, the degree of danger in all cases being governed by the values of onnected load and the various earth electrode resistances. Trouble on a neutral conductor go undetected for some considerable time, some of the only symptoms being reduced ges on appliances, lights, etc. and slight to severe shocks from earthed metalwork. rhead-line distribution systems are, of course, particularly prone so far as broken or ontinuous neutral conductors are concerned.

The aspect of earthed concentric wiring is important in the context of PME. For E systems, the conventional four-core (three phases and neutral) armored cable can be aced by a three-core metallic sheathed and armored cable where the sheath and armor are d for the earthed neutral. For consumer wiring, the sheath-return concentric cable, in ch the sheath acts as both the neutral and earth conductor, is a logical extension of the E principle and is covered by IEE Regulations Section 546. The main advantage of sheath-urn wiring is that a separate epe is not required. This is because the chances of a complete connection of the earth neutral conductor
hout breaking the included phase conductors are remote.

Sheath return usually means that mineral-insulated cable is used. While the cost of MI cable is slightly higher than other types of cable (including any necessary nduit) this is offset considerably by the saving in labor resulting from ease of handling, the all diameter, and the reduced amount of chasing work required. Sheathreturn wiring can sult in savings in installed cost of about 30 per cent compared with a conventional direct-rthed system using plastic insulated cable in black-enameled screwed conduit. For single-ase supplies, single-core MI sheath-return cables are used. Twincore cables are used for vo-way switching. Multi-core cables are used from multiswitch points and rising mains to nction boxes where a number of separate outlets are situated close together. Since the outer eath of the MI cable is used for neutral and earth connections, care has to be taken at erminations which are made with pot-type seals and glands into switchgear and terminal oxes at which sockets, ceiling roses, etc., are fined. Duplicate bonding is used to ensure that e contact remains good at all tines. A special seal, with an earth-bonding lead, is used.

### 4.3 Circuit-Protective Conductors

The circuit-protective conductor (CPC) is defined as, 'a protective conductor connecting exposed conductive pans of equipment to the main earthing terminal' The IEE

Regulations go into some considerable detail to identity the specific requirements which CPCs must satisfy, if they are to perform their function in the context of ensuring that should an earth fault occur, the resulting current is carried for the time it takes for the associated circuit over current protective device to operate.

IEE Regulations Section 543, and specifically Regulation 543-02-02, indicates the following types of circuit protective conductor, which are generally recognized. All these types of conductor are regarded as being normally dormant (that is, they do not carry current) until a fault to earth occurs.

**a) Conductor contained in a sheathed cable**, known as a composite cable. In this cable, the sheath can be of metal, rubber, or PVC; the conductors are the circuit conductors and the CPC (e.g. 2.5 mm2 twins with CPC). The conductor is either singlestrand or multi-stranded, depending on the size of the circuit conductors. And it is uninsulated. If the sheath is of metal, the conductor is always single-stranded. Inspection of samples of cables will reveal that the cross-sectional area of CPCs in metal-sheathed cables is less than their counterparts in insulated-sheathed cables; this is because the metal sheath and conductor are in parallel and together constitute a conducting path of very low resistance.

Where these CPCs are made off at, say, a switch position or ceiling rose, they should be insulated with a green-colored sleeve.

**b) Conductor in a flexible cable or flexible cord**. The requirement is that the CPC should have a cross-sectional area equal to that of the largest associated circuit conductor in the cable or cord. The color of the CPC, which is insulated in this case, is green and yellow.

**c) The separate Cpc**. The requirement in this case is that the CPC should have a cross-sectional area not less than the appropriate value. The minimum size is 2.5 mm2, but in practice the size depends on the size of the associated circuit conductors. The reason for this is that if the circuit conductors are rated to carry I amperes, then the CPC should be able to carry a similar current, in the event of an earth fault, for sufficient time to allow a fuse to blow or a circuit-breaker to open. The resistance of a CPC of a material other than copper should not exceed that of the associated copper conductor.

Additional requirements for the separate CPC are that it. shall be insulated and colored green.

**d) Metal sheath of MICS CABLE**. Where the sheath of MICS cable is used as a CPC, the effective cross-sectional area of the sheath should be not less than one-half of the largest current-carrying conductors, subject to a minimum of 2.5 mm2 ~ requirement is not applicable to MICS cables used in earthed concentric wiring systems.

**e) Conduits, ducting, trunking**, Wiring systems, which comprise metalwork, such as it, trunking, and ducting, are used as the CPC of an installation. The requirement here is he resistance of the CPC should not he more than twice that of the largest current-ng conductor of the circuit. All joints must be mechanically sound and be electrically uuous.

**Additional Requirements**

**traneous Metalwork**. The IEE Regulation recommends that extraneous fixed lwork be bonded and earthed. This is particularly important where exposed metalwork of pparatus, which is required by the Regulations to be earthed, might come into contact extraneous fixed metalwork. Two solutions are offered: the bonding of such metalwork, segregation. The latter course is often very difficult to achieve and appreciable voltage rences may arise between points of contact. The extraneous fixed metalwork includes s and exposed metal pipes, radiators, sinks and tanks. where there are no metal-to-metal s of negligible resistance; structural steelwork; and the framework of mobile equipment hich electrical apparatus is mounted, such as cranes and lifts.

**athrooms**. Additional precautions are required to be taken to prevent risk of shock in rooms; these places are usually associated with dampness and condensation from steam. athroom is regarded as any room containing a fixed bath hower. First, all parts of a lamp holder likely to be touched by a person replacing a lamp l be constructed 01 or shrouded in, insulating material and, for BC lamp holders, should ined with a protective shield of insulating material. The Regulations strongly recommend lighting fittings should be of a totally enclosed type. Switches or other means of control uld be located so that they cannot be touched by a person using a fixed bath or shower. s means location of the control switch either outside the room itself or be ceiling-mounted h an insulating cord for its operation. No stationary appliances are allowed in the room, ess the heating elements cannot he touched. There should be no provision for socket-lets, except to supply an electric ver from a unit complying with BS 3052.

**Bell and similar circuits**. Where a bell or similar circuit is energized from a blic supply by means of a double-wound transformer, the secondary circuit, the core of the nsformers, and the metal casing if any, should be connected to earth.

**Portable appliances**. To reduce the risk of electric shock when portable appliances are ed, the appliance is often supplied with a reduced voltage. A double wound transformer duces the mains voltage to a suitable level. The secondary winding has one point earthed so should a fault to earth occur on the appliance the shock received will be virtually nless. Another method of protecting the user of a portable appliance from electric shock is rovide the appliance with automatic protection. In the event of an earth-fault the supply is omatically disconnected from the appliance.

## 5 Protective Methods

### 5.1 Insulation.

easures to prevent dangerous voltages occurring on exposed talwork of electrical equipment are divided into three classes: earthed equipment; otective insulation extra-low voltage (less than 50 V to earth). The second class (protective ulation) is sub-divided into all-insulated equipment and double-insulated equipment All-ulated equipment is recognized by the majority of Regulations and Specifications as an ernative to earthing. The principles of design of all-insulated equipment are simple and erefore difficult to abuse. It is the only protective measure that will meet all the quirements of safety. The advent in recent years of modem reinforced plastics has met all e practical requirements of strength, stability and incombustibility.

The Factories Act Memorandum on the Electricity Regulations, Regulation 21, covers e precautions to be taken either by earthing or other suitable means to prevent ny metal other than a conductor from becoming electrically charged. The memorandum cognizes the possibility of providing apparatus with covers and handles of insulating aterial, which should also be incombustible and mechanically strong, as an alternative to rting. The recent advances in plastics technology have made available reinforced combustible plastics and polycarbonate material which will withstand mechanical damage etter than many of the average metal enclosures upplied for equipment today.

A British Standards Memorandum sates.

If the outside of the protective case is made entirely of insulating material, to a atisfactory standard, no further protection is necessary.

In general, it is accepted, despite the TEE Regulations' emphasis on the earthing of netalwork, that insulation is a better and more effective method than earthing for medium voltage installations.

The insulation necessary for the proper functioning of electrical equipment and for basic protection against electric shock is known as 'functional' insulation. 'Protective' lation is provided externally to the functional insulation. With 'double' insulation, essible metal parts are separated from live pans by both functional and protective ilation. With 'all-insulated' equipment, all conductive pans are safely and permanently ered with a substantially continuous cover of insulating material. A good example of 'all-ilation' is a PVC-sheathed cable. The basic principles of all "totally-insulated' equipment that the protective insulation must not be penetrated by conducting parts, however small, ich could assist a voltage path to the outside of the enclosure in the event of a fault. In lition, it must be impossible for inactive conductive parts inside the totally insulated nponent or enclosure to be connected to an earth conductor.

Double-insulated equipment is marked with the internationally recognized symbol for iss II equipment: two concentric squares. An additional label is also affixed, approved by H.M. Senior Electrical Factory Inspector, to draw attention to the characteristics of the iipment. It states:

e metal mounting plate and other con current carrying metal parts are not connected to rth, and therefore earthing terminals are not provided. Fuses are recognized by the 16th lition of the IEE Wiring Regulations as having a pan to play in the disconnection of circuits which an earth fault occurs. Of necessity, fault currents in excess of the fusing factors of e fuses are required before the device will operate and this requirement itself presents oblems, not least the rise in voltage on protected metalwork, which occurs while the fuse erated. A number of Tables in the IEE Regulations are specifically concerned with the aximum values of earth fault loop impedance for circuits supplying (a) socket outlets and ) fixed equipment. In each of

ese cases, the disconnection times are, respectively, 0.4 second and 5 seconds. Recognizing at the fusing characteristics of different types of fuses vary, even among devices of the same ting, the Regulations offer detailed information regarding the maximum values of earth loop npedance which are not to be exceeded if the disconnection of the faulty circuit is to be chieved in less than the stated times for disconnection.

Fuses, however, do not provide a wholly satisfactory answer to the problem of increasing ne safety factor in respect of electric shock from earth-leakage currents. For example, take a 0 A metal sub distribution hoard protected by 40 A HRC fuses with a fusing factor of 1.5. The metal case is caroled by a steel-wire4rnoured cable direct to the consumer's earthing lead. The earth loop test at 3 times the rated current of the circuit gives an impedance of 2 ohms nd the circuit protective conductor is satisfactory at one

ohm. If an earth-fault of negligible impedance occurs (at 240 V) then a current of 120 A ows. This current through the I-ohm CPC impedance will raise the potential of the steel nclosure of the board to 120 V above the consumer's main earth potential for the time taken or the fuse to blow, about 20 seconds.

Any increase in the earth leakage impedance due to a partial earth fault or arcing causes a lower current to flow for a longer time. If the total earth-loop impedance the mpedance of the partial earth fault, is 3 ohms, the fault current will be 80 And the board metal enclosure will rise to 80 V above earth for more than four minutes while the fuse melts. During this time a person could receive a dangerous or fatal shock on touching the board metalwork.

Fuses do not provide sensitive protection, whether or not they are of the semi-enclosed type of cartridge fuses with fusing factors which exceed [5. The rapid cut-off of earth fault current, which is desirable for protection against serious electric shock, can be achieved only with earth-fault loops of much lower impedances now called for by the IEE Regulations. Indeed, lower impedance values are advised for industrial premises, in which the maximum earth-fault loop impedance should be equal to:

phase-to-neutral voltage

__________________________ohms

Minimum fusing current x 2

Fuses are insensitive devices because they must operate above the full-load current of the protected circuit, and also have an appreciable time lag even on higher currents.

Circuit-breakers over current circuit-breakers, like fuses, do not altogether provide a satisfactory protection against earth-leakage currents, The IEE Regulations, however, recognize that these protective devices offer some degree of protection; and in view of the low tripping factors of these devices they are in many ways better than fuses. it is generally accepted that protection can be provided by over current circuitbreakers in situations where the level of earth fault current available to operate the device exceeds 1.5 times the tripping current of the device.

Equipment in which extra-low voltage supplies are used have the disadvantage that, to achieve modem power requirements, impracticably high currents are involved and applications are restricted to control circuits, small portable tools, lighting circuits and the

/irtually complete safety from shock to earth, however, can be provided by limiting the e to earth to a non-lethal value. A large nunber of es at 55 V or less to earth have been proved to be almost free from electrical accidents. V. systems should be used wherever practicable for socket outlets and in dangerous ions. The cost involved in purchasing low-voltage appliances, and the problems raised creased loading, limit the use of F. L.V. voltages to a small ortion of the instances in which protection is required.

**Earth-Monitoring Devices And Portable Equipment**

applications such as the protection of portable equipment where (due to the use of ble or trailing leads) the reliability of the circuit protective conductor may by suspect, ct methods of protection are required. The use of E.L. V. supplies is not always ticable. If an earth fault occurs whilst an appliance is being handled, neither a fuse nor an r current circuit-breaker may operate quickly enough to protect the user. If the actual fault ent is only of the order of three times the fuse retiring (a good rule of thumb limit) the e can easily take a matter often seconds or so to blow - a time delay which may welt have l consequences. Again, if the circuit of an appliance becomes completely opencircuited, an th fault on an appliance may leave its casing alive at a voltage to earth which is almost ual to the phase-to-neutral voltage of the supply. This condition is by no means uncommon h portable and transportable equipment where the earthing conductor of the flexible cable y break or come adrift from its terminal. Special risks arise when the appliance is held in e hand.

Earth-monitoring devices are designed to ensure that earth connections to particular ns of an installation exist during the time it is energized. A small current is made to flow und a circuit consisting of the earth, and pilot conductors and the trip coil of a circuit-eaker. The trip is prevented from operating while the coil is energized. But as soon as the onitoring circuit is opened, the circuit-breaker is tripped. Earth monitoring requires an dditional conductor and special socket-outlets; installation costs are thereby increased. The ystem is insensitive to appreciable impedances in the monitoring circuits and completely so o resistance or open-circuit in the earth path before the monitored circuit.

The use of the 'Butcher' system of protection for portable appliances involves a centre-apped isolating transformer and a voltage operated earth-leakage circuit-breaker. Socket outlets are supplied at 240 V. The advantage of this method of protection is that if an earth fault occurs (even if it is only due to someone touching a live conductor) the earth-leakage nust return to the transformer via the trip coil of the circuitbreaker. Hence, provided operating current of the trip coil is below the lethal limit of body current, it is cally impossible to receive a lethal shock from any of the socket outlets supplied from ting transformer.

**rth-Leakage Circuit-Breakers**

eakage and earth-fault protection are systems of protection arranged to disconnect the automatically from an installation or circuit when the earth-leakage or earth-fault exceed predetermined values. Similarly, protection is offered when the voltage n non current-carrying metalwork of the installation and earth rises above a ermined

alue. Such a system may be made to operate more rapidly and at lower values of e or fault current than one depending on over current protective devices such as fuses, l trips etc. Automatic protection is therefore used where the impedance of the earth-oop limits the current flowing in it to a value less than three times the current rating of se of 1.5 times the over current setting of the circuit-breaker.

-leakage or earth-fault protection is generally effected by means of a device known as an leakage circuit-breaker (ELCB). There are two types; (i) the fault-voltage and (ii) the ual-current.

**i) Fault-voltage operated ELCBs** are units designed to be directly responsive to fault ges appearing on protected metalwork. Their primary function is to give protection st earth-leakage shock risk. If the only connection to earth is through the ELCB, leakage nts of as low as 50 mA will produce immediate circuit isolation. The fault-voltage ELCB nds for its operation on a voltage which, existing between the apparatus to be protected he general mass of earth, is itself dependent not only on the circuit-breaker, but also on -electrode resistance. Depending on design, the units trip at 24 V to earth with a 200-ohm electrode, or 40 V with a SOO-ohm earth electrode. The ELCBs are instantaneous in ation. The nonnal operating time is less than one cycle.

The unit consists of an operating or trip coil, which is connected between a reference h-electrode and the protected metalwork of the installation. Any fault current, which ears in the metalwork, will flow through the coil to energize it and trip the circuit-breaker solate the faulty circuit from the supply. In present-day practice, there are two conditions which the fault-voltage ELCB may function:

trip coil is connected between an earth-electrode and the metal to be d, which are not otherwise connected with earth.

The trip coil is connected in earth-electrode with the metal to be protected, which is in unavoidably connected directly with earth, e.g. a metallic waterpipe system.

making the earth connection, care is taken to ensure that the earth electrode of CB is at least 2 meters away from any buried metalwork, or the consumer's earth le, if one is installed. As far as possible, the operating coil of the unit should carry any urrent, which occurs, and not by-pass it by means of another path. The effect of l' earth connection is to deprive the operating coil of the necessary current which is d to trip the circuit-breaker.

nits are generally provided with a test switch. The primary purpose of this switch is to he existence of an adequate earth path. Failure of the unit to trip indicates potentially ous conditions in the installation such as excessive earth-electrode resistance or a earth lead. The test switch also checks that the sensitivity of the tripping mechanism is . The switch, generally a push-button, connects a highohmic value resistance in series e live conductor and the operating coil to allow ent current to flow to operate the circuit-breaker.

he fault voltage ELCB is susceptible to nuisance trapping, because it is not selective in ion and will trip out if the installation metalwork becomes live, irrespective of the of the leakage current. This gives rise to several problems. It is virtually impossible to vide large installations, because of the difficulty in isolating sections of installation vork associated with individual earth-leakage circuit-breakers. This difficulty applies qual force to the parallel condition of a number of installations in the same building, as is encountered with flats. Even when the dwellings are quite separate, trouble has encountered with a common vater pipe transmitting faults from one house to another.

This particular disadvantage may lead to another difficulty if the installation on which a fault occurs does not have adequate earth-fault protection. The leakage current the first dwelling may then flow to earth through the trip coil of the fault-voltage ELCB second earth through the trip coil of the fault-voltage ELCB in the second dwelling. effect of this fault condition is a bum-out of the trip coil.

The protection offered by the fault-voltage ELCB is ideally suited to the small country-ge installation: relatively remote from other dwellings, with poor earthing facilities and out a piped water supply. The most awkward problem associated with these units is g a suitable location for the reference earth electrode. It must be located outside the ance area of any metallic pipes or gas pipes or any other metalwork associated with the lation. This problem has recently become particularly acute in recent years with the bonding of water pipes to the electrical earth-continuity system, which automatically ts from the installation of immersion heaters in household hot-water tanks.

**ii) A residual-current ELCE** is a device consisting of a transformer having opposed ings, which carry the incoming and outgoing current of the load. In a healthy circuit, e the values of current in the windings are equal, their magnetic effects cancel out in the sformer core. A fault causes an out-of-balance circuit condition and creates an effective netic flux in the core which links with the turns of a secondary winding and induces an in it. The secondary winding is permanently connected to the trip coil of the circuit ker. When the circulating current reaches a pre-determined value, it pulls out the release h to open the main contacts which are normally held closed against strong springs.

In contrast to the fault-voltage ELCB, this type can he used to provide criminative protection for individual circuits. In practice, the normal order of sensitivity ges from about one ampere out-of-balance, for a 15 A unit, up to about 3 A out-of-balance a 60 A unit.

These units are also known as 'low-sensitivity units' to distinguish them from the 'high-sitivity units'. The latter units operate within 1125 of a heart cycle and can detect a fault rent of 30 mA to earth or less. The operating time is in the region of 30 milliseconds. rtain units are available which do not require an earth connection; they rely for their eration on the actual fault current to earth through a person's body. The rapid time of eration, however, ensures that no electrical accident occurs.

One fault found with these high-sensitivity units is that they are also susceptible to what called nuisance tripping. This occurs because the units can detect very low currents of the der of 25-30 mA, which are often found as normal leakage current from, say, cooker boiling lates and immersion elements.

Regulation 4 13-02-16 indicates that a residual current device shall be used only where he product of its operating current in amperes and the earth-loop impedance in ohms does not xceed 50. Where such a unit is used, the consumer's earthing terminal shall be connected to a uitable earth electrode. It is recommended that the operating current of a residual-current levice should not exceed 2 per cent of the normal rates current of the circuit. Operating currents less than 500 mA is not regarded as necessary unless the value of earth-loop mpedance is such that a lower operating current is essential.

wever, residual-current devices of 30 mA sensitivity are coming into general use of their reliability, the simplicity of their installation, and their low cost. They are y recommended because they are considered effective in providing more positive on. They are also suitable for earthing installations having loop impedances of 80 less, and are regarded as being effective in reducing fire risks.

vices of below 500 mA sensitivity fail into two broad groups: those requiring al amplification, and those using a combination of permanent and electromagnetic The latter are independent of the electrical supply for their operation. The electrically ed types have a wide range of loadings and interruption ratings. Primary windings are cessary: the load cables are simply taken through an aperture in the core of the nner. The magnetically assisted types depend on delicate tripping mechanisms and are re subject to the effects of vibration and shock. They require primary windings, which o limit their load capacity and makes them vulnerable to thennal and magnetic stresses hey are subjected to high fault currents. They are satisfactory where conditions are not dangerous.

Response tunes of 30 to 50 ma are common to most sensitive relays and the maximum severity that can be experienced on metalwork protected by these units is well within its of safety prescribed by the International Labor Office (500 mA sec at SO mA, to 50 c at 600 mA).

sensitivity units are particularly recommended for protection in laundries, boiler s and for electrically heated food-trolleys as used in hospitals. They are also ideal for nting the ignition of concentrations of explosive vapors by sparking along earth-fault and at the same time avoid the sudden interruption of the supply to an operating theatre an operation is in progress. Circuits to operating theatres are fed from an isolating onner with a 40-ohm resistor, having its mid-point earthed, connected across the output nals. This limits the maximum earth-fault current and energy to small values. And the y need not be interrupted until it can be manually discontinued, without danger or venience to the patient and operating staff, to enable the fault to be removed. Healthy langerous conditions are indicated by the use of indicating lamps (colored green and red ctively).

**Earth Testing**

IEE Regulations requires that tests he made on every installation to ensure that the ing arrangement provided for that installation is effective and offers the users of the llation a satisfactory degree of protection against earth-leakage currents. The following individual tests prescribed by the Regulations.

**Circuit-Protective Conductors**

Regulation 7 13-02-01 requires that every circuit-protective conductor (CPC) be to verify that it is electrically sound and correctly connected. The IEE Regulations nce Notes on inspection and testing give details on the recognized means used to test PC. For each final circuit, the CPC fonns part of the earth-loop impedance path, its se being to connect all exposed conductive parts in the circuit to the main earth tenninal CPC can take a number of fonns. If metallic conduit or trunking is used, the usual figure mic resistance of one meter length is 5 milliohms/m.

Generally if the total earth-loop impedance (Zn) for a particular final circuit is within aximum Zs limits, the CPC is then regarded as being satisfactory.

However, some testing specifications for large installations do require a separate test ach CPC to be carried out. The following descriptions of such tests refer to a.c. llations.

**Reduced A.c. Test**

ertain circumstances, the testing equipment in the a.c. test described above is not always lable and it is often necessary to use hand-testers, which deliver a low value of test current e frequency of the mains supply. After allowing for the resistance of the test lead, a value impedance of 0.5 ohm maximum should be obtained where the CPC, or part of it, is made n steel conduit. If the CPC is in whole or in part made of copper, copper-alloy or minum, the maximum value is one ohm.

Direct current. Where it is not convenient to use a.c. for the test, d.c. may be used ead. Before the d.c. is applied, an inspection must be made to ensure that no inductor is orporated in the length of the CPC. Subject to the requirements of the total earth loop edance, the maximum values for impedance for the CPC should be 0.5 ohm (if of steel) or e ohm (if of copper, copper-alloy or aluminum).

The resistance of an earth-continuity conductor, which contains imperfect joints, varies th the test current. It is therefore recommended that a d.c. resistance test for quality be de, first at low current, secondly with high current, and finally with low current. The low-rrent tests should be made with an instrument delivering not more than 200 mA into one m; the high-current test should be made at lOA or such higher current as is practicable. The en-circuit voltage of the test set should be less than 30 V. Any substantial variations in the ngs (say 25 per cent) will indicate faulty joints in the conductor; these should be ied. If the values obtained are within the variation limit, no further test of the CPC is ssary.

**Residual Current Devices**

Regulation 713-12-01 requires that where an RCD provides protection against ect contact, the unit must have its effectiveness tested by the simulation of a fault ition. This test is independent of the unit's own test facility. The latter is designed for use ne consumer who is advised to ensure that the RCD trips when a test current, provided by ternal resistor, is applied to the trip-coil of the unit. Thus, on pressing the 'Test' button the should trip immediately. If it does not it may indicate that a fault exists and the unit ıld not be used with its associated socket-outlet, particularly if the outlet is to be used for loor equipment.

ıe RCD has a normal tripping current of 30 mA and an operating time not eeding 40 ms at a test current of 150 mA.

RCD testers are commercially available, which allow a range of tripping currents to be lied to the unit, from 10 mA upwards. In general the lower the tripping current the longer will be the time of disconnection.

It should be noted that a double pole RCD is required for caravans and caravan sites and for agricultural and horticultural installations where socket-outlets are igned for equipment to be used other than 'that essential to the welfare of livestock.

**.4 Earth-Electrode Resistance Area**

The general mass of earth is used in electrical work to maintain the potential of any rt of a system at a definite value with respect to earth (usually taken as zero volts). It also ows a current to flow in the event of a fault to earth, so that protective gear will operate to olate the faulty circuit. One particular aspect of the earth electrode sistance area is that its resistance is by no means constant. It varies with the amount of oisture in the soil and is therefore subject to seasonal and other changes. As the general ass of earth forms part of the earth-fault loop path, it is essential at times to know its actual lue of resistance, and particularly of that area within the vicinity of the earth electrode. The effective resistance area of an earth electrode extends for some stance around the actual electrode; but the surface voltage dies away very rapidly as the istance from the electrode increases. The basic method of measuring the earthelectrode istance is to pass current into the soil via the electrode and to measure the voltage needed produce this current. The type of soil largely determines its resistivity. The ability of the l to conduct currents is essentially electrolytic in nature, and is therefore affected by isture in the soil and by the chemical composition and concentration of salts dissolved in contained water. Grain size and distribution, and closeness of packing are also ntributory factors, since these control the manner in which moisture is held in the soil. any of these factors vary locally. The following table shows some typical values of soil sistivity.

| Table of soil-resistivity values | Approximate value in ohm-em |
|---|---|
| Type of soil | 200 to 350 |
| Marshy grund | 400 to 15, 000 |
| Loam and clay Chalk | 6000 to 40,000 |
| Sand | 9000 to 800,000 |
| Peat | 5000 to 50,000 |
| Sandy gravel rock | 100,000 upwards |

When the site of an earth electrode is to be considered, the following types of soil re recommended, in order of preference:

1. Wet marshy ground, which is not too well drained.
2. Clay, loamy soil, Arabic land, clayey soil, and clayey soil mixed with small quantities of sand.
3. Clay and loam mixed with varying proportions of sand, gravel, and stones.
4. Damp and wet sand, peat.

Dry sand, gravel, chalk, limestone, whinstone, granite and any very stony ground should be avoided, as should all locations where virgin rock is very close to the surface.

Chemical treatment of the soil is sometimes used to improve its conductivity Common salt is very suitable for this purpose. Calcium chloride, sodium carbonate and other substances are also beneficial, but before any chemical treatment is applied it should be verified that no corrosive actions would be set up, particularly on the earth electrode. Either a hand-operated tester or a mains-energized double-wound transformer can be used, the latter requiring an ammeter and a high-resistance voltmeter. The former method gives a direct reading in ohms on the instrument scale; the latter method requires a calculation in the form:

$$\text{sistance} = \frac{\text{Voltage}}{\text{Current}}$$

e procedure is the same in each case. An auxiliary electrode is driven into the ground at a stance of about 30 meters away from the electrode under test (the consumers electrode). A rd electrode is driven midway between them. To ensure that the resistance area of the first o electrodes do not overlap, the third electrode is moved 6 meters farther from, and nearer the electrode under test. The three tests should give similar results, the average value being ken as the mean resistance of the earth electrode.

One disadvantage of using the simple method of earth electrode resistance easurement is that the effects of emfs (owing to electrolytic action in the soil) have to

be taken into account when testing, also there is the possibility of stray earth currents eing leakages from local distribution systems. Because of this it is usual to use a commercial strument, the Megger earth tester being a typical example.

### .6.5 Earth-Fault Loop Impedance

Regulation 113-11-01 stipulates that where earth-leakage relies on the operation of ver current devices, an earth-loop impedance test should be carried out to prove the ffectiveness of the installation's earthing arrangement. Although the supply authority makes s own earth-loop impedance tests, the electrical contractor is still required to carry out his wn tests. The tests carried out by a supply authority will not absolve the contractor from his egal responsibilities for the safe and effective operation of protection equipment which he nay install as part of a wiring installation. This applies both to new installations and xtensions to existing installations. Earth-loop impedance tests must be carried out on all xtension work of major importance to ensure that the earth-continuity path right back to the onsumer's earthing terminal is effective and will enable the protective equipment to operate nder fault conditions.

### 4.6.6 Phase-Earth Loop Test

This test closely simulates the condition which would ariseshould an earth- fault occurs. The instruments used for the test create an artificial fault to earth between the 'me and earth ductors, and the fault current, which is limited by a resistor or some other means, is wed to flow for a very short period. During this time, there is a voltage drop across the ting device, the magnitude of which depends on the value of the earth loop. The voltage p is used to operate an instrument movement, with an associated scale calibrated in ohms. contribution of the consumer's earthing conductor should be not more than one ohm. This o ensure that the voltage drop across any two Points on the conductor is kept to a low value l, under fault conditions there will be no danger to any person touching it at the time of the t.

e testers, which are commercially available, include both digital readouts and analogue les, and incorporate indications of the circuit condition (correct polarity and a proven earth nnection). The readings are in ohms and represent the earth-loop
npedance (Zs). Once a reading is obtained, reference must be made to IEE Regulations bles 4IBI to 41D, which give the maximum values of Zs which refer to: (a) the type of over rrent device used to protect the circuit and (b) the rating of the device. Reference should so be made to any previous test reading to see whether any increase in Zs has occurred in e meantime. Any increase may indicate a deteriorating condition in the CPC or earthing lead nd should be investigated immediately. The values of Zs indicated in the Tables are aximum values which must not be exceeded if the relevant circuits are to be disconnected ithin the disconnection times stated.

Before a test is made, the instrument should be 'proved' by using a calibration unit, which vill ensure that it reads correctly during the test. It is also recommended that the serial umber and type or model used for the test should be recorded, so that future tests made by he same tester will produce readings which are correlated.

**4.7 Protection**

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

The initial design of any installation must take into account the potential effects on wiring system and equipment of environmental and working conditions. BS 5490 is a British Standard concerned with protection against mechanical, or physical, damage and gives full of the Index of Protection Code to which all electrical equipment must conform. The s based on a numbering system with each number indicating the degree of protection .

rst characteristic numeral indicates the protection level offered to persons against t with live or moving parts inside an enclosure and also the protection of the enclosure gainst the ingress of solid bodies, such as dust particles. The numbers range from 0 (no tion of equipment against the ingress of solid bodies and no protection against contact ve or moving parts) to 6 (complete protection).

The second characteristic numeral indicates the degree of protection of equipment t the ingress of liquid and ranges from 0 to 8. Thus an equipment with IP44 means that s protection against objects of a thickness greater than 1.0 mm and ıst liquid splashed from any direction.

**Mechanical Damage**

This tenn includes damage done to wiring systems, accessories and equipment by t, vibration and collision, and damage due to corrosion. Typical examples of ntion include single-core conductors in conduit and trunking, the use of steel enclosures lustrial situations, the proper supporting of cables, the minimum bending radius for s, the use of annored cables when they are installed underground, and the supports ed for conductors in a vertical run of conduit and trunking.

Some types of installation present greater risks of damage to equipment and cables than s, for example on a building or construction site and in a busy workshop. In general, the ng conditions should be assessed at the design stage of an installation and, if they have een foreseen, perhaps due to a change of activity in a particular area, further work may eded to meet the new working conditions.

Electrical fires are caused by (a) a fault, defect or omission in the wiring, (b) faults or ts in appliances and (c) mal-operation or abuse of the electrical circuit (e.g. overloading). electrical proportion of fire causation today is around the 20 per cent mark. The majority stallation fires are the result of insulation damage, that is, electrical faults accounting for y three-quarters of cables and flex fires. Another aspect of protection against the risk of s that many installations must be fireproof or flameproof~ The definition of a flameproof is a device with an enclosure so designed and constructed that it will withstand an nal explosion of the particular gas for which it is certified, and also prevent any spark or e from that explosion leaking out of the enclosure and igniting the surrounding atmosphere. In general, this protection is effected by wide-machined flanges, which damp or otherwise quench the flame in its passage across the metal, but at the same time allows the pressure generated by the explosion to be dissipated.

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

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

There are two types of flameproof apparatus: (a) mining gear, which is used solely with armored cable or special flexible; and (b) industrial gear, which may be used with solid-drawn steel conduit, MIMS cables, aluminum-sheathed cables or armored cables. Mining gear is known as 'Group l' gear and comes into contact with only one fire hazard: firedamp or methane. Industrial gear, on the other hand, may well be installed in situations where a wide range of explosive gases and liquids are present. Three types of industrial hazards are to be found: explosive gases and vapors inflammable liquids - and explosive dusts. The first two hazards are covered by what is called 'Group II' and 'Group III' apparatus. Explosive dusts may be of either metallic or organic origin. Of the former, magnesium, aluminum, silicon, zinc and ferromanganese are hazards, which can be minimized by the installation of flameproof apparatus; the flanges of which are well greased before assembly. The appropriate British Standard Code of Practice is BS 5345 Electrical Apparatus and Associated Equipment for Use in Explosive Atmospheres of Gas or Vapor, other than Mining Applications.

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

All conduit installations for hazardous areas must be carried out in solid-drawn 'Class B', h certified draw-boxes, and accessories. Couplers are to be of the flameproof type with a nimum thread length of 50 mm. All screwed joints, whether entering into switchgear, ction boxes or couplers, must be secured with a standard heavy locknut. This is done to sure a tight and vibration-proof joint, which will not

cken during the life of the installation, and thus impair both continuity and flameproof ss. The length of the thread on the conduit must be the same as the fitting plus sufficient for e locknut. Because of the exposed threads, running couplers are not recommended. ecially designed unions are manufactured which are flameproof and are designed to nnect two conduits together or for securing conduit to an internally threaded entry.

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

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

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

eing essentially a closed installation, a flameproof conduit system may suffer condensation. topper boxes prevent the passage of moisture from one section to Draining of condensate om an installation should be carried out only by an person. Alterations or modifications ust never be made to certified gear. Because flexible metallic tubing is not recognized as ameproof, to movable motors (e.g. on slide-rails) should be of the armored flexible cable ith suitable cable-sealing boxes fitted at both ends. It is necessary to ensure that, as far as ossible, contact between flameproof

pparatus, conduit, or cables, and pipe work carrying inflammable liquids should be avoided. f separation is not possible, the two should be effectively bonded together. When maintaining quipment in hazardous areas, care should be taken to ensure that circuits are dead before emoving covers to gain access to terminals. Because flexible cables are a potential source of anger, they should he inspected frequently. All the equipment should be inspected and xamined for mechanical [units, cracked glasses, deterioration of well-glass cement, lackened conduit joints and corrosion. Electrical tests should be carried out at regular ntervals.

### 4.7.2 Corrosion

Wherever metal is used, there is often the attendant problem of corrosion and its prevention. There are two necessary conditions for corrosion:

(a) A susceptible metal and (b) a corrosive environment. Nearly all of the common metals corrode under most natural conditions. Little or no specific approach was made to the study of corrosion until the early years of the nineteenth century. Then it was discovered that corrosion was a natural electrochemical process or reaction by which a metal reverts in the presence of moisture to a more stable form usually of the type in which it is found in nature. It was Humphry Davy who suggested that protection against corrosion could result if the electrical condition of a metal and its surroundings were changed.

Corrosion is normally caused by the flow of direct electrical currents, which may be self-generated or imposed from an external source (e.g. an earth-leakage fault-current). Where direct current flows from a buried or submerged metal structure into the surrounding electrolyte (the sea or soil), no corrosion takes place. It is an interesting fact to record that where a pipe is buried in the soil there is a 'natural' potential of from O.3V to -0.6 V between the pipe and the soil. In electrical installations, precautions against the occurrence of corrosion le:

The prevention of contact between two dissimilar metals(e.g. copper and aluminum).

The prohibition of soldering fluxes, which remain acidic or Corrosive at the completion oldering operation (e.g. cable joint).

) The protection of cables, wiring systems and equipment against the corrosive action of oil and dampness, unless they are suitably designed to withstand these conditions.

) The protection of metal sheaths of cables and metal conduit linings where they come ontact with lime, cement and plaster and certain hard woods (e.g. oak and beech).

) The use of bituminized paints and PVC over heating on metallic surfaces liable to sion in service.

Dampness can affect conduit Systems both on the inside and externally. With enamel es, it is important that the enamel is preserved as intact as possible, particularly at the l entry to fittings. Also, the breaking of the galvanizing finishing

on galvanized conduit presents a great risk of rusting simply because this type of conduit pecified to cope with damp or wet working conditions. Thus any breaks in the finish be repaired with the use of a suitable paint to prevent rusting

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

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

While copper is fairly resistant to corrosion, there are situations in which the material orrode. This is why MI copper-sheathed cables are provided with PVC

sheaths and clips are also covered with PVC.

**Under-Voltage**

s an electrical protection required by Regulation 552-4, and is a provision in cuit of an electric motor to prevent automatic restarting after a stoppage of the due either to an excessive drop in the supply voltage, or a complete failure of the , where unexpected restarting of the motor might cause injury to an operator. These s are found in dc motor starters (No-volt releases). In ac contactor starters failure of the stops the motor.

**Over Currents**

Over current protection is one of the requirements of Statutory and the IEE Regulations. Regulation 130-03-01 states: 'Where necessary to prevent danger, every installation and circuit thereof shall be protected against over current by devices which (i) will operate atically at values of current which are suitably related to the safe current ratings of the t, and (ii) are of adequate breaking capacity and, where appropriate, making capacity. ient over currents are due mainly to motor-starting currents and the inrush currents iated with such apparatus as capacitors, transformers and fluorescent lamp and other arge lighting circuits. Sustained over currents are the result of indiscriminate additions to isting circuit. Generally termed 'overloading', the additions cause current to flow, which excess of the current rating of the cables. Some transient currents can become sustained. dental single-phasing on three phase induction motors means the loss of one phase ed by a fuse blowing in one of the lines; faulty operation of a contactor; or an open-circuit e of the motor windings. Contactor faults and fuse blowing are frequent. When single ing occurs, the motor, in order to produce its designed performance characteristics, finds it mist draw more current from the supply. With normal motor designs, a 5 per cent lance in supply voltage can lead to a 15-20 per cent increase in the current in one phase ull load. This fault condition is very dangerous and can cause damage to the and nvenience to the user (unless, of course, the motor circuit has been provided with uate protection which disconnects it from the supply). The main problem associated with le-phasing is that because in practice the majority of small and medium-phasing induction ors operate on no more than 50-80 per cent full load, they will continue to run in a single-sed condition. Single-phasing stator damage is characterized by signs of uneven rheating. If an attempt is made to start the motor with a single-phase condition, damage occur to the squirrel-cage rotor in the form -of localized overheating caused by high uced rotor-bar currents in positions corresponding to the number of poles in the stator ding.

## 7.5 Short-Circuit Currents

short-circuit occurs for any of the following reasons

Incorrect connection during the initial installation or after a modification.

Failure of the insulation of cables or equipment.

Excessive arcing leading to a phase-to-phase or phase-to-earth short.

Disconnection of a cable or wire leading to a phase-to-phase or phase-to-earth

ort.

The energy of the s40rt-circuit, which can be taken as a link between points of ffering potentials of negligible resistance or impedance, is fed from the point of supply, sually via the h.v. /Lv. transformer. This energy is dissipated in the complete distribution stem as IR losses. The sub-division of this energy is in proportion to the resistance and actance of the various items in the system or circuit, e.g., h.v. reactance, transformer actance, and busbar and cable resistance and reactance. The value of the maximum short-rcuits at any point in the installation can be calculated, provided the following data are nown:

. The high-voltage MV A rating.

. The transformer rating and its percentage impedance.

. The total resistance and reactance of the busbar and cables up to the point of the installation here the value of the theoretical fault current is required.

The items which have the greatest influence on the value of the fault are:

**1**. The percentage impedance and current rating of the transformer and the econdary circuit ohmic resistance.

**2**. The remaining items affect the fault current by usually less than 20 per cent. hese can be taken into account or omitted at discretion.

For example, a 415 V. three-phase transformer of 750 kV A and a 4.75 per cent mpedance (this value is standard for the majority of transformers conforming to the lectricity Boards T.L. Specification) will have a full-load current of 1050 A at unity power actor. The 4.75 per cent impedance means that if the secondary terminals of the transformer vere bolted together and the primary voltage was reduced to 4.75 per cent of its rated voltage, hen the rated secondary full-load current of the transformer would flow in the short-circuited onnection. Thus, when full voltage is applied, the short circuit will be:

Rated current x 100/4. 75
h in the above transformer will be
050 x 21 =22 kA (r.m.s.).

a cable resistance of 0.01 ohm per phase is added, the fault current will be reduced to -14 kA.

his value of the fault current is the symmetrical fault level in amperes (r.m.s.) and the thermal damage to equipment.The asymmetrical fault current depends on the ance of the circuit and the point on the sine wave at which the fault occurs. This peak t, under the worst conditions can reach twice the symmetrical fault current peak value x 1.414 = 2.828 x r.m.s. symmetrical value.In the example given above the worst netrical current would be 62 kA (peak).

The asymmetrical short-circuit current is responsible for the mechanical damage which s from the high oscillating mechanical forces (proportional to 12) set up between two ctors which are adjacent and parallel to each other. For example, if
nitial peak current 31 MVA system is about 110 kA, this would mean a force in kg per un of bus bars, assuming a 76 mm spacing between conductors, of about 100 kgf, which her repealing or attracting depending upon the direction of the currents at the instant of circuit.

In summary, when a short-circuit fault occurs, for any given supply voltage, two main rs will be seen to control the severity of the fault. These are the magnitude
and the power factor of the fault current. In this connection, two terms are worthy of prospective and actual values of fault current.

The 'prospective' level of fault current is the r.m.s. symmetrical current that would flow circuit due to the nominal applied voltage when a short-circuiting link of negligible dance replaces the designed circuitry. In other words, it corresponds to a circuit condition ro fault impedance. In a similar manner, the prospective value of power factor is assumed tain with zero fault-impedance.

The actual current, however, can never exceed the prospective value and usually it is iderably less. Almost any fault has some impedance, to which must be added the edances and resistances, which exist in the circuit. These additional elements usually bine to limit the actual fault current to about 30 per cent or less the full prospective value; also raise the actual short-circuit power factor to a value which approaches unity. The ct of a low power factor can be serious, because in such a circuit condition, there will be a rable amount of stored energy to be dissipated during the time taken to clear the fault.

**otection By Fuses**

The fuse offers a means of protection against over currents. In its basic form, the nsists of a short length of suitable material, often in the form of a wire, which has a nall cross-sectional area compared with that of its associated circuit conductors. When nt flows which is greater than the current rating of the wire, the wire will get hot and, ılly, melt. This occurs because its resistance per 'unit length is much greater than that ssociated circuit conductors (so giving greater power loss and heat), and because this ed beat is concentrated in the smaller volume of the material.

**'use Terminology**

The following terms are used in connection with fuses:

**Current rating**. This is a current, less than the minimum fusing current, stated by the acturer as the current that the first will carry continuously without deterioration. The t rating is chosen in consideration of the temperature rise while the fuse element carries ecified current Because a fuse is a thermal device, the ambient temperature m which it es is very important. Where fuses are used in high-temperature situations, a derating of signed current rating may be necessary for ambient temperatures of 35°C and above.

**Applied voltage**. It is important that the applied voltage of a circuit does not exceed the ge rating of any fuse used for its protection. This is because a fuse is particularly voltage- ive immediately before and after it operates to break the circuit current. The rated ge is that assigned to the fuse by the manufacturer to indicate the nominal system voltage which the fuse may normally be associated. It is important to note that the voltage rating use may not apply equally to both a.c. and d.c. circuits.

**Breaking capacity rating**. This is a prospective current stated by the manufacturer as greatest prospective current that may be associated with the fuse under prescribed itions of voltage and power factor or time constant. Fuses of different breaking-capacity gs are available according to the several categories listed in British Standards. The gory of duty assigned to a fuse should take into account the prospective current and the ient behavior of the circuit during shortcircuits conditions (for instance, the degree of nmetry in the a.c circuits).

8.2 **Rated Minimum Fusing Current**

s is the current, which will cause the fuse to operate in a specified time under prescri 1 ed
ditions.

) **Fuse**

is is the ratio, greater than unity, of the rating minimum fusing current to the current
ting.

A fuse, which carries its rated current, does not suffer any deterioration. However, if the rrent carried approaches the rated minimum fusing current, it will eventually reach a nperature at which its fuse element will begin to melt. A fuse is not intended to be run at rrents between the values given for prolonged periods; if this does happen the aracteristics of the fuse will change.

Let-through energy this is the specific energy to which a protected circuit is subjected uring the pre-arcing time.

### 4.9.1 Rewirable Fuses

The rewirable fuse is a simple device. It consists of a short length of wire,generally of inned copper. The current at which the wire will melt depends on the length of the wire and ts cross-sectional area. If it is very short, the beat generated (12R watts) will be conducted away from the wire by the contacts or securing screws. Also, if the wire is open to the atmosphere, it will cool much more quickly than if it was surrounded by a thermal insulator such as an asbestos sleeve. In view of these and other factors, the rewirable fuse is a device with a number of variables, which affect its performance; anyone, or all, of these can differ between similar fuses. Though the rewirable fuse is cheap, involving only the replacement of the fuse-element, it has a number of disadvantages and limitations:

**1**. The fuse element is always at a fairly high temperature when in use. This leads to oxidization of the element material, which is a form of corrosion, and results in a reduction in the cross-sectional area of the element, so that it fuses at a current lower than its rating. Fuses, which carry their rated current for long periods generally, require replacement at two-yearly periods, otherwise nuisance blowing will be experienced on the circuit.

**2**. It is very easy for an inexperienced person to replace a blown fuse element with a wire of incorrect size or type.

**3.** When a fault occurs on a circuit, the time for the fuse to blow may be as long as several seconds, during which time considerable electrical and physical damage may occur to rcuit conductors and the equipment being protected.

4. The calibration of a rewirable fuse can never be accurate, which fact renders this type se unsuitable for circuits, which require discriminative protection.

5. Lack of discrimination means that it is possible in certain circuit conditions for a 15 ed fuse-clement to melt before a 10 A-rated element. Also, the type is not capable of iminating between a transient high current (e.g., motor starting current) and a continuous current.

6. Owing to the fact that intense heat must be generated in the fuse-element before it perform its protective action, there is an associated fire risk. Also in this context, should ault current be particularly high, though the wire fteaks, an arc may still be maintained by circuit voltage and flow through the air and metallic vapor. The rewirable fuse has thus a rupturing capacity, which is the product of the maximum current, which the fuse will rrupt, and the supply voltage. The capacity is measured in kV A. Generally a limit of 5000 A is placed on rewirable fuses.

Semi-enclosed or rewirable fuses are not regarded as devices, which will offer sely, controlled protection, particularly where important circuits are concerned. As seen n the above, they cannot be guaranteed as to their performance, which is why their use is alized in the IEE Wiring Regulations.

### 9.2 Cartridge Fuses

The cartridge fuse was developed to overcome the disadvantages of the rewirable type of e, particularly because with the increasing use of electricity, the energy flowing in circuits s growing larger. The main trouble with the rewirable fuse was oxidation and premature lure even when carrying normal load currents, causing interruptions in supply and loss of oduction in factories. Thus the fully enclosed or cartridge fuse came into existence. Non-terioration of the fuse-element was, and stilt is, one of the most valuable features of this pe of fuse. The advantage also of the cartridge fuse is that its rating is accurately known. owever, it is also more expensive to replace than the rewirable type and it is also unsuitable r really high values of fault current.

It finds common application for domestic and small industrial loads. As houseservice ttout fuse links (BS 88), they are used by Supply Authorities as services fuses. Ferrule-cap se links (BS 1361) are used in domestic 250 V consumer control units, switch fuses and witch splitters. The domestic cartridge fuse links (BS 1361) were designed for use pecifically in 13 A fused rectangular-pin plugs. Domestic cartridge fuse links (BS 646) are use specifically in 15 A, round-pin plugs where the load taken ftom a 15 A socket-outlet is ıll (e.g. radio, TV or table lamp), in relation to the

A fuse which protects the circuit at the distribution board. In addition, there are other rridge fuses for particular applications (e.g. in fluorescent fittings). All these cartridge fuses so designed that they cannot be interchanged except within their own group.

Essentially the cartridge fuse is a ceramic barrel containing the fuse element. The barrel filled with non-fusible sand, which helps to quench the resultant arc produced when the ment melts.

The short-time characteristics of the HRC fuse enable it to take care of shortcircuits nditions when used to protect motor circuits. Tests have shown that HRC fuses have a ort-circuit fusing time as low as 0.0013 second. On large ratings they will open circuit in s than 0.02 second. HRC fuses are discriminating, which means that they are able to stinguish between a high starting current taken by a motor (which lasts only a matter of conds) and a high fault or overload current (which lasts longer).

### 10 Selection of Fuses

The selection of a particular fuse for circuit-protection duty should never be a ısual matter. The important factors to be considered are:

1. The Voltage Rating of the fuse which should be not less than the highest voltage obtainable between the conductors of the circuit.

2. Ampere Rating of the fuse should be suitable for the circuit and the type of apparatus to be protected

3. The Service Condition& These fall into two categories. First, the ambient temperature ıat will affect the operational characteristics of the fuse. In high ambient temperatures the urrent-ratings of fuses should be reduced to ensure that the total temperature does not exceed he permitted values calculated for materials and insulation. The total temperature varies with use size and application and it is thus advisable for advice to be sought from manufacturers egarding the derating factors to be used. Secondly, an altitude of 1000 meters will result in he derating of a fuse.

### 4.10.1 Protection By Circuit-Breakers

There are few industrial power switching requirements which cannot be dealt with by standard circuit-breakers. And for the smaller-rated loads such as commercial and domestic installations, the molded-case and miniature circuit-breakers are finding an increasing role to play for both the control and protection of circuits. Essentially, switchgear links the various ents of an electrical system together to provide normal operational facilities and permit nmediate disconnection of faulty apparatus and circuits. To do this it must be able to rm some or all of the following duties without damage to itself or other equipment and out danger to personnel:

irry full-load currents continuously.

ithstand normal and possible abnormal system voltages.

pen and close the circuit on no-load.

Make and break on normal operating currents.

lake short-circuit currents.

reak short-circuit currents.

he different switching devices available, all must perform (1) and (2); the isolating switch ormally designed to perform (3) although certain types can perform (4); the circuit-breaker st perform (3), (4), (5) and (6).

The actual making or breaking of the circuit takes place at the contacts; these must be e to carry continuously the full-load current of the circuit without excessive temperature , i.e. they must have a very low contact resistance; they must also be able to pass, in a ction of a second, from the state in which they carry a short-circuit current with a negligible t drop to the state in which they can withstand full system voltage across them. This rapid ange can only be effected as a result of the arc that takes place when current-carrying ntacts are separated. The main problem in switch, circuit-breaker or fuse design is the oper control of this arc. But other important associated problems are the provision of equate insulation, the countering of the high mechanical forces due to short-circuit currents, d the devising of suitable operating mechanisms for rapidly closing and opening the ntacts. The most arduous duty is the interrupting of short-circuit currents.

the medium voltage range (up to 660 V) oil-and air-break circuit-breakers are For plications at 3.3 kV, 6.6 kV and 11 kV, oil-break, air-break and (for special applications at 1 kV) air-blast circuit-breakers are also available. The several factors which affect the election of the right circuit-breaker for a particular application include: service voltage and oad current; the type of duty; environment of installation; ancillaries and other features equired. BS 116 and BS 936 contain appendices, which gives guidance on the selection of ircuit-breakers. They contain details of methods, which should be used to determine the ymmetrical current; BS 116 also gives guidance on the calculation of asymmetrical fault current. BS 162 Electrical Power Switch gear and Associated Apparatus coordinates equirements of circuit breakers and those of associated apparatus and provides information neral matters appertaining to switchgear.

Circuit-breakers must not he allowed to carry current in excess of their rated current as normally have little, if any, overload capacity. An approximate of symmetrical fault nts to be anticipated on systems supplied through can be made by neglecting the dance on the supply side of the transformers. The formula used

$$\text{t MV A} = \frac{\text{Transformer rated kV A}}{\text{\% impedance of the transformer x 10}}$$

Allowance has also to be made for the fault contribution of rotating machinery. It irable to take advantage of the reduction in fault current, which can occur on medium tage Systems due to the impedance of all connections.

Various types of operating mechanisms are used in circuit-breakers. Manual chanisms are not recommended for use in 11 kV and 6.6 kV installations are the fault els exceed 150 MV A. Where manual mechanisms are required, it is necessary to ensure t the design incorporates features such as instantaneous trip and trip-free features, which n add greatly to the safety with which circuit-breakers can with their fault-making duty. For nanual spring-operated arrangement, a handle is provided whereby a spring is charged and eased in one stroke. A charged spring closes the circuit-breaker, the energy of the spring ving been checked on short-circuit tests, thus ensuring safe closing of the circuit-breaker ring fault conditions. The band-charged spring arrangement is similar, except that the arging of the spring is carried out manually and the closing of the circuit-breaker is carried it by a separate action to release the charged spring. In the spring motor-wound rangement, manual charging is dispensed with.

mongst the service conditions which must be taken into account when considering the hoice of suitable equipment are the temperatures and climatic circumstances under which it intended to operate. For instance, when circuit-breakers are installed in places subject to bnormally low temperatures, a suitable low-freeze oil should be selected not only for the reaker itself but also for the over current dashpots. To prevent the oil from freezing, heaters re sometimes built into the circuit-breaker tanks. Special low-temperature greases may be equired to maintain the correct functioning of mechanical parts. On the other hand, where the num temperature exceeds 40°C, or the average ambient over a 24-hour period exceeds derating of the standard circuit-breaker may be necessary.

Where excessive dust exists, as in steel Millis, cement works and boiler houses, special utions may be necessary and the breaker may be required to be enclosed in a recognized sure. In general, oil circuit-breakers, because they tend to be totally enclosed, are more ant of dusty and dirty locations. Than are their air-break counterparts. Application oors involves equipment specifically designed for outdoor use or, alternatively, the ication of indoor equipment within weatherproof enclosures.

**.2 Moulded Case Circuit-Breakers**

The molded case circuit-breaker is designed to provide circuit protection for ium-voltage distribution systems. It is defined as an air-break circuit-breaker, designed to e no provision for maintenance, having a supporting and enclosing housing of molded lating material forming an integral part of the unit. It is capable of making, carrying and aking currents under specified abnormal circuit conditions such as those of short-circuit. usual current ratings are fromlO-1200 A up to 600 V in single-, double-, or triple-pole ts with a breaking capacity of up to 50kA (r.m.s.) at power factors of 0.25 to 0.4.

The breakers were developed because of the advantages they had over ordinary tches and fuses in the control and protection of circuits and apparatus They have a eatable non-destructive performance, safety in operation under fault conditions, and, in the e of the triple-pole circuit-breaker, simultaneous opening of all three phases, even under a gle-phase fault to earth. All breakers have, as a standard feature, the ability to disconnect omatically under overload conditions, usually up to 8-10 times the rated current via netal over current trips in each pole. An essential feature of all mounded-case circuit-eakers is the quick-make-and-break operation of the contacts, independent of operating rsonnel, and a high contact pressure; both these features are essential ifhigh fault currents e to be switched safely.

The function of the breaker trip elements is to trip the operating mechanism in the event a prolonged overload or short circuit. To accomplish this, a thermal-magnetic rip action is normally provided. The thermal trip action is achieved through the use of a metal heated by the load current. On a sustained overload, the bimetal will deflect, causing e operating mechanism to trip. Because bimetals are responsive to the heat generated by the urrent flow, they allow a long time delay on light overloads and have a faster response on eavier overloads. Magnetic trip action is achieved through the use of a simple electromagnet ries with the load current and thermal device. This provides instantaneous tripping when urrent reaches too high a value for the thermal trip element to provide sufficiently rapid ing.

### 0.3 Miniature Circuit-Breakers

These devices are in many ways similar to the molded-case breakers. The dividing between the two types of breaker is drawn on a basis of current rating and shortcircuits acity. The m.c.b. has found an increasing role for final circuit protection in domestic and nmercial installations. It offers these circuits better protection, and a better fire risk tection, particularly when overload conditions are being considered, than the fuse ernative.

### .11 Discrimination

The term discrimination is applied to a circuit condition, under the circumstances of an cess-current flow, where, for example, one fuse blows before another. If the blown fuse is e 'minor' fuse in the circuit, then the other, the 'major' device has discriminated with the inor unit. In practice, if two fuses appear to have discriminated with each other, the criterion discrimination is, however, not merely that one is opencircuited and the other is not. It is sential for the unblown fuse to continue to give satisfactory service after the fault has been moved and the minor fuse replaced.

Discrimination may be defined as 'the ability of fuses and circuit-breakers to interrupt e supply to a faulty circuit without interfering with the source of supply to the remaining ealthy circuits in the system'. This requires that a larger fuse nearer to the source of supply vill remain unaffected by fault currents, which would cause a smaller fuse, further from the ource of supply, to operate.

In practice, fairly good discrimination, as required by Regulation 533-01-06 can be achieved between different fuse ratings when the prospective current of the circuit is small and the fuse operates in more than approximately 0.02 second. If, however, the prospective current is large, resulting in operating times of less than 0.1 second, discrimination will be more difficult and a ratio of not less than 2: 1 between major and

minor fuses may become necessary. Reference to standard time/current curves will enable a fairly close approximation of discrimination to be made for operating times of not less than 0.02 second.

n practice, too, it is often the case that a system of circuits contains protection offered .C fuses, semi-enclosed fuses, and circuit-breakers; circuits are also protected by one only or two or more m combination. In these circumstances the advice of fuse facturers should be sought. Where circuit-breakers and HRC fuses are used, either as eans of protection or in combination, it is a relatively simple matter to choose ratings to e discrimination by referring to standard curves issued by the manufacturers.

**Relays**

ver current protective relay has been a common means of protection against s currents for large and small systems for many years and is now finding new cations. With the ever-growing size of electrical power systems and the increasing use of onnection, it is often difficult to secure the really accurate and discriminative nnection of the supply when circuit conditions become unhealthy. Relays are used in iation with circuit-breakers which are tripped by a series connected, direct acting, over nt trip oil. This device is electromagnetic in operation and consists of either an romagnet and armature, or a solenoid with a central plunger. The coil of the romagnet (or the solenoid) consists of a few turns of conductor connected in series with nain circuit. The armature (or plunger) is arranged to operate the circuit-breaker trip anism. The operating current of such a device is usually adjustable by means of variation ther the magnetic gap or a restraining spring.

Some items of electrical equipment, such as transformers, can carry an overload for a t time without damage; this time will decrease with heavier overloads. The overload trip in consequence, is required to impose a time delay between the incidence of an overload the tripping of the circuit-breaker, this time delay being arranged to decrease with easing current, Le., an inverse-time characteristic. One method of obtaining this racteristic is by means of an oil dashpot.

disadvantage of the direct-acting overload trip-coil is that it has to carry the main circuit rent and it must also be capable of carrying, without damage, shortcircuit currents. Instead, direct-acting overload device can be arranged to operate via a current-transfonner. This thod has advantages where it is necessary to insulate the trip device from the main circuit. addition, since a current-transfonner will saturate on heavy over-current, it is possible to ain overload settings which are lower than those obtainable with a series connected coil; is because the saturation of the current-transfonner relieves the coil of the overload trip ice from the stresses due to short-circuit currents. When current-transfonner operation is ed, it is possible to obtain a time lag on overloads by means of a time-limit fuse. This fuse is ected across the trip coil, and consequently the overload trip device is prevented from ting until the fuse melts due to a current in excess of its rating. The thennal characteristic e fuse provides a satisfactory time lag for overload currents.

Perhaps the most familiar relay is the induction-type over current relay It consists of an ating coil which is tapped, the tapings being brought out to a plug bridge; the tapings espond to different current settings. A closed secondary winding is wound on upper and r magnets. The fluxes produced by the primary (operating coil) and secondary windings separated in phase and space and produce a torque, as in the shaded-pole induction disc or. The disc experiences a torque, which depends on the current, and will move against a aining spring provided the current, is large enough. The time of travel is adjustable by ns of a stop, which adjusts the distance of disc travel to contacts connected to the trip coil he associated circuit-breaker.

The thennal relay is suitable for the protection against serious overload of such items equipment as motors and transfonners. The relay has a relatively slow action, due to the nnal lag. But this can be an advantage where a time lag is needed in the circuit. The relay l therefore not operate on momentary overloads such as occur during motor starting. An vantage is that the overload is integrated over a period of time, since the heating action is ntinuous due to the fact that the relay does not reset immediately load is removed, but only covers gradually as the bimetal cools down.

The thennal relay action is not suitable for coping with short-circuit currents, which ust be interrupted as quickly as possible. Some types of relay incorporate an instantaneous gh-set element which operates immediately a predetennined value of current is exceeded, as presented by short-circuit conditions.

The use of relays for the protection of motors is becoming common place. Overload otection is arranged to carry the starting current for the starting period without tripping. In e case of direct-on-line starting, the initial starting current may be
as high as 8 x F.L., and the starting period as long as 25 seconds. Under these conditions the rotection is usually by means of thermal relays. Instantaneous high-set over-current devices re recommended for short-circuit currents.

## 4.13 Protection For Cables

Cables require protection against excess currents , from small overloads to the highest values of short-circuit currents. The introduction of plastics in recent years has resulted in cables insulated and sheathed with such materials being more sensitive to over nt conditions than rubber-compounds, paper and mineral insulation. The HRC fuse can ide short-circuit protection up to the highest values of fault currents and, in tion, limit the fault energy so as to keep the fault damage to a minimum.

zone in which protection is probably most difficult to provide is at the low load/long-time region. Investigations have proved that PVC-insulated cables are able to stand currents not exceeding 150 percent of their rating for 4 hours when installed in air. st other forms of cable in common use have a higher withstand value than this; the lication in this is that an over current protective device which will protect PVC and similar les will, within reason, be satisfactory for other types.

en a capacitor is switched into a circuit, a heavy inrush of current results and to ensure that es do not blow unnecessarily in these circumstances higher rated fuses are required in the cuit. In general, if the fuses fitted are rated at 125-150 per cent of

capacitor rating, nuisance blowing of the fuses will be avoided. Transformer and orescent lighting circuits may also require higher rated fuse links to deal with the inrush rrents associated with this class of gear. Fuse links with a rating about 50 per cent greater an the normal current of the apparatus to be protected are usually found to be satisfactory.

ne use of semi-conductor devices for rectification and for system control purposes has creased rapidly in recent years, with specific problems in their protection. The result has een the introduction of specialized ranges of fuses. The semi-conductor device has a low ermal withstand compared with its rating and is, therefore, capable only of accepting a omparatively small input of fault energy. Protection must be capable of rapid operation and rovide a high degree of energy limitation. The special HRC fuse is the only protective device t present capable of being matched to a semi-conductor. When such a fuse does blow, it is xtremely important that it is replaced with a fuse link of exactly the same make and type. Published data are available which discuss the various types of basic circuitry at present in use.

# CHAPTER 5: ILLUMINATION INSTALLATION

It is the most using illumination system of electric energy in todays. Such that reason it necessary to produce the light installation to respond the diverse demands inside and side of building .

Illumination installation works with alternative current exept spuralreason. Its linked ectly into long by neuter switch illumination installation.

Lamps can be controlled by switch at light installation.

e distinction between terms used in illumination often presents difficulties. The following le shows units and definitions.

| rm | Definition | Symbol | Unit |
|---|---|---|---|
| minous intensity | Light source | I | Candela |
| minous flux | Light emitted from a source | Φ | Lumen |
| umination | Density of luminous flux falling on a working plane | E | Lumen/m2 or Lux(lx) |

## .1 Inverse Square Law

The illumination falling on a working plane varies inversely as the square of the istance of that surface from the light source.

The illumination (in lumens per square metre) at a point below a light ource on a horizontal work plane (Fig. 16.2) is calculated as follows:

$$E = \frac{I}{d^2}$$

Vhere;

E = illumination in lumens per square metre,

= luminous intensity in candelas,

l = distance from light source in metres.

**sine Law**

The illumination at a point on a horizontal working plane which is at an

o the light source is calculated as follows:

$$E = \frac{I}{d^2}.COS\Theta$$

**her Factors in Illumination**

**enance Factor**

This factor (a number without units) takes into consideration losses in light output due

(a) ageing of lamps and

(b) dirt collecting on lamps and fittings.

The maintenance factor taken between 1.25-1.75.

**icient of Utilization**

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

(a) light output of lamp (lumens),

(b) the type of reflector used,

(c) height and spacing of fittings,

(d) the colouring of the walls, ceiling, and floor.

These factors are taken into consideration in the coefficient of utilization (a number out units)

ficient of Utilization= (Light received on working plane)/(light output of lamps)

**rage lighting calculations**

$$k = \frac{(axb)}{h(a+b)}$$

$$\Phi_T = \frac{(E.A.d)}{\eta}$$

$$n = \frac{\Phi_T}{\Phi_L}$$

re,

ıtilisation factor

= the total luminance flux

the area of working place

= luminance flux of one lamp

room index

the length of the working place

the width of the working place

the height of the working place

illumination

maintenance factor

= utilization factor

## Lamps

### .1 Incandescent Lamp

Principle of Operation . Light energy is produced by passing a current through a nductor (usually tungsten) enclosed in an evacuated glass bulb. The operating temperature 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 allows an increased perating temperature (about 2500°C) giving increased light, as it minimizes the losses from e filament due to evaporation. The life of the lamp is also increased (minimum 1000 hours).

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

The efficiency of the lamp is approximately 121m/W.

NOTE. The efficiency of a lamp is detpendent on

(a) the rating of the lamp (efficiency increases with lamp size);

(b) the age of the lamp;

) the operating voltage

Efficiency is decreased when run at values less than rated voltage.

## : Discharge Lamp

Principle of Operation. When an electrical pressure is applied across a glass tube aining a certain gas (e.g., neon) an electrical discharge takes place and energy in the form ight is given off. The gas under these conditions is said to be ionized. The electrical nections inside the tube are called electrodes.

Ionization is caused by the movement of electrons in the gas. These electrons nbard' the atoms of gas and free other electrons. Light is given off during this' nbardment'.

The flow of current through the tube increases with ionization as a 'chain reaction' es place:

Increased ionization.

Decreased resistance of the discharge path.

Increased current.

The cycle is repeated.

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 xide 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 isintegrate

## .4.3 The Flourescent Lamp

It's the lamp which operates between 4-120 watt according to the principles of lecharge tube. It's the more preferable than the other lamps due to have more light receiver, egular light distribution and become long life but there is only one drawback, you need subsidiary vehicles.

It can operate when we bind 2x20 watt fluorescent lamps on the ballast with 40 watt as a series. But this bindings don't preferable because of line voltage doesn't less than 220V and in the case of any out of order on the switch or the lamp, It can not use as a system.

The flourescent lamps are fed by three phased systems especially we may usually cross to this system at the workshops.

If the lamps are fed by one phase which is called stroboskobic event, that may cause ccidients because this event shows us as objectşves are not moving whether moves or ıs to turning adverse direction. To prevent this kind of accident we must do system is that three phased distribution illuminations at workshop in where works with ıery.

**The Lamps With Mercury Steam** :

It is the decharge lamps with high-pressure. Decharge comes out and illuminates when ry steams as a result of fire the mercury inside the decharge. Illuminations value is so s a watt/lumen we use it on the streer illuminating. In addition of Fleman, the kind self- without ballasts of system advanced further.

**The Sodium Steamed Lamps**

It is the decharge lamps when it uses at normal voltage. Volfram Flemans are covered rium oxide. When it get warm under low pressure , sodium turns to steam inside the and it illuminates. For instance, we may come across them at traffic avenues and the places in where we need to see capability.

**Arc Lamps**

It is the source of light which emits most powerfull light on certain point. It operates t 65 volt direct current (DC) and alternative current (AC) . Firstly each one contacts each r and send current. Two coal electrot light come out after arc maker calls.

It is connecting parallel and differential, series to fix the intermediates among coals. tive electrots are thick because of more eroded in the direct current. But in the alternative ent both electrode has thickness.

**7 Light Pipes**

It is the decharge lamp which has basic gases with low-pressured operating in high age to use for advertising. It is related the lengths of operating high voltage value.

TABLE OF CONTENTS

## ACKNOWLEDGMENTS

Firstly I wish to thank my supervisor, Özgür Özerdem for intellectual support, encaurагement, enthusiasm which made this thesis possible, and for he explained my questions patiently.

I also wish to thank who helped to me about my thesis and my teachers in the faculty of engineering for giving us lectures.

Finally I also wish to thank my friend especially Fatma İkbal Temiz in the faculty of engineering.

# ABSTRACT

The electrical installation is one of the most impotant subject of an electrical gineering. According to this, the thesis is about an electrical installation of a hospital.

The main objective of this thesis is to provide an electrical installation with AutoCAD. For this thesis AutoCAD is very important. Also, with the help of AutoCAD, you can easily draw the part of you installation project.

According to this thesis you can learn to use AutoCAD and also learn to make especially cost calculation and lighting calculation for electrical installation as well.

# INTRODUCTION

The thesis is about an electrical installation, The electrical installation is one of the most impotant subject of an electrical engineering. So I decided to choose this subject, because I believed, it will help me in my future carrier as well.

My thesis is about electrical installation of hospital. In this thesis firstly I research how I can design an electrical installation of the building .After I designed this thesis with an autocad. In this thesis I considered to many application for electrical installation. There are installation type(e.g ring for socets), earthing, protection, illumination, cables and conductors, weak current installation, generation and transmission, cost calculation , etc...

This thesis consist of introduction, 9 chapter and conclusion.

Chapter 1 is about history of electricity.

Chapter 2 is about weak current installation.

Chapter 3 is about conductors and cables.

Chapter 4 is about electrical safety, protection and earthing.

Chapter 5 is about illumination.

Chapter 6 is about circuit control devices.

Chapter 7 is about domestic installation.

# CHAPTER 1 :THE HİSTORY OF ELECTRICITY

Today's scientific question is: What in the world is electricity? And where does it go after it leaves the toaster?

Here is a simple experiment that will teach you an important electrical lesson: On a cool, dry day, scuff your feet along a carpet, then reach into a friend's mouth and touch one of his dental fillings. Did you notice how your friend twitched violently and cried out in pain? This teaches us that electricity can be a very powerful force, but we must never use it to hurt others unless we need to learn an important electrical lesson. It also teaches us how an electrical circuit works. When you scuffed your feet, you picked up small batches of "electrons," which are very small objects that carpet manufacturers weave into carpets so they will attract dirt. (That will cause the carpet to wear out faster so you will need to buy a new one sooner, but that's another story.) The electrons travel through your blood stream and collect in your finger, where they form a spark that leaps to your friend's filling, then travels down to his feet and back into the carpet, thus completing the circuit. Amazing Electronic Fact: If you scuffed your feet long enough without touching anything, you would build up so many electrons that your finger would explode! But this is nothing to worry about unless you have carpeting.

Although we modern persons tend to take our electric lights, radios, mixers, etc for granted, hundreds of years ago people did not have any of these things,which is just as well because there was no place to plug them in. Then came along the first Electrical Pioneer, Benjamin Franklin, who flew a kite in a lightning storm and electrical shock. This proved that lightning was powered by the same force as carpets, but it also damaged Franklin's brain so badly that he started speaking in maxims, such as "a penny saved is a penny earned." (Eventually he got so bad he had to be given a job running the post office, but that's another story.)

After Franklin came a herd of Electrical Pioneers whose names have become part of our electrical terminology: Myron Volt, Mary Louise Amp, James Watt, Bob Transformer, etc. These pioneers conducted many important electrical experiments. For example, in 1780 Luigi Galvani discovered this is the truth by the way) when he attached two different kinds of metal to the leg of a frog, an electrical current developed and the frog's leg kicked, even though it was no longer attached to the frog, which was dead anyway. Galvani's discovery led to enormous advances in the field of amphibian medicine. Today skilled veterinary surgeons can take a frog that has been seriously injured or killed, implant pieces of metal in its muscles, nd watch it hop back into the pond just like a normal frog, except for the fact that it sinks like stone. But the greatest Electrical Pioneer of them all was Thomas Edison, who was a brilliant inventor despite the fact that he had little formal training and lived in New Jersey. Edison's first major invention in 1877, was the phonograph, which could be found in thousands of American homes, where it basically sat until 1923 when the record was invented. But Edison's greatest achievement came in 1879, when he invented the electric company. Edison's design was a brilliant adaptation of the simple electric circuit: The electric company sends electricity through a wire to a customer, then immediately gets the electricity back through another wire, then (this is the brilliant part) sends it right back to the customer again. This means the electric company can sell a customer the same batch of electricity thousands of times a day and never get caught, since very few customers take the time to examine their electricity closely. In fact the last year any new electricity was generated in the United States was 1937; the electric companies have merely been reselling it ever since, which is why they have so much free time to apply for rate increases. Today, thanks to men like Edison and Franklin, and frog's like Galvani's, we receive unlimited benefits from electricity. For example, in the past decade scientists developed the laser, an electronic appliance so powerful that it can vaporize a bulldozer 2,000 yards away, yet so precise that doctors can use it to perform delicate operations on the human eye, provided they remember to change the power setting from "Vaporize Bulldozer" to "Delicate."

## 1.1Generation And Transmission

In north cyprus elecrical enerjy is generate by Teknecik Power plant and Kalecik power plant. The generation of electric is to convert the mechanical energy into the electrical energy. Mechanical energy means that motors which makes the turbine turn. Electrical energy must be at definite value. And also frequency must be 50Hz or at other countries 60Hz. The voltage which is generated (the output of the generator) is 11KV. After the station the lines which transfer the generated voltage to the costumers at expected value. These can be done in some rules. If the voltage transfers as it is generated up to costumers. There will be voltage drop and looses. So voltage is stepped up. When the voltage is stepped up, current will decrease. That is why the voltage is increased. This is done as it is depending on ohm's law. Actually these mean low current. Used cables will become thin. This will be economic and it will be easy to install transmission lines. If we cannot do this, we will have to use thicker cable.

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

a-) line to line – 415V

b-) line to neutral – 240V

c-) line to earth – 240V

d-) earth to neutral – 0V

## CHAPTER 2: WEAK CURRENT INSTALLATION

In generally, we call the weak current installation as an installation which has less than 65v. Voltage inside and outside of building. The values of voltage are 3v-5v-8v-12v-24v and 48v. The choosen voltage value within weak current subject to the capacity of installation and operating voltage of installation.

Most important one of the weak current installation is the notification installation which has produced for diverse and variant reason. Notification installation; it is the installation which has which has produced notify the any kind of news, event or danger through the faraway place by the sound notify tools or luminous notify tools. Especially installations which are necessary to have every time electricity such as fire alarm, burglar alarm and timing alarm. Such that reason it is necessary to have storage battery which must be continuously charge the battery to feed the installation.

Principal weak current installations which of them placed inside and outside of building are;

1- Bell Installation
2- Door Check (Door lock) Installation
3- Numerator Installation
4- Sound, Luminous Call installation
5- Burglar Notification Installation
6- Fire Notification Installation
7- Electricity clock Installation
8- Diaphone Installation
9- Telephone Installation
10- Radio Antenna Installation
11- Television Antenna Installation
12- Postsynching Installation

### 2.1 Bell Installation

Bell notification installations are one of the most operating tools. Notification installations come about with such conducter as notification tools (bells), button and energy sources.

Bell as a structure separate into two groups which are mechanic and electronic. There is one or two electromagnet, flipper, beetle, bell and base plate at the mechanic bell. But there not beetle and bell at the buzz bell which benefits from the mechanic sound in which come ut of the continuous movement of the track and the name of other mechanic bell is melody ell.

Electronic bells sound with the condenser, circuit in transistor and the other tools. 20 / 3-5-8v, 220 / 15v, 220 / 24v transformer can be used in the bells, if there is not lectricity energy in the installation, we can benefit the battery with 4,5 and 9 volt as an lternative current (AC). Neuter is directly given to bells.

### 2.2 Door Check

Door check occur by lock bolt or a coil which moves the slide rod. Door check can be control with control with one or more button.

### 2.3 Numerator Installations

Such this installations produced to call one person from more than one place and notify the place of calling. Numerators sell in blocks with 3 and 5. we may combine the blocks whether make a call from more than one place and we may use transformer (220/8.12v) as aenergy source.

Numerator shows the calling place with ıts numbers and warns the caller person with buzz sounds.

### 2.4 Luminous, Sound, Calling Installation

Luminous buzz installations uses to prevent distrupting bell sounds at such a place, hospital, hotel, official buildings... etc. and it uses to faciliate the determination of calling place. It uses 220/24 volt transformer as a energy source.

### 2.5 Burglar Notification Installation

On the cause of burglar has apportunity to enter inside the door and window so it is necessary to secure such a place with a strained back layer of conductor. By breaking conductor away, the power of relay circuit will cut so it may provide the notification by operation of bell or lumination of lamp.

The other kind of installation is that, the system which produced over the door-crate. It also used relay in this system the bell and lamp use a vehicle of notification.

## Fire Notification Installation

This installation produced to secure the buildings against fire. There are two method in s installation. First; fire notification button placed into rooms, corridors to notify the fire by person who see the condition. When the button is pushed, the alarm circuit will get off and alarm will begin to ring by passing energy across on the relay circuit.

The second kind of notification installation is that; Bimetal termic tools replaced to tton. We may use the termic tools on the place in which there is posibility to have fire. ne tools close the switch notify the fire automatically when the heat get high. To reach fire ace in short time we do installation with numarator link.

## 7 Electric Clock Installations

Electric clock installation can be changeable according to company which produces lectric clock.

## .8 Diaphone Installation

It is the kind of installations which provides mutual conversation. It used for communal announcement or mutual dialog with desired place from one center. There re mutual conversation buttons, amplification and laudspeakers.

## 2.9 Telephone Installations

It is the vehicle for mutual conversation. It connects the people in two different place place by telephone instrument and telephone installation. Telephone instrument has a pushing and turning switch to transform the sounds into electric current by a microphone and earphone which transform electric current into sound and ring bell.

## 2.10 Radio Antenna Installations

Antenna is a conductive which receive the electromagnetic waves. In todays world, it is loosing its importance to use a roof antenna (permanent antenna) for radio receiver. In todays, the instrument include radio as an antenna mission. We use generally $1.5mm^2$ - $2.5mm^2$ copper conductor as an antenna conductor.

## 2.11 Television Antenna Installations

It is a installation between antenna and television instrument, television antennas divides into two group according to its production properties such as cone antenna and yogi antennas. It has three section;

1- Dipsle

2- Reflector

3- Director

## 2.12 Sounds Installations

Such installations produced to announce from certain place or to listen music.

# CHAPTER 3 : CONDUCTORS AND CABLES

## 3.1 Conductors

### 3.1.1 Definition of Conductors

A conductor is a material which offers a low resistance to a flow of current. Conductors for everyday use must be;

(a) of low electrical resistance,

(b) mechanically strong and flexible,

(c) relatively cheap.

For example, silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are tin, lead, and iron.

### 3.1.2 Conductor Identification

The wiring regulations require that all conductors have to be identified by some meaning to indicate their functions i.e. phase conductors of a 3 phase system are colored by red, yellow, blue with neutral colored by black, protective conductors are identified by green or yellow/green. In British Standard;

| | |
|---|---|
| Red | Phase |
| Black | Neutral |
| Green | Earth |

We have some methods to identify the conductors.

1.Colouring of the conductor insulation

2.Printed numbers on the conductor

3.Coloruede adhesive cases at the termination of the conductor

4.Colored see levels types at the termination of the conductors

5.Numbered paint for bare conductors

6.Colored discs fixed to the termination of conductors' e.g. on a distribution board.

### 3.1.3 Formation of Conductors

Electrical conductors are usually made of copper, although aluminium is being used to a greater extent, particularly as the price of copper increases. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. The copper wire is then dipped into a tank containing molten tin.

is is done for two reasons:

(a) to protect the copper if the wire is to be insulated with vulcanized rubber, as this ntains sulphur which attacks the copper;

(b) to make the copper conductor easier to solder. Aluminium wire is also drawn from solid block but is not tinned.

## 1.4 Comparision of Alluminium and Copper As Conductor

### .1.4.1 Alluminium

Smaller weight for similar resistance and current-carrying capacity

Easier to machine

Greater current density because larger heat-radiating surface .

Resistivity 2.845 μΩ-cm

Temperature coefficient practically similar (0.004Ω/Ω degC)

### .1.4.2 Copper

Better electrical and thermal conductor, therefore lower C.S.A. required for same voltage drop.

-Greater mechanical strength

-Corrosion resistant

-High scrap value

-Much easier to joint

-Lower resistivity: 1.78 μΩ-cm

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

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

The size of a stranded conductor is given by the number of strands and the diameter of the individual strands. For example, a 7/0.85 mm cable consists of seven strands of wire, each trand having a diameter (not cross-sectional area) of 0.85 rom. Solid (nonstranded) onductors are now being used in new installations.

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

The following precautions must be taken with open bus-bar systems (above extra-low voltage). They must be:

(a) inaccessible to unauthorized persons,

(b) free to expand and contract,

(c) effectively insulated. Where bare conductors are used in extra-low voltage systems they must be protected against the risk of fire.

## 3.2 Cables

### 3.2.1 Definition of Cables

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor (solid or stranded), or of two or more such conduetors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors mayor 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.

### 3.2.2 Types of Cables

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

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

**Single Core Cable**

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

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

**2 Two-Core**

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

**3 Three-Core**

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

**.4 Composite Cables**

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

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

**2.5 Power Cables**

Heavy cables, generally lead sheathed and annored; control cables for electrical ipment. Both copper and aluminum conductors.

**2.2.6 Wiring Cables**

vitchboard wiring; domestic at workshop flexible cables and cords. Mainly copper nductors.

## .7 Mining Cables

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

## 2.8 Ship-Wiring Cables

These cables are generally lead-sheathed and annored, and mineral-insulated, metal-thed. Cables must comply with Lloyd's Rules and regulations and with Admiralty irements.

## 2.9 Overhead Cables

Bare, lightly insulated and insulated conductors of copper, copper vadmiuim and ninum generally. Sometimes with steel core for added strength. For overhead distribution les are PVC and in most cases comply with British Telecom requirements.

## 2.10 Coaxiel Cable (antenna cable)

Antenna cables is a special cable which is used to transfer high frequancy. This cable a type of flexible cables. We use this cale for TV. We are using this type of cable between vision sockets and from television to antenna.

## .2.11 Telephone Cable

Telephone cable is special cable. We use telephone circuit in the buildings and also intercom circuits. This cables are very slim. Telephone cables are not same as electric oles. There are a lot of size the telephone cables. Telephone cables are 0.5mm and erytime one cable is extra near this cables.

## .2.12 Welding Cables

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

## .2.13 Electric-Sign Cables

PVC and rubber insulated cables foe high voltage discharge lamps able to withstand e high voltages.

14 Equipment Wires

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

.15 Appliance Wiring Cables

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

.16 Heating Cables

Cables for floor warming, road heating, soil warming, ceiling heating and similar ications.

2.17 Flexible Cords

A flexible cord is defined as a flexible cable in which the csa of each conductor does exceed 4 mm squared. The most common types of flexible cords are used in domestic and t industrial work. The diameter of each strand or wire varies from 0.21 to 0.31 mm. ible cord come in many sizes and types; for convenience they are groups as follows:

**Twin-Twisted**

These consist of one single insulated stranded conductors twisted together to form a e-cable. Insulation used is vulcanized rubber and PVC. Color identification in red and ck is often provided. The rubber is protected by a braiding of cotton, glazed-cotton, and on barding and artificial silk. The PVC insulated conductors are not provided with litional protection.

**Three-Core (twisted)**

Generally as two twisted cords but with a third conductor colored green, for eating hting fittings.

**Three-Core (circular)**

Generally as twin-core circular except that the third conductorcolored green and llow for earthling purposes.

**Four-Core (circular)**

Generally as twin-core circular. Colors are brown and blue.

**Parallel Twin**

These are two stranded conductors laid together in parallel and insulatedto form a niform cable with rubber or PVC.

**f) Twin-Core (flat)**

This consists of two stranded conductors insulated with rubber, colored red and black. Lay side-by-side and braided with artificial silk.

**g) High Temperature Lighting, Flexible Cord**

With the increasing use of filament lamps which produce very high temperatures, the temperature at the terminals of a lamp holder can reach 71 centigrade or more. In most instances the usual flexible insulators (rubber and PVC) are quite unsuitable and special flexible cords for lighting are now available. Conductors are generally of nickel-plated copper wires, each conductor being provided with two lapping of glass fiber. The braiding is also varnished with silicon. Cord is made in the twisted form (two and three-core).

**h) Flexible Cables**

These cables are made with stranded conductors, the diameters being 0.3, 0.4, 0.5 and 0.6 mm. they are generally used for trailing cables and similar applications where heavy currents up to 630 A are to be carried, for instance, to welding plant.

### 3.2.3 Cable Sizes ( Use of I.E.E. Tables)

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

These tables supply:

(a) cross-sectional area, number, and diameter of conductors;

(b) type of insulation;

(c) length of run for I V drop;

(d) current rating (a.c. and d.c.), single and bunched.

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

(a) ambient temperature

(b) rating factor

### 3.2.4 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.

### 3.2.5 Rating Factor

This is a number, without units, which is multiplied with the current to find the new nt-carrying capacity as the operating conditions of the cable change.

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

### 6 Permissible Voltage Drop in Cable

Voltage drop is another essential feature in the calculation of cable size, as it is useless lling a cable which is capable of supplying the required current if the voltage at the umer's equipment is too low. Low voltage at the consumer's equipment leads to the ficient operation of lighting, power equipment, and heating appliances. The maximum age drop allowed between the consumer's terminals and any point in the installation is 2.5 cent of the voltage supplied by the Electricity Board, including motor circuits.

### 7 Voltage Drop and the I.E.E. Tables

I.E.E. tables state the voltage drop across a section of cable when maximum current is ving through it. If the current is halved, the voltage drop will also be halved. For example, mm2 twin-core cable has a current rating of 24 A and a voltage drop of 10m V per ampere metre. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per pere per metre.

### .8 New Voltage Bands

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

### .9 Current Density and Cable Size

The current density of a conductor is the amount of current which the conductor can ely carry without undue heating per unit cross-sectional area. For example, if a copper nductor has a current density of 300 A/cm2 a copper conductor of cross-sectional area 0,5 n2 will be capable of carrying one half of 300 A, that is, 150 A.

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

**Current-carrying capacity = current density x cross-sectional area**

**Resistance of a Conductor**

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

(a) the length of the conductor,

(b) its cross-sectional area,

(c) type of material used.

## 3.3 Insulators

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

### 3.3.1 Electrical Properties

It must have a high resistance.

### 3.3.2 Mechanical Properties

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

### 3.3.3 Physical Properties

The perfect insulator would have the following physical properties:

(a) non-absorbent;

(b) capable of withstanding high temperatures.

### 3.3.4 Chemical Properties

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

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

# CHAPTER 4: ELECTRICAL SAFETY-PROTECTION-EARTHING

## .1 Electrical safety

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

) The use of insulation (screening live parts, and keeping live parts out of reach).

:) Ensuring, by means of earthling that any metal in electrical installation other than the conductor, is prevented from becoming electrically charged. Earthing basically provides a path of low resistance to earth for any current, which results from a fault between a live conductor and earthed metal.

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

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

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

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

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

t is a recommendation of the IEE regulations that every domestic installation be tasted vals of five years or less. The completion and inspection certificates in the IEE ons show the details required in every inspection. And not only should the electrical ion be tested, but all current-using appliances and apparatus used by the consumer.

llowing are some of the points, which the inspecting electrician should look for: **1)**

cables not secure at plugs

d cables

s without mechanical protection

f unearthed metalwork

its over-fused

or broken earth connections, and especially sign of corrosion

arded elements of the radiant fires.

thorized additions to final circuits resulting in overloaded circuit cables.

otected or unearthed socket-outlets.

liances with earthing requirements being supplied from two-pin BC adaptors.

ire used to carry mains voltages.

portable heating appliances in bathrooms.

n connectors, such as plugs.

of heating at socket-outlet contacts.

ving are the requirements for electrical safety:

ing that all conductors are sufficient in csa for the design load current of

ll equipment, wiring systems and accessories must be appropriate to the conditions.

rcuits are protected against over current using devices, which have ratings iate to the current-carrying capacity of the conductors

ll exposed conductive pans are connected together by means of CPCs.

l extraneous conductive parts are bonded together by means of main bonding rs and supplementary bonding conductors are taken to the installation main earth

ll control and over current protective devices are installed in the phase or.

All electrical equipment has the means for their control and isolation.

lljoints and connections must be mechanically secure and electrically continuous and sible at all times.

o additions to existing installations should be made unless the existing ors are sufficient in size to carry the extra loading.

All electrical conductors have to be installed with adequate protection against physical and be suitably insulated for the circuit voltage at which they are to operate.

In situations where a fault current to earth is not sufficient to operate an over device, an RCD must be installed.

All electrical equipment intended for use outside equipotent zone must be n socket-outlets incorporating an RCD.

The detailed inspection and testing of installation before they are connected ains supply, and at regular intervals there after.

**arthing**

An efficient eartling arrangement is an essential part of every electrical tion and system to guard against the effects of leakage currents, short-circuits, static s and lightning discharges. The basic reason for earthing is to prevent or minimize the f shock to human beings and livestock, and to reduce the risk of fire hazard. The g arrangement provides a low-resistance discharge path for currents, which would vise prove injurious or fatal to any person touching the metalwork associated with the circuit. The prevention of electric shock risk in installations is a matter, which has been close attention in these past few years, particularly since the rapid increase in the use of city for an ever-widening range of applications.

**ric shock**

An electric shock is dangerous only when the current through the body reaches a n minimum value. The degree of danger is dependent not only on the current but also on me for which it flows. A low current for a long time can easily prove just as dangerous igh current for a relatively brief period. The applied voltage is in itself only important in ıcing this minimum current through the resistance of the body. In human beings, the ance between band and hand, or between band and foot, can be as low as 500 ohms. If ody is immersed in a conducting liquid (e.g. as in a bath) the resistance may be as low as ohms. In the case of a person with a body resistance of 500 ohms, with a 240 V supply esulting current would be
mA, or 1.2 A in the more extreme case. However, much smaller currents are lethal, It has estimated that about 3 mA is sufficient for a shock to be felt, with a tingling sensation. veen 10 mA and 15 mA, a tightening of the muscles is experienced and mere is difficulty leasing any object being gripped. Acute discomfort is felt at this current level. Between nA and 30mA the dangerous level is reached, with the extension of muscular tightening, icularly to the thoracic muscles. An over 50 mA result in fibrillation of the heart which is erally lethal if immediate specialist anention is not given. Fibrillation of the heart is due to gular contraction of the heart muscles.

The object of earthing, as understood by the IEE Regulations, is, so far as is possible, educe the amount of current available for passage through the human body in the event of he occurrence of an earth-leakage current in an installation.

It has been proved that more than 25 per cent of alt electrical deaths are the result of a failure or lack of earthing.

**4.2.1 Lightning Protection**

Lightning discharges can generate large amounts of heat and release considerable mechanical forces, both due to the large currents involved. The recommendations for the protection of structures against lightning are contained in BS Code of Practice 6651 (Protection of Structures Against Lightning). The object of such a protective system is to lead away the very high transient values of voltage and current into the earth where they are safely dissipated. Thus a protective system, to be effective, should be solid and permanent. Two main factors are considered in determining whether a structure should be given protection against lightning discharges:

1. Whether it is located in an area where lightning is prevalent and whether, because of its height and/or its exposed position, it is most likely to be struck.

2. Whether it is one to which damage is likely to be serious by virtue of its use, contents, importance or interest (e.g. explosives factory, church monument, railway station, spire, radio mast, wire fence, etc.).

It is explained in BS Code of Practice 6651 that the 'zone of protection' of a single vertical conductor fixed to a structure is considered to be a cone with an apex at the highest point of the conductor and a base of radius equal to the height. This means that a conductor 30 meters high will protect that part of the structure which comes within a cone extending to 60 meters in diameter at ground level Care is therefore necessary in ensuring that the whole of a structure or building falls within the protective zone; if it does not, two down conductors must be run to provide two protective zones within which the whole structure is contained. All metallic objects and projections, such as metallic vent pipes and guttering, should be bonded to form part of the alrtermination network. All down conductors should be cross-bonded.

The use of multiple electrodes is common. Rule 5 of the Phoenix Fire Office Rules states:

Earth connections and number. The earth connection should be made either by means of a copper plate buried in damp earth, or by means of the tubular earth system, or by connection to the water mains (not nowadays recommended). The number of connections should be in proportion to the ground area of the building, and there are few vhere less than two are necessary Church spires, high towers, factory chimneys down conductors should have two earths which may be interconnected.

the component parts of a lightning-protective system should be either castings of nmetal, copper, naval brass or wrought phosphor bronze, or sheet copper or pronze. Steel, suitably protected from corrosion, may be used in special cases where compressive strength is needed.

r terminations constitute that part of dice system which distributes discharges into, s discharges from, the atmosphere. Roof conductors are generally of soft annealed rip and interconnect the various air terminations. Down conductors, between earth r terminations are also of soft-annealed copper strip. Test points are joints in down rs, bonds, earth leads, which allow resistance tests to be made. The earth ons are those parts of the system designed to collect discharges from, or distribute nto, the general mass of earth. Down conductors are secured to the face of the by 'holdfasts' made from gunmetal The 'building in' type is used for new structures; a type is used for existing structures.

Vith a lightning protection system, the resistance to earth need not be less than 10 ut in the case of important buildings, seven ohms is the maximum resistance. Because ctiveness of a lightning conductor is dependent on its connection with moist earth, a th connection may render the whole system useless The 'Hedges' patent tubular earth s a permanent and efficient earth connection, which is inexpensive, simple in ction and easy to install These earths, when driven firmly into the soil, do not lose ficiency by changes in the soil due to drainage; they have a constant resistance by of their being kept in contact with moist soil by watering arrangements provided at level. In addition, tubular or rod earths are easier to install than plate earths, because er require excavation.

Lightning conductors should have as few joints as possible. If these are necessary, han at the testing-clamp or the earth-electrode clamping points, flat tape should be soldered and riveted; rod should be screw-jointed.

htning protective systems should he examined and tested by a competent engineer after etion, alteration and extension. A routine inspection and test should be made once a nd any defects remedied. In the case of a structure containing explosives or other nmable materials, the inspection and test should be made every six months. The tests d include the resistance to earth and earth continuity. The methods of testing are similar o those described in the IEE Regulations, though tests for earth-resistance of earth electrodes equire definite distances to be observed.

### .2.2 Anti-Static Earthing

'Static', which is a shortened term for 'static electric discharge' has been the subject of ncreasing concern in recent years partly due to the increasing use of highly insulating naterials (various plastics and textile fibbers).

### 5.2.3 Earthing Practice 1. Direct Earthing

The term 'direct earthing' means connection to an earth electrode, of some recognized type, and reliance on the effectiveness of over current protective devices for protection against shock and fire hazards in the event of an earth fault. If non-currentcarrying metalwork is protected by direct earthing, under fault conditions a potential difference will exist between the metalwork and the general mass of earth to which the earth electrode is connected. This potential will persist until the protective device comes into operation. The value of this potential difference depends on the line voltage, the substation or supply transformer earth resistance, the line resistance, the fault resistance and finally, the earth resistance at the installation. Direct earth connections are made with electrodes in the soil at the consumer's premised A further method of effecting connection to earth is that which makes use of the metallic sheaths of underground cables. But such sheaths are more generally used to provide a direct metallic connection for the return of earth-fault current to the neutral of the supply system rather than as a means of direct connection to earth.

The earth electrode, the means by which a connection with the general mass of earth is made, can take a number of forms, and can appear either as a single connection or as a network of multiple electrodes. Each type of electrode has its own advantages and disadvantages.

The design of an earth electrode system takes into consideration its resistance to ensure that this is of such a value that sufficient current will pass to earth to operate the protective system. It must also be designed to accommodate thermally the maximum fault current during the time it takes for the protective device to clear the fault. In designing for a specific ohmic resistance, the resistivity of the soil is perhaps the most important factor, although it is a variable one.

The current rating or fault-current capacity of earth electrodes must be adequate for the 'fault-currentftime-delay' characteristic of the system under the worst possible conditions.

Undue heating of the electrode, which would dry out the adjacent soil and increase the earth resistance, must be avoided. Calculated short-time ratings for earth electrodes of various types are available from electrode manufacturers. These ratings are based on the short-time current rating of the associated protective devices and a maximum temperature, which will not cause damage to the earth connections or to the equipment with which they may be in contact.

In general soils have a negative temperature coefficient of resistance. Sustained current loadings result in an initial decrease in electrode resistance and a consequent rise in the earth-fault current for a given applied voltage. However, as the moisture in the soil is driven away from the soil/electrode interface, the resistance rises rapidly and will ultimately approach infinity if the temperature rise is sufficient. This occurs in the region of 100°C and results in the complete failure of the electrode.

The current density of the electrode is found by:

$$\text{Current density} = \frac{I}{A}$$

where I = short-circuit fault current; A = area (in cm2); t time in seconds (duration of the fault current).

The formula assumes a temperature rise of 120°C, over an ambient temperature of 25°C, and the use of high-conductivity copper. The formula does pot allow for any dissipation of heat into the ground or into the air.

Under fault conditions, the earth electrode is raised to a potential with respect to the earth surrounding it. This can be calculated from the prospective fault current and the earth resistance of the electrode. It results in the existence of voltages in soil around the electrode, which may harm telephone and pilot cables (whose cores are substantially at earth potential) owing to the voltage to which the sheaths of such cables are raised. The voltage gradient at the surface of the ground may also constitute a danger to life, especially where cattle and livestock are concerned. In rural areas, for instance, it is not uncommon for the earth-path resistance to be such that faults are not cleared within a short period of time and animals which congregate near the areas in which current carrying electrodes are installed are liable to e fatal shocks. The same trouble occurs on farms where earth electrodes are sometimes or individual appliances.

The maximum voltage gradient over a span of 2 meters to a 25 mm diameter lectrode is reduced from 85 per cent of the total electrode potential when the top of the ode is at ground level to 20 per cent and 5 per cent when the electrode is buried at 30 cm 100 cm respectively. Thus, in areas where livestock are allowed to roam it is nmended that electrodes be buried with their tops well below the surface of the soil.

Corrosion of electrodes due to oxidation and direct chemical attack is sometimes a em to be considered. Bare copper acquires a protective oxide film under normal spheric conditions which does not result in any progressive wasting away of the metal. It however, tend to increase the resistance of joints at contact surfaces. It is thus important sure that all contact surfaces in copper work, such as at test links, be carefully prepared hat good electrical connections are made. Test links should be bolted up tightly. trodes should not be installed in ground, which is contaminated by corrosive chemicals. If oer conductors must be run in an atmosphere containing hydrogen sulphide, or laid in nd liable to contamination by corrosive chemicals, iliey should be protected by a ering of PVC adhesive tape or a wrapping of some other suitable material, up to the point onnection with the earth electrode. Electrolytic corrosion will occur in addition to the er forms of attack if dissimilar metals are in contact and exposed to the action of moisture. ts and rivets used for making connections in copper work should be of either brass or per. Uninsulated copper should not be run in direct contact with ferrous metals. Contact ween bare copper and the lead sheath or armoring of cables should be avoided, especially lerground. If it is impossible to avoid the connection of dissimilar metals, these should be tected by painting with a moisture-resisting bituminous paint or compound, or by apping with PVC tape, to exclude all moisture.

e following are the types of electrodes used to make contact with the general mass of earth:

**a) Plates**. These are generally made from copper, zinc, steel or cast iron, and dlay be lid or the lattice type. Because of their mass, they tend to be costly. With the Steel or cast-on types care must he taken to ensure that the termination of the earthing ad to the plate is water-proofed to prevent cathodic action taking place at the joint, If this ppens, the conductor will eventually become detached from the plate and render ilie ectrode practically useless. Plates are usually installed on edge in a hole in the ground about 3 meters deep, which is subsequently refilled with soil. Because one plate electrode is ldom sufficient to obtain a low-resistance earth connection, the cost of excavation ed with this type of electrode can be considerable. In addition, due to the plates being d relatively near the surface of the ground, the resistance value is liable to fluctuate out the year due to the seasonal changes in the water content of the soil. To increase a of contact between the plate and the surrounding ground, a layer of charcoal can be sed. Coke, which is sometimes used as an alternative to charcoal, often has a high r content, which can lead to serious corrosion and even complete destruction of the . The use of hygroscopic salts such as calcium chloride to keep the soil in a moist on around the electrode can also lead to corrosion.

**b) Rods** In general rod electrodes have many advantages over other types of de in that they are less costly to install. They do not require much space, are convenient and do not create large voltage gradients because the earth-fault current is dissipated lly. Deeply installed .electrodes is not subject to seasonal resistance changes. There are l types of rod electrodes. The solid copper rod gives e-xcellent conductivity and is resistant to corrosion. But it tends to be expensive and, being relatively soft, is not y suited for driving deep into heavy soils because It is likely to bend if it comes up st a large rock. Rods made from galvanized steel a.re inexpensive and remain rigid when installed. However, the life of galvanized steel in acidic soils is short. Another vantage is that the copper earthing lead connection to the rod must be protected to nt the ingress of moisture. Because the inductivity of steel is much less than that of er, difficulties may arise, particularly under heavy fault current conditions when the erature of the electrode wilt rise and therefore its inherent resistance. This will tend to out the sunrounding soil, icreasing its resistivity value and resulting in a general increase e earth resistance of the electrode. In fact, in very severe fault conditions, the resistance e rod may rise so rapidly and to such an extent that protective equipment may fail to ate.

bimetallic rod has a steel core and a copper exterior and offers the best alternative to er the copper or steel rod. The steel core gives the necessary rigidity while the copper rior offers good conductivity and resistance to corrosion. In the extensible type of steel-ed rod, and rods made from bard-drawn copper, steel driving caps are used to avoid ying the rod end as it is being driven into the soil. The first rod is also provided with a nted steel tip. The extensible rods are fitted with bronze screwed couplings. Rods should installed by means of a power driven hammer fitted with a special head. Although rods uld be driven vertically into the ground, an angle not exceeding 600 to the vertical is ommended in order to avoid rock or other buried obstruction.

**c) Strip**. Copper strip is used where the soil is shallow and overlies rock. It should be uried in a trench to a depth of not less than 50 cm and should not be used where there is a ossibility of the ground being disturbed (e.g. on farmland). The strip electrode is most effective if buried in ditches under hedgerows where the bacteriological action arising from he decay of vegetation maintains a low soil resistivity.

**d) Earths mat**. These consist of copper wire buried in trenches up to one meter deep. The mat can be laid out either linearly or in 'star' form and terminated at the down lead from the transformer or other items of equipment to be earthed. The total length of conductor used can often exceed 100 meters. The cost of trenching alone can be expensive. Often scrap overhead line conductor was used but because of the increasing amount of aluminum now being used, scrap copper conductor is scarce. The most common areas where this system is still used are where rock is present near the surface of the soil, making deep excavation impracticable. As with plate electrodes, this method of earthing is subject to seasonal changes in resistance. Also, there is the danger of voltage gradients being created by earth faults along the lengths of buried conductor, causing a risk to livestock.

**e) Cable sheaths**. These form a metallic return path and are provided by the supply undertaking. They are particularly useful where an extensive underground cable system is available; the combination of sheath and armoring forms a most effective earth electrode. In most cases the resistance to earth of such a system is less than one ohm. Cable sheaths are, however, more used to provide a direct metallic connection for the return of fault current to the neutral of a supply system rather than as a means of direct connection with earth this ,even though such cables are served with the gradual deterioration of the final jute or Hessian serving.

In rural areas with overhead distribution, there is a problem, for any direct metallic return path must consist of an additional conductor. This, when provided, is known as a continuous earth wire. The disadvantage, apart from the cost of the extra conductor and its installation, is that an open-circuited earth wire could remam undetected for a long time. The earth wire is connected at the source of supply to the neutral and to the low-voltage distribution earth electrode.

### 4.2.4 Protective Multiple Earthing

This form of earthing is popularly known by the abbreviation PME. It is an extremely reliable system and is being used increasingly in this country. Basically the system uses the neutral of the incoming supply as the earth point. In this way all circuit protective ictors connect all the protected metalwork in an installation to this common point: the earthing terminal. Allline-to-earth faults are convened to lineto-neutral faults, the ion being to ensure that sufficient current flows under the fault conditions to bring over nt protective devices into operation.

There are two main hazards associated with PME. The first is that owing to the ased earth-fault currents, which are encouraged to flow, there is an enhanced fire risk g the time it takes for the protective device to operate. Also, with this method of earthing essential to ensure that the neutral conductor cannot rise to a dangerous potential relative rth. This is because the interconnection of neutral and protected metalwork would natically extend the resultant shock risk to all the protected metalwork on every llation connected to this particular supply distribution network. As a result of these rds, stringent requirements are laid down to cover the use of PME on any particular ibution system. In accordance with the new system of carting arrangements identified by EE Regulations, PME is officially known as TNC-S. Three points of interest might be tioned here. First, the neutral conductor must be earthed at a number of points on the em, and the maximum resistance from neutral to earth must not exceed 10 ohms. In tion, an earth electrode at each consumer's installation is recommended, Secondly, so fir e consumer is concerned, there must be no fusible cutout, single-pole switch, removable or automatic circuitbreaker in any neutral conductor in the installation. Thirdly, the ral conductor at any point must be made of the same material and be at least of equal s-sectional area as the phase conductor at that point.

PME can he applied to a consumer's installation only if the supply authority's feeder is tiple earthed. This restricts PME to new distribution networks, though conversions from systems can be made at a certain cost, which varies according to the type of consumer. supply authority has to obtain permission in accordance with
e provisions laid down by the Minister of Energy and Secretary of State for Scotland ish Telecom approval must also be obtained for each and every PME installation, and is uired since it was once thought that the flow of currents from PME neutrals to the general ss of earth could cause interference with and/or corrosion of their equipment. In practice, vever, no such problems have occurred although the board still retains its right to approve otherwise a proposed PME installation.

Should a break occur in a neutral conductor of a PME system, the conductor will come live with respect to earth on both sides of the break, the actual voltage distribution pending on the relative values of the load and the earth electrode resistances of the two ons of the neutral distributor. All earthed metalwork on every installation supplied from articular distribution system would become live. Highresistance joints on the neutral can have a similar effect, the degree of danger in all cases being governed by the values of onnected load and the various earth electrode resistances. Trouble on a neutral conductor go undetected for some considerable time, some of the only symptoms being reduced ges on appliances, lights, etc. and slight to severe shocks from earthed metalwork. rhead-line distribution systems are, of course, particularly prone so far as broken or ontinuous neutral conductors are concerned.

The aspect of earthed concentric wiring is important in the context of PME. For E systems, the conventional four-core (three phases and neutral) armored cable can be aced by a three-core metallic sheathed and armored cable where the sheath and armor are d for the earthed neutral. For consumer wiring, the sheath-return concentric cable, in ch the sheath acts as both the neutral and earth conductor, is a logical extension of the E principle and is covered by IEE Regulations Section 546. The main advantage of sheath-urn wiring is that a separate epe is not required. This is because the chances of a complete connection of the earth neutral conductor hout breaking the included phase conductors are remote.

Sheath return usually means that mineral-insulated cable is used. While the cost of MI cable is slightly higher than other types of cable (including any necessary nduit) this is offset considerably by the saving in labor resulting from ease of handling, the all diameter, and the reduced amount of chasing work required. Sheathreturn wiring can sult in savings in installed cost of about 30 per cent compared with a conventional direct-rthed system using plastic insulated cable in black-enameled screwed conduit. For single-ase supplies, single-core MI sheath-return cables are used. Twincore cables are used for o-way switching. Multi-core cables are used from multiswitch points and rising mains to nction boxes where a number of separate outlets are situated close together. Since the outer eath of the MI cable is used for neutral and earth connections, care has to be taken at rminations which are made with pot-type seals and glands into switchgear and terminal oxes at which sockets, ceiling roses, etc., are fined. Duplicate bonding is used to ensure that e contact remains good at all tines. A special seal, with an earth-bonding lead, is used.

### 4.3 Circuit-Protective Conductors

The circuit-protective conductor (CPC) is defined as, 'a protective conductor connecting exposed conductive pans of equipment to the main earthing terminal' The IEE

Regulations go into some considerable detail to identity the specific requirements which CPCs must satisfy, if they are to perform their function in the context of ensuring that should an earth fault occur, the resulting current is carried for the time it takes for the associated circuit over current protective device to operate.

IEE Regulations Section 543, and specifically Regulation 543-02-02, indicates the following types of circuit protective conductor, which are generally recognized. All these types of conductor are regarded as being normally dormant (that is, they do not carry current) until a fault to earth occurs.

**a) Conductor contained in a sheathed cable**, known as a composite cable. In this cable, the sheath can be of metal, rubber, or PVC; the conductors are the circuit conductors and the CPC (e.g. 2.5 mm2 twins with CPC). The conductor is either singlestrand or multi-stranded, depending on the size of the circuit conductors. And it is uninsulated. If the sheath is of metal, the conductor is always single-stranded. Inspection of samples of cables will reveal that the cross-sectional area of CPCs in metal-sheathed cables is less than their counterparts in insulated-sheathed cables; this is because the metal sheath and conductor are in parallel and together constitute a conducting path of very low resistance.

Where these CPCs are made off at, say, a switch position or ceiling rose, they should be insulated with a green-colored sleeve.

**b) Conductor in a flexible cable or flexible cord**. The requirement is that the CPC should have a cross-sectional area equal to that of the largest associated circuit conductor in the cable or cord. The color of the CPC, which is insulated in this case, is green and yellow.

**c) The separate Cpc**. The requirement in this case is that the CPC should have a cross-sectional area not less than the appropriate value. The minimum size is 2.5 mm2, but in practice the size depends on the size of the associated circuit conductors. The reason for this is that if the circuit conductors are rated to carry I amperes, then the CPC should be able to carry a similar current, in the event of an earth fault, for sufficient time to allow a fuse to blow or a circuit-breaker to open. The resistance of a CPC of a material other than copper should not exceed that of the associated copper conductor.

Additional requirements for the separate CPC are that it. shall be insulated and colored green.

**d) Metal sheath of MICS CABLE**. Where the sheath of MICS cable is used as a CPC, the effective cross-sectional area of the sheath should be not less than one-half of the largest current-carrying conductors, subject to a minimum of 2.5 mm2 ~ requirement is not applicable to MICS cables used in earthed concentric wiring systems.

**e) Conduits, ducting, trunking**, Wiring systems, which comprise metalwork, such as it, trunking, and ducting, are used as the CPC of an installation. The requirement here is he resistance of the CPC should not he more than twice that of the largest current-ng conductor of the circuit. All joints must be mechanically sound and be electrically uuous.

**\dditional Requirements**

**:traneous Metalwork**. The IEE Regulation recommends that extraneous fixed lwork be bonded and earthed. This is particularly important where exposed metalwork of pparatus, which is required by the Regulations to be earthed, might come into contact extraneous fixed metalwork. Two solutions are offered: the bonding of such metalwork, ; segregation. The latter course is often very difficult to achieve and appreciable voltage rences may arise between points of contact. The extraneous fixed metalwork includes ; and exposed metal pipes, radiators, sinks and tanks. where there are no metal-to-metal s of negligible resistance; structural steelwork; and the framework of mobile equipment /hich electrical apparatus is mounted, such as cranes and lifts.

**3athrooms**. Additional precautions are required to be taken to prevent risk of shock in rooms; these places are usually associated with dampness and condensation from steam. athroom is regarded as any room containing a fixed bath hower. First, all parts of a lamp holder likely to be touched by a person replacing a lamp l be constructed 01 or shrouded in, insulating material and, for BC lamp holders, should fined with a protective shield of insulating material. The Regulations strongly recommend lighting fittings should be of a totally enclosed type. Switches or other means of control uld be located so that they cannot be touched by a person using a fixed bath or shower. s means location of the control switch either outside the room itself or be ceiling-mounted h an insulating cord for its operation. No stationary appliances are allowed in the room, ess the heating elements cannot he touched. There should be no provision for socket-lets, except to supply an electric ıver from a unit complying with BS 3052.

**) Bell and similar circuits**. Where a bell or similar circuit is energized from a blic supply by means of a double-wound transformer, the secondary circuit, the core of the nsformers, and the metal casing if any, should be connected to earth.

**Portable appliances**. To reduce the risk of electric shock when portable appliances are ed, the appliance is often supplied with a reduced voltage. A double wound transformer luces the mains voltage to a suitable level. The secondary winding has one point earthed so should a fault to earth occur on the appliance the shock received will be virtually nless. Another method of protecting the user of a portable appliance from electric shock is rovide the appliance with automatic protection. In the event of an earth-fault the supply is omatically disconnected from the appliance.

## 5 Protective Methods

### 5.1 Insulation.

easures to prevent dangerous voltages occurring on exposed talwork of electrical equipment are divided into three classes: earthed equipment; otective insulation extra-low voltage (less than 50 V to earth). The second class (protective ulation) is sub-divided into all-insulated equipment and double-insulated equipment All-ulated equipment is recognized by the majority of Regulations and Specifications as an ernative to earthing. The principles of design of all-insulated equipment are simple and erefore difficult to abuse. It is the only protective measure that will meet all the quirements of safety. The advent in recent years of modem reinforced plastics has met all e practical requirements of strength, stability and incombustibility.

The Factories Act Memorandum on the Electricity Regulations, Regulation 21, covers e precautions to be taken either by earthing or other suitable means to prevent ny metal other than a conductor from becoming electrically charged. The memorandum cognizes the possibility of providing apparatus with covers and handles of insulating aterial, which should also be incombustible and mechanically strong, as an alternative to rting. The recent advances in plastics technology have made available reinforced combustible plastics and polycarbonate material which will withstand mechanical damage etter than many of the average metal enclosures upplied for equipment today.

A British Standards Memorandum sates.

If the outside of the protective case is made entirely of insulating material, to a atisfactory standard, no further protection is necessary.

In general, it is accepted, despite the TEE Regulations' emphasis on the earthing of netalwork, that insulation is a better and more effective method than earthing for medium voltage installations.

The insulation necessary for the proper functioning of electrical equipment and for basic protection against electric shock is known as 'functional' insulation. 'Protective' lation is provided externally to the functional insulation. With 'double' insulation, ssible metal parts are separated from live pans by both functional and protective lation. With 'all-insulated' equipment, all conductive pans are safely and permanently ered with a substantially continuous cover of insulating material. A good example of 'all-lation' is a PVC-sheathed cable. The basic principles of all "totally-insulated' equipment that the protective insulation must not be penetrated by conducting parts, however small, ich could assist a voltage path to the outside of the enclosure in the event of a fault. In lition, it must be impossible for inactive conductive parts inside the totally insulated nponent or enclosure to be connected to an earth conductor.

Double-insulated equipment is marked with the internationally recognized symbol for ss II equipment: two concentric squares. An additional label is also affixed, approved by H.M. Senior Electrical Factory Inspector, to draw attention to the characteristics of the uipment. It states:

e metal mounting plate and other con current carrying metal parts are not connected to rth, and therefore earthing terminals are not provided. Fuses are recognized by the 16th lition of the IEE Wiring Regulations as having a pan to play in the disconnection of circuits which an earth fault occurs. Of necessity, fault currents in excess of the fusing factors of e fuses are required before the device will operate and this requirement itself presents oblems, not least the rise in voltage on protected metalwork, which occurs while the fuse erated. A number of Tables in the IEE Regulations are specifically concerned with the aximum values of earth fault loop impedance for circuits supplying (a) socket outlets and ) fixed equipment. In each of

ese cases, the disconnection times are, respectively, 0.4 second and 5 seconds. Recognizing at the fusing characteristics of different types of fuses vary, even among devices of the same ting, the Regulations offer detailed information regarding the maximum values of earth loop npedance which are not to be exceeded if the disconnection of the faulty circuit is to be chieved in less than the stated times for disconnection.

Fuses, however, do not provide a wholly satisfactory answer to the problem of increasing he safety factor in respect of electric shock from earth-leakage currents. For example, take a 0 A metal sub distribution hoard protected by 40 A HRC fuses with a fusing factor of 1.5. The metal case is caroled by a steel-wire4rnoured cable direct to the consumer's earthing lead. The earth loop test at 3 times the rated current of the circuit gives an impedance of 2 ohms nd the circuit protective conductor is satisfactory at one

ohm. If an earth-fault of negligible impedance occurs (at 240 V) then a current of 120 A ows. This current through the I-ohm CPC impedance will raise the potential of the steel enclosure of the board to 120 V above the consumer's main earth potential for the time taken or the fuse to blow, about 20 seconds.

Any increase in the earth leakage impedance due to a partial earth fault or arcing causes a lower current to flow for a longer time. If the total earth-loop impedance the impedance of the partial earth fault, is 3 ohms, the fault current will be 80 And the board metal enclosure will rise to 80 V above earth for more than four minutes while the fuse melts. During this time a person could receive a dangerous or fatal shock on touching the board metalwork.

Fuses do not provide sensitive protection, whether or not they are of the semi-enclosed type of cartridge fuses with fusing factors which exceed [5. The rapid cut-off of earth fault current, which is desirable for protection against serious electric shock, can be achieved only with earth-fault loops of much lower impedances now called for by the IEE Regulations. Indeed, lower impedance values are advised for industrial premises, in which the maximum earth-fault loop impedance should be equal to:

phase-to-neutral voltage

___________________________ohms

Minimum fusing current x 2

Fuses are insensitive devices because they must operate above the full-load current of the protected circuit, and also have an appreciable time lag even on higher currents.

Circuit-breakers over current circuit-breakers, like fuses, do not altogether provide a satisfactory protection against earth-leakage currents, The IEE Regulations, however, recognize that these protective devices offer some degree of protection; and in view of the low tripping factors of these devices they are in many ways better than fuses. it is generally accepted that protection can be provided by over current circuitbreakers in situations where the level of earth fault current available to operate the device exceeds 1.5 times the tripping current of the device.

Equipment in which extra-low voltage supplies are used have the disadvantage that, to achieve modem power requirements, impracticably high currents are involved and applications are restricted to control circuits, small portable tools, lighting circuits and the

/irtually complete safety from shock to earth, however, can be provided by limiting the e to earth to a non-lethal value. A large nunber of es at 55 V or less to earth have been proved to be almost free from electrical accidents. V. systems should be used wherever practicable for socket outlets and in dangerous ions. The cost involved in purchasing low-voltage appliances, and the problems raised creased loading, limit the use of F. L.V. voltages to a small ortion of the instances in which protection is required.

**Earth-Monitoring Devices And Portable Equipment**

applications such as the protection of portable equipment where (due to the use of ble or trailing leads) the reliability of the circuit protective conductor may by suspect, ct methods of protection are required. The use of E.L. V. supplies is not always ticable. If an earth fault occurs whilst an appliance is being handled, neither a fuse nor an r current circuit-breaker may operate quickly enough to protect the user. If the actual fault ent is only of the order of three times the fuse retiring (a good rule of thumb limit) the can easily take a matter often seconds or so to blow - a time delay which may welt have l consequences. Again, if the circuit of an appliance becomes completely opencircuited, an th fault on an appliance may leave its casing alive at a voltage to earth which is almost al to the phase-to-neutral voltage of the supply. This condition is by no means uncommon h portable and transportable equipment where the earthing conductor of the flexible cable y break or come adrift from its terminal. Special risks arise when the appliance is held in hand.

Earth-monitoring devices are designed to ensure that earth connections to particular ns of an installation exist during the time it is energized. A small current is made to flow und a circuit consisting of the earth, and pilot conductors and the trip coil of a circuit-eaker. The trip is prevented from operating while the coil is energized. But as soon as the onitoring circuit is opened, the circuit-breaker is tripped. Earth monitoring requires an dditional conductor and special socket-outlets; installation costs are thereby increased. The ystem is insensitive to appreciable impedances in the monitoring circuits and completely so resistance or open-circuit in the earth path before the monitored circuit.

The use of the 'Butcher' system of protection for portable appliances involves a centre-apped isolating transformer and a voltage operated earth-leakage circuit-breaker. Socket outlets are supplied at 240 V. The advantage of this method of protection is that if an earth fault occurs (even if it is only due to someone touching a live conductor) the earth-leakage nust return to the transformer via the trip coil of the circuitbreaker. Hence, provided operating current of the trip coil is below the lethal limit of body current, it is cally impossible to receive a lethal shock from any of the socket outlets supplied from ting transformer.

**rth-Leakage Circuit-Breakers**

akage and earth-fault protection are systems of protection arranged to disconnect the automatically from an installation or circuit when the earth-leakage or earth-fault exceed predetermined values. Similarly, protection is offered when the voltage n non current-carrying metalwork of the installation and earth rises above a rmined

alue. Such a system may be made to operate more rapidly and at lower values of e or fault current than one depending on over current protective devices such as fuses, l trips etc. Automatic protection is therefore used where the impedance of the earth-oop limits the current flowing in it to a value less than three times the current rating of se of 1.5 times the over current setting of the circuit-breaker.

-leakage or earth-fault protection is generally effected by means of a device known as an leakage circuit-breaker (ELCB). There are two types; (i) the fault-voltage and (ii) the al-current.

i) **Fault-voltage operated ELCBs** are units designed to be directly responsive to fault ges appearing on protected metalwork. Their primary function is to give protection st earth-leakage shock risk. If the only connection to earth is through the ELCB, leakage nts of as low as 50 mA will produce immediate circuit isolation. The fault-voltage ELCB nds for its operation on a voltage which, existing between the apparatus to be protected the general mass of earth, is itself dependent not only on the circuit-breaker, but also on -electrode resistance. Depending on design, the units trip at 24 V to earth with a 200-ohm electrode, or 40 V with a SOO-ohm earth electrode. The ELCBs are instantaneous in ation. The nonnal operating time is less than one cycle.

The unit consists of an operating or trip coil, which is connected between a reference h-electrode and the protected metalwork of the installation. Any fault current, which ears in the metalwork, will flow through the coil to energize it and trip the circuit-breaker solate the faulty circuit from the supply. In present-day practice, there are two conditions which the fault-voltage ELCB may function:

trip coil is connected between an earth-electrode and the metal to be d, which are not otherwise connected with earth.

The trip coil is connected in earth-electrode with the metal to be protected, which is in unavoidably connected directly with earth, e.g. a metallic waterpipe system.

making the earth connection, care is taken to ensure that the earth electrode of CB is at least 2 meters away from any buried metalwork, or the consumer's earth le, if one is installed. As far as possible, the operating coil of the unit should carry any irrent, which occurs, and not by-pass it by means of another path. The effect of l' earth connection is to deprive the operating coil of the necessary current which is d to trip the circuit-breaker.

nits are generally provided with a test switch. The primary purpose of this switch is to he existence of an adequate earth path. Failure of the unit to trip indicates potentially ous conditions in the installation such as excessive earth-electrode resistance or a earth lead. The test switch also checks that the sensitivity of the tripping mechanism is . The switch, generally a push-button, connects a highohmic value resistance in series e live conductor and the operating coil to allow ent current to flow to operate the circuit-breaker.

ne fault voltage ELCB is susceptible to nuisance trapping, because it is not selective in ion and will trip out if the installation metalwork becomes live, irrespective of the of the leakage current. This gives rise to several problems. It is virtually impossible to vide large installations, because of the difficulty in isolating sections of installation vork associated with individual earth-leakage circuit-breakers. This difficulty applies qual force to the parallel condition of a number of installations in the same building, as is encountered with flats. Even when the dwellings are quite separate, trouble has encountered with a common vater pipe transmitting faults from one house to another.

This particular disadvantage may lead to another difficulty if the installation on which a fault occurs does not have adequate earth-fault protection. The leakage current the first dwelling may then flow to earth through the trip coil of the fault-voltage ELCB second earth through the trip coil of the fault-voltage ELCB in the second dwelling. effect of this fault condition is a bum-out of the trip coil.

The protection offered by the fault-voltage ELCB is ideally suited to the small country-ge installation: relatively remote from other dwellings, with poor earthing facilities and out a piped water supply. The most awkward problem associated with these units is g a suitable location for the reference earth electrode. It must be located outside the ance area of any metallic pipes or gas pipes or any other metalwork associated with the lation. This problem has recently become particularly acute in recent years with the bonding of water pipes to the electrical earth-continuity system, which automatically s from the installation of immersion heaters in household hot-water tanks.

**ii) A residual-current ELCE** is a device consisting of a transformer having opposed ings, which carry the incoming and outgoing current of the load. In a healthy circuit, e the values of current in the windings are equal, their magnetic effects cancel out in the sformer core. A fault causes an out-of-balance circuit condition and creates an effective netic flux in the core which links with the turns of a secondary winding and induces an in it. The secondary winding is permanently connected to the trip coil of the circuit ker. When the circulating current reaches a pre-determined value, it pulls out the release h to open the main contacts which are normally held closed against strong springs.

In contrast to the fault-voltage ELCB, this type can he used to provide criminative protection for individual circuits. In practice, the normal order of sensitivity ges from about one ampere out-of-balance, for a 15 A unit, up to about 3 A out-of-balance a 60 A unit.

These units are also known as 'low-sensitivity units' to distinguish them from the 'high-sitivity units'. The latter units operate within 1125 of a heart cycle and can detect a fault rent of 30 mA to earth or less. The operating time is in the region of 30 milliseconds. rtain units are available which do not require an earth connection; they rely for their eration on the actual fault current to earth through a person's body. The rapid time of eration, however, ensures that no electrical accident occurs.

One fault found with these high-sensitivity units is that they are also susceptible to what called nuisance tripping. This occurs because the units can detect very low currents of the rder of 25-30 mA, which are often found as normal leakage current from, say, cooker boiling lates and immersion elements.

Regulation 4 13-02-16 indicates that a residual current device shall be used only where ne product of its operating current in amperes and the earth-loop impedance in ohms does not xceed 50. Where such a unit is used, the consumer's earthing terminal shall be connected to a uitable earth electrode. It is recommended that the operating current of a residual-current levice should not exceed 2 per cent of the normal rates current of the circuit. Operating currents less than 500 mA is not regarded as necessary unless the value of earth-loop mpedance is such that a lower operating current is essential.

wever, residual-current devices of 30 mA sensitivity are coming into general use of their reliability, the simplicity of their installation, and their low cost. They are y recommended because they are considered effective in providing more positive on. They are also suitable for earthing installations having loop impedances of 80 less, and are regarded as being effective in reducing fire risks.

ices of below 500 mA sensitivity fail into two broad groups: those requiring l amplification, and those using a combination of permanent and electromagnetic The latter are independent of the electrical supply for their operation. The electrically ed types have a wide range of loadings and interruption ratings. Primary windings are essary: the load cables are simply taken through an aperture in the core of the nner. The magnetically assisted types depend on delicate tripping mechanisms and are re subject to the effects of vibration and shock. They require primary windings, which limit their load capacity and makes them vulnerable to thennal and magnetic stresses hey are subjected to high fault currents. They are satisfactory where conditions are not dangerous.

Response tunes of 30 to 50 ma are common to most sensitive relays and the maximum severity that can be experienced on metalwork protected by these units is well within its of safety prescribed by the International Labor Office (500 mA sec at SO mA, to 50 c at 600 mA).

sensitivity units are particularly recommended for protection in laundries, boiler s and for electrically heated food-trolleys as used in hospitals. They are also ideal for nting the ignition of concentrations of explosive vapors by sparking along earth-fault and at the same time avoid the sudden interruption of the supply to an operating theatre an operation is in progress. Circuits to operating theatres are fed from an isolating onner with a 40-ohm resistor, having its mid-point earthed, connected across the output nals. This limits the maximum earth-fault current and energy to small values. And the y need not be interrupted until it can be manually discontinued, without danger or venience to the patient and operating staff, to enable the fault to be removed. Healthy langerous conditions are indicated by the use of indicating lamps (colored green and red ctively).

**Earth Testing**

IEE Regulations requires that tests he made on every installation to ensure that the ing arrangement provided for that installation is effective and offers the users of the llation a satisfactory degree of protection against earth-leakage currents. The following individual tests prescribed by the Regulations.

**Circuit-Protective Conductors**

Regulation 7 13-02-01 requires that every circuit-protective conductor (CPC) be to verify that it is electrically sound and correctly connected. The IEE Regulations nce Notes on inspection and testing give details on the recognized means used to test PC. For each final circuit, the CPC fonns part of the earth-loop impedance path, its se being to connect all exposed conductive parts in the circuit to the main earth tenninal CPC can take a number of fonns. If metallic conduit or trunking is used, the usual figure mic resistance of one meter length is 5 milliohms/m.

Generally if the total earth-loop impedance (Zn) for a particular final circuit is within aximum Zs limits, the CPC is then regarded as being satisfactory.

However, some testing specifications for large installations do require a separate test ach CPC to be carried out. The following descriptions of such tests refer to a.c. llations.

**2Reduced A.c. Test**

ertain circumstances, the testing equipment in the a.c. test described above is not always lable and it is often necessary to use hand-testers, which deliver a low value of test current e frequency of the mains supply. After allowing for the resistance of the test lead, a value impedance of 0.5 ohm maximum should be obtained where the CPC, or part of it, is made n steel conduit. If the CPC is in whole or in part made of copper, copper-alloy or minum, the maximum value is one ohm.

Direct current. Where it is not convenient to use a.c. for the test, d.c. may be used ead. Before the d.c. is applied, an inspection must be made to ensure that no inductor is orporated in the length of the CPC. Subject to the requirements of the total earth loop pedance, the maximum values for impedance for the CPC should be 0.5 ohm (if of steel) or e ohm (if of copper, copper-alloy or aluminum).

The resistance of an earth-continuity conductor, which contains imperfect joints, varies th the test current. It is therefore recommended that a d.c. resistance test for quality be ade, first at low current, secondly with high current, and finally with low current. The low-rrent tests should be made with an instrument delivering not more than 200 mA into one m; the high-current test should be made at lOA or such higher current as is practicable. The en-circuit voltage of the test set should be less than 30 V. Any substantial variations in the ngs (say 25 per cent) will indicate faulty joints in the conductor; these should be ied. If the values obtained are within the variation limit, no further test of the CPC is ssary.

**Residual Current Devices**

Regulation 713-12-01 requires that where an RCD provides protection against ect contact, the unit must have its effectiveness tested by the simulation of a fault ition. This test is independent of the unit's own test facility. The latter is designed for use ne consumer who is advised to ensure that the RCD trips when a test current, provided by ternal resistor, is applied to the trip-coil of the unit. Thus, on pressing the 'Test' button the should trip immediately. If it does not it may indicate that a fault exists and the unit ıld not be used with its associated socket-outlet, particularly if the outlet is to be used for loor equipment.

e RCD has a normal tripping current of 30 mA and an operating time not eeding 40 ms at a test current of 150 mA.

RCD testers are commercially available, which allow a range of tripping currents to be lied to the unit, from 10 mA upwards. In general the lower the tripping current the longer will be the time of disconnection.

It should be noted that a double pole RCD is required for caravans and caravan sites and for agricultural and horticultural installations where socket-outlets are igned for equipment to be used other than 'that essential to the welfare of livestock.

**.4 Earth-Electrode Resistance Area**

The general mass of earth is used in electrical work to maintain the potential of any rt of a system at a definite value with respect to earth (usually taken as zero volts). It also ows a current to flow in the event of a fault to earth, so that protective gear will operate to olate the faulty circuit. One particular aspect of the earth electrode sistance area is that its resistance is by no means constant. It varies with the amount of oisture in the soil and is therefore subject to seasonal and other changes. As the general ass of earth forms part of the earth-fault loop path, it is essential at times to know its actual lue of resistance, and particularly of that area within the vicinity of the earth electrode. The effective resistance area of an earth electrode extends for some stance around the actual electrode; but the surface voltage dies away very rapidly as the istance from the electrode increases. The basic method of measuring the earthelectrode istance is to pass current into the soil via the electrode and to measure the voltage needed produce this current. The type of soil largely determines its resistivity. The ability of the l to conduct currents is essentially electrolytic in nature, and is therefore affected by isture in the soil and by the chemical composition and concentration of salts dissolved in contained water. Grain size and distribution, and closeness of packing are also ntributory factors, since these control the manner in which moisture is held in the soil. any of these factors vary locally. The following table shows some typical values of soil sistivity.

Table of soil-resistivity values

| Type of soil | Approximate value in ohm-em |
|---|---|
| Marshy grund | 200 to 350 |
| Loam and clay Chalk | 400 to 15, 000 |
| Sand | 6000 to 40,000 |
| Peat | 9000 to 800,000 |
| Sandy gravel rock | 5000 to 50,000 |
| | 100,000 upwards |

When the site of an earth electrode is to be considered, the following types of soil re recommended, in order of preference:

1. Wet marshy ground, which is not too well drained.
2. Clay, loamy soil, Arabic land, clayey soil, and clayey soil mixed with small quantities of sand.
3. Clay and loam mixed with varying proportions of sand, gravel, and stones.
4. Damp and wet sand, peat.

Dry sand, gravel, chalk, limestone, whinstone, granite and any very stony ground should be avoided, as should all locations where virgin rock is very close to the surface.

Chemical treatment of the soil is sometimes used to improve its conductivity Common salt is very suitable for this purpose. Calcium chloride, sodium carbonate and other substances are also beneficial, but before any chemical treatment is applied it should be verified that no corrosive actions would be set up, particularly on the earth electrode. Either a hand-operated tester or a mains-energized double-wound transformer can be used, the latter requiring an ammeter and a high-resistance voltmeter. The former method gives a direct reading in ohms on the instrument scale; the latter method requires a calculation in the form:

Voltage

sistance = ___________

Current

e procedure is the same in each case. An auxiliary electrode is driven into the ground at a tance of about 30 meters away from the electrode under test (the consumers electrode). A rd electrode is driven midway between them. To ensure that the resistance area of the first o electrodes do not overlap, the third electrode is moved 6 meters farther from, and nearer the electrode under test. The three tests should give similar results, the average value being ken as the mean resistance of the earth electrode.

One disadvantage of using the simple method of earth electrode resistance easurement is that the effects of emfs (owing to electrolytic action in the soil) have to be taken into account when testing, also there is the possibility of stray earth currents eing leakages from local distribution systems. Because of this it is usual to use a commercial strument, the Megger earth tester being a typical example.

### .6.5 Earth-Fault Loop Impedance

Regulation 113-11-01 stipulates that where earth-leakage relies on the operation of ver current devices, an earth-loop impedance test should be carried out to prove the ffectiveness of the installation's earthing arrangement. Although the supply authority makes s own earth-loop impedance tests, the electrical contractor is still required to carry out his wn tests. The tests carried out by a supply authority will not absolve the contractor from his egal responsibilities for the safe and effective operation of protection equipment which he nay install as part of a wiring installation. This applies both to new installations and xtensions to existing installations. Earth-loop impedance tests must be carried out on all xtension work of major importance to ensure that the earth-continuity path right back to the onsumer's earthing terminal is effective and will enable the protective equipment to operate nder fault conditions.

### 4.6.6 Phase-Earth Loop Test

This test closely simulates the condition which would ariseshould an earth- fault occurs. The instruments used for the test create an artificial fault to earth between the 'me and earth ductors, and the fault current, which is limited by a resistor or some other means, is wed to flow for a very short period. During this time, there is a voltage drop across the ting device, the magnitude of which depends on the value of the earth loop. The voltage p is used to operate an instrument movement, with an associated scale calibrated in ohms. contribution of the consumer's earthing conductor should be not more than one ohm. This o ensure that the voltage drop across any two Points on the conductor is kept to a low value l, under fault conditions there will be no danger to any person touching it at the time of the t.

e testers, which are commercially available, include both digital readouts and analogue les, and incorporate indications of the circuit condition (correct polarity and a proven earth nnection). The readings are in ohms and represent the earth-loop npedance (Zs). Once a reading is obtained, reference must be made to IEE Regulations bles 4IBI to 41D, which give the maximum values of Zs which refer to: (a) the type of over rrent device used to protect the circuit and (b) the rating of the device. Reference should so be made to any previous test reading to see whether any increase in Zs has occurred in e meantime. Any increase may indicate a deteriorating condition in the CPC or earthing lead nd should be investigated immediately. The values of Zs indicated in the Tables are aximum values which must not be exceeded if the relevant circuits are to be disconnected ithin the disconnection times stated.

Before a test is made, the instrument should be 'proved' by using a calibration unit, which vill ensure that it reads correctly during the test. It is also recommended that the serial umber and type or model used for the test should be recorded, so that future tests made by he same tester will produce readings which are correlated.

**4.7 Protection**

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

The initial design of any installation must take into account the potential effects on wiring system and equipment of environmental and working conditions. BS 5490 is a British Standard concerned with protection against mechanical, or physical, damage and gives full of the Index of Protection Code to which all electrical equipment must conform. The s based on a numbering system with each number indicating the degree of protection .

rst characteristic numeral indicates the protection level offered to persons against t with live or moving parts inside an enclosure and also the protection of the enclosure gainst the ingress of solid bodies, such as dust particles. The numbers range from 0 (no ion of equipment against the ingress of solid bodies and no protection against contact ve or moving parts) to 6 (complete protection).

The second characteristic numeral indicates the degree of protection of equipment t the ingress of liquid and ranges from 0 to 8. Thus an equipment with IP44 means that s protection against objects of a thickness greater than 1.0 mm and ist liquid splashed from any direction.

**Mechanical Damage**

This tenn includes damage done to wiring systems, accessories and equipment by t, vibration and collision, and damage due to corrosion. Typical examples of ntion include single-core conductors in conduit and trunking, the use of steel enclosures lustrial situations, the proper supporting of cables, the minimum bending radius for s, the use of annored cables when they are installed underground, and the supports ed for conductors in a vertical run of conduit and trunking.

Some types of installation present greater risks of damage to equipment and cables than s, for example on a building or construction site and in a busy workshop. In general, the ng conditions should be assessed at the design stage of an installation and, if they have een foreseen, perhaps due to a change of activity in a particular area, further work may eded to meet the new working conditions.

Electrical fires are caused by (a) a fault, defect or omission in the wiring, (b) faults or ts in appliances and (c) mal-operation or abuse of the electrical circuit (e.g. overloading). electrical proportion of fire causation today is around the 20 per cent mark. The majority stallation fires are the result of insulation damage, that is, electrical faults accounting for y three-quarters of cables and flex fires. Another aspect of protection against the risk of s that many installations must be fireproof or flameproof~ The definition of a flameproof is a device with an enclosure so designed and constructed that it will withstand an nal explosion of the particular gas for which it is certified, and also prevent any spark or e from that explosion leaking out of the enclosure and igniting the surrounding atmosphere. In general, this protection is effected by wide-machined flanges, which damp or otherwise quench the flame in its passage across the metal, but at the same time allows the pressure generated by the explosion to be dissipated.

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

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

There are two types of flameproof apparatus: (a) mining gear, which is used solely with armored cable or special flexible; and (b) industrial gear, which may be used with solid-drawn steel conduit, MIMS cables, aluminum-sheathed cables or armored cables. Mining gear is known as 'Group l' gear and comes into contact with only one fire hazard: firedamp or methane. Industrial gear, on the other hand, may well be installed in situations where a wide range of explosive gases and liquids are present. Three types of industrial hazards are to be found: explosive gases and vapors inflammable liquids - and explosive dusts. The first two hazards are covered by what is called 'Group II' and 'Group III' apparatus. Explosive dusts may be of either metallic or organic origin. Of the former, magnesium, aluminum, silicon, zinc and ferromanganese are hazards, which can be minimized by the installation of flameproof apparatus; the flanges of which are well greased before assembly. The appropriate British Standard Code of Practice is BS 5345 Electrical Apparatus and Associated Equipment for Use in Explosive Atmospheres of Gas or Vapor, other than Mining Applications.

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

All conduit installations for hazardous areas must be carried out in solid-drawn 'Class B', h certified draw-boxes, and accessories. Couplers are to be of the flameproof type with a nimum thread length of 50 mm. All screwed joints, whether entering into switchgear, ction boxes or couplers, must be secured with a standard heavy locknut. This is done to sure a tight and vibration-proof joint, which will not

cken during the life of the installation, and thus impair both continuity and flameproof ss. The length of the thread on the conduit must be the same as the fitting plus sufficient for e locknut. Because of the exposed threads, running couplers are not recommended. ecially designed unions are manufactured which are flameproof and are designed to nnect two conduits together or for securing conduit to an internally threaded entry.

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

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

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

eing essentially a closed installation, a flameproof conduit system may suffer condensation. topper boxes prevent the passage of moisture from one section to Draining of condensate om an installation should be carried out only by an person. Alterations or modifications ust never be made to certified gear. Because flexible metallic tubing is not recognized as ameproof, to movable motors (e.g. on slide-rails) should be of the armored flexible cable ith suitable cable-sealing boxes fitted at both ends. It is necessary to ensure that, as far as ossible, contact between flameproof

pparatus, conduit, or cables, and pipe work carrying inflammable liquids should be avoided. f separation is not possible, the two should be effectively bonded together. When maintaining quipment in hazardous areas, care should be taken to ensure that circuits are dead before emoving covers to gain access to terminals. Because flexible cables are a potential source of anger, they should he inspected frequently. All the equipment should be inspected and xamined for mechanical [units, cracked glasses, deterioration of well-glass cement, lackened conduit joints and corrosion. Electrical tests should be carried out at regular ntervals.

### 4.7.2 Corrosion

Wherever metal is used, there is often the attendant problem of corrosion and its prevention. There are two necessary conditions for corrosion:

(a) A susceptible metal and (b) a corrosive environment. Nearly all of the common metals corrode under most natural conditions. Little or no specific approach was made to the study of corrosion until the early years of the nineteenth century. Then it was discovered that corrosion was a natural electrochemical process or reaction by which a metal reverts in the presence of moisture to a more stable form usually of the type in which it is found in nature. It was Humphry Davy who suggested that protection against corrosion could result if the electrical condition of a metal and its surroundings were changed.

Corrosion is normally caused by the flow of direct electrical currents, which may be self-generated or imposed from an external source (e.g. an earth-leakage fault-current). Where direct current flows from a buried or submerged metal structure into the surrounding electrolyte (the sea or soil), no corrosion takes place. It is an interesting fact to record that where a pipe is buried in the soil there is a 'natural' potential of from O.3V to -0.6 V between the pipe and the soil. In electrical installations, precautions against the occurrence of corrosion le:

The prevention of contact between two dissimilar metals(e.g. copper and aluminum).

The prohibition of soldering fluxes, which remain acidic or Corrosive at the completion ɔldering operation (e.g. cable joint).

) The protection of cables, wiring systems and equipment against the corrosive action of oil and dampness, unless they are suitably designed to withstand these conditions.

) The protection of metal sheaths of cables and metal conduit linings where they come ɔntact with lime, cement and plaster and certain hard woods (e.g. oak and beech).

) The use of bituminized paints and PVC over heating on metallic surfaces liable to sion in service.

Dampness can affect conduit Systems both on the inside and externally. With enamel es, it is important that the enamel is preserved as intact as possible, particularly at the l entry to fittings. Also, the breaking of the galvanizing finishing

on galvanized conduit presents a great risk of rusting simply because this type of conduit pecified to cope with damp or wet working conditions. Thus any breaks in the finish be repaired with the use of a suitable paint to prevent rusting

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

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

While copper is fairly resistant to corrosion, there are situations in which the material orrode. This is why MI copper-sheathed cables are provided with PVC

sheaths and clips are also covered with PVC.

**Under-Voltage**

s an electrical protection required by Regulation 552-4, and is a provision in cuit of an electric motor to prevent automatic restarting after a stoppage of the due either to an excessive drop in the supply voltage, or a complete failure of the , where unexpected restarting of the motor might cause injury to an operator. These s are found in dc motor starters (No-volt releases). In ac contactor starters failure of the stops the motor.

**Over Currents**

Over current protection is one of the requirements of Statutory and the IEE Regulations. Regulation 130-03-01 states: 'Where necessary to prevent danger, every installation and circuit thereof shall be protected against over current by devices which (i) will operate atically at values of current which are suitably related to the safe current ratings of the t, and (ii) are of adequate breaking capacity and, where appropriate, making capacity. ient over currents are due mainly to motor-starting currents and the inrush currents iated with such apparatus as capacitors, transformers and fluorescent lamp and other arge lighting circuits. Sustained over currents are the result of indiscriminate additions to isting circuit. Generally termed 'overloading', the additions cause current to flow, which excess of the current rating of the cables. Some transient currents can become sustained. dental single-phasing on three phase induction motors means the loss of one phase ed by a fuse blowing in one of the lines; faulty operation of a contactor; or an open-circuit e of the motor windings. Contactor faults and fuse blowing are frequent. When single ing occurs, the motor, in order to produce its designed performance characteristics, finds it mist draw more current from the supply. With normal motor designs, a 5 per cent lance in supply voltage can lead to a 15-20 per cent increase in the current in one phase ull load. This fault condition is very dangerous and can cause damage to the and nvenience to the user (unless, of course, the motor circuit has been provided with uate protection which disconnects it from the supply). The main problem associated with le-phasing is that because in practice the majority of small and medium-phasing induction ors operate on no more than 50-80 per cent full load, they will continue to run in a single-sed condition. Single-phasing stator damage is characterized by signs of uneven rheating. If an attempt is made to start the motor with a single-phase condition, damage occur to the squirrel-cage rotor in the form -of localized overheating caused by high uced rotor-bar currents in positions corresponding to the number of poles in the stator ding.

## 7.5 Short-Circuit Currents

short-circuit occurs for any of the following reasons

Incorrect connection during the initial installation or after a modification.

Failure of the insulation of cables or equipment.

Excessive arcing leading to a phase-to-phase or phase-to-earth short.

Disconnection of a cable or wire leading to a phase-to-phase or phase-to-earth

ort.

The energy of the s40rt-circuit, which can be taken as a link between points of ffering potentials of negligible resistance or impedance, is fed from the point of supply, sually via the h.v. /Lv. transformer. This energy is dissipated in the complete distribution ystem as IR losses. The sub-division of this energy is in proportion to the resistance and eactance of the various items in the system or circuit, e.g., h.v. reactance, transformer eactance, and busbar and cable resistance and reactance. The value of the maximum short-ircuits at any point in the installation can be calculated, provided the following data are nown:

. The high-voltage MV A rating.

. The transformer rating and its percentage impedance.

. The total resistance and reactance of the busbar and cables up to the point of the installation vhere the value of the theoretical fault current is required.

The items which have the greatest influence on the value of the fault are:

**1**. The percentage impedance and current rating of the transformer and the econdary circuit ohmic resistance.

**2**. The remaining items affect the fault current by usually less than 20 per cent. hese can be taken into account or omitted at discretion.

For example, a 415 V. three-phase transformer of 750 kV A and a 4.75 per cent mpedance (this value is standard for the majority of transformers conforming to the lectricity Boards T.L. Specification) will have a full-load current of 1050 A at unity power actor. The 4.75 per cent impedance means that if the secondary terminals of the transformer vere bolted together and the primary voltage was reduced to 4.75 per cent of its rated voltage, hen the rated secondary full-load current of the transformer would flow in the short-circuited onnection. Thus, when full voltage is applied, the short circuit will be:

Rated current x 100/4. 75

h in the above transformer will be

050 x 21 =22 kA (r.m.s.).

a cable resistance of 0.01 ohm per phase is added, the fault current will be reduced to -14 kA.

his value of the fault current is the symmetrical fault level in amperes (r.m.s.) and the thermal damage to equipment.The asymmetrical fault current depends on the ance of the circuit and the point on the sine wave at which the fault occurs. This peak t, under the worst conditions can reach twice the symmetrical fault current peak value x 1.414 = 2.828 x r.m.s. symmetrical value.In the example given above the worst netrical current would be 62 kA (peak).

The asymmetrical short-circuit current is responsible for the mechanical damage which s from the high oscillating mechanical forces (proportional to 12) set up between two ctors which are adjacent and parallel to each other. For example, if nitial peak current 31 MVA system is about 110 kA, this would mean a force in kg per un of bus bars, assuming a 76 mm spacing between conductors, of about 100 kgf, which her repealing or attracting depending upon the direction of the currents at the instant of circuit.

In summary, when a short-circuit fault occurs, for any given supply voltage, two main rs will be seen to control the severity of the fault. These are the magnitude and the power factor of the fault current. In this connection, two terms are worthy of prospective and actual values of fault current.

The 'prospective' level of fault current is the r.m.s. symmetrical current that would flow circuit due to the nominal applied voltage when a short-circuiting link of negligible dance replaces the designed circuitry. In other words, it corresponds to a circuit condition ro fault impedance. In a similar manner, the prospective value of power factor is assumed tain with zero fault-impedance.

The actual current, however, can never exceed the prospective value and usually it is iderably less. Almost any fault has some impedance, to which must be added the dances and resistances, which exist in the circuit. These additional elements usually bine to limit the actual fault current to about 30 per cent or less the full prospective value; also raise the actual short-circuit power factor to a value which approaches unity. The ct of a low power factor can be serious, because in such a circuit condition, there will be a rable amount of stored energy to be dissipated during the time taken to clear the fault.

**otection By Fuses**

The fuse offers a means of protection against over currents. In its basic form, the nsists of a short length of suitable material, often in the form of a wire, which has a nall cross-sectional area compared with that of its associated circuit conductors. When nt flows which is greater than the current rating of the wire, the wire will get hot and, ally, melt. This occurs because its resistance per 'unit length is much greater than that ssociated circuit conductors (so giving greater power loss and heat), and because this ed beat is concentrated in the smaller volume of the material.

**'use Terminology**

The following terms are used in connection with fuses:

**Current rating**. This is a current, less than the minimum fusing current, stated by the acturer as the current that the first will carry continuously without deterioration. The t rating is chosen in consideration of the temperature rise while the fuse element carries ecified current Because a fuse is a thermal device, the ambient temperature m which it es is very important. Where fuses are used in high-temperature situations, a derating of signed current rating may be necessary for ambient temperatures of 35°C and above.

**Applied voltage**. It is important that the applied voltage of a circuit does not exceed the ge rating of any fuse used for its protection. This is because a fuse is particularly voltage-ive immediately before and after it operates to break the circuit current. The rated ge is that assigned to the fuse by the manufacturer to indicate the nominal system voltage which the fuse may normally be associated. It is important to note that the voltage rating use may not apply equally to both a.c. and d.c. circuits.

**Breaking capacity rating**. This is a prospective current stated by the manufacturer as greatest prospective current that may be associated with the fuse under prescribed itions of voltage and power factor or time constant. Fuses of different breaking-capacity gs are available according to the several categories listed in British Standards. The gory of duty assigned to a fuse should take into account the prospective current and the ient behavior of the circuit during shortcircuits conditions (for instance, the degree of nmetry in the a.c circuits).

8.2 Rated Minimum Fusing Current

s is the current, which will cause the fuse to operate in a specified time under prescri 1 ed ditions.

) Fuse

is is the ratio, greater than unity, of the rating minimum fusing current to the current ting.

A fuse, which carries its rated current, does not suffer any deterioration. However, if the rrent carried approaches the rated minimum fusing current, it will eventually reach a nperature at which its fuse element will begin to melt. A fuse is not intended to be run at rrents between the values given for prolonged periods; if this does happen the aracteristics of the fuse will change.

Let-through energy this is the specific energy to which a protected circuit is subjected uring the pre-arcing time.

### 4.9.1 Rewirable Fuses

The rewirable fuse is a simple device. It consists of a short length of wire,generally of inned copper. The current at which the wire will melt depends on the length of the wire and ts cross-sectional area. If it is very short, the beat generated (12R watts) will be conducted away from the wire by the contacts or securing screws. Also, if the wire is open to the atmosphere, it will cool much more quickly than if it was surrounded by a thermal insulator such as an asbestos sleeve. In view of these and other factors, the rewirable fuse is a device with a number of variables, which affect its performance; anyone, or all, of these can differ between similar fuses. Though the rewirable fuse is cheap, involving only the replacement of the fuse-element, it has a number of disadvantages and limitations:

1. The fuse element is always at a fairly high temperature when in use. This leads to oxidization of the element material, which is a form of corrosion, and results in a reduction in the cross-sectional area of the element, so that it fuses at a current lower than its rating. Fuses, which carry their rated current for long periods generally, require replacement at two-yearly periods, otherwise nuisance blowing will be experienced on the circuit.

2. It is very easy for an inexperienced person to replace a blown fuse element with a wire of incorrect size or type.

3. When a fault occurs on a circuit, the time for the fuse to blow may be as long as several seconds, during which time considerable electrical and physical damage may occur to

rcuit conductors and the equipment being protected.

4. The calibration of a rewirable fuse can never be accurate, which fact renders this type se unsuitable for circuits, which require discriminative protection.

5. Lack of discrimination means that it is possible in certain circuit conditions for a 15 ed fuse-clement to melt before a 10 A-rated element. Also, the type is not capable of iminating between a transient high current (e.g., motor starting current) and a continuous current.

6. Owing to the fact that intense heat must be generated in the fuse-element before it perform its protective action, there is an associated fire risk. Also in this context, should ault current be particularly high, though the wire fteaks, an arc may still be maintained by circuit voltage and flow through the air and metallic vapor. The rewirable fuse has thus a rupturing capacity, which is the product of the maximum current, which the fuse will rrupt, and the supply voltage. The capacity is measured in kV A. Generally a limit of 5000 A is placed on rewirable fuses.

Semi-enclosed or rewirable fuses are not regarded as devices, which will offer sely, controlled protection, particularly where important circuits are concerned. As seen n the above, they cannot be guaranteed as to their performance, which is why their use is alized in the IEE Wiring Regulations.

### 9.2 Cartridge Fuses

The cartridge fuse was developed to overcome the disadvantages of the rewirable type of e, particularly because with the increasing use of electricity, the energy flowing in circuits s growing larger. The main trouble with the rewirable fuse was oxidation and premature lure even when carrying normal load currents, causing interruptions in supply and loss of oduction in factories. Thus the fully enclosed or cartridge fuse came into existence. Non-terioration of the fuse-element was, and stilt is, one of the most valuable features of this pe of fuse. The advantage also of the cartridge fuse is that its rating is accurately known. owever, it is also more expensive to replace than the rewirable type and it is also unsuitable r really high values of fault current.

It finds common application for domestic and small industrial loads. As houseservice itout fuse links (BS 88), they are used by Supply Authorities as services fuses. Ferrule-cap ise links (BS 1361) are used in domestic 250 V consumer control units, switch fuses and witch splitters. The domestic cartridge fuse links (BS 1361) were designed for use pecifically in 13 A fused rectangular-pin plugs. Domestic cartridge fuse links (BS 646) are use specifically in 15 A, round-pin plugs where the load taken ftom a 15 A socket-outlet is ll (e.g. radio, TV or table lamp), in relation to the

A fuse which protects the circuit at the distribution board. In addition, there are other tridge fuses for particular applications (e.g. in fluorescent fittings). All these cartridge fuses so designed that they cannot be interchanged except within their own group.

Essentially the cartridge fuse is a ceramic barrel containing the fuse element. The barrel filled with non-fusible sand, which helps to quench the resultant arc produced when the ment melts.

The short-time characteristics of the HRC fuse enable it to take care of shortcircuits nditions when used to protect motor circuits. Tests have shown that HRC fuses have a ort-circuit fusing time as low as 0.0013 second. On large ratings they will open circuit in s than 0.02 second. HRC fuses are discriminating, which means that they are able to stinguish between a high starting current taken by a motor (which lasts only a matter of conds) and a high fault or overload current (which lasts longer).

**10 Selection of Fuses**

The selection of a particular fuse for circuit-protection duty should never be a sual matter. The important factors to be considered are:

1. The Voltage Rating of the fuse which should be not less than the highest voltage obtainable between the conductors of the circuit.

2. Ampere Rating of the fuse should be suitable for the circuit and the type of apparatus to be protected

3. The Service Condition& These fall into two categories. First, the ambient temperature hat will affect the operational characteristics of the fuse. In high ambient temperatures the urrent-ratings of fuses should be reduced to ensure that the total temperature does not exceed he permitted values calculated for materials and insulation. The total temperature varies with use size and application and it is thus advisable for advice to be sought from manufacturers egarding the derating factors to be used. Secondly, an altitude of 1000 meters will result in he derating of a fuse.

**.10.1 Protection By Circuit-Breakers**

There are few industrial power switching requirements which cannot be dealt with by standard circuit-breakers. And for the smaller-rated loads such as commercial and domestic installations, the molded-case and miniature circuit-breakers are finding an increasing role to play for both the control and protection of circuits. Essentially, switchgear links the various ents of an electrical system together to provide normal operational facilities and permit nmediate disconnection of faulty apparatus and circuits. To do this it must be able to rm some or all of the following duties without damage to itself or other equipment and out danger to personnel:

arry full-load currents continuously.

ithstand normal and possible abnormal system voltages.

pen and close the circuit on no-load.

Make and break on normal operating currents.

lake short-circuit currents.

reak short-circuit currents.

he different switching devices available, all must perform (1) and (2); the isolating switch ormally designed to perform (3) although certain types can perform (4); the circuit-breaker st perform (3), (4), (5) and (6).

The actual making or breaking of the circuit takes place at the contacts; these must be e to carry continuously the full-load current of the circuit without excessive temperature , i.e. they must have a very low contact resistance; they must also be able to pass, in a ction of a second, from the state in which they carry a short-circuit current with a negligible t drop to the state in which they can withstand full system voltage across them. This rapid ange can only be effected as a result of the arc that takes place when current-carrying ntacts are separated. The main problem in switch, circuit-breaker or fuse design is the oper control of this arc. But other important associated problems are the provision of equate insulation, the countering of the high mechanical forces due to short-circuit currents, d the devising of suitable operating mechanisms for rapidly closing and opening the ntacts. The most arduous duty is the interrupting of short-circuit currents.

the medium voltage range (up to 660 V) oil-and air-break circuit-breakers are For plications at 3.3 kV, 6.6 kV and 11 kV, oil-break, air-break and (for special applications at 1 kV) air-blast circuit-breakers are also available. The several factors which affect the election of the right circuit-breaker for a particular application include: service voltage and oad current; the type of duty; environment of installation; ancillaries and other features equired. BS 116 and BS 936 contain appendices, which gives guidance on the selection of ircuit-breakers. They contain details of methods, which should be used to determine the ymmetrical current; BS 116 also gives guidance on the calculation of asymmetrical fault urrent. BS 162 Electrical Power Switch gear and Associated Apparatus coordinates equirements of circuit breakers and those of associated apparatus and provides information neral matters appertaining to switchgear.

Circuit-breakers must not he allowed to carry current in excess of their rated current as normally have little, if any, overload capacity. An approximate of symmetrical fault nts to be anticipated on systems supplied through can be made by neglecting the dance on the supply side of the transformers. The formula used

$$\text{t MV A} = \frac{\text{Transformer rated kV A}}{\text{\% impedance of the transformer x 10}}$$

Allowance has also to be made for the fault contribution of rotating machinery. It irable to take advantage of the reduction in fault current, which can occur on medium tage Systems due to the impedance of all connections.

Various types of operating mechanisms are used in circuit-breakers. Manual chanisms are not recommended for use in 11 kV and 6.6 kV installations are the fault els exceed 150 MV A. Where manual mechanisms are required, it is necessary to ensure t the design incorporates features such as instantaneous trip and trip-free features, which 1 add greatly to the safety with which circuit-breakers can with their fault-making duty. For nanual spring-operated arrangement, a handle is provided whereby a spring is charged and eased in one stroke. A charged spring closes the circuit-breaker, the energy of the spring ving been checked on short-circuit tests, thus ensuring safe closing of the circuit-breaker ring fault conditions. The band-charged spring arrangement is similar, except that the arging of the spring is carried out manually and the closing of the circuit-breaker is carried ıt by a separate action to release the charged spring. In the spring motor-wound rangement, manual charging is dispensed with.

mongst the service conditions which must be taken into account when considering the hoice of suitable equipment are the temperatures and climatic circumstances under which it intended to operate. For instance, when circuit-breakers are installed in places subject to bnormally low temperatures, a suitable low-freeze oil should be selected not only for the reaker itself but also for the over current dashpots. To prevent the oil from freezing, heaters re sometimes built into the circuit-breaker tanks. Special low-temperature greases may be equired to maintain the correct functioning of mechanical parts. On the other hand, where the num temperature exceeds 40°C, or the average ambient over a 24-hour period exceeds derating of the standard circuit-breaker may be necessary.

Where excessive dust exists, as in steel Millis, cement works and boiler houses, special utions may be necessary and the breaker may be required to be enclosed in a recognized sure. In general, oil circuit-breakers, because they tend to be totally enclosed, are more ant of dusty and dirty locations. Than are their air-break counterparts. Application oors involves equipment specifically designed for outdoor use or, alternatively, the ication of indoor equipment within weatherproof enclosures.

### .2 Moulded Case Circuit-Breakers

The molded case circuit-breaker is designed to provide circuit protection for ium-voltage distribution systems. It is defined as an air-break circuit-breaker, designed to e no provision for maintenance, having a supporting and enclosing housing of molded lating material forming an integral part of the unit. It is capable of making, carrying and aking currents under specified abnormal circuit conditions such as those of short-circuit. usual current ratings are fromlO-1200 A up to 600 V in single-, double-, or triple-pole s with a breaking capacity of up to 50kA (r.m.s.) at power factors of 0.25 to 0.4.

The breakers were developed because of the advantages they had over ordinary tches and fuses in the control and protection of circuits and apparatus They have a eatable non-destructive performance, safety in operation under fault conditions, and, in the e of the triple-pole circuit-breaker, simultaneous opening of all three phases, even under a gle-phase fault to earth. All breakers have, as a standard feature, the ability to disconnect omatically under overload conditions, usually up to 8-10 times the rated current via netal over current trips in each pole. An essential feature of all mounded-case circuit-eakers is the quick-make-and-break operation of the contacts, independent of operating rsonnel, and a high contact pressure; both these features are essential ifhigh fault currents e to be switched safely.

The function of the breaker trip elements is to trip the operating mechanism in the event a prolonged overload or short circuit. To accomplish this, a thermal-magnetic rip action is normally provided. The thermal trip action is achieved through the use of a metal heated by the load current. On a sustained overload, the bimetal will deflect, causing e operating mechanism to trip. Because bimetals are responsive to the heat generated by the urrent flow, they allow a long time delay on light overloads and have a faster response on eavier overloads. Magnetic trip action is achieved through the use of a simple electromagnet ries with the load current and thermal device. This provides instantaneous tripping when urrent reaches too high a value for the thermal trip element to provide sufficiently rapid ing.

## 0.3 Miniature Circuit-Breakers

These devices are in many ways similar to the molded-case breakers. The dividing between the two types of breaker is drawn on a basis of current rating and shortcircuits acity. The m.c.b. has found an increasing role for final circuit protection in domestic and nmercial installations. It offers these circuits better protection, and a better fire risk tection, particularly when overload conditions are being considered, than the fuse ernative.

## .11 Discrimination

The term discrimination is applied to a circuit condition, under the circumstances of an cess-current flow, where, for example, one fuse blows before another. If the blown fuse is e 'minor' fuse in the circuit, then the other, the 'major' device has discriminated with the inor unit. In practice, if two fuses appear to have discriminated with each other, the criterion discrimination is, however, not merely that one is opencircuited and the other is not. It is sential for the unblown fuse to continue to give satisfactory service after the fault has been moved and the minor fuse replaced.

Discrimination may be defined as 'the ability of fuses and circuit-breakers to interrupt e supply to a faulty circuit without interfering with the source of supply to the remaining ealthy circuits in the system'. This requires that a larger fuse nearer to the source of supply vill remain unaffected by fault currents, which would cause a smaller fuse, further from the ource of supply, to operate.

In practice, fairly good discrimination, as required by Regulation 533-01-06 can be achieved between different fuse ratings when the prospective current of the circuit is small and the fuse operates in more than approximately 0.02 second. If, however, the prospective current is large, resulting in operating times of less than 0.1 second, discrimination will be more difficult and a ratio of not less than 2: 1 between major and

minor fuses may become necessary. Reference to standard time/current curves will enable a fairly close approximation of discrimination to be made for operating times of not less than 0.02 second.

n practice, too, it is often the case that a system of circuits contains protection offered .C fuses, semi-enclosed fuses, and circuit-breakers; circuits are also protected by one only or two or more m combination. In these circumstances the advice of fuse facturers should be sought. Where circuit-breakers and HRC fuses are used, either as eans of protection or in combination, it is a relatively simple matter to choose ratings to ve discrimination by referring to standard curves issued by the manufacturers.

**Relays**

ver current protective relay has been a common means of protection against s currents for large and small systems for many years and is now finding new cations. With the ever-growing size of electrical power systems and the increasing use of onnection, it is often difficult to secure the really accurate and discriminative nnection of the supply when circuit conditions become unhealthy. Relays are used in iation with circuit-breakers which are tripped by a series connected, direct acting, over nt trip oil. This device is electromagnetic in operation and consists of either an romagnet and armature, or a solenoid with a central plunger. The coil of the romagnet (or the solenoid) consists of a few turns of conductor connected in series with main circuit. The armature (or plunger) is arranged to operate the circuit-breaker trip hanism. The operating current of such a device is usually adjustable by means of variation ther the magnetic gap or a restraining spring.

Some items of electrical equipment, such as transformers, can carry an overload for a t time without damage; this time will decrease with heavier overloads. The overload trip in consequence, is required to impose a time delay between the incidence of an overload the tripping of the circuit-breaker, this time delay being arranged to decrease with easing current, Le., an inverse-time characteristic. One method of obtaining this racteristic is by means of an oil dashpot.

disadvantage of the direct-acting overload trip-coil is that it has to carry the main circuit rent and it must also be capable of carrying, without damage, shortcircuit currents. Instead, direct-acting overload device can be arranged to operate via a current-transfonner. This thod has advantages where it is necessary to insulate the trip device from the main circuit. addition, since a current-transfonner will saturate on heavy over-current, it is possible to ain overload settings which are lower than those obtainable with a series connected coil; is because the saturation of the current-transfonner relieves the coil of the overload trip ice from the stresses due to short-circuit currents. When current-transfonner operation is ed, it is possible to obtain a time lag on overloads by means of a time-limit fuse. This fuse is ected across the trip coil, and consequently the overload trip device is prevented from ting until the fuse melts due to a current in excess of its rating. The thennal characteristic e fuse provides a satisfactory time lag for overload currents.

Perhaps the most familiar relay is the induction-type over current relay It consists of an ating coil which is tapped, the tapings being brought out to a plug bridge; the tapings espond to different current settings. A closed secondary winding is wound on upper and r magnets. The fluxes produced by the primary (operating coil) and secondary windings separated in phase and space and produce a torque, as in the shaded-pole induction disc or. The disc experiences a torque, which depends on the current, and will move against a aining spring provided the current, is large enough. The time of travel is adjustable by ns of a stop, which adjusts the distance of disc travel to contacts connected to the trip coil he associated circuit-breaker.

The thennal relay is suitable for the protection against serious overload of such items equipment as motors and transfonners. The relay has a relatively slow action, due to the nnal lag. But this can be an advantage where a time lag is needed in the circuit. The relay l therefore not operate on momentary overloads such as occur during motor starting. An vantage is that the overload is integrated over a period of time, since the heating action is ntinuous due to the fact that the relay does not reset immediately load is removed, but only covers gradually as the bimetal cools down.

The thennal relay action is not suitable for coping with short-circuit currents, which ust be interrupted as quickly as possible. Some types of relay incorporate an instantaneous gh-set element which operates immediately a predetennined value of current is exceeded, as presented by short-circuit conditions.

The use of relays for the protection of motors is becoming common place. Overload otection is arranged to carry the starting current for the starting period without tripping. In e case of direct-on-line starting, the initial starting current may be
as high as 8 x F.L., and the starting period as long as 25 seconds. Under these conditions the rotection is usually by means of thermal relays. Instantaneous high-set over-current devices re recommended for short-circuit currents.

## 4.13 Protection For Cables

Cables require protection against excess currents , from small overloads to the highest values of short-circuit currents. The introduction of plastics in recent years has resulted in cables insulated and sheathed with such materials being more sensitive to over nt conditions than rubber-compounds, paper and mineral insulation. The HRC fuse can ide short-circuit protection up to the highest values of fault currents and, in tion, limit the fault energy so as to keep the fault damage to a minimum.

zone in which protection is probably most difficult to provide is at the low load/long-time region. Investigations have proved that PVC-insulated cables are able to stand currents not exceeding 150 percent of their rating for 4 hours when installed in air. st other forms of cable in common use have a higher withstand value than this; the lication in this is that an over current protective device which will protect PVC and similar les will, within reason, be satisfactory for other types.

en a capacitor is switched into a circuit, a heavy inrush of current results and to ensure that es do not blow unnecessarily in these circumstances higher rated fuses are required in the cuit. In general, if the fuses fitted are rated at 125-150 per cent of

capacitor rating, nuisance blowing of the fuses will be avoided. Transformer and orescent lighting circuits may also require higher rated fuse links to deal with the inrush rrents associated with this class of gear. Fuse links with a rating about 50 per cent greater an the normal current of the apparatus to be protected are usually found to be satisfactory.

ne use of semi-conductor devices for rectification and for system control purposes has creased rapidly in recent years, with specific problems in their protection. The result has een the introduction of specialized ranges of fuses. The semi-conductor device has a low ermal withstand compared with its rating and is, therefore, capable only of accepting a omparatively small input of fault energy. Protection must be capable of rapid operation and rovide a high degree of energy limitation. The special HRC fuse is the only protective device t present capable of being matched to a semi-conductor. When such a fuse does blow, it is xtremely important that it is replaced with a fuse link of exactly the same make and type. Published data are available which discuss the various types of basic circuitry at present in use.

# CHAPTER 5: ILLUMINATION INSTALLATION

It is the most using illumination system of electric energy in todays. Such that reason it necessary to produce the light installation to respond the diverse demands inside and side of building .

Illumination installation works with alternative current exept spuralreason. Its linked ectly into long by neuter switch illumination installation.

Lamps can be controlled by switch at light installation.

e distinction between terms used in illumination often presents difficulties. The following le shows units and definitions.

| rm | Definition | Symbol | Unit |
|---|---|---|---|
| minous intensity | Light source | I | Candela |
| minous flux | Light emitted from a source | Φ | Lumen |
| umination | Density of luminous flux falling on a working plane | E | Lumen/m2 or Lux(lx) |

## .1 Inverse Square Law

The illumination falling on a working plane varies inversely as the square of the istance of that surface from the light source.

The illumination (in lumens per square metre) at a point below a light ource on a horizontal work plane (Fig. 16.2) is calculated as follows:

$$E = \frac{I}{d^2}$$

Where;

E = illumination in lumens per square metre,

= luminous intensity in candelas,

d = distance from light source in metres.

**sine Law**

The illumination at a point on a horizontal working plane which is at an
o the light source is calculated as follows:

$$E = \frac{I}{d^2}.COS\Theta$$

**her Factors in Illumination**

**enance Factor**

This factor (a number without units) takes into consideration losses in light output due

(a) ageing of lamps and

(b) dirt collecting on lamps and fittings.

The maintenance factor taken between 1.25-1.75.

**icient of Utilization**

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

(a) light output of lamp (lumens),

(b) the type of reflector used,

(c) height and spacing of fittings,

(d) the colouring of the walls, ceiling, and floor.

These factors are taken into consideration in the coefficient of utilization (a number out units)

ficient of Utilization= (Light received on working plane)/(light output of lamps)

**rage lighting calculations**

$$k = \frac{(axb)}{h(a+b)}$$

$$\Phi_T = \frac{(E.A.d)}{\eta}$$

$$n = \frac{\Phi_T}{\Phi_L}$$

re,

utilisation factor

= the total luminance flux

the area of working place

= luminance flux of one lamp

room index

the length of the working place

the width of the working place

the height of the working place

illumination

maintenance factor

= utilization factor

## 4 Lamps

### .1 Incandescent Lamp

Principle of Operation . Light energy is produced by passing a current through a nductor (usually tungsten) enclosed in an evacuated glass bulb. The operating temperature 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 allows an increased perating temperature (about 2500°C) giving increased light, as it minimizes the losses from e filament due to evaporation. The life of the lamp is also increased (minimum 1000 hours).

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

The efficiency of the lamp is approximately 121m/W.

NOTE. The efficiency of a lamp is detpendent on

(a) the rating of the lamp (efficiency increases with lamp size);

(b) the age of the lamp;

) the operating voltage

Efficiency is decreased when run at values less than rated voltage.

**: Discharge Lamp**

Principle of Operation. When an electrical pressure is applied across a glass tube aining a certain gas (e.g., neon) an electrical discharge takes place and energy in the form ight is given off. The gas under these conditions is said to be ionized. The electrical nections inside the tube are called electrodes.

Ionization is caused by the movement of electrons in the gas. These electrons nbard' the atoms of gas and free other electrons. Light is given off during this' nbardment'.

The flow of current through the tube increases with ionization as a 'chain reaction' es place:

Increased ionization.

Decreased resistance of the discharge path.

Increased current.

The cycle is repeated.

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 xide 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 isintegrate

**.4.3 The Flourescent Lamp**

It's the lamp which operates between 4-120 watt according to the principles of lecharge tube. It's the more preferable than the other lamps due to have more light receiver, egular light distribution and become long life but there is only one drawback, you need subsidiary vehicles.

It can operate when we bind 2x20 watt fluorescent lamps on the ballast with 40 watt as a series. But this bindings don't preferable because of line voltage doesn't less than 220V and in the case of any out of order on the switch or the lamp, It can not use as a system.

The flourescent lamps are fed by three phased systems especially we may usually cross to this system at the workshops.

If the lamps are fed by one phase which is called stroboskobic event, that may cause ccidients because this event shows us as objectşves are not moving whether moves or is to turning adverse direction. To prevent this kind of accident we must do system is that three phased distribution illuminations at workshop in where works with iery.

**The Lamps With Mercury Steam** :

It is the decharge lamps with high-pressure. Decharge comes out and illuminates when ry steams as a result of fire the mercury inside the decharge. Illuminations value is so s a watt/lumen we use it on the streer illuminating. In addition of Fleman, the kind self-vithout ballasts of system advanced further.

**The Sodium Steamed Lamps**

It is the decharge lamps when it uses at normal voltage. Volfram Flemans are covered rium oxide. When it get warm under low pressure , sodium turns to steam inside the and it illuminates. For instance, we may come across them at traffic avenues and the places in where we need to see capability.

**Arc Lamps**

It is the source of light which emits most powerfull light on certain point. It operates t 65 volt direct current (DC) and alternative current (AC) . Firstly each one contacts each r and send current. Two coal electrot light come out after arc maker calls.

It is connecting parallel and differential, series to fix the intermediates among coals. tive electrots are thick because of more eroded in the direct current. But in the alternative ent both electrode has thickness.

**7 Light Pipes**

It is the decharge lamp which has basic gases with low-pressured operating in high age to use for advertising. It is related the lengths of operating high voltage value.

# CHAPTER 6: CIRCUIT CONTROL DEVICES

**uit Conditions Contacts**

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

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

ome switches are operated by an electromagnet; these include contactors used for ing heating loads, large lighting loads and are also incorporated in motor starters. e specialized type of electromagnet-operated device is the relay.

Although circuit-breakers tend to be regarded as devices used for protection of circuits st over current (overload and short-circuit), they also perform a duty as switches.

**1.1 Circuit conditions**

Electrical circuit has its own characteristics, which means that it will show some iar electrical property depending on the type of load connected to it. For instance, a it which has a purely resistive load (a resistor used as a lamp filament, or heater element) show a current, which rises when the circuit is first switched on and then falls as the ent reaches its normal operating condition. This means that the switch or other circuit-rol device must at least be able to break the full-load current taken by the resistor. This ies particularly if the circuit has a de supply. 11 however, the supply is ac, when the ch contacts separate there may be a small arc drawn out between the contacts. This acteristic is even more noticeable when the resistor is in the form of a coil (e.g. in a fire element). This effect is caused by the electrical property, which a coil has in an ac circuit. called the 'inductive effect'.

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

he circuit has a capacitor included in it, it will also show certain characteristics, nay be shown as arcing between switch contacts as they separate. The most ced effects of the inclusion of an inductor or a capacitor in a circuit is seen when an y is used. However, small capacitors are often used connected across switch contacts b the sparking caused by contact separation. Used in this way they are sometimes adio-interference suppressors' (e.g. in fluorescent lamp switch starters)

ıus, before a circuit-control device is chosen the circuit to be controlled must be so that the device can handle, without damage to itself or the associated circuit wiring, ditions in the circuit when it is connected or disconnected from its supply. The sections chapter, which follow, indicate the type of control for a circuit which various devices

**ontacts**

s in existence an extremely wide range of electrical-contact types used to control the f an electric current in a circuit. The action of any pair or pairs of contacts is (a) to to allow the current to flow, and (b) to 'break', to prevent the current flow. When this is contained in a specially designed wiring accessory or apparatus it becomes one of the forms of devices used to control circuits: switches, contactors, circuit-breakers and the

The basic requirements of any pair of contacts are (a) low resistance of the contact al and (b) low resistance between the two contact surfaces when they meet to make the t.

When these requirements are satisfied, the two main factors, which lead to switch es, are very much reduced. Though one can choose a low-resistance contact material copper), one cannot always control the amount of pressure required to keep the two ct surfaces closed sufficiently to reduce what is called 'contact resistance'. A switch, for nce, which is operated many times, will eventually reach a state when its springs become ened, with the result that pressure of the contacts is lost to such an extent that heat is rated and a breakdown of the switch follows.

The higher the resistance of contact material the more heat (12R walls) there will be n a current passes along it. The second factor involved in the design of switch contacts is amount of pressure needed to keep the two contact surfaces together. All circuit-control ces, which meet the relevant specifications of the BSI, are tested very rigorously to ensure they stand up to more wear and tear than they would meet with in normal use. Even so, t contact troubles met with in practice involving the use of circuit-control devices can be ed to insufficient contact pressures.

The material most often used for contacts is copper; this is because it is available in nmercial quantities and it has a very low resistance. The terminals associated with the tacts, to which cables and wires are attached, are most often made from brass or phosphor nze. These two metals are much harder than copper and so can withstand a certain amount rough handling with screwdrivers when wiring is being carried out.

The insulating materials used in circuit-control devices include vitrified ceramic (for the ses of switches), bakelite (for switch covers and cases), nylon and mica (for carrying the ving contacts of switches), and insulating oil (used in oil-break circuitbreakers)

In many circuit-control devices silver is used, either as a contact facing, or as the ntact itself the material has a resistance lower than that of copper; it also has high heat-ssipation characteristics and is, for this application, economical to use. Motorcontrol itches sometimes have contacts of silver-cadmium oxide to reduce thetendency to weld gether with heat.

Liquid mercury is also used in special switches called mercury switches. This material s a low contact resistance and a high load-Carrying capacity, and can be used in situations ith ambient temperatures from about - 17 to 204 DC.

Because the contacts are the bean of the circuit-control device; it follows that their rfaces must be kept clean at all times. Cleaning fluids are available for this purpose. Other aintenance points are the periodic tightening up of conductor terminals and connections, and nsuring that springs have not weakened through use, or that cam surfaces have not become vorn.

There are two classes of duty for circuit-control devices: (a) light current and (b) eavy current. Into the first class fall generally lighting switches, relays and bell pushes; the econd class includes contactors and circuit-breakers.

### 6.2 Circuit-Breakers

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

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

A circuit-breaker is selected for a particular duty, taking into consideration the wing. (a) The normal current it will have to carry and (b) the amount of current which the ly will feed into the circuit fault, which current the circuit-breaker will have to interrupt out damage to itself.

The circuit-breaker generally has a mechanism which, when in the closed position, s the contacts together. The 'contacts are separated when the release mechanism of the iit-breaker is operated by hand or automatically by magnetic means. The circuitbreaker magnetic 'tripping' (the term used to indicate the opening of the device) employs a noid, which is an air cooled coil. In the hollow of the coil is located an iron cylinder ched to a trip mechanism consisting of a series of pivoted links. When the circuit-breaker osed, the main current passes through the solenoid. When the circuit rises above a certain ie (due to an overload or a fault), the cylinder moves within the solenoid to cause the ched linkage to collapse and, in turn, separate the circuit-breaker contacts.

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

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

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

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

**.3 Contactor**

When a switching device has one or more switches in the form of pivoted contact arms, which are actuated automatically by an electromagnet, the device is known as a contactor. The coil of the electromagnet is energized by a small current, which is just sufficient to hold he pivoted contact arm against the magnet core, and in turn so hold the contacts (fixed and moving) together. Contactors are used in an extremely wide range of applications. They fall into two general types: (a) 'maintained' and (b) 'latched-in'. In the first type, the contact arm is maintained in position by the electromagnet. In the latched-in type, the contact arm is retained in the closed position by mechanical means.

Contact design and material depend on the size, rating and application of the contactor. Contactors with double-break contacts usually have silver cadmium-oxide contacts to provide low contact-resistance, improve arc interruption and anti- welding characteristics. Large contactors with single-break contacts use copper contacts for economy. Usually single-break contacts are designed with a wiping action to remove the copper-oxide film which readily forms on the copper tips. Since copper oxide is not a good conductor, it must be eliminated in this way for good continuity.

When the contacts open, an arc is drawn between them. The longer the arc remains, the more the contact material is consumed, and so the shorter is the contact lift-. The arc can be extinguished by two means: long contact travel, or by use of arc interrupters.

The typical arc interrupter is called a 'blow-out' coil. This uses magnetic means to force arc and its products away from the surfaces of the contacts, thus lengthening and akening the arc so that it is eventually extinguished.

Contactors are used to control heating loads, and are often used in conjunction with time itches and thermostats, which close or open the electromagnet current as required. With the ntactor, a small current (for the electromagnet) can be used to control a relatively large rrent in another circuit.

**4 Thermostat**

The thermostat is used to control an electric heating appliance or apparatus so that definite temperature is maintained. it is, therefore, a switch, which operates with a change in mperature and is used in the temperature control of rooms, water-heaters, irons, cooker vens and toasters. It maintains a temperature within defined limits by switching off the ppliance when a higher temperature is attained, and switching it on gain when a lower temperature has been reached.

The methods used to operate the switch contacts of a thermostat include the expansion f a metal rod, expansion of a liquid or a gas or the bending of a bimetallic strip. Applications fthese methods are, respectively, water-heaters, ovens and irons.

The illustrations show the basic elements of each type of thermostat.

The speed of response of a thermostat to a change in temperature depends to a large extent on the material used to convey the heat, called the controller. A thermostat whose hermally sensitive elements are directly opposed to the heat transfer medium will respond faster than one whose elements are shielded by a housing. Liquid-filled systems respond more quickly than gas-filled systems.

**6.5 Switches and Switch Fuses**

A switch is a device for controlling a circuit or pan of a circuit. The control function consists of energizing an electrical circuit, or in isolating it from the supply.

The type of switch generally indicates the form, which this control takes. For instance, a single-pole switch (usually called 'one-way') controls the Jive pole of a supply. A double pole switch controls two poles.

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

Switches are designed for use on de and/or ac. In a de circuit, when the switch contacts parate, an arc tends to be drawn out between the separating surfaces. This arc is xtinguished only when the contacts are for enough apart and when the breaking movement is uick.

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

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

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

The single-pole, one-way switch provides the ON and OFF control of a circuit from one position only. When the switch is closed, the lamp is on; when the switch is open, the lamp is off One-way switches are mounted with the word TOP', which appears on the back of the switch plate, at the top. This is to ensure that when the switch rocker is in the up position, the circuit is disconnected from the supply. The switch is, of course, connected in connected in the phase conductor only. The double-pole switch is used in any situation where the voltage of the neutral conductor of a supply system is likely to rise an appreciable amount above earth potential: use of the double-pole switch means that a two-wire circuit can be completely isolated from the supply. The usual application is for the main control of sub-circuits and for the local control of cookers, water-heaters, wall-mounted radiators, and other fixed current using apparatus. The double-pole switch is often used for the 'master' control of circuits, the switch being operated by a 'secret key' attachment, and in consumer units for the complete isolation of an electrical installation from the supply.

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

Though the two-way switch is still used extensively for stair lighting, it is also to be d wherever it is necessary to have one or more lights controlled from anyone of two tions. They are nowadays to be found in bedrooms (door and bedside), long hails (at each and particularly in any room with two entry doors (one at each door). In design, the ch has four terminals, two of which are permanently connected ther inside the switch by a small copper bar on what is called the 'bar' side. One of the bar inals is blanked off 40 form a non-separable contact. The switch feed is taken to the other n terminal on the bar side. The two other terminals are connected to the 'strapping wires'. o-way switches are used in pairs, interconnected so that the switch wire of the light circuit aken from the open terminal on the bar side of the second switch.

The intermediate switch offers control of a circuit from anyone of three positions, the er two positions being at the two two-way switches with which the intermediate switch is st often used. The intermediate wiring circuit is basically a two-way circuit in which the apping wires are cross connected by the two ON positions of the intermediate switch. There two different kinds of intermediate switch, one of which is in common use. It is thus visable to check the type with an ohmmeter, or bell-andbattery set, because the method of nnecting up differs. Shows the two common forms of connection made within each type of itch.

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

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

The switch fuse is often found as the 'main switch', near the supply-intake position. It is unit in which the main switch (for installation control) and the main uses (for the protection of the installation) are combined. In all instances, the switch of the switch fuse cannot be operated when the cover is open, nor can the cover be removed while the switch fuse is closed. The switch fuse, which usually controls a separate n board, is of the double or triple-pole type, depending on the supply system.

ınd triple-pole switches are found in metal-clad units called isolators. An s the fireman's emergency switch, painted red and found beside high-voltage gas-lamps such as neon. Isolators are also used to isolate the supply from motors, and ıd non-portable appliances.

consumer control unit is the most common means used to isolate a complete installation from the supply. It incorporates a double-pole switch and a 'live' busbar the fmal circuits' protection are connected, and either semi-closed es, cartridge fuses, or miniature circuit-breakers the latter becomeing increasingly because of their definite action in the event of overloading and circuit faults, coupled ety in their operation. Allthough originally intended for domestic installations, these being used in commercial and industrial installations where small lighting and power e involved.

e extremely wide range of switchgear types available today can be found in makers' erature, study of which is advised so as to become familiar with what is offered for electrical installations. All circuit-control devices, whether switches or other types, nform to the relevant BS specifications, which thus ensure a minimum guarantee of and suitability for use.

**ecial Switches**

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

Three-heat switch

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

The three-heat switch is essentially a rotary or turn switch. The positions are OFF, , MEDIUM, HIGH. The switches are available as a single-pole type (four terminals) or a e-pole type (five terminals).

switch

indicated by its definition, the time switch introduces a time element' into an cal circuit, so that automatic control of the circuit is available at predetermined times. switches fall into two general groups: spring-driven and motor-driven. The former uses hanism similar to that found in clocks The latter group uses as the driving unit a small c (synchronous) motor whose speed is constant and varies only with the 50 Hz ency of the mains supply. Similar motors are used in electric clocks.

There are many applications for time switches: shop-window lighting, driveway ng, street lighting, staircase lighting in multi-tenanted buildings and heating loads, the being switched on during 'off-peak' periods when a cheaper tariff is available.

The time-switch control of lighting circuits is often found in such particular applications ultry houses, where banks of switches control the lighting to simulate summer-daylight tions and so introduce a 'longer-day'. The same technique is also used in horticulture, to n the growth of seedlings and plants, particularly during off-season periods of the year.

For normal work, the contacts (either single- or double-pole) are silvered copper, or ely silver. For heavy currents, mercury-contact time switches are used.

**Mercury Switch**

This is basically a sealed glass tube with a small amount of liquid mercury inside it The s are fused into the glass. When the tube is tilted, mercury flows over a second tenninal first being in pennanent contact with the mercury). Thus, contact is made to make the it. Mercury switches are made in a very wide variety of types, each type being designed a particular duty and application in mind.

witches of this type have many advantages: low force required to operate them, low act-resistance, high load-carrying capacity, low cost, and a long life because of the -no r' characteristic of the contacts. it is also relatively insensitive to ambient temperature ditions; a range from _4°C to over 204°C has been specified for some switches. Because glass is hennetically sealed, the mercury switch is effectively immune to dust, oil and densation, and can be used where corrosive fumes are present.

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

Because glass is used as the switch container, the contacts are always visible for pection; and mercury tends to resist heat and arc effects. The materials used for the ntacts include tungsten, iron or iron alloys (e.g. nickel-iron) and Mercury pools.

Mercury switches are operated by a tilting motion; the method of mounting a switch on its application, shape of the actuating member, and the motion produced by it. In e of a single-throw switch, the glass tube is tilted from the horizontal. Mountings bimetallic strips, cams and rotating levers. A time-lag element can be introduced by ng the flow of mercury from one position to another; this is done by a wall placed the tube. The wall contains a hole, the diameter of which detennines the amount of elay.

**Rotary Switch**

The rotary or turn switch offers the facility of controlling a large number of s from a local position by using one switch. The three-heat switch is one of the most on examples of the rotary switch. Others include the switches used on switchboards in nction with ammeters and voltmeters on three-phase systems to indicate phase-to-phase ts and voltages.

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

**Micro-Gap Switch**

This switch derives its type name from the fact that when its contacts (usuaUy silver) are they are separated by an extremely smaU gap: anything up \0 3 rom. A.s indicated er in the section on contacts, such switches can be used only on ac circuits. They have y applications apart from 'ac only' lighting circuits.

Thermostats using a 'snap-acting' bimetallic element are in effect micro-gap switches are to be found in the temperature control of irons, toasters, and cooker heating elements. industrial application is where a motor overheats and a bimetallic, snap-acting device switch off the energizing current to stop the motor and so protect its winding.

The snap action is always positive in these switches, no matter how rapidly or how tly the force is applied to the operating button. The button can be moved by a plunger, a f spring, or a roller and a lever.

**.4 Starter Switch**

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

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

**.5 Two-Way-And-Off Switch**

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

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

**.6.6 Series-Parallel Switch**

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

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

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

Relays are either nonnally closed (NC) or nonnally open (NO). In the first type, when coil is energized the contacts are open; the contacts close when the coil is reenergized. In NO relay, the contacts are closed when the coil is energized, and open when it is de-gized. In effect, the relay is an automatic switch. Relays are nonnally designed to operate n a very small current flows in the coil. Thus, a small current can be made to switch a er current on or off just as a contactor functions from a distant point (remote control). y are also used in bell and telephone systems, and have a wide application in industry.

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

Induction and impedance relays operate by the movement of a pivoted disc in the field an electromagnet; the protective device (usually a circuit-breaker) with which these types associated is operated by small contacts on the moving disc which, when they close, trip circuit-breaker. They are used in the protective systems for supply systems, motors, nerators and transformers.

The thermal rel~y consists of a bimetallic strip, which heats up when the operating or cuit current flows through it or through an adjacent heating coil. The bending of the strip uses the contacts to either make or break.

### .7 Fireman's Switch

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

### 6.8 Emergency Switching

his is a requirement of the Wiring Regulations. The switches take the form of large ushroom-head buttons, which can be knocked in the event of an emergency, say, in a orkshop. The switch then disconnects the circuit or machine.

### General Requirements

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

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

All lighting switches must be connected m the phase conductor only and the correct or coding of the connecting wires is required by the Wiring Regulations. Any exposed talwork (such as a metal switch plate) must be earthed. The switch must be of an adequate rent rating. If they are used for inductive loads such as fluorescent circuits, they must be y rated for the value of inductive current taken. If they are not, then they must not carry y more than half their rating, e.g. 2.5 A in the case of a 5 Arated switch. Where switches are ed as isolators for motor circuits, they should be located close to the motor position. If this not possible, the switch handle should be able to be padlocked in the OFF position so that ork can be carried out without fear of the circuit becoming live.

# CHAPTER 7 : DOMESTIC INSTALLATION

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

1- The 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 dublicated if the permission of the Authority is tained.

## 1 Domestic Consumer's Control Unit

This type of unit is usually made up of the following:

a-Main switch (60A) which isolates both the phase and the neutral conductors.

b-One 30A fuse for the cooker circiuti

c-One 30A fuse for the 13Aring circiut (capable of taking two 7/0.85 in cables)

d-One or two 5 A fuses for lighting circuits.

## .2 Loading of Final Sub-circuits

The assumed current demand from points is as follows

| | |
|---|---|
| 15 A socket outlet | 15 A |
| 5 A socket outlet | 5 A |
| 2A socket outlet | at least ½A |
| Lighting outlet | minimum 100 W |

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

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

**omestic Ring Circuit**

Regulations as 'a final sub-circuit in which the current-carry-ing and earth-continuity ıctors are connected in the form of a loop, both ends of which are connected to a single n a distribution fuse board or its equivalent. A spur of a ring circuit shall be a branch having conductors of a cross-sectional area not smaller than that of the conductors ng the ring'.

Cable size: minimum twin 2.5 $mm^2$ and earth p.v.c or t.r.s.

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

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

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

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

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

Apparatus permanently connected to the ring circuit without a fused plug or socket outlet be protected by a local fuse or circuit-breaker with a rating not exceeding 15 A. The ratus must have anjacent controlling switch.

purpose of the ring circuit is:

To minimize trailing flexes.

To take advantage of the fact that all outlets in a domestic installation.

**Domestic Lighting**

Domestic lighting circuits are usually wired in 1 $mm^2$ twin t.r.s. or p.v.c.(twin 1.5 mm may be used). The protecting fuse is generally 5 A (20 mm tinned copper wire or cartridge with white body). Conductors in a lighting final sub-circuit (or any final sub-circuit) uld never be interconnected with other final sub-circuits. For example, a final sub-circuit tral should never be used to feed more than one final sub-circuit. Each neutral conductor uld be connected to its individual terminal at the neutral block: 'bunching' is not mitted. An earthing terminal must be provided at every lighting point. The earth continuity nductor of the final sub-circuit must be connected to this terminal. Nonmetallic switches st also be supplied with and earthing to which the final sub-circuit earth continuity nductor must be connected. The earthing terminal is not required where earthed metal es are used which have a fixing for the metal switch plate giving reliable electrcial contact ween the plate and the metal box.

ight switches are usually of the 5A (A.C.) quick-make-slow-break (Q.M.S.B.) type, flush ounting. Switches used in fluorescent lamp circuits must be capable of carrying twice the rmal circuit current in order to withstand the inductive effect of the choke.

**5 Water Heaters**

omestic water heaters are generally rated at 3kW and are usually supplied from the ring rcuit. Asbestos-covered cable should be used to terminate the conductors at the immersion ater since p.v.c and tir.s cables are normally expected to be used where the surrounding mperature (the ambient temperature) does not exceed 30°C. The temperature range of water eaters is between 43°C and 82°C.

The thermostat, in common withall other switching devices, musts always be fitted in the hase conductor.

**.6 Bathroom**

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

**7.7 Garages**

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

**7.8 Cooker Control Unit**

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

The cooker control unit is generally supplied from a separate way in the consumer's control unit and wired with 10mm² twin and earth p.v.c or t.r.s cable. It is fused at 30A which is sufficient to protect a maximum of 9kW (3-plate cooker). The current demand from a stationary cooking appliance is calculated as follows: 10A+30 per cent of the total remaining ad current. Every stationary cooking appliance in domestic premises must have an nt control switch fitted within 2 m of the appliance.

# APPENDIX ILLUMINATION CALCULATION

## BODRUM KAT

; Muayene($31.92m^2$)

a:4.80m    b:7.85m    h:3m    A:$31.92m^2$

- **Ceiling:** 0.80    **Wall**:0.50    **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm

- $k = \dfrac{axb}{hx(a+b)} = \dfrac{4.8x7.85}{3x(4.8+7.85} = 0.99$

- **Efficiency of Illumination**:

**k: $x_1$**:0.80    **η: $y_1$**:0.29
**k: $x_2$**:0.99    **η: $y_2$**:?
**k: $x_3$**:1.00    **η: $y_3$**:0.33

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.308$$ **η:**0.31

- $\Phi_T = \dfrac{ExAxa}{\eta} = \dfrac{250x31.92x1.25}{0.31} = 32177$

- **n** = $\dfrac{\Phi_T}{\Phi_L} = \dfrac{32177}{4200} = 7.66$    8 Armature

## BODRUM KAT

ografi(48.35m²)

:9m	b:7.7m	h:3m	A:48.35m²

- **Ceiling:** 0.80	**Wall**:0.50	**Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \frac{axb}{hx(a+b)} = \frac{9x7.7}{3x(9x7.7)} = 1.38$
- **Efficiency of Illumination**:

**k: $x_1$**: 1.25	**η: $y_1$**: 0.38
**k: $x_2$**:1.38	**η: $y_2$**:?
**k: $x_3$**:1.50	**η: $y_3$**:0.41

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)}x(y3-y1) = 0.395$$ **η:**0.40

- $\Phi_T = \frac{ExAxa}{\eta} = \frac{250x48.35x1.25}{0.40}$=37773
- **n** = $\frac{\Phi_T}{\Phi_L} = \frac{37773}{4200}$=8.99	9 Armature

## BODRUM KAT

nı Bölümü(31.95m²)

a:6.1m   b:6m   h:3m   A:31.95m²

- **Ceiling:** 0.80   **Wall**:0.50   **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{6.7x4.7}{3x(6.7+4.7)} = 0.92$

- **Efficiency of Illumination**:

**k: $x_1$**: -   **η: $y_1$**:-
**k: $x_2$**: -   **η: $y_2$**:-
**k: $x_3$**: -   **η: $y_3$**:-

- **Interpolation**

$y2 = y1 + \dfrac{(x2-x1)}{(x3-x1)} x(y3-y1) = -$   **η:**0.33

- $\Phi_T = \dfrac{ExAxa}{\eta} = \dfrac{250x31.5x1.25}{0.33} = 30256$

- **n** = $\dfrac{\Phi_T}{\Phi_L} = \dfrac{30256}{4200} = 7.20$   7Armature

## BODRUM KAT

aboratuvar(16.2m$^2$)

a:3.6m b:4.5m h:3m A:16.2m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:300 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \frac{axb}{hx(a+b)} = \frac{3.6x4.5}{3x(3.6+4.5)} = 0.67$
- **Efficiency of Illumination**:

**k: $x_1$**:0.60 **η: $y_1$**:0.23
**k: $x_2$**:0.67 **η: $y_2$**:?
**k: $x_3$**:0.80 **η: $y_3$**:0.29

- **Interpolation**

$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.251$ **η:**0.25

- $\Phi_T = \frac{ExAxa}{\eta} = \frac{300x16.2x1.25}{0.25} = 24300$

- n = $\frac{\Phi_T}{\Phi_L} = \frac{24300}{4200} = 5.78$ 6 Armature

# BODRUM KAT

asta Muayene Odası(16.8m$^2$)

:4.80m b:3.5m h:3m A:16.8m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm

- $k = \frac{axb}{hx(a+b)} = \frac{4.8x3.5}{3x(4.8+3.5)} = 0.68$

- **Efficiency of Illumination**:

**k: $x_1$**:0.60 **η: $y_1$**:0.23
**k: $x_2$**:0.68 **η: $y_2$**:?
**k: $x_3$**:0.80 **η: $y_3$**:0.29

- **Interpolation**

$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.254$ **η**:0.25

- $\Phi_T = \frac{ExAxa}{\eta} = \frac{250x16.8x1.25}{0.25} = 1000$

- n = $\frac{\Phi_T}{\Phi_L} = \frac{21000}{4200} = 5$ 5 Armature

## BODRUM KAT

2. Hasta Muayene Odası(15.3m$^2$)

a:5.1m b:3m h:3m A:15.3m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- **k:axb/hx(a+b):**5.1x3 /3(5.1+3)=0.63
- **Efficiency of Illumination**:

**k: $x_1$**:0.60 **η: $y_1$**:0.23
**k: $x_2$**:0.63 **η: $y_2$**:?
**k: $x_3$**:0.80 **η: $y_3$**:0.29

- **Interpolation**

$$y2 = y1 + \frac{(x2 - x1)}{(x3 - x1)} x(y3 - y1) = 0.236$$ **η**:0.24

- $$\Phi_T = \frac{ExAxd}{\eta} = \frac{250x15.3x1.25}{0.24} = 19922$$

- $$n = \frac{\Phi_T}{\Phi_L} = \frac{19922}{4200} = 4.74$$ 5 Armature

## BODRUM KAT

asta Muayene Odası(17.1m$^2$)

a:3.80m b:4.5m h:3m A:17.1m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{3.8x4.5}{3x(3.8+4.5)} = 0.69$
- **Efficiency of Illumination**:

**k: $x_1$**:0.60 **η: $y_1$**:0.23
**k: $x_2$**:0.69 **η: $y_2$**:?
**k: $x_3$**:0.80 **η: $y_3$**:0.29

- **Interpolation**

$$y2 = y1 + \frac{(x2 - x1)}{(x3 - x1)} x(y3 - y1) = 0.257$$ **η:**0.26

- $\Phi_T = \dfrac{ExAxd}{\eta} = \dfrac{250x17.1x1.25}{0.26} = 20553$
- $n = \dfrac{\Phi_T}{\Phi_L} = \dfrac{20553}{4200} = 4.89$ 5 Armature

## BODRUM KAT

Hasta Muayene Odası(13.5m$^2$)

a:3m b:4.5m h:3m A:13.5m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{3x4.5}{3x(3+4.5)} = 0.60$
- **Efficiency of Illumination**:

**k: $x_1$**: - **η: $y_1$**:-
**k: $x_2$**: - **η: $y_2$**:-
**k: $x_3$** :- **η: $y_3$**:-

- **Interpolation**

$$y2 = y1 + \frac{(x2 - x1)}{(x3 - x1)} x(y3 - y1) = -$$ **η**:0.23

- $\Phi_T = \dfrac{ExAxd}{\eta} = \dfrac{250x13.5x1.25}{0.23} = 18343$
- **n** = $\dfrac{\Phi_T}{\Phi_L} = \dfrac{18343}{4200}$ =4.367 4 Armature

## BODRUM KAT

azan dairesi(22.5m$^2$)

a:3.02m b:7.5m h:3m A:22.5m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:1x80w
- **Armature Light Flux:$\Phi_L$**:5600 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{3.02x7.5}{3x(3.02+7.5)} = 0.7$
- **Efficiency of Illumination**:

**k: $x_1$**: 0.6 **η: $y_1$**:0.23
**k: $x_2$**: 0.7 **η: $y_2$**:?
**k: $x_3$** :0.8 **η: $y_3$**:0.29

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.53$$ **η**:0.53

- $\Phi_T = \dfrac{ExAxd}{\eta} = \dfrac{250x22.5x1.25}{0.53} = 13266.5$
- n = $\dfrac{\Phi_T}{\Phi_L} = \dfrac{13266.5}{5600}$ =2.4 3 Armature

## ZEMİN KAT

sta Muayene odası(31.50m$^2$)

:6.7m b:4.7m h:3m A:31.50m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \frac{axb}{hx(a+b)} = \frac{6.7x4.7}{3x(6.7+4.7)} = 0.92$
- **Efficiency of Illumination**:

k: $x_1$:0.80 η: $y_1$:0.29
k: $x_2$:0.92 η: $y_2$:?
k: $x_3$:1.00 η: $y_3$:0.33

- **Interpolation**

$$y2 = y1 + \frac{(x2 - x1)}{(x3 - x1)} x(y3 - y1) = 0.314$$ η:0.31

- $\Phi_T = \frac{ExAxa}{\eta} = \frac{250x31.5x1.25}{0.31} = 31754$
- $n = \frac{\Phi_T}{\Phi_L} = \frac{31754}{4200} = 7.56$ 8 Armature

# ZEMİN KAT

asta Muayene odası(31.50m$^2$)

a:4.95m b:8m h:3m A:39.6m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \frac{axb}{hx(a+b)} = \frac{4.95X8}{3X(4.95+8)}$=1.00
- **Efficiency of Illumination**:

**k: $x_1$**: - **η: $y_1$**: - **η**:0.33
**k: $x_2$**: - **η: $y_2$**:-
**k: $x_3$**: - **η: $y_3$**:-

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)}x(y3-y1) = -$$

- $\Phi_T = \frac{ExAxd}{\eta} = \frac{250X39.6X1.25}{0.33}$=37500
- **n** = $\frac{\Phi_T}{\Phi_L} = \frac{37500}{4200}$=8.928 9 Armature

## ZEMİN KAT

: 4.Hasta Muayene odası(15.3m$^2$)

:3.55m b:4.3m h:3m A:15.3m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm

- $k = \dfrac{axb}{Hx(a+b)} = \dfrac{3.55x4.3}{3x(3.55+4.3)} = 0.65$

- **Efficiency of Illumination**:

**k: $x_1$**: 0.60 **η: $y_1$**: 0.23
**k: $x_2$**:0.65 **η: $y_2$**:?
**k: $x_3$**:0.80 **η: $y_3$**:0.29

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)}x(y3-y1) = 0.245$$ **η**:0.25

- $\Phi_T = \dfrac{ExAxa}{\eta} = \dfrac{250x15.3x1.25}{0.25} = 19125$

- $n = \dfrac{\Phi_T}{\Phi_L} = \dfrac{19125}{4200} = 4.55$ 5 Armature

## ZEMİN KAT

a Muayene odası($15.3m^2$)

.2m b:4.3m h:3m A:$26.7m^2$

**Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10

**Dirty Factor:d**:1.25

**Light Level:E**:250 lux

**Armature Type**:4x18 w

**Armature Light Flux:$\Phi_L$**:4200 lm

$$k = \frac{axb}{hx(a+b)} = \frac{6.2x4.3}{3x(6.2+4.3)} = 0.85$$

**Efficiency of Illumination**:

: **$x_1$**: 0.80 **η: $y_1$**: 0.29
: **$x_2$**:0.85 **η: $y_2$**:?
: **$x_3$**:1.00 **η: $y_3$**:0.33

**Interpolation**

$$2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.30$$ **η**:0.30

$$\Phi_T = \frac{ExAxa}{\eta} = \frac{250x26.7x1.25}{0.30} = 27812.5$$

$$\mathbf{n} = \frac{\Phi_T}{\Phi_L} = \frac{7812.5}{4200} = 6.622$$ 6 Armature

## 1. ve 2. KAT

a Muayene Odası(28.8m²)

7m b:4.8m h:3m A:28.8m²

**Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10

**Dirty Factor:d**:1.25

**Light Level:E**:150 lux

**Armature Type**:2x18 w

**Armature Light Flux:**$\Phi_L$:2100 lm

$$k = \frac{axb}{hx(a+b)} = \frac{4.8x6.7}{3x(4.8+6.7)} = 0.93$$

**Efficiency of Illumination**:

$x_1$:0.80 **η:** $y_1$:0.29
$x_2$:0.93 **η:** $y_2$:?
$x_3$:1.00 **η:** $y_3$:0.33

**Interpolation**

$$2 = y1 + \frac{(x2-x1)}{(x3-x1)}x(y3-y1) = 0.316$$ **η:**0.32

$$\Phi_T = \frac{ExAxd}{\eta} = \frac{150x28.8x1.25}{0.32} = 16875$$

$$\mathbf{n} = \frac{\Phi_T}{\Phi_L} = \frac{16875}{2100} = 8.0357$$ 8 Armature

## 1. ve 2. KAT

ı Muayene Odası(16.50m$^2$)

90m b:4.30m h:3m A:16.50m$^2$

**Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10

**Dirty Factor:d**:1.25

**Light Level:E**:150 lux

**Armature Type**:2x18 w

**Armature Light Flux:$\Phi_L$**:2100 lm

$$k = \frac{axb}{hx(a+b)} = \frac{4.9x4.3}{3x(4.9+4.3)} = 0.76$$

**Efficiency of Illumination**:

$x_1$:0.60 **η: $y_1$**:0.23
$x_2$:0.76 **η: $y_2$**:?
$x_3$:0.80 **η: $y_3$**:0.29

**Interpolation**

$$= y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.278$$ **η:**0.28

$$\Phi_T = \frac{ExAxd}{\eta} = \frac{150x16.50x1.25}{0.28} = 11049$$

$$\mathbf{n} = \frac{\Phi_T}{\Phi_L} = \frac{11049}{2100} = 8.0357$$ 5 Armature

## 1. ve 2. KAT

4. Hasta Muayene Odası(13.50m$^2$)

:3.60m b:4.30m h:3m A:13.50m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:150 lux
- **Armature Type**:2x18 w
- **Armature Light Flux:$\Phi_L$**:2100 lm
- $k = \frac{axb}{hx(a+b)} = \frac{3.6x4.3}{3x(3.6+4.3)} = 0.65$
- **Efficiency of Illumination**:

**:** **$x_1$**:0.60 **η: $y_1$**:0.23
**:** **$x_2$**:0.65 **η: $y_2$**:?
**:** **$x_3$**:0.80 **η: $y_3$**:0.29

- **Interpolation**

$$y2 = y1 + \frac{(x2 - x1)}{(x3 - x1)} x(y3 - y1) = 0.245$$ **η:**0.25

- $\Phi_T = \frac{ExAxa}{\eta} = \frac{150x13.5x1.25}{0.25} = 10125$
- **n** = $\frac{\Phi_T}{\Phi_L} = \frac{10125}{2100} = 4.82$ 5 Armature

## 1. ve 2. KAT

Hasta Muayene Odası($24m^2$)

a:6.2m b:4.30m h:3m A:$24m^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:150 lux
- **Armature Type**:2x18 w
- **Armature Light Flux:$\Phi_L$**:2100 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{6.2x4.3}{3x(6.2+4.3)} = 0.85$
- **Efficiency of Illumination**:

**k: $x_1$**:0.80 **η: $y_1$**:0.29
**k: $x_2$**:0.85 **η: $y_2$**:?
**k: $x_3$**:1.00 **η: $y_3$**:0.33

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.30$$ **η**:0.30

- $\Phi_T = \dfrac{ExAxa}{\eta} = \dfrac{150x24x1.25}{0.30} = 15000$
- **n** = $\dfrac{\Phi_T}{\Phi_L} = \dfrac{15000}{2100} = 15000/2100 = 7.142$ 7 Armature

## 1. ve 2. KAT

ta Muayene Odası(11.51$m^2$)

.10m b=3.50m h:3m A:11.51$m^2$

**Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10

**Dirty Factor:d**:1.25

**Light Level:E**:150 lux

**Armature Type**:2x18 w

**Armature Light Flux:$\Phi_L$**:2100 lm

$$k = \frac{axb}{hx(a+b)} = \frac{4.10x3.50}{3x(4.10+3.50)} = 0.63$$

- **Efficiency of Illumination**:

: $x_1$:0.60 η: $y_1$:0.23
: $x_2$:0.63 η: $y_2$:?
: $x_3$:0.80 η: $y_3$:0.29

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.239$$ η:0.24

- $$\Phi_T = \frac{ExAxd}{\eta} = \frac{150x11.51x1.25}{0.24} = 8992$$

- $$n = \frac{\Phi_T}{\Phi_L} = \frac{8992}{2100} = 4.282$$ 4 Armature

## 1. ve 2. KAT

ta Muayene Odası(17.55m$^2$)

.0m b:4.350m h:3m A:17.55m$^2$

**Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10

**Dirty Factor:d**:1.25

**Light Level:E**:150 lux

**Armature Type**:2x18 w

**Armature Light Flux:$\Phi_L$**:2100 lm

$$k = \frac{axb}{hx(a+b)} = \frac{6.0x4.5}{3x(6.0+4.5)} = 0.86$$

**Efficiency of Illumination**:

**$x_1$**:0.80 **$\eta$: $y_1$**:0.29
**$x_2$**:0.86 **$\eta$: $y_2$**:?
**$x_3$**:1.00 **$\eta$: $y_3$**:0.33

**Interpolation**

$$2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.302$$ **$\eta$**:0.30

$$\Phi_T = \frac{ExAxa}{\eta} = \frac{150x17.55x1.25}{0.30} = 10969$$

$$\mathbf{n} = \frac{\Phi_T}{\Phi_L} = \frac{10969}{2100} = 5.223$$ 5 Armature

## 1. ve 2. KAT

: Hol($40.1m^2$)

a:11.10m b:3.50m h:3m A:$40.1m^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:150 lux
- **Armature Type**:2x18 w
- **Armature Light Flux:$\Phi_L$**:2100 lm
- $k = \frac{axb}{hx(a+b)} = \frac{11.10x3.50}{3x(11.10+3.50)} = 0.89$
- **Efficiency of Illumination**:

**k: $x_1$**:0.80 **η: $y_1$**:0.29
**k: $x_2$**:0.89 **η: $y_2$**:?
**k: $x_3$**:1.00 **η: $y_3$**:0.33

- **Interpolation**

$$y2 = y1 + \frac{(x2 - x1)}{(x3 - x1)} x(y3 - y1) = 0.308$$ **η**:0.31

- 150x40.1x1.25/0.31=24254
- **n** = $\frac{\Phi_T}{\Phi_L} = \frac{24254}{2100} = 11.54$ 12 Armature

**Ameliyathane(3.Kat)**

meliyathane(32.50m$^2$)

:4.8m b:6.7m h:3m A:32.50m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:500 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{4.8x6.7}{3x(4.8+6.7)} = 0.93$
- **Efficiency of Illumination**:

**k: $x_1$**:0.80 **η: $y_1$**:0.29
**k: $x_2$**:0.93 **η: $y_2$**:?
**k: $x_3$**:1.00 **η: $y_3$**:0.33

- **Interpolation**

$y2 = y1 + \dfrac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.316$ **η**:0.32

- $\Phi_T = \dfrac{ExAxa}{\eta} = \dfrac{500x32.5x1.25}{0.32} = 63477$
- **n** $= \dfrac{\Phi_T}{\Phi_L} = \dfrac{63477}{4200} = 15.1135$ 15 Armature

**Ameliyathane(3.Kat)**

neliyathane(30.13m$^2$)

:4.9m b:6.15m h:3m A:30.13m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:500 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{4.9x6.15}{3x(4.9+6.15)} = 0.91$
- **Efficiency of Illumination**:

k: $x_1$:0.80 η: $y_1$:0.29
k: $x_2$:0.91 η: $y_2$:?
k: $x_3$:1.00 η: $y_3$:0.33

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.312$$ η:0.31

- $\Phi_T = \dfrac{ExAxd}{\eta} = \dfrac{500x30.13x1.25}{0.31} = 60746$
- n = $\dfrac{\Phi_T}{\Phi_L} = \dfrac{60746}{4200} = 15.1135$ 14 Armature

**Ameliyathane(3.Kat)**

umhane(20.1m$^2$)

:6m b:4.6m h:3m A:20.1m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm

- $k = \frac{axb}{hx(a+b)} = \frac{6x4.6}{3x(6+4.6)} = 0.87$

- **Efficiency of Illumination**:

**k: $x_1$**:0.80 **η: $y_1$**:0.29
**k: $x_2$**:0.87 **η: $y_2$**:?
**k: $x_3$**:1.00 **η: $y_3$**:0.33

- **Interpolation**

$y2 = y1 + \frac{(x2 - x1)}{(x3 - x1)} x(y3 - y1) = 0.304$ **η**:0.30

- $\Phi_T = \frac{ExAxa}{\eta} = \frac{250x20.1x1.25}{0.30} = 20938$

- **n** = $\frac{\Phi_T}{\Phi_L} = \frac{20938}{4200} = 4.9852$ 5 Armature

## Ameliyathane(3.Kat)

ik Doğumhane(15.6m$^2$)

:4.1m b:3.7m h:3m A:15.6m$^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:250 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $k = \dfrac{axb}{hx(a+b)} = \dfrac{4.1x3.7}{3x(4.1+3.7)} = 0.65$
- **Efficiency of Illumination**:

k: $x_1$:0.60 η: $y_1$:0.23
k: $x_2$:0.65 η: $y_2$:?
k: $x_3$:0.80 η: $y_3$:0.29

- **Interpolation**

$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)} x(y3-y1) = 0.245$$ η:0.25

- $\Phi_T = \dfrac{ExAxa}{\eta} = \dfrac{250x15.63x1.25}{0.25} = 19500$
- $n = \dfrac{\Phi_T}{\Phi_L} = \dfrac{19500}{4200} = 4.6428$ 5 Armature

## Ameliyathane(3.Kat)

ın Bakım Odası($31.3m^2$)

:7.3m b:4.3m h:3m A:$31.3m^2$

- **Ceiling:** 0.80 **Wall**:0.50 **Floor:** 0.10
- **Dirty Factor:d**:1.25
- **Light Level:E**:400 lux
- **Armature Type**:4x18 w
- **Armature Light Flux:$\Phi_L$**:4200 lm
- $$k = \frac{axb}{hx(a+b)} = \frac{7.3x4.3}{3x(7.3+4.3)} = 0.90$$
- **Efficiency of Illumination**:

**k: $x_1$**:0.80 **η: $y_1$**:0.239
**k: $x_2$**:0.90 **η: $y_2$**:?
**k: $x_3$**:1.00 **η: $y_3$**:0.33

- **Interpolation**

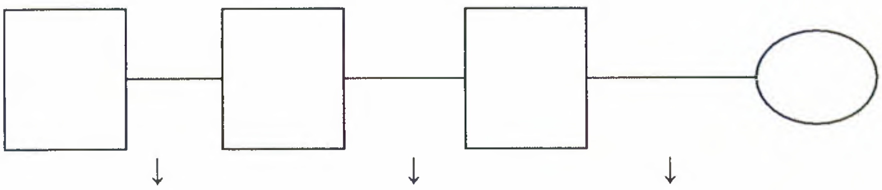
$$y2 = y1 + \frac{(x2-x1)}{(x3-x1)}x(y3-y1) = 0.31$$ **η**:0.31

- $$\Phi_T = \frac{ExAxa}{\eta} = \frac{400x31.3x1.25}{0.31} = 50484$$
- $$n = \frac{\Phi_T}{\Phi_L} = \frac{50484}{4200} = 12$$ 12 Armature

## VOLTAGE DROP CALCULATION

**UNTER** **MAIN BOARD** **SECONDARY BOARD** **3 PHASE MOTOR**

12.44m 4.9m 1.0m 1.5kW



$3(4x150mm^2)$ $4x35mm^2$ $4x2.5mm^2$

1210 A 171 A 11 A

d 'IEE Wiring Regulations – 14th Edition' and find **g:** Voltage drop value.

$g_1=g_{400}=0.17mV/A.m$ $g_2=g_{35}=1.0mV/A.m$ $g_3=g_{2.5}=15mV/A.m$

voltage drop value should not be greater than 2.5% of the nominal value.
nominal value for

Single phase circuits (Line):6V ($\Delta V_{max}$)
Three phase circuits (Line):10.375V ($\Delta V_{max}$)

**g x L x I (mv)**

$_n$ = 0.17 x 12.44 x 1210 = 4366.9 mV

$_s$ =1.0 x 4.9 x 171 = 8379 mV

$_n$ =15 x 1.0 x 11 = 165 mV

**Total Voltage Drop**= 4366.9 + 8379 + 165 = 11.10 V

$\approx 2.6\,\% > 2.5\,\%$

Total voltage drop must be less than or equal 2.5 %. If voltage drop greater than 2.5 %, cross on between the counter and the main board should be increased. Everytime we must use this rule.

nt 450 mm² cross section cables but IEE regulation book has not got 450 mm² cross ion cables. Because this cross section cables have not got in the market. And than I 3(4x150mm²) cables. After that Iused IEE regulation book tables and find 400mm² s section cables voltage drop values. Than 50mm² cross section is not calculated, in way is not applied above rule. But when we use 50mm² total voltage drop equal to 6.

## COST CALCULATION

ELEKTRİK TESİSATI MAALİYET HESABI

| YAPILACAK İŞ | MİKTAR | BİRİM | B.FİYATI (YTL) | TUTARI (YTL) |
|---|---|---|---|---|
| 4x18W floresent tesisatı | 198 | Adet | 382.50 | 75,735.00 |
| 2x18W floresent tesisatı | 110 | Adet | 200.00 | 22,000.00 |
| Duvar globu tesisatı | 26 | Adet | 50.60 | 1,315.60 |
| Duvar apliği tesisatı | 34 | Adet | 98.50 | 3,349.00 |
| 1x80W w/p floresent tesisatı | 14 | Adet | 284.00 | 3,976.00 |
| 1x80W floresent tesisatı | 1 | Adet | 91.75 | 91.75 |
| Askı tipi lamba tesisatı | 1 | Adet | 42.30 | 42.30 |
| Priz tesisatı (1x13A) | 120 | Adet | 56.00 | 6,720.00 |
| Priz tesisatı (2x13A) | 58 | Adet | 67.00 | 3,886.00 |
| w/p Priz tesisatı (1x13A) | 10 | Adet | 145.00 | 1,450.00 |
| fan coil tesisatı | 53 | Adet | 99.00 | 5,247.00 |
| Telefon prizi tesisatı | 18 | Adet | 61.25 | 1,102.50 |
| TV anten prizi tesisatı | 34 | Adet | 75.25 | 2,558.50 |
| Yangın ihbar santralı (6 zone) | 1 | Adet | 5,000.00 | 5,000.00 |
| Elektro-Optik alev dedektörü | 56 | Adet | 457.75 | 25,634.00 |
| Yangın ihbar butonu | 12 | Adet | 169.25 | 2,031.00 |
| Yangın ihbar sireni | 5 | Adet | 239.00 | 1,195.00 |
| İnterkom tesisatı(4 abone) | 1 | Adet | 660.00 | 660.00 |
| numaratör tesisatı (8 abone) | 2 | Adet | 602.00 | 1,204.00 |
| 3 faz cihaz tesisatı (70 kVA) | 1 | Adet | 490.00 | 490.00 |
| 3 faz cihaz tesisatı (50 kVA) | 1 | Adet | 490.00 | 490.00 |
| 3 faz cihaz tesisatı (100 kW) | 1 | Adet | 490.00 | 490.00 |
| Motor tesisatı (3faz 5.5kW) | 2 | Adet | 110.00 | 220.00 |
| Motor tesisatı(3faz 1.5kW) | 6 | Adet | 75.00 | 450.00 |
| Motor tesisatı(3faz 2.2kW) | 3 | Adet | 75.00 | 225.00 |
| Motor tesisatı(3faz 17kW) | 1 | Adet | 159.25 | 159.25 |
| ADT (3x12 yollu 630A) MCCB'li | 1 | Adet | 7,100.00 | 7,100.00 |
| ADT (3x12) yollu | 3 | Adet | 811.25 | 2,433.75 |
| ADT (3x8) yollu | 2 | Adet | 737.50 | 1,475.00 |
| ADT (3x6) yollu | 1 | Adet | 666.25 | 666.25 |
| ADT (3x4) yollu | 1 | Adet | 612.50 | 612.50 |
| MCB 3x10A | 2 | Adet | 157.50 | 315.00 |
| MCB 3x5A | 9 | Adet | 157.50 | 1,417.50 |
| MCB 3x30A | 1 | Adet | 157.50 | 157.50 |
| MCB 1x30A | 17 | Adet | 34.00 | 578.00 |
| MCB 1x5A | 45 | Adet | 34.00 | 1,530.00 |

| | | | | |
|---|---|---|---|---|
| :B 1x8A | 53 | Adet | 34.00 | 1,802.00 |
| :B 1x15A | 3 | Adet | 34.00 | 102.00 |
| :B 1x20A | 1 | Adet | 34.00 | 34.00 |
| :lam Işığı Tesisatı | 1 | Adet | 56.40 | 56.40 |
| :CB+ELCB (3x630A) | 1 | Adet | 4,288.00 | 4,288.00 |
| :CB (3x630A) | 4 | Adet | 3,187.50 | 12,750.00 |
| :CB (3x225A) | 1 | Adet | 853.75 | 853.75 |
| :CB (3x100A) | 3 | Adet | 536.25 | 1,608.75 |
| :CB (3x63A) | 6 | Adet | 353.75 | 2,122.50 |
| oprak otomatiği (3x63A) | 6 | Adet | 481.00 | 2,886.00 |
| oprak otomatiği (3x100A) | 1 | Adet | 1,112.00 | 1,112.00 |
| erkezi topraklama | 1 | Adet | 2,250.00 | 2,250.00 |
| x150+70)mm2 ç.z kablo sisatı | 40 | metre | 175.50 | 7,020.00 |
| x120+70)mm2 XLPE kablo s. | 45 | metre | 150.00 | 6,750.00 |
| x35+16)mm2 ç.z kablo tes. | 25 | metre | 48.50 | 1,212.50 |
| x35+16)mm2 PVC kablo tes. | 5 | metre | 38.25 | 191.25 |
| x16+6)mm2 PVC kablo tes. | 150 | metre | 12.75 | 1,912.50 |
| | | | TOPLAM | 228,959.05 |

# CONCLUSION

his thesis is about electrical installation of a hospital. In this thesis I was learn, how I gn an electrical installation of the building and what are need to design for electrical ion.

The thesis is given some information about History of electricity, Weak current ion, Conductors and Cables, Electrical safety-protection_earthing, Illumination ion, Circuit control devices, Domestic installation and Cost and Illumination on.

the practical part for drawing installation project by using AutoCAD is prepared. ulation part is by using excel is prepared.

## REFERENCES


Thompson F.G.,Electrical Installation and Workshop Technology,Volume One , d., Longman Groub U.K. Limited,1992

Thompson F.G.,Electrical Installation and Workshop Technology,Volume Two, 4th Longman Groub U.K. Limited,1992

Chamber of Electrical Engineers.Project Drawing Principles and Help Information's

k 5th ed., Nicosia,2002

Theraja B.L.,Electrical Technology in S.I. System of Units,22th ed., Niraja

struction & Development Co.(P) Ltd., New Delhi,1987.