TITLE:- CONDUCTORS

LECTURER:

DATE:-

EQUIPMENT:- COPPER, ALUMINIUM, IRON, NICHROME WIRE, BI-METAL SWITCH, CARBON

The definition of a conductor (S.A.A. 0.5.22) shall mean a wire, cable, or other form of metal suitable for carrying current but shall not include wire cables or other metallic parts directly employed in converting electrical energy into another form of energy.

Generally, any materials that will conduct electricity relatively easily are termed conductors. Conductivity is a word which describes the ease which a current will flow through a conductor.
Silver = 106, Copper = 100, Gold = 72, Aluminium = 62, Lead = 8.
This shows, with copper as a standard, that Silver is 6% better than copper, whereas Aluminium is only 62% as good as copper.

For a material to be accepted, it must have certain properties.

1. High conductivity.
2. Flexibility of use, i.e. as wires, rods, etc.
3. Good all-round mechanical properties i.e. machinability, ductility, malleable etc.
4. Essy to joint.
5. Resistant to corrosion.

Copper, aluminium, and their alloys, ferrous metals, bi-metals, superconductivity, semi-conductors, silicon, carbon, structural materials, and applications.

Copper; although not the best of the conductors listed, is the one which is most widely used as it fulfills almost all the property requirements listed above. Copper, being not so plentiful, has a high market value. This is an advantage as the scrap value is also high. When alloyed with certain other metals, further properties are developed, e.g. Copper and Tin make Phosphor Bronze which is a hard springy metal. Brass being suited for nuts, bolts and castings etc. is an alloy of Copper and Zinc.

Aluminium; is not as good a conductor as copper; it is nevertheless becoming used more as an electrical conductor chiefly because of its weight and reduced costs. Previously its use was limited due to jointing difficulties due to speed of oxidation. This has now been made simpler and it is now possible to fuse aluminium and copper by friction, thereby eliminating electrolytic action.
Its uses include squirrel cages in motor design, aerial conductors (tension is taken by strands of spring steel wire), instruments, power meters etc. Solid strand cables - 2, 3, and 4-core are now being made for general use. These cables generally have larger cores than similar copper cables to compensate for the poorer conductivity, but it is still a lighter cable and requires less man power for installation.
Alloys of aluminium make its electrical and mechanical properties much better.

Ferrous metals:- The greatest part played by ferrous metals is in the magnetic circuits of various pieces of electrical equipment such as:- motors, transformers, relays, lifting magnets, generators etc. All commercial magnetic materials contain iron, other elements such as nickel and cobalt have magnetic properties and it is possible to make non-ferrous magnets.

Permanent or hard magnets retain magnetism, tungsten and chromium steel are the oldest specially manufactured metals for permanent magnets and are sufficiently stable for all purposes.
Cobalt steel alloys have a high efficiency which increases with higher cobalt content. It is used for measuring instruments, telephony, and synchronous motors.

Temporary or soft magnets do not retain magnetism. They are usually laminated to reduce the effects of eddy currents. Nickel-Iron-Cobalt alloys are available for special purposes.

Resistance wire used in electrical heating appliances is usually alloys of Nickel & Chromium (80:20 is Brightray) and Nickel-Chromium -Iron (Glowray - 65:15:20).
Brightray used mostly for temp's between 850°C & 1100°C.
Glowray used for temperatures up to 850°C.

Bi-metals Two metals of dissimilar coefficients of expansion are bonded together and rolled into strips. On heating either directly or indirectly, the bi-metal will bend. This bending can then be used to trip or trigger other equipment.
Bi-metals are available in various shapes and forms - discs, flat, coils, U-shaped etc., each with its own characteristics and rates of bending.

Superconductivity At very low temperatures, most metallic elements lose all trace of electrical resistance. The temperatures are different for each material ranging from 0.35°K to 9.2°K.
Magnetism and its effect on a conductor which is cooled to super-conductivity can destroy the properties of superconductivity.
The current flowing in a superconductor flows around the surface of the conductor to a depth of 10-5 cm.
One theory of superconductivity is that the oscillations of the atoms within the structure ceases when superconductivity is achieved.

Semi-conductors:- is a term used to describe certain materials which are neither good conductors, nor good insulators. This can be said about almost all substances. There are, however, some substances which have a peculiar behaviour when used in electrical circuits; mainly their non-linearity of relationship between E.I.& R.

Semi-conductors are classes as (a) NON-METALLIC RESISTANCE MATERIALS, used in the manufacture of certain resistors, or (b) NON-LINEAR ELEMENTS, used in the manufacture of diodes, transistors etc. Silicon and germanium are the two main basic elements used in the manufacture of these solid state devices. The reason for using these elements lies in the structure of its atom which has 4 electrons in the outer (valence) shell which are bound in a crystalline lattice. Some of these electrons can move freely within the lattice, and heat increases the number of free electrons.
It is usually a doped form of silicon used, i.e. a small amount of tri-valent, or pentavalent material is combined with the silicon or germanium to give more free electrons, or less free electrons.

Silicon is a light metal having a specific gravity of 2.34. It is brittle and therefore is limited in industrial use. It is used to alloy with steel for making magnetic stampings because of the fact that it has a high resistivity and therefore reduces eddy currents. It is amaterial that is very resistant to atmospheric corrosion and to attack by many chemicals.

Carbon occurs naturally in 2 forms.. 1. amorphous (charcoal, coal lampblack etc.) 2. crystalline (Diamond, and graphite).
Carbon used for electrical purposes is a compound of powdered carbon and/or graphite with pitch or resin to bind it together. The mixture is baked to 900°C with air excluded, the volatile part of the binding material is driven off and the remainder carbonised.
The peculiarity of carbon is that it has a negative temperature co-efficient. i.e. the higher the temp., the lower the resistance. Its greatest use being in brushes for motors and generators, because it is self-lubricating, good conductivity, high contact resistance, high durability. Other uses are for arc lamps, welding electrodes, and for resistance rods in furnaces, bakers ovens etc. (it is silicon carbide, carborundum).

TITLE:- INSULATORS

LECTURER:-

DATE:-

EQUIPMENT:- MICA, VARNISH, P.V.C. BAKELITE, EBONITE, SILK TAPE, ASBESTOS, ZELEMITE

Electrical Insulating Materials are otherwise known as insulators or dielectrics and offer a high resistance to the passage of current.

The base materials used in the manufacture of insulators are cotton, glass, silks, linen, and asbestos which can be used in an untreated condition or can be impregnated or coated with insulating varnish or compound to increase resistance. They can also be in the form of solids, liquids or gases and vary considerably in cost from air to mica and resins.

Physical properties:- Specific gravity is important in varnishes and oils and other liquids. Moisture absorption causes failure of oils and fibrous materials, and can cause corrosion.
The physical properties will influence the choice and application of insulating materials e.g. melting point, coefficient of expansion, viscosity, uniformity of thickness, porosity, and the presence of pinholes in enamel used to insulate wires.

Mechanical properties:- These properties must also be considered when selecting insulating materials, and include tensile, compressive, and shearing strength, machineability (drilling, punching etc.) and resistance to splitting.

Electrical properties:- It must insulate and resist leakage current. Factors which affect dielectric strength are sharp edges on electrodes, increases in voltage, overstressed for long periods, moisture content, location, temperature change and frequency of supply voltage.

Chemical properties:- Resistance to external chemical effects such as attack by acids etc., effect of oils i.e. in transformers, effects of solvents, oxidation, atmospheric conditions especially dampness and direct sunlight and the effects of impurities in the insulation.

Types of Insulating Materials

Gaseous dielectrics:- Air is the most important gas, its dielectric strength varies with atmospheric conditions. Nitrogen is used as a dielectric in gas cooled high voltage cables, capacitors, and transformers. Argon is used in gas filled lamps, and sulphur dioxide for refrigeration etc.

Liquid Dielectrics:- Refined mineral oil and synthetic oils are the only liquids used for insulation purposes. Used as a filling and cooling medium in transformers and cables, as an arc quenching medium in switch-gear and as an impregnating medium.

The most important properties necessary are as follows:-
(a) Dielectric strength
(b) Viscosity
(c) Chemical stability
(d) Flash-point

Other types of oils have quite good insulating properties but are not suitable for general use as insulation.

Varnishes & Paints:- Are used to form solid films for protecting wires etc. The properties depend on the basic materials such as resins and oxiding oils, mostly mixed with driers and plasticisers to improve hardness.
It can be used as an external coating for protection against moisture etc., for impregnation of windings and improvement of electrical and heat properties.

Solid Insulating Materials:- Laminated boards are mostly used and consist of paper fabric bonded together with gums, shellac, synthetic resins etc., under heat and pressure such as bakelite and other laminates.

Asbestos cement boards are good heat resistant materials and are used in switchgear etc. It is also available in the form of rods and tubes.
Vulcanised fibre and pressed boards are used for coils, transformers etc. Principle trade names are Leatheroid, Micatex etc.
Papers are made from cotton, manilla fibre etc. and are used in capacitors, cables, coils.
Cotton cloth ranging from fine to heavy cambric are generally treated with varnish and used in coils. It is a base material of compounds and used in the manufacture of varnished cloths and tapes (empire tape).
Asbestos and glass cloth are used when temperatures become too high for textile materials.

Insulating tapes:- Varnished cloth, silk tapes, rubber adhesive tape, glass fibre, cotton and silk are all used in electrical work. Other well known tapes are based on plastic and cellulose, but have certain limitations of operating temperatures.

Sleeving and Flexible Tubing:- These are made from varnished cambric, cotton, silk, asbestos, glass fibre and P.V.C. The application of each depends on voltage, temperature, and operating conditions etc.

Cable Insulation:- Generally, vulcanised rubber, paper, varnished cloth, bitumen compound, neoprene, are used. The most widely used is p.v.c. because of its longevity, toughness, cost, and it is non-inflammable.

TITLE:- MAGNETIC MATERIALS

LECTURER:-

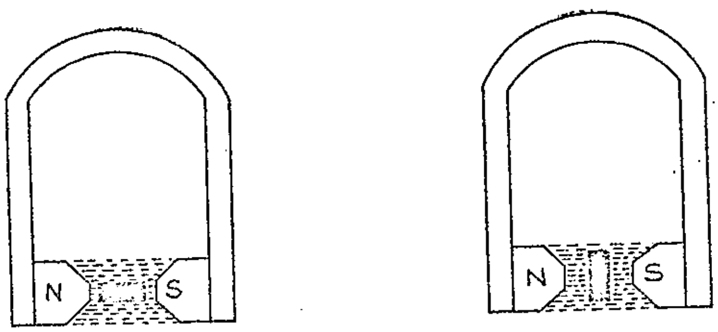
DATE:-

EQUIPMENT:-

Introduction - the first known magnetic material was a lead-coloured stone, called "lodestone", which was discovered by the Chinese. It was found to have certain qualities - e.g. ability to attract iron or similar materials - and it was termed "permanent magnet". However, in regard to modern electro-magnetic equipment, it is very impractical and, consequently, science has discovered other materials which will give the same, and in some cases, better magnetic qualities. "Artificially" made magnets have many distinct advantages in that they are more obtainable, they can be shaped to suit a specific purpose and, due to modern technology, a high degree of permeability and associated qualities are obtained.

Materials - only a few substances are noticeably affected by magnets. Wood, plastics and most metals are examples of those substances which are magnetically "feeble". In these substances, the atomic magnetic forces do not extend beyond the boundaries of the atom - in some cases a very weak magnetic force is detected beyond the boundaries. As a group, they are called non-magnetic materials. However, a few of those substances whose atomic fields extend beyond the atom boundaries can be made to produce very strong magnetic fields, which extend beyond the boundaries of the substance. Such substances are termed magnetic materials.
The materials can be divided into 3 categories -.

(1) Diamagnetic - in a few substances, e.g. copper, gold, zinc and bismuth, the various atomic magnetic fields neutralize each other and no magnetic field exists beyond the atom boundaries. These substances are called dia-magnetic substances. However, their atomic magnetism affects their behaviour when they are placed under the influence of a permanent magnetic field - it causes it to align itself at right angles to the main field (less energy is required to retain it in this position). "Dia" means "across" - diamagnetic materials lie across the direction of the applied field.



PARA-MAGNETIC DIA-MAGNETIC

(2) Paramagnetic - substances which are not dia-magnetic, will set themselves parallel ("para") with the main field and are called paramagnetic substances. The atomic magnetism of para-magnetic materials extends beyond the atom boundaries, although these fields are weak in all but a few substances.

(3) Ferromagnetic - those exceptions are called ferro-magnetic materials, because the strongest paramagnetic material is iron - "ferrum" is the Latin name for iron.
The important ferro-magnetic materials are iron, nickel, cobalt and their alloys. Ferro-magnetic materials may be roughly divided into

two classes, "Hard" and "Soft".
A _magnetically hard_ material is one which, when magnetically induced by a permanent magnet, retains its magnetism after the permanent magnet has been removed. These "hard" materials are used for making permanent magnets for use in electrical equipment such as meters. Generally, materials which are physically hard, such as tempered steel, are magnetically hard.
A _magnetically soft_ material is one which is magnetized readily but loses its magnetic property when magnetising force is removed. A typical example of soft ferro-magnetic material is pure iron. Magnetically soft materials are used in various electrical equipment where it is not desirable to have a permanently "magnetised core" (Contactors etc).

Permeability - _all_ materials allow magnetic flux to pass through them, but in varying degrees. The ease with which a magnetic flux can pass through a substance is called the _permeability_ of the substance. When comparing the permeability of different materials, air is taken as unity.

(a) Dia-magnetic materials oppose magnetic flux and have a permeability _less_ than air i.e. extremely low permeability.
(b) Para-magnetic materials have a permeability _equal_ to, or slightly _greater_ than air.
(c) Ferro-magnetic materials have a permeability _appreciably greater_ than air - it varies with flux density.

TITLE:- CHEMICAL MATERIALS

LECTURER:-

DATE:-

EQUIPMENT:- C.R.C., Bees wax, pitch, silastic, heat-shrink tube, heat gun.

Impregnating and filling compounds (protective & waterproofing):

Two widely different classes of materials are dealt with, viz. (1) The older impregnating and filling compounds, primarily the bitumens and waxes, which are generally melted in place, and which remain permanently heat-softening, and (2) The newer, important synthetic products of polymer chemistry - the "solvent-reactive", or "solventless" resins. The latter, when properly applied, (usually vacuum, or pressure), can be induced to react (polymerize) in situ, and thus provide solid, more "void-free" insulation.
The impregnation and sealing of all forms of porous insulating materials, windings, wire coverings, joints, etc., are essential in securing satisfactory insulation, where appreciable voltage stresses will be encountered.
To achieve intelligent selection, from the many materials available today, attention should be directed to many properties other than initial electrical and physical properties. Some of these considerations, involve voltage endurance (i.e., ability of the insulation system to withstand required voltage stress, throughout the life expectancy of the electrical equipment). No less important, are considerations involving the thermal endurance of electrical insulating systems, which reflect a combination of thermal and oxidative degradation, of the organic materials which make up the impregnant, whether solid or liquid.

Bitumins: The term "bitumin" includes a large number of inflammable mineral substances, consisting mainly of hydrocarbons, and including the hard, solid, brittle varieties termed "asphalt", the semi-solid naphtha and mineral tars, the oily petroleum, and even the light volatile naphthas.

Wax: Is defined as any of a class of natural substances, composed of carbon, hydrogen, and oxygen. In this class are included bees-wax, spermaceti, etc. Waxes, when melted, are good impregnating agents, being water-proof but usually not oil-proof.

Bituminous insulating compounds:
Are prepared from a variety of different formulas, but in most cases, their compositions are guarded as manufacturing secrets, and they are marketed under trade names. Semi-solid to solid compounds, capable of melting under heat, are combined in many ways, often with the addition of other substances, including resins, rubber, animal and vegetable oils and fats, animal, vegetable and mineral waxes. Such compounds are resistant to moisture, acids, alkalies, temperature changes, and in many cases, exposure to the weather. They also have reasonably high dielectric strength, ranging from 200 - 1200V (r.m.s.)/mil at 60 cycles.

Filling & sealing compounds:
When these are used to fill voids, and to seal enclosures against the entrance of moisture, they should have a low temp. co-efficient of contraction and expansion, high flash and fire points, low dielectric loss and power factor, high dielectric strength, freedom from volatile matter, very high moisture resistance, and chemical inertness. These compounds should be tested for softening point, evaporation, melting or pouring point, flash point, burning point, chemical activity, and effect of moisture, and electrical properties.

Plastic & hard filling compounds:
Are usually made of asphalt or of pitch derived from asphaltic - base petroleum. Almost all of them are ductile rather than brittle, at operating temperatures.

Most hard compounds form a seal against the admission of moisture or the emission of oil, while the plastic compounds are effective only against moisture, and then only partly so. The hard compounds are therefore well adapted for filling low-voltage pot-heads when it is necessary to seal the end of the cable. They have been used with cable voltages as high as 26 KV, but owing to the danger of voids, they are generally used only for lower voltages.

Epoxy resins:
Epoxy resins are a class of materials, which contain usually more than one epoxide group. They are capable of polymerzing with a number of compounds (called hardeners). The various types of epoxy resins which are available commercially, differ essentially in:
(a) The source and degree of polymerzation of the groups.
(b) The type of catalyst and hardener employed.
(c) The presence or absence of flexibilizing or modifying agents.
Some epoxies can be cured at room temp., others must be cured at higher temp., commonly in the range of 100 to 150°C. Adhesion is usually excellent, which assists greatly in excluding moisture. Chemical resistance is excellent.

Adhesive/Sealants for Electrical/Electronic applications:
A wide use is made of silicone rubber; one type, which has many uses, is a general purpose, flexible, heat resistant adhesive and sealant. It adheres to a wide variety of insulating materials. A few of its many applications are: Sealing joints and lead wire entries - Bonding wires - Sealing connectors - Repair and splicing of cable and lead wire - Dust-proofing and cabinet sealing - Adhesive for thermistor mounting - Weather-strip adhesive and seal, for electrical/electronic housing and enclosures. One such adhesive sealant, is marketed under the trade name - "Silastic 732". Another silicone rubber protective sealant (Dow Corning 1890), is ideal for applying a thin, rubbery overcoat to protect insulated motor windings, which are subjected to such conditions as - Abrasive dust - Moisture - and chemicals. Motor windings which are completely coated, can be readily cleaned by hosing with water.

Heat-shrinkable tubing:
A non-thermoplastic, chemically cross-linked material, (Silastic 1412) this tubing remains flexible and resilient. The tubing shrinks to form a snug fit even over objects of irregular shape, or dissimilar diameters.
Some of the benefits of this tubing are -
Eliminates taping - Handles easily, no special training is needed in application techniques - Needs no new equipment (use existing heat sources; heatgun or lamp etc.) - Can be removed if required, without damaging the part, on which it is shrunk.

Cleaning & Anti-corrosion agents:
These agents have been developed, to satisfy the need created, by the fact that in the course of recent years, the switching elements of electronic gear, were progressively miniaturised, so that it became increasingly difficult to clean the contact points. In aerosol form these agents contain additives that dissolve oxide and sulphide layers, they do not conduct electricity and possess a relatively high insulation resistance. By virtue of this property, and the suitably selected mixture of solvents, no harmful influences, such as current leaks, can intervene, when components in the vicinity of the contacts are hit by the spray.
Other agents i.e.; "C.R.C." - "Kontakt 101" - displace moisture, and penetrates under water. In addition to its highly water repellant and anti-corrosive ingredients, it has a unique capacity to penetrate beneath other fluids, thereby lifting moisture from the sprayed component.
It re-establishes immediately, normal electrical constants and resistance values, and can be used successfully in either the electronic or auto-electrical fields.

<u>TITLE:</u> Earthing

<u>LECTURER:</u>

<u>DATE:</u>

<u>EQUIPMENT:</u> S.A.A. Rule Book

Reasons For Earthing

Even when all materials for an installation are carefully selected and then carefully installed to comply with specifications and wiring rules, the possibility of insulation failure in the wiring or equipment is always present. Should such a failure occur, it immediately introduces hazards to life or equipment by:

1. Electric Shock
2. Fire
3. Unstable voltage conditions

In section 'O' of the S.A.A. Wiring Rules, there are terms relative to earthing systems which are covered by definitions and rules.

It is important that these definitions and rules are known by all electricians. "Learnt as soon as entering the trade and never forgotten".

Source of Supply

This refers to the substation or generation station from which electrical energy is supplied.

Earth Connection

This term usually is taken to mean the main earthing connection between the main earthing conductor and the earth electrode (Rule 5.3.1.1.).

Any connection between the earth wire of a final subcircuit and the appliance is also commonly termed as "Earth Connection".

Earth Electrode

The earth electrode is the accessory by means of which final connection is achieved between the general mass of earth and the earthing system. The most common is the driven electrode (Rule 5.7.2.2.) but there are other possible types specified in rule 5.7.2.

Earth Resistance

Refers to the resistance existing between the main earth connection (Earth Electrode) and the general mass of earth.

The resistance value is a specified maximum for direct earthing (Rule 5.9.1.) and ELCB (Rule 5.10.1.).