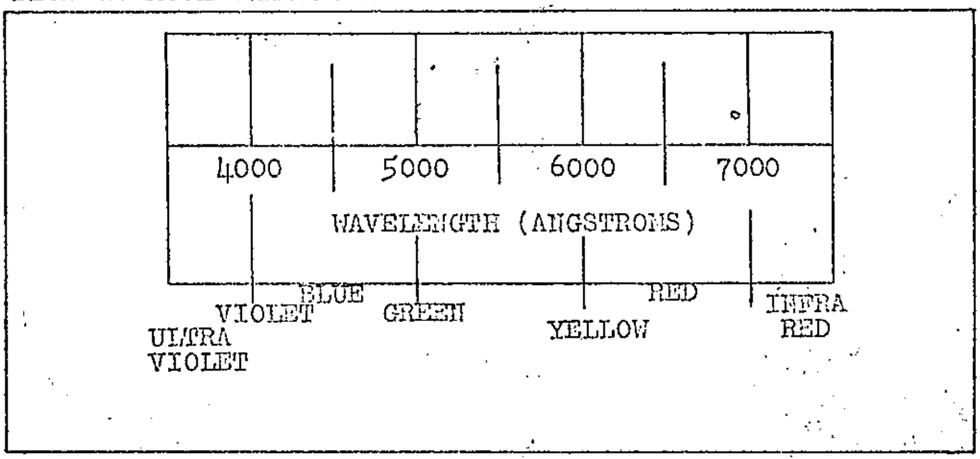
TITLE:- ILLUMINATION

LECTURER:-

DATE:-

EQUIPMENT:- Fluorescent tube, starter, choke, Mercury vapour lamp, Quartz iodine lamp, Sodium vapour lamp.

Light may be described as radiant energy, which affects our eyes so as to produce the sensation of vision. All radiant energy, travels through space at the speed of light (300,000 Km/Sec.).
The difference between different rays i.e., X-Ray, Radio waves, Gamma-rays etc. is only their wavelengths, or frequencies (no. of cycles per second).
There is a narrow band of frequencies which give us a sensation of light and colour. At one end of this band, (or SPECTRUM) is radiation called ULTRA-VIOLET, at the other end is radiation called INFRA-RED. Both of these radiations are invisible. Between ultra-violet and infra-red radiations, is what is known as the VISIBLE SPECTRUM.
The unit of wavelength is the ANGSTROM - One Angstrom is a wavelength of one hundred millionth of a centimetre.
The visible spectrum is within the spectrum between 4,000 - 7,000 Angstroms. Daylight has a spectral composition of 1/3 each of RED-GREEN-BLUE at noon summertime:



To compare the relative properties and calculations of different forms of illumination, there are four main quantities to be measured -

(1) Intensity of light in any one direction.
(2) Total flow of light in all directions from the source.
(3) Brightness of the source.
(4) Illumination of a surface.

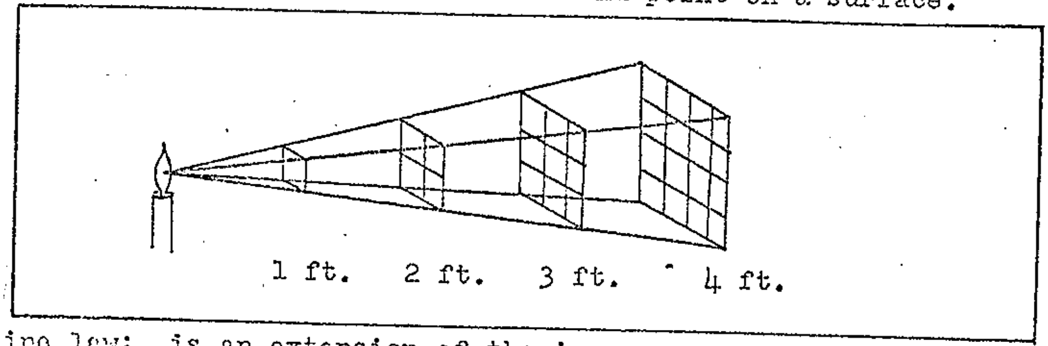
(1) CANDELA is the unit of luminous intensity, and is defined as 1/60 of the luminous intensity of a "black-body" radiator at the temperature of the solidification of platinum (2046°K). The original definition was in terms of the strength of a flame source.

Blackbody: Is a temperature radiator, which absorbs all the radiant energy that falls upon it. In practice it is a cavity, with opaque walls at uniform temperature, with a small opening for observation purposes.

Lumen: Is the unit of luminous flux, and is the time/rate flow of light. ONE LUMEN = flux on a square foot of surface, all points of which are one foot from a point source of one candela. Light sources are rated in lumens.

Inverse square law: States that the illumination at a point on a surface varies inversely with the square of the distance, between the point and the light source. $E = 1/D^2$, E = Illumination in ft.

candles at a point on the surface, I = luminous intensity in candles, D = distance between source and point on a surface.



Cosine law: is an extension of the inverse square law, and takes account of the case when the surface is not normal to the direction of the light ray. If the surface is inclined at any angle to the incident ray, the illumination becomes proportional to the cosine of the angle of incidence.

$$E = \frac{I \cos \phi}{D}$$

Luminaires: are complete lighting fittings, and are classified according to the amount of, and direction in which the light shines.

Direct	0-10% upwards	90-100% downwards
Semi-direct	10-40% "	60-90% "
General diffuse	40-60% "	60-40% "
Semi-indirect	60-90 "	10-40% "
Indirect	90-100% "	0-10% "

TITLE:- ILLUMINATION (LAMPS)

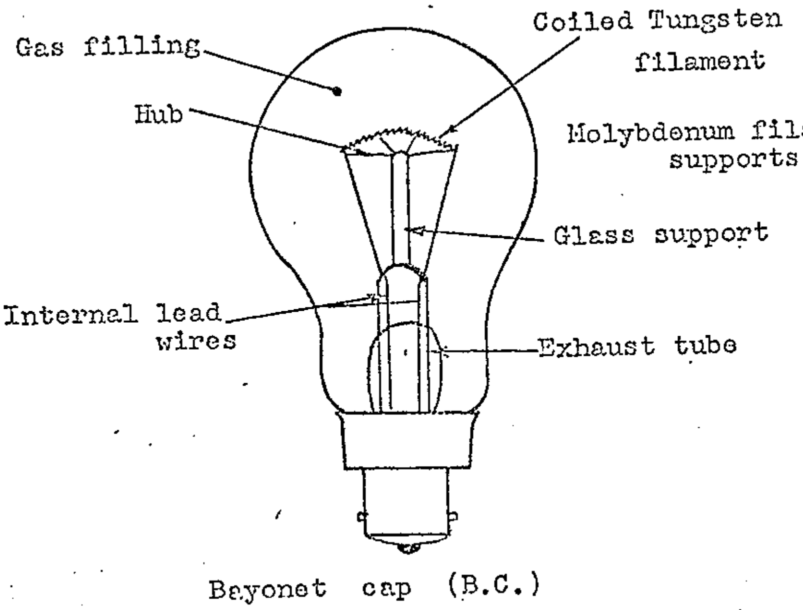
LECTURER:-

DATE:-

EQUIPMENT:-

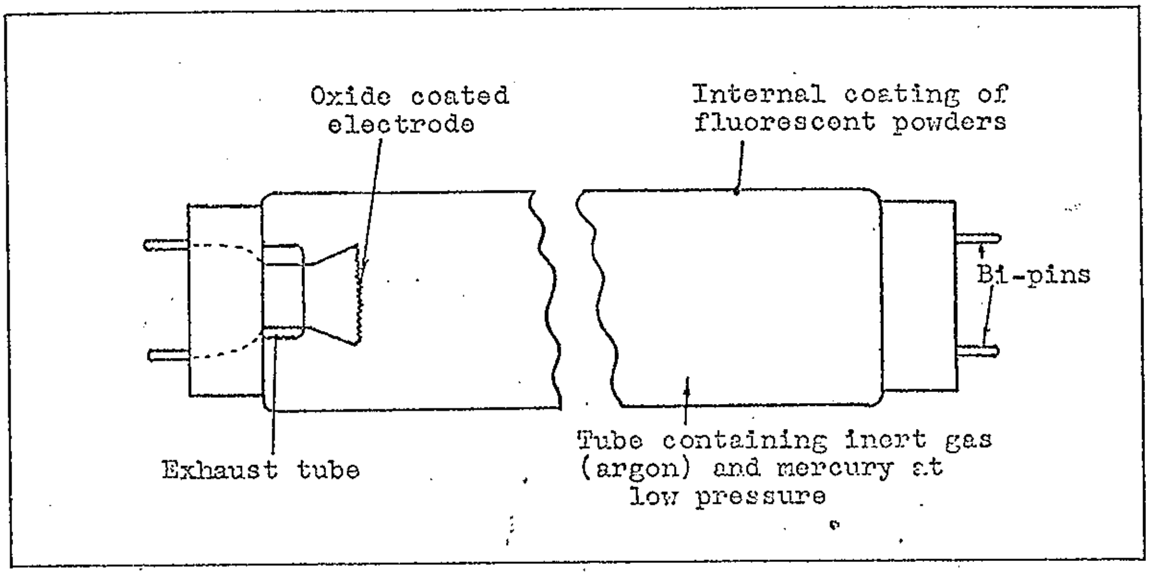
Tungsten filament lamps: if sufficient current is passed through a wire, it will reach a temperature and become incandescent and emit light. Tungsten for lamp filaments has the highest melting point of all metals; 3380°C (6120°F), more than twice that of iron. The filament length and diameter, limits its range of operation between 1.5 and 300V. At 1.5 to 12 Volts, the filament is very short and thick, and is relatively rugged, it will withstand the shock of motor vehicles etc.
At a voltage of 250V, the filament is very long and thin and fragile making it difficult to support.
In order to obtain a reasonably efficient light source, it is necessary to operate the filament at a high temperature. Because lamp life is determined by filament evaporation, gas filled lamps are used in preference to vacuum lamps. The lamp consists of a glass container or bulb, inside of which, is an assembly, carrying the filaments and supports. This is cemented to an end cap, then evacuated of air and filled with an inert gas such as argon-nitrogen. The filament is coiled into a very tight spiral, in which the turns are so closely spaced that the flow of gas through the coil is restricted, and a coiled coil filament, in which the filament spiral is wound into another spiral, is a further step to increase the total operating time, through the reducing of the cooling effect of the gas. General service lamps up to 150W may be obtained with internal frosted or pearl bulbs, producing additional diffusion. Glare may be reduced by the use of opal glass lamps, or internal frosted bulbs. Most of the energy supplied to a tungsten filament lamp is converted as follows:-

(a)	Heat lost as convection	20%
(b)	Heat lost through support & leads	5%
(c)	Heat radiated	67%
(d)	Light	8%



Beyonet cap (B.C.)

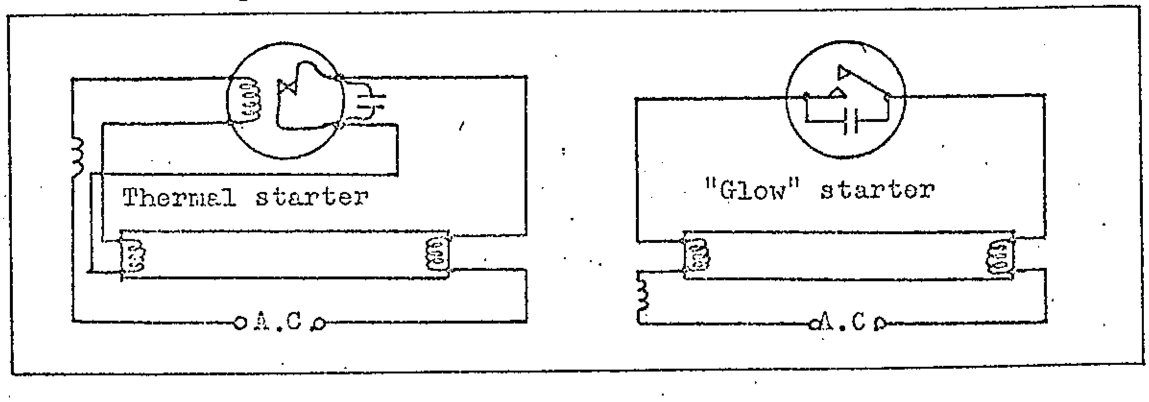
Fluorescent lamps: All fluorescent lamps are basically low-pressure mercury-discharge lamps, designed to emit a maximum portion of their energy, in the 2537 A° line of the mercury spectrum. This short-wave ultra-violet energy is converted by the phosphors coating the inside of the tube, into light.
The glass tubes, 38 mm in diameter, are cut to length, according to the wattage required:- 8, 5, 4, 3, 2, 1½ ft. and end caps (bi-pin or bayonet cap) are fitted, with the pins connected to oxide coated electrodes, (one at each end). Air is replaced with ARGON gas at a low pressure, a small amount of MERCURY is added, and the tube is sealed.



Starters: Two types are generally available, i.e., Glow type and Thermal.

Glow type starter: This is the most commonly used, as it is the most efficient, and requires less wiring. It consists of a small glass envelope, in which are two bi-metallic contacts which are not touching. The envelope is filled with NEON gas. A capacitor is connected across the terminals on the outside of the envelope. This is for radio interference suppression. When a voltage is applied, the neon gas ionises, causing heat to be generated, which bends the bi-metals, causing them to touch. This allows a heavy current to flow through the lamp circuit, ionisation ceases, and the contacts cool and open. The opening of the contacts causes a high, self-induced E.M.F. to appear at the choke, which then starts ionisation of the main tube.

Thermal type starter: These are fitted with normally closed contacts, which are in close proximity to a heating filament. The filament is connected in series with the choke, and the contacts across opposite ends of the tube. Current flows through the heater, causing the contacts to open, thus providing means of obtaining the high starting voltage. The heater must remain in circuit, to keep the contacts open.



The choke: This is a coil of thousands of turns of fine gauge wire, wound on a laminated, closed loop iron core. It is used to supply a high back E.M.F. for starting the lamp, and to limit the lamp current to a safe running value.

Operation: The circuit starts from the active, which is connected to one end of the tube. The adjacent pin is connected to the starter, then from the starter to the other end of the tube. A wire from the adjacent pin of the tube goes to the choke, the other side of the choke goes to neutral.
When the power is switched on, there is no current flow, as the lamp appears as a high resistance and the starter (glow type) contacts are open. The voltage across the starter contacts is 240V, and this causes ionisation in the starter. The contacts close, and a current flows through the tube filament, starter and choke.
A magnetic field is built up in the core of the choke, and the tube filaments are heated. Since there is a current flow through the circuit, ionisation in the starter ceases and the contacts open, which causes the magnetic field in the choke to collapse, and in doing so, it induces a high e.m.f., which appears across the length of the tube. Ionisation of the argon gas occurs, and creates an ultra-violet radiation.
Because the tube is now conducting, its resistance is much lower, and the starter contacts appear as an open circuit.
The low resistance of the tube would cause excessive current flow if the choke was not in the circuit.
Phosphorescent powders change the wave-length of the ultra-violet rays, by absorbing energy and the light output is increased. 70% of energy supplied appears as light. The fluorescent is the most efficient. Heat produced is 1/3 that of a tungsten filament lamp. Glare is reduced, costs are reduced, and lamp life can be increased by reducing or minimising switching operations.

Black-light lamps: Near ultra-violet radiant energy, (energy not visible to the human eye) causes certain materials to fluoresce (emit visible light). The normal human eye is sensitive only to radiant energy between 4,000 and 7,000 A° in wavelength. Thus, lamps which produce primarily near-ultraviolet radiant energy in the 3,200-3,800 A° range, are popularly called "black" lights. This term is quite descriptive, since the ultra-violet energy from the light source cannot be seen by the human eye, but the effects of the radiation on special materials can be visually dramatic.
When "black light" is directed at a fluorescent material, an energy conversion takes place. The material or chemical, sensitive to ultra-violet energy, absorbs the energy, then re-radiates it at longer wavelengths (4,000-7,000 A° range) to which the eye is sensitive. The energy conversion is similar to that which takes place in fluorescent lamps; i.e., ultra-violet energy in the lamp, activates the fluorescent phosphor coating. to produce visible light in white or any other colour.
Black-light lamps are generally enclosed in a red-purple filter glass bulb which looks black. They are used for theatrical and advertising effects, industrial and food inspection, detection of counterfeits and forgeries, medical diagnosis, vermin traps etc.

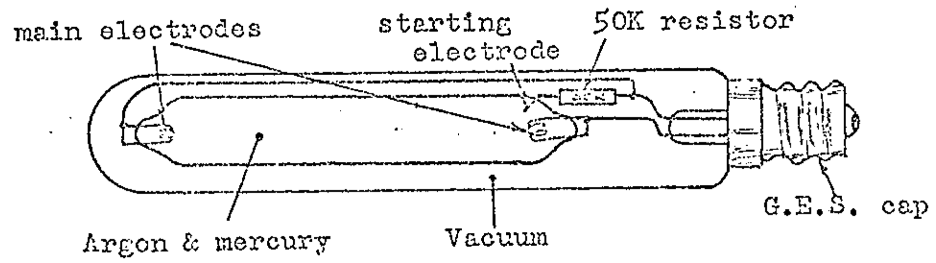
Mercury Vapour Lamps: All electric discharge lamps operate by passing an electric current through gas or vapour. In most gaseous discharge lamps, however, the LUMINOSITY results from the GAS itself - neon, argon, krypton, mercury etc. The COLOUR of the light depends on the GAS and its PRESSURE.

Commercial Mercury vapour lamps include 5 types:-

(1) Low pressure low voltage lamps in long tubes e.g. fluorescent lamps.
(2) High pressure high voltage lamps in short tubes - mostly for industry.

(3) High pressure high voltage lamps in long tubes - photochemical etc.
(4) Very high pressure, very high voltage lamps in short tubes e.g. Water cooled 1000W mercury vapour lamp.
(5) Very high pressure, very low voltage lamps in spherical bulbs.

The practical limit of a M.V. lamp's current carrying capacity is how high a temperature it's enclosing tube can withstand without rupturing. By connecting an impedance in series with the lamp, the current can be limited. In most lamps, about 50% of the supply voltage is absorbed by a series ballasting device.
One disadvantage of the M.V. lamp, is the effect of power supply interruptions, or voltage dips lasting more than one second. The lamp will extinguish, and will not re-ignite, until the pressure in the tube drops, after the temperature drops. This usually takes 3-4 minutes.
Lamps are constructed on similar lines, regardless of size or voltage - A glass, or quartz tube, is fitted with two large electrodes, one at each end: at one end, an additional small starting electrode is fitted and connected via a 50K resistor to the opposite electrode.
This assembly is placed inside a larger glass envelope, and sealed. The inner tube is filled with ARGON and a small amount of MERCURY. The space between the two glass walls is evacuated, to act as an insulator.

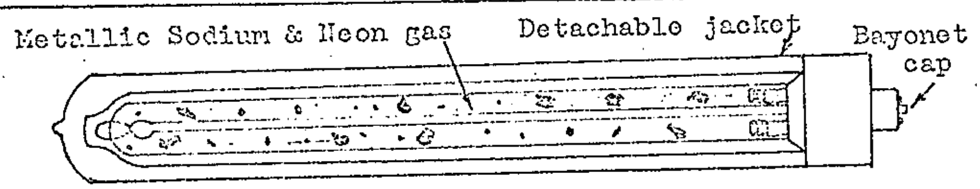


400W HIGH PRESSURE
MERCURY DISCHARGE LAMP

All M.V. lamps have coded letters printed on them. This code tells the following data:-

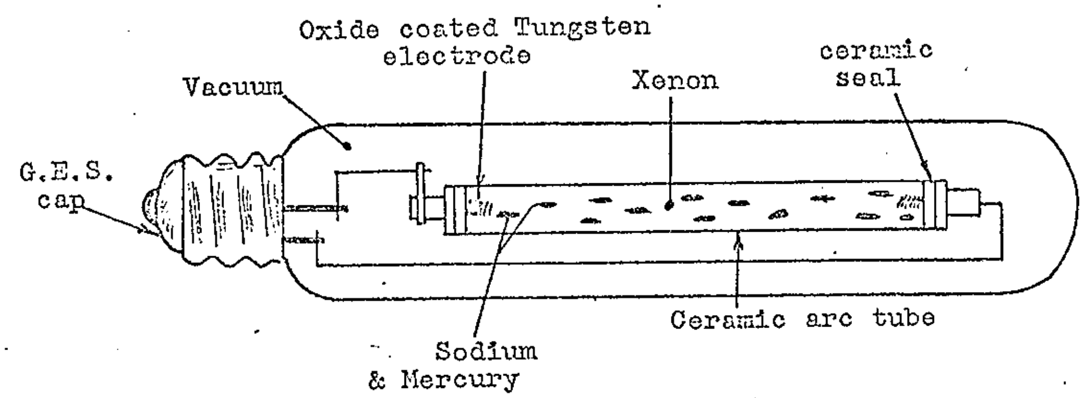
A - Glass envelope over 10W/cm. of arc length.
B - Quartz envelope below 100W/cm. of arc length.
C - Glass envelope below 10W/cm. of arc length.
D - Quartz envelope with forced liquid cooling.
E - Quartz envelope above 100W/cm. of arc length.
F - Fluorescent coating.
T - Tungsten filament lamp incorporated.
/V- Vertical cap up.
/D- Vertical cap down.
/H- Horizontal position.
/U- Any position.

Sodium vapour lamps (Low Pressure): Metallic sodium and neon gas are enclosed in a "U" shaped glass tube, which is approx. 18 mm. dia. and 700-800 mm. long. In the ends, are inserted oxide coated electrodes, which are connected to the supply via a bayonet cap lamp-holder. The "U" tube is sealed inside another glass chamber, from which the air has been evacuated, or it may be placed inside a double walled vacuum flask. A thin strip of metal is fitted between the legs of the U-tube, and is connected to one of the electrodes. The "U" shaped tube provides more concentrated light. The vacuum flask retains heat, to enable the lamp to work at a temperature above the melting point of sodium. The thin strip of metal helps in starting, and has a capacitive effect. The oxide coated electrodes reduce the rate of evaporation.
For its operation, a transformer is necessary to step up the mains voltage, to initiate the ionisation of the gas. Heat produced by ionisation gradually melts and vaporises the sodium. The colour of the lamp changes from Red, to Orange/Yellow whilst the sodium is vaporising.
After starting, the transformer acts as a current limiting device. This is necessary, because the lamp resistance (when ON) is virtually nil: 50 and 60 watt lamps can be operated in any position whilst the 85 and 145 watt tubes must operate in the horizontal position. This is to avoid the hot sodium collecting at one end. If this occurs, the lamp will operate as a neon discharge, for the greater length of the tube, and, in addition, the sodium may attack the glass in the region of the seal wires.
Special fireproof wrappings are provided for the transport of the inner tube, to avoid fire should the tube be broken, and the sodium come in contact with moisture. When a tube has to be disposed of, it should be placed in a dry steel container and broken into small fragments. Using a hose, water should be sprayed onto the glass etc. This will cause the sodium to burn and explode, whilst in a safe place.



140W SODIUM DISCHARGE LAMP

<u>Sodium Vapour Lamps (High Pressure)</u>: The high pressure sodium vapour lamp has different physical, electrical and photometic characteristics from those of other high pressure lamps, however light is produced in a similar manner, by the passage of an electric current through a vapour under pressure in a tube.
Similar to the low pressure lamp, this type uses a ballast for initiating ionisation in the tube. The principle radiating element in the arc of the lamp is SODIUM. Mercury is added for colour and voltage control. XENON gas is also introduced to facilitate starting. A special starting circuit is used, to supply a short, high voltage pulse, on each cycle or half cycle. This pulse has sufficient amplitude and duration, to ionize the XENON gas, and to initiate the starting sequence of the lamp. The warm-up period of this lamp is 3 - 4 minutes. During warm-up, there are several changes in the colour of the light.
Initially, there is a very dim, bluish-white glow, produced by ionized ZENON, which is quickly replaced by a typical blue, brighter mercury light. With the increase in brightness, there is a change to mono-chromatic yellow, which is characteristic of sodium at low pressure and temperature. Then as the pressure in the arc tube increases, the lamp comes to full brightness, with a golden white light. Should there be a momentary interruption of power, the "re-strike" time is approx. one minute.
Similar to M.V. and Sodium vapour (L.P.) lamps, it has "two bulb" construction, with an outer bulb "jacket", and an inner "arc tube". The ceramic arc tube contains the electrodes, sodium, and small amounts of mercury and xenon. The outer bulb of weather-resistant glass protects the arc tube from damage, and contains a vacuum, which reduces convection heat loss from the arc tube to ensure high efficiency.
The ceramic arc tube, is responsible for the high lumen output. An improved "Monolithic" seal for the arc tube eliminates the previously used metal cap, and provides excellent mechanical characteristics to withstand the high temperature discharge of metallic sodium. The new seal also provides excellent resistance to the strains of expansion and contraction, and the corrosive action of the sodium atmosphere. The electrodes are wound tungsten coils, coated with metal oxides, similar to those used in mercury lamps. The pencil thin ceramic arc-tube, is made of translucent poly-crystalline alumina ceramic, which will withstand extremely high temperatures. It is extremely resistant to the corrosive effects of hot sodium. Sodium, at these high temperatures, deteriorates quartz and similar materials very quickly.



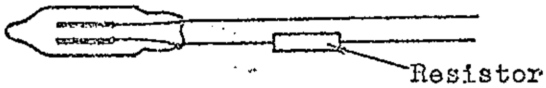
HIGH PRESSURE SODIUM VAPOUR
DISCHARGE LAMP

Glow lamps: A glow lamp consists of electrodes, sealed in a glass envelope filled with gas. The most commonly used gas is NEON, which gives a reddish glow, when current flows through the lamp. Less commonly used gases, are argon, and a mixture of helium and argon, which produces a blue and violet glow respectively. The light from a glow lamp is produced by a "cushion" of luminous gas surrounding the negative electrode. In alternating current usage, the rapid switch in polarity of the electrodes, gives the impression of both electrodes glowing continuously. Glow lamps consume low wattage and are mechanically rugged. Their light output, however, is low. Like other discharge lamps, they require a current limiting device, usually a resistor.

Neon - Red

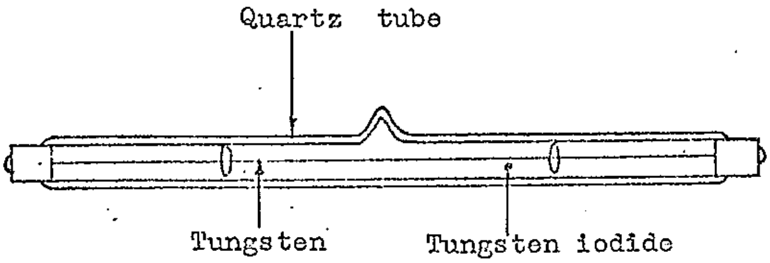
Helium - Blue

Argon - Violet



GLOW LAMP

Quartz iodine lamps: As the name suggests, the bulb of this type of lamp is made of quartz, in tubular form, and the iodine regeneration cycle is used to minimise bulb blackening. Since quartz has a melting point of 1650°C, it is ideal both for the iodine cycle and for smaller enclosures of high wattage filaments.
Ordinarily, tungsten, evaporating from a hot filament, is carried to the relatively cool bulb wall, where it accumulates and forms a black deposit.
However, with temperatures of several hundred degrees C, tungsten vapour and iodine vapour, combine to form Tungsten iodide, which does not adhere to the bulb wall, but is borne by convection currents, back to the filament, where it is reduced, and the tungsten re-deposited on the filament; the iodine vapour recirculates to continue the re-generative cycle.
Because of high temperature, the lamp should not be touched with bare hands for several minutes after it has been turned off. Portions of the bulb may reach 600°C; hence, precautions must be taken to keep combustible materials away from the bulb. Oil, grease or moisture from hands can cause early bulb failure.
Some applications of the quartz iodine lamp are:- Industrial and commercial interiors - Sports field lighting - Show windows - Building facades - Out-door work areas - Airport runways.



Wattage range :- 250 - 1500W

Life 2000 - 4000 hours

QUARTZ IODINE LAMP

TITLE:- ILLUMINATION (SAFETY)

LECTURER:-

DATE:-

EQUIPMENT:- Fluorescent tube, Sodium vapour lamp, Tungsten filament lamp.

If you have ever changed a lamp at home, you will have noticed that it becomes very hot, after operating for a short period.
Most lamps used in the works are in operation continuously, so should you have to change one, it is safest to treat it as though it had just "blown". Imagine what could happen if you were working from a high ladder and touched a hot lamp, the reflex action could cause you to lose balance and result in a serious injury. The lamps here, operate at a much higher wattage than domestic lamps, so the risk of being a victim of this type of hazard is greater. Another hazard is carrying lamps, tubes etc., inside the shirt. Admittedly, this leaves the hands free for climbing a ladder, but consider the risk should the lamp break. It is safe practice to use a hand line to bring materials and tools etc. up a ladder.
Although a fluorescent tube does not get as hot as a lamp, there is still a hazard. Should a tube break and shatter, the inside of the tube is coated with phosphorescent material, so great care must be taken when handling it. The safest method of disposing a used tube, is to put the used tube in the new tube's carton and then break it under cover; this will prevent small particles from flying out and causing an injury.
For the disposal of Sodium vapour lamps, they should be placed in a dry, steel container and broken into small fragments.
Using a hose, and from a safe distance, spray water on the fragments. This will cause the sodium to burn and explode whilst in a safe place.
New tubes are wrapped in aluminium foil, to minimise the risk of fire due to breakages and moisture in transit.
The high pressure sodium lamp, must only be used in fixtures and circuits, wired with compatible auxiliary equipment. Operation with incompatible equipment can cause the lamp to shatter, which may result in personal injury and damage to equipment.
DO NOT insert, or remove any lamp while the power is on.
If the outer bulb is broken, shut off the supply immediately, and remove lamp to prevent exposure to ultra-violet energy. This is a vacuum jacketed lamp and it may implode if broken. Do not scratch the lamp, or subject it to undue pressure, as either may cause shattering. Electrically insulate any metal support in contact with the outer bulb, to avoid glass decomposition. Although the outer bulb is made of heat resistant glass, external protection of the lamp is required, to minimise the chance of breakage, due to direct contact with water during lamp operation.

TITLE:- DIRECT CURRENT GENERATORS

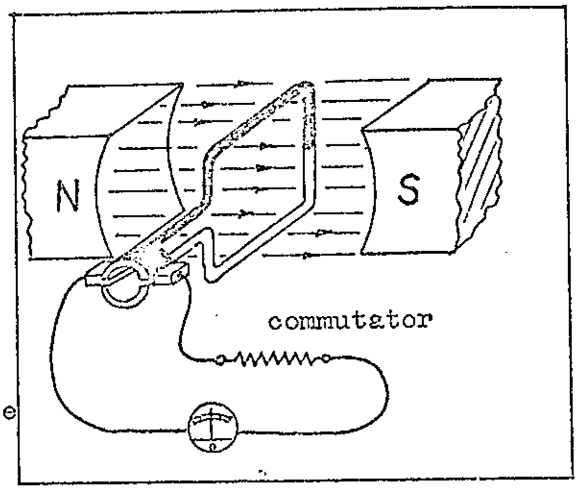
LECTURER:-

DATE:-

EQUIPMENT:-

A generator converts mechanical energy into electrical energy.

A magnetic field is represented by continuous lines of flux, considered to emerge from a north pole and to enter a south pole. When a conductor moves in such a way as to cut magnetic lines of force, there will be an E.M.F. generated in the conductor. Consider an elementary generator. A loop of wire rotating in a magnetic field forms an elementary generator, and is connected to an external circuit through a commutator. The commutator acts as an automatic reversing switch on the generator shaft which switches coil connections to the brushes every half revolution. Its purpose is to provide a d.c. output. Since the e.m.f. and current flow of an elementary generator reverse in polarity every time the armature loop rotates 180°, the output of such a generator would be A.C. if a commutator was not used.



In a practical generator, many coils are used in the armature and more segments are used to form the commutator. This is to smooth out the d.c. taken from the generator. A practical generator has a voltage output which is near maximum at all times, and which has only a slight ripple variation.

Generators can be either separately excited or self excited. Separately excited generators have their fields supplied from either another smaller generator (exciter), batteries etc. and there is no electrical connection between the field and the armature.
Self excited generators use part of the generator's output to supply excitation current to the field. The build up of the field happens as follows:-
When not in operation, the field poles retain a certain amount of "residual magnetism" from a previous run. When started up, this "residual magnetism" provides a very weak field which induces a low e.m.f. in the armature. This low e.m.f. strengthens the field which increases the output voltage. This process continues until the field builds up to full strength.

Construction

The mechanical and electrical design of both D.C. motors and D.C. generators is generally similar, and some machines operate either as a generator or as a motor, therefore the constructional details can be considered for both at once.

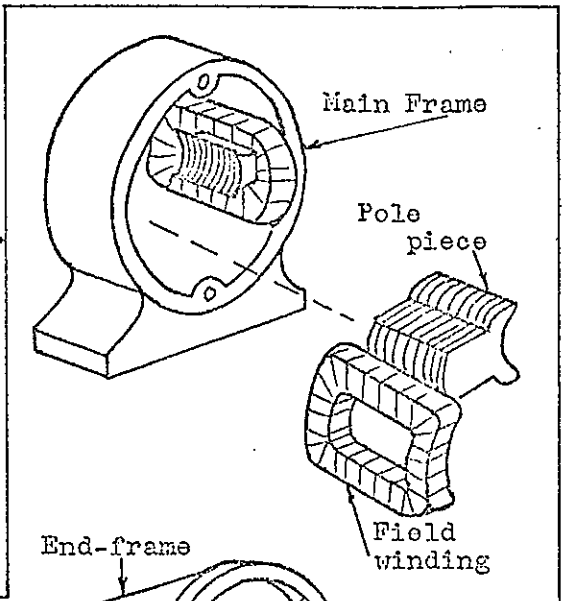
Main Frame Sometimes called the "yoke". It is the foundation of the machine and supports the other components. It also serves to complete the magnetic field between the pole pieces.

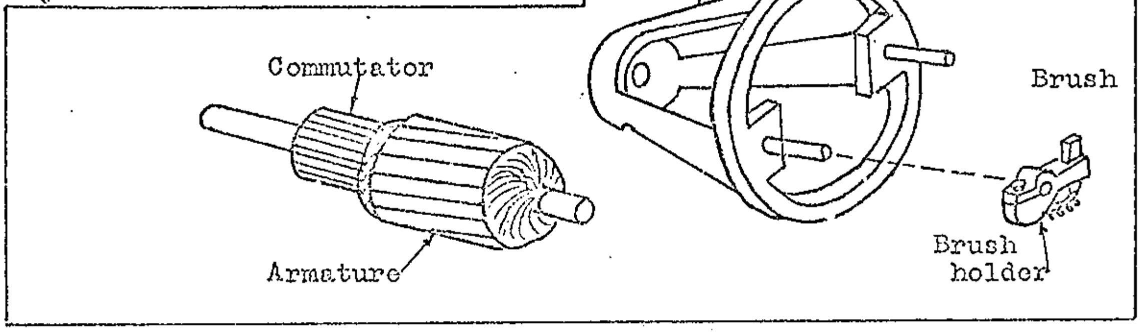
Pole pieces Made of laminations formed together and bolted to the inside of the frame. They provide a support for field coils, and are designed to produce a concentrated field. By laminating the poles, eddy currents are reduced.

Field Windings These, when mounted on the pole pieces, form electromagnets which provide the magnetic field necessary for generator action. The windings and pole pieces together are often called the field. The windings are coils of insulated wire wound to fit closely around the pole pieces whose current provides the field.

<u>End Frames</u> These are attached to the end of the main frame and contain the bearings for the armature. The rear housing usually supports the bearing only, while the front housing also supports the brush assemblies.

<u>Brush holder</u> This component supports the brushes and their connecting wires. The brush holders are secured to the front end housing with clamps. On some generators, the brush holders can be rotated around the shaft for adjustment.





<u>Armature assembly</u> In practically all d.c. generators, the armature rotates between the poles of the field. The armature assembly is made up of a shaft, armature core, armature windings and commutator. The core is laminated and is slotted to take the armature windings. The armature windings are usually wound on formers and then placed in the core slots.
The commutator is made up of copper segments, insulated from one another and from the shaft by mica. They are secured by retainer rings to prevent movement due to centrifugal forces. Either small slots or risers are provided at the back of segments for connection to the windings.
The shaft supports the entire assembly and rotates in the end bearings.
A minimum air gap is left between armature and pole pieces in order to keep field strength to a maximum.

<u>Brushes</u> The brushes ride on the commutator, and carry the generated voltage to the load. They are usually made of a high grade of carbon, and are held in place by brush holders. The brushes are able to slide up and down in their holders so as to be able to follow irregularities in the surface of the commutator. A flexible braided conductor called a "pigtail" connects each brush to the external circuit.

TITLE:- DIRECT CURRENT MOTORS

LECTURER:-

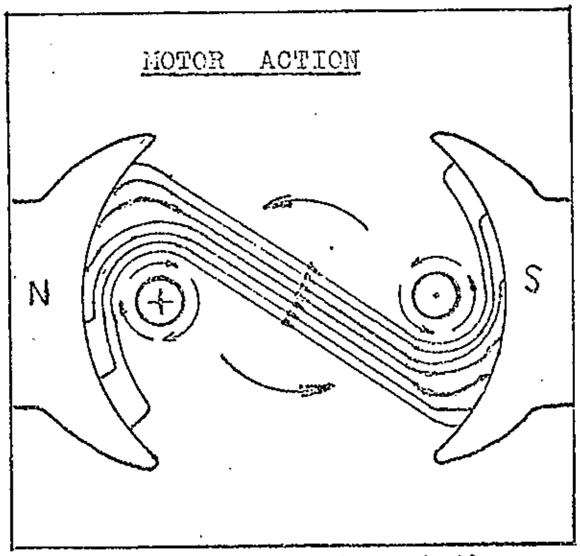
DATE:-

EQUIPMENT:-

Motors are used to convert electrical power to mechanical power.

In spite of the fact that a standard D.C. motor costs more than an induction motor, and that the majority of present day power distribution is by alternating current, the scope for d.c. motors is large, particularly for drives requiring speed control or having some special feature.
D.C. motors can be built in sizes ranging from fractional horsepower up to over 5000 H.P. (used in steelworks).

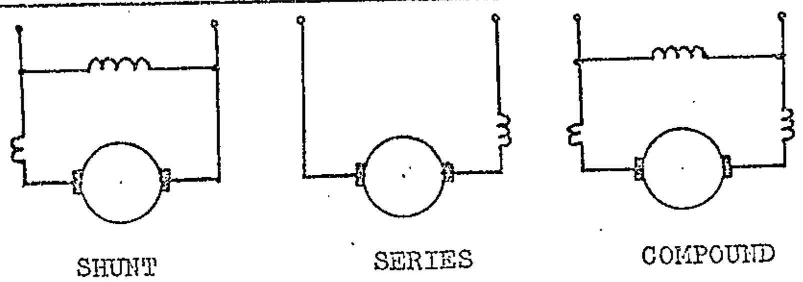
Principles of D.C. motors Any conductor which carries current is surrounded by a magnetic field. If it lies in the field between the poles of a magnet, the two fields interact. Where the conductors lines of force oppose those of the main field, the main field will be weakened. Where the conductors lines of force assist the main field, it will be strengthened. The result of this interaction as can be seen in the diagram is a distortion of the main field i.e. Field is weakened on top of R.H. conductor and bottom of Left hand conductor, and strengthened at bottom of R.H. conductor and top of L.H. conductor.
The main field, in trying to straighten out, moves the conductor anti-clockwise direction, but then the next armature conductor moves into the main field to take the first one's place and the procedure is repeated. This results in continuous motion of the armature.



This continuous motion causes the armature conductors to cut the magnetic field of the main poles. All three conditions for generation of an e.m.f. are now present, i.e. conductors, motion, flux. An e.m.f. is therefore induced in the conductors which, by Lenz's law, opposes the applied voltage. It is therefore called the "back E.M.F." The back E.M.F. is never as great as the applied e.m.f.: the difference between the applied e.m.f. and back e.m.f. is always such that current can flow in the conductor and produce motion.
D.C. motors are classified according to their method of field excitation, i.e. shunt, series compound.
Shunt motors are classed as constant speed machines. The field winding has a constant voltage applied to it so that the flux will be constant at all loads and the torque will be proportional to armature current.
Series motors Whereas the shunt motor is essentially a constant flux machine, the series motor is a variable flux machine. The armature and field windings are connected in series.
Since there is only one circuit through the motor, any change in the load causes a change in the current and the working flux. Neglecting motor resistance, the speed is inversely proportional to the flux if the supply voltage is constant.
At light loads, the current is small and hence the flux is small as the field coils are energised by the main current.
As the load is increased, the current increases and the consequent increase in the magnetic field results in a reduction in the speed.

Series motors are not used in cases where light load running is possible such as belt drives, which could break or slip the pulley. The reason for this is that under light or no load conditions, the motor could build up to a self-destructing speed. They are suitable for hoists, cranes etc.

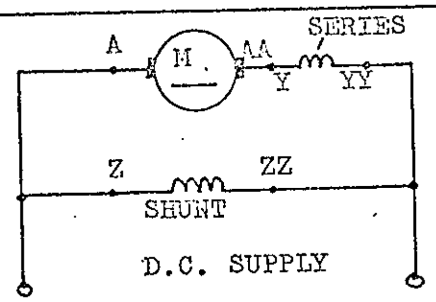
Compound motors The speed of a shunt motor is seen to be almost constant at all loads and the speed of a series motor is seen to vary considerably, falling in a marked manner as the load is increased.
By using both shunt and series coils so that the series winding assists the shunt, the motor characteristic can be made intermediate between them.
The chief application of the compound motor is when used in conjunction with a flywheel to give up its stored energy when a sudden load comes on such as with presses etc. Also used for driving pumps and other heavy duty machinery.



D.C. MOTORS OR GENERATORS

Compounding a d.c. motor A compound motor must be connected in the proper manner to ensure that it rotates in the proper direction, and also to prevent damage.
6 leads are brought out to the terminal block of the motor and should be labelled as follows -

A - AA is the armature
Y - YY is the series field
Z - ZZ is the shunt field



Connect the motor as shown in the diagram.

Follow these steps to check direction -

(1) Disconnect the motor from drive if reversal will cause damage.
(2) Short out series field Y-YY.
(3) Inch motor and note direction.
(4) Remove short from series field Y-YY.
(5) Disconnect shunt field terminal Z. If a field failure relay is fitted in the control circuit, this will have to be wedged in.
(6) Inch the motor and note direction. DO NOT ALLOW THE MOTOR TO ACCELERATE.
If the motor is controlled by a reversing drive, put the controller in the same direction as in step 3 and operate the same pushbutton.
(7) Interchange the leads A-AA or Z-ZZ to allow the motor to run in the correct direction with respect to the controller or pushbutton as follows:-

Step 2 correct, step 5 correct - do not interchange any leads
Step 2 correct, step 5 incorrect- interchange Y-YY (series)
Step 2 incorrect, step 5 correct - interchange Z-ZZ (shunt)
Step 2 incorrect, step 5 incorrect - interchange A-AA (armature)

TITLE:- D.C. MOTOR STARTING & SPEED CONTROL

LECTURER:-

DATE:-

EQUIPMENT:-

All D.C. motors are simultaneously generators while they are motoring. Obviously, motor action predominates under this condition because electrical energy drives the armature, and this means that armature current is delivered by the source.
The generated e.m.f., which results from the conductors in the armature cutting the field as they revolve, is a back e.m.f. (Lenz Law) therefore the magnitude of armature current depends upon the difference between the Applied e.m.f. and the back e.m.f.
In fact, it is the back e.m.f. which exercises a limiting effect upon armature current and causes the motor to adjust its speed and torque automatically to suit varying demands of the load.
At the instant a motor is started, the back e.m.f. is zero because the armature is not revolving. This means that some external resistance must be inserted in series with the low armature-winding resistance to offset the lack of back e.m.f. if excessive values of armature current are to be avoided. As the motor accelerates, and more back e.m.f. becomes available, the accelerating resistance can be cut out or short circuited in steps and when it is entirely removed, the armature is connected directly across the line and is running at full speed.

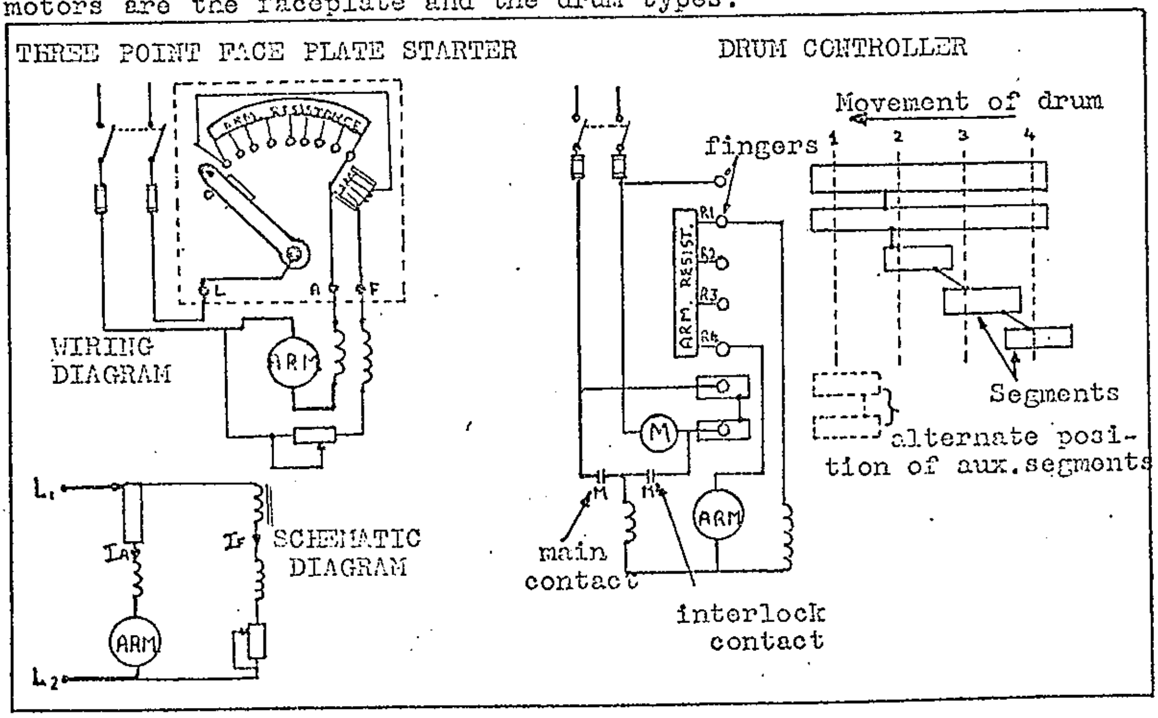
Example The armature of a 75 h.p. 230 volt 275 amp shunt motor has a resistance of 0.067 ohms. If the inrush current to armature is to be limited to 150 per cent of rated line value (a) calculate the resistance of the accelerating resistor (b) what approximate inrush current can be expected if the motor is started directly from 230 volt source without accelerating resistor?

Solution

(a) $R\ accel = \dfrac{230}{1.5 \times 275} - .067 = 0.557 - 0.067 = \underline{0.49\,ohm}$

(b) $I\ inrush = \dfrac{230}{0.067} = \underline{3,440\ amps}$

Two widely used manually operated starters for both A.C. and D.C. motors are the faceplate and the drum types.



Automatic Starters

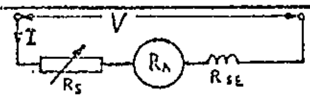
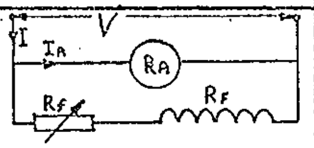
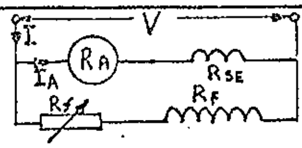
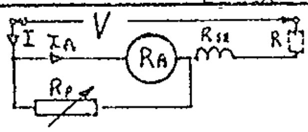
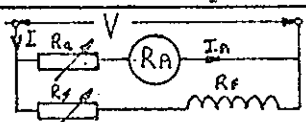
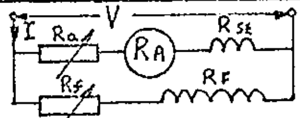
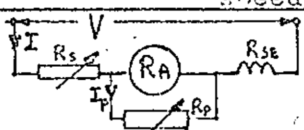
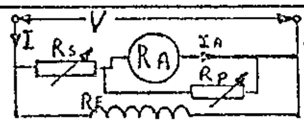
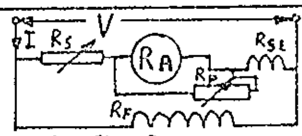
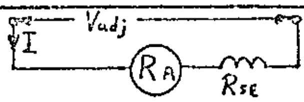
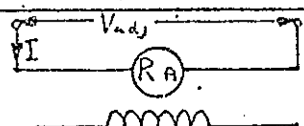
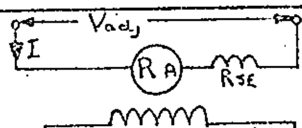
The reasons for using accelerating resistors are:-

(1) To limit inrush currents that are commutated because excessive current would tend to produce arcing and commutator burning.
(2) To minimize line disturbances caused by high inrush currents that produce excessive line resistance drops.
(3) To provide smooth acceleration so that driven machinery and equipment will not be subjected to undue mechanical stresses caused by sudden application of high torques.

There are many types of automatic starters for D.C. motors but all are classified under two general methods of acceleration, namely (1) current limit acceleration, and (2) definite time acceleration. With the first of these, a set of series or current relays is made to function i.e., pick up and drop out, for changing values of armature current as the motor accelerates; the relays in turn, operate to energize contactors which cut out (short circuit) the resistors in steps.
The definite time acceleration method employs a set of timed relays that function in sequence at a definite rate, regardless of load. These relays act on contactors which then progressively short circuit a group of resistors.
It should be noted that with the first method, the load will determine how rapidly the motor is brought up to full speed while with the second method, the motor will repeatedly cause the motor to operate on a given time cycle regardless of load.

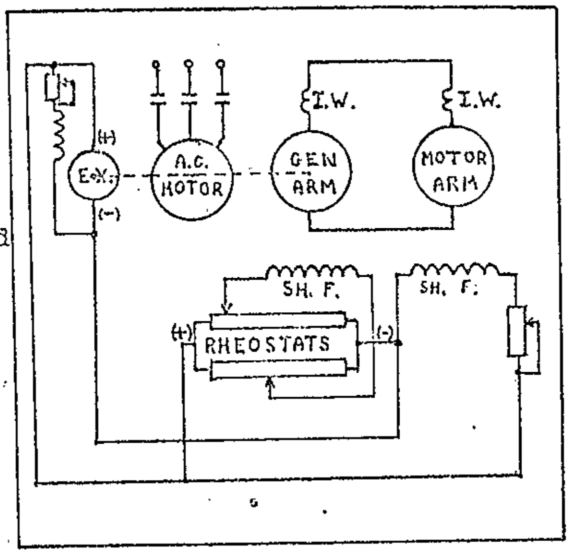
Speed control One of the D.C. motor's most valuable characteristics is its ability to provide a wide range of easily adjustable speeds. This is important because a high degree of speed control is often essential to certain motor-driven installations. It is significant that d.c. machines can be made to serve effectively for such applications because voltage and flux changes greatly influence the behaviour of these motors; this is in contrast to the A.C. induction type motor, whose speed does not change substantially under such conditions.

The following table gives the various means used to change speeds of D.C. motors:-

CONTROLLED ELEMENT	I-SERIES	II-SHUNT	III-COMPOUND
A FIELD RESISTOR	 raise Rs, lower speed	 raise Rf, raise speed	 raise Rf, raise speed
B FIELD AND ARMATURE RESISTORS	 lower Rf, lower speed	 raise Ra, lower speed raise Rf, raise speed	 raise Ra, lower speed raise R, raise speed
C SERIES AND SHUNT ARMATURE RESISTORS	 raiseRs, lower speed lowerRp, lower speed	 Raise Rs, lower speed lowerRp, lower speed	 raiseRs, lower speed lowerRp, lower speed
D TERMINAL VOLTAGE	 raise V, raise speed	 Separate exciter raise V, raise speed	 Separate exciter raise V, raise speed

Ward Leonard Speed Control This system uses the adjustable voltage method of speed control and offers many advantages over other methods. Although an expensive installation, it has wide application wherever low and high speeds must be accurately made, and where the service is severe and exacting. Rotation can be reversed by reversing polarity of the main generator. (used for main rolls in steelworks).
All control is centred in a rather small rheostat in the field circuit of the main generator.
The Ward Leonard system of speed control offers the following advantages:-

(1) Speed range much greater than that obtainable with shunt motor with armature and field control.
(2) Control component is generally a small field rheostat whose power requirement is about 1 to 2 per cent of total input so control is practically stepless.
(3) All heavy contactors eliminated because loop circuit is solidly connected. Motor is started, accelerated, speed adjusted, stopped and reversed by merely adjusting generator voltage.
(4) Generators with special characteristics can be matched to specific motor load requirements. This is particularly desirable in certain machine tools and for such heavy equipment as excavators.



With Compound motor - Shunt field should not be weakened too much or motor becomes a Series Motor (Effective)

Braking

Plug Braking - Reverse current applied to armature while still running in forward or vice versa thus C.E.M.F. ADDS to applied E.M.F. to bring motor to quick stop.

Dynamic Braking Applied current is removed from armature and C.E.M.F. is allowed to flow in armature CCT to bring motor to quick stop.

Regenerative Braking Used on hoists, cranes etc. to limit (Govern) speed when lowering. Motor overruns above critical speed and becomes generator therefore armature current reverses and holds armature to a maximum speed.

Note: Critical speed is speed at which C.E.M.F. Equals applied E.M.F.

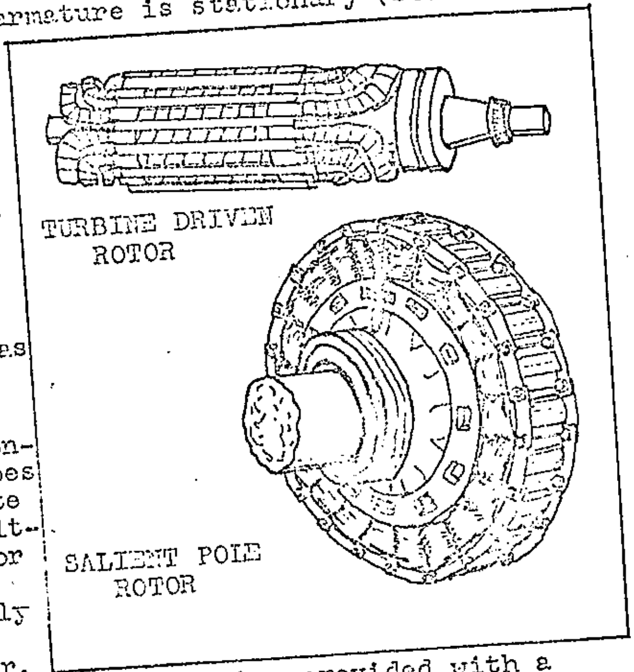
TITLE:- ALTERNATING CURRENT GENERATOR

LECTURER:-

DATE:-

EQUIPMENT:-

The A.C. generator, sometimes called the synchronous generator or alternator, consists essentially of the same two parts as the D.C. generator, i.e. the field magnet system and the armature. Unlike the arrangement in a D.C. generator however, the field magnets usually rotate (Rotor), and the armature is stationary (Stator) with the large types.



With the small types, the construction is similar, the main difference being that power is drawn off through slip rings instead of a commutator. These slip rings are essentially rings of copper, insulated from the shaft and each other and connected to the ends of the windings. Carbon brushes ride on these rings in the same manner as with a commutator but deliver A.C. to the load. (M.12.1)

The advantage of using a stationary armature with the large types is that it is easier to insulate armature coils for the high voltages usually generated (6,600 or 11,000 volts). By making the field magnet system rotate, only two slip rings are required (+ and -). There is no commutator. They are separately excited, each machine being provided with a small D.C. Generator, called an exciter, mounted on the same shaft: this supplies the magnetising current for the field magnets, usually at 110V or 250V.

Rotor Types

Rotors can be either salient pole or smooth cylindrical.

(1) Salient pole type is used with slow speed machines. Generators having this type of rotor are characterised by their large diameter and short axial length. A number of poles (from six up to about forty) are either bolted or fixed by using dovetails to a magnet wheel which is of large diameter. The poles are usually built up of steel stampings.

(2) Smooth cylindrical type suitable for turbo-generators. Number of poles, two or four. The rotor diameter is relatively small, but it is of large axial length. The useful range of two pole machines extends to about 50,000 KVA, but with four poles, units up to 200,000 KVA are possible.

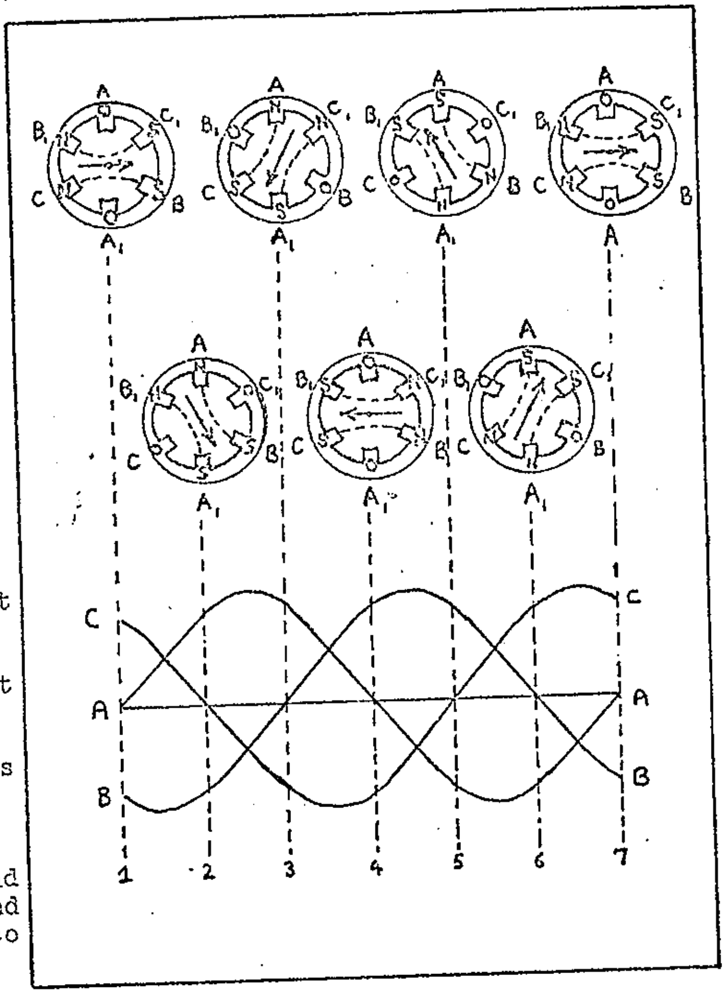
TITLE:- ALTERNATING CURRENT MOTORS

LECTURER:-

DATE:-

EQUIPMENT:-

Alternating current motors are of two kinds. Synchronous and Asynchronous.
They can be single phase or polyphase.
The principle of operation hinges around what is known as a rotating field. The diagram shows the waveform of a 3 phase supply applied to the stator. These wave forms are 120° out of phase with each other. The waveforms can represent either the three alternating magnetic fields generated by the 3 phases, or the currents in the phases. The waveforms are lettered to correspond to their associated phases. Using the waveforms, we can combine the magnetic fields generated every one sixth of a cycle (60 degrees) to determine the direction of the resultant magnetic field. At point 1, C is positive and B is negative. This means that current flows in opposite directions through phases B and C and so establishes the magnetic polarity of phases B & C. Observe that B1 is a north pole and B is a south pole, and that C is a north pole and C1 is a south pole. Since there is no current through A at this point, its magnetic field is zero.



At point 2, 60 degrees later, the input current waveforms to phase A and B are equal and opposite and C is zero. The resultant magnetic field will then be in the direction shown (a shift of 60 degrees).
At point 3, B is zero and the resultant magnetic field has rotated through another 60 degrees.
From points 1 to 7, (corresponding to one cycle of A.C.) it will be seen that the magnetic field rotates through 360° for every cycle of A.C.
The rotating field is said to turn at "synchronous" speed.
To determine the synchronous speed of a motor, the following formula may be used:

$$N = \frac{120f}{P}$$, where N = Synchronous speed
f = frequency
P = No. of poles of stator

Synchronous motor: Similar in construction to alternators; as the name implies, they run at the same average speed as the rotating field.

A simple form of small synchronous motor uses a permanent magnet as a rotor. When the field is energised, and a rotating field is set up, the magnet follows the rotating field and "locks in", so that the rotor turns at the same speed as the rotating field in the stator, i.e. synchronous speed.
Small single phase synchronous motors are used to operate electric clocks, timers etc. to a high degree of accuracy.
Large synchronous motors have their rotors energised by D.C. from a separate source, fed in via slip rings.
The speed of these machines depends upon the supply frequency and the number of poles.

Advantages of synchronous motors are:-

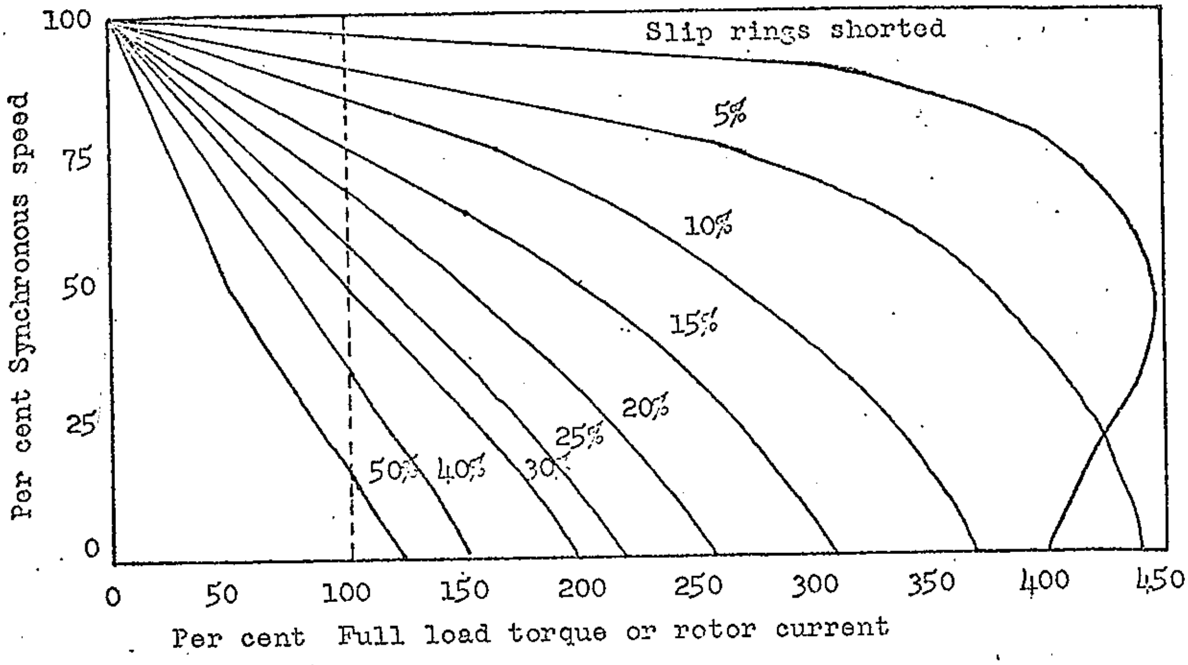
(1) Constant speed.
(2) Power factor can be varied over a wide range to suit the requirements of the load.
(3) Higher efficiency than other types of A.C. motors.

Disadvantages

(1) Speed is not adjustable.
(2) Single phase motors not self starting.
(3) Tendency to hunt.
(4) Separate D.C. source required.

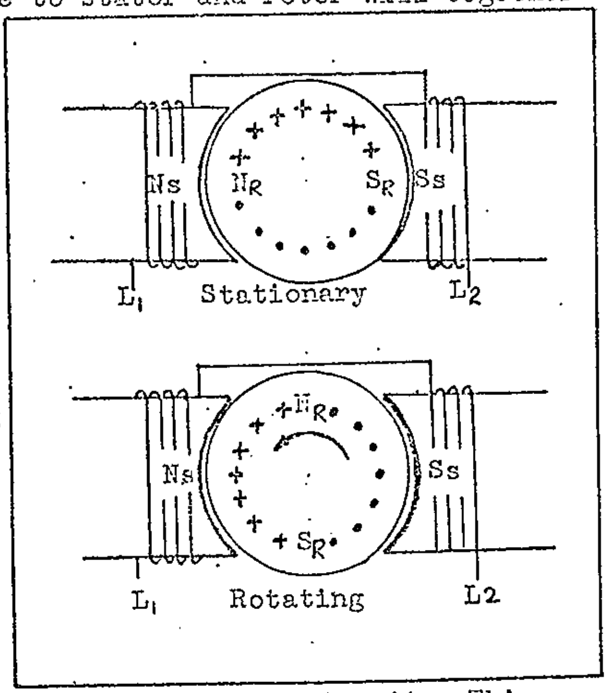
Induction motors: All A.C. machinery operating at non synchronous speeds are referred to as asynchronous machines. Induction motors are of this type.
An induction motor is similar electrically to a transformer whose magnetic circuit is separated into two parts, one of which is capable of being rotated. The stationary part, (stator) contains the primary winding which is energised by the supply mains. The rotating part, called the rotor, contains the secondary winding; this winding is not connected to any source of power, but has voltage and current induced in it by the alternating flux set up by the primary current. It may consist of a number of bars connected directly to heavy copper rings at each end of the rotor. This is called a squirrel cage rotor. It is from this induction between stator and rotor that the motor derives its name.
The effect of the current in the stator windings is to produce a magnetic flux in the stator core, which crosses the air gap between stator and rotor and completes its circuit in the rotor core.
This flux crosses the air gap and produces magnetic poles at the same mean distance apart as the pitch of the stator coils.
When supplied with an appropriate poly phase supply, the stator field will rotate and produce on the rotor the same effects as if it were surrounded by a system of rotating poles of constant strength.
The rotating flux cuts the conductors of the rotor and induces a current in it, and a torque is set up between rotor and stator.
For the motor to operate, the rotor must rotate slower than the field, because if the speed caught up there would be no relative motion, hence no currents induced in the rotor, and no torque.
The difference between rotor speed and the speed of the rotating field (synchronous speed) is called "slip".

Wound rotor motor: The rotor is made up of wound insulated coils which are carried out and terminated in three slip rings with this type of induction motor. Carbon brushes mounted on the slip rings are connected to a 3 phase external resistance bank, which is used to vary the resistance in the rotor circuit, and by this means, torque and speed can be regulated as the following table shows:-



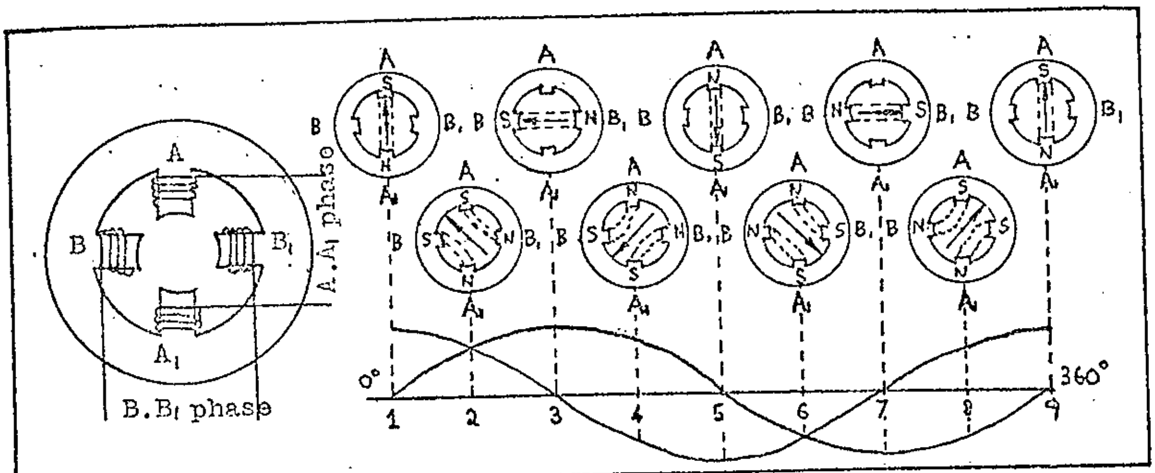
The advantage of the wound rotor and starter resistance is that starting current can be controlled and the starting torque is higher than with a squirrel cage rotor, also speed can be controlled. This type of motor is more expensive than the squirrel cage type, however.

Single Phase Motors: A single phase alternating current produces an alternating and not a rotating magnetic field. If however, the rotor of a single phase motor is made to rotate rapidly while the stator is supplied with an alternating current, the currents induced in the rotor conductors will themselves produce a magnetic field, and since this field will be out of phase with the primary field, the two magnetic field due to stator and rotor will together form a rotating field.

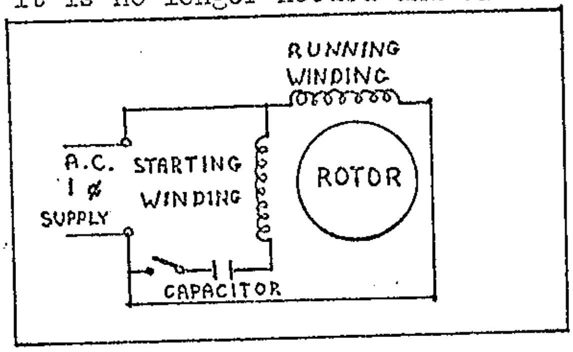


It should be clear that once a single phase motor is started turning by some means it will continue to turn by itself. It is impractical to start a motor by turning it over by hand so some electrical device must be incorporated into the stator circuit to make a rotating field be set up on starting.
Once the motor has started this device can be out of circuit since stator and rotor together will generate their own rotating field to keep the motor turning.

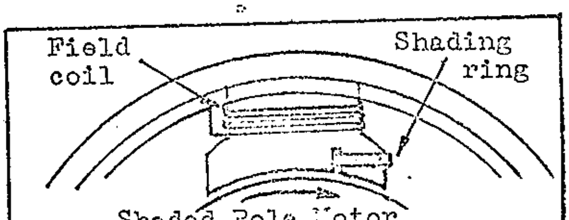
One of the most common methods used is to "split" the phase by having the running winding made up of a low resistance, high impedance winding i.e. comparatively few turns of quite large diameter wire, wound to embrace the maximum amount of iron in the core. A start winding is introduced into the circuit. This winding has large no. of turns of fine wire for maximum resistance and embraces minimum amount of iron in the core for low impedance. This design gives a phase displacement between the two windings, and if they are placed in the stator with a 90° physical displacement, a rotating field effect can be obtained which is sufficient to start the motor.
The effect obtained is similar to a two phase rotating field as shown:-



The starting winding is switched out by a centrifugal switch at about 75 per cent full speed since it is no longer needed and also since it would soon overheat due to the fine size of the wire.



Placing a capacitor in series with the start winding gives a larger phase displacement between the two windings. This has a two fold effect:- Firstly, the starting torque is greatly improved and secondly, the inrush current when starting is reduced.
The direction of rotation is reversed with these types of motor by either reversing the start connections or the run connections but not both.



Shaded Pole Motor

Shaded Pole Motor: This type of motor, one of the simplest and cheapest to manufacture, is an induction machine provided with an auxiliary short circuited winding displaced in magnetic position from the main winding. In its most usual form it has salient poles surrounded by a main coil and a short circuited turn of copper strap around a portion of the pole piece.
Being an induction motor with a squirrel cage rotor, the latter receives power in much the same way as does the rotor of a polyphase induction motor. One important difference concerns the motion of the magnetic field however. The field of the shaded pole motor merely shifts from one side of the salient pole to the other since the field set up by the shading ring lags the main field and is offset from it.
The torque of such motors, generally made in very small sizes, is therefore not uniform but varies from instant to instant.
These motors are generally used on fans and other small apparatus.
To reverse the direction of a shaded pole motor, the stator has to be physically reversed.

The advantages of single phase induction motors are:-
(1) Can be operated from a single phase supply.
(2) Require no extra starter for most sizes.
(3) Rotation in most cases easily reversed.
(4) Robust in construction and do not require a commutator and brushgear.
(5) Since they have no brushgear they are suitable for use in inflammable locations.

(6) Fairly silent running.
(7) Operate at nearly constant speed.
(8) Do not cause radio interference.

Limitations are:-

(1) Speed can only be changed in fixed steps by using expensive pole changing windings.
(2) Speed fixed by number of poles and mains frequency.
(3) Maximum possible speed is 2900 R.P.M. on 50 cycles supply with a 3 pole motor.
(4) Split phase type has low starting torque, high starting currents and low overload capacity.
(5) Relatively low power factor and efficiency.

TITLE:- A.C. MOTOR STARTERS & SPEED CONTROL

LECTURER:-

DATE:-

EQUIPMENT REQUIRED:

Direct On Line Starting Since the A.C. impedance of a stator winding of an A.C. motor is considerably higher than is the resistance of the armature winding of a D.C. motor, inrush currents to the former, with the application of full voltage is very much less than the latter. This means, therefore, that the smaller type of A.C. motors, need not, for the most part, be restricted to the usual current-limiting starting procedures of D.C. motors, although reduced voltage methods are used with larger types, not so much to protect the motors against high inrush currents and sever electromagnetic stresses as to minimise line voltage disturbances. In particular, it can be said that initial surge currents to A.C. motors with full voltage starting rarely exceeds six to seven times rated value, and these high currents are of a short duration only and also, they pass directly into the windings through wired connections and not sliding contacts.

Reduced Voltage Starters If it is desired to limit the starting currents to lower values than those indicated above, one of four schemes may be employed. In each case, less than rated voltage is applied to the motor terminals during a major part of the accelerating period, under which condition the inrush current is reduced in proportion to the voltage reduction. However, due to less torque being available, the motor is likely to accelerate slowly at the reduced voltage, causing excessive motor heating, especially if frequently repeated. Great care should be taken in choosing a starter to avoid this condition.

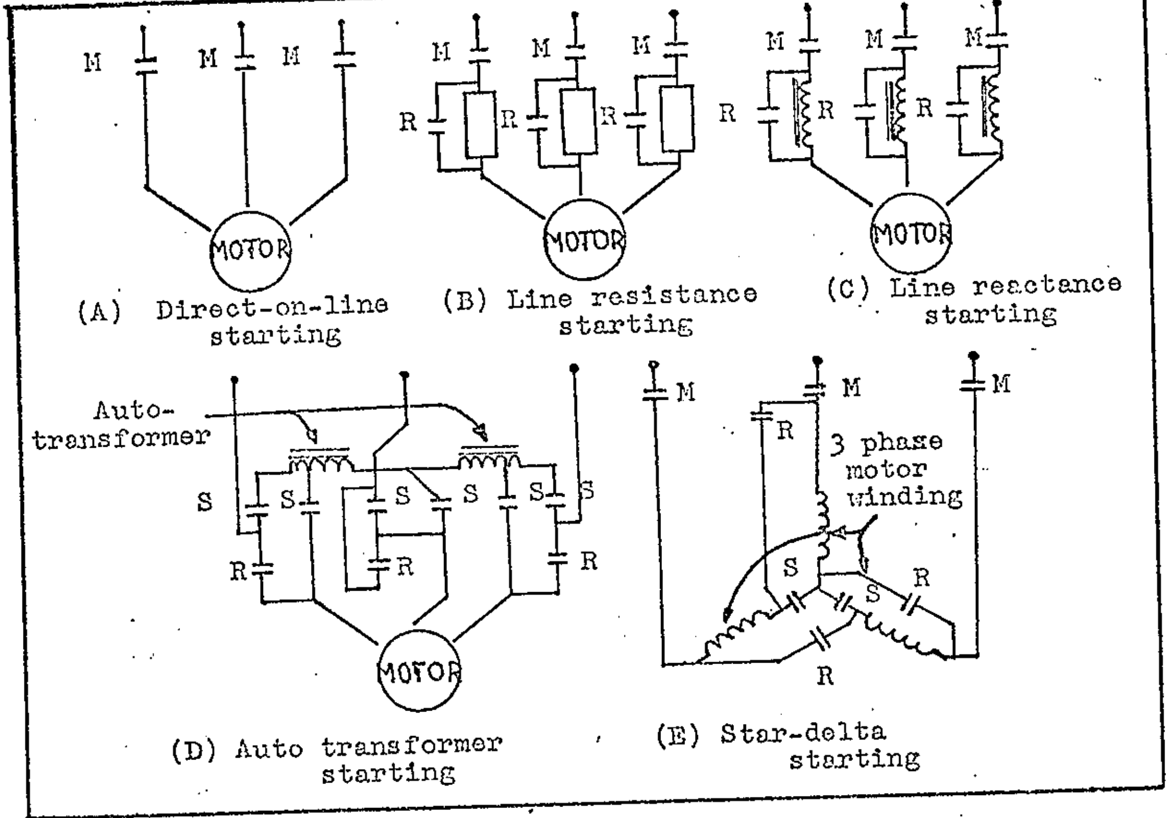
The main types of starters are:-

(1) The insertion of line resistors to introduce artificial voltage drops, Fig. B.

(2) The insertion of line reactors for the same reason. Fig. C. From the sketches of the power circuits it can be seen the resistors and reactors incur voltage drops during the accelerating period, when the (M) main contacts only are closed, and thus permit the motor to start under reduced-voltage conditions. After the motor reaches full, or nearly full speed, the (R) run contacts close to short circuit the resistors or reactors when a contactor is energised, under which condition normal operation continues.

(3) Fig. D represents a typical autotransformer (compensator) starting arrangement in which the customary open-delta connection is employed.
In the actual compensator, the two windings shown are placed on the two outside legs of a three legged core and reduced voltage taps are brought out at the 50, 65 and 85 per cent points. As indicated, when the (S) start contacts close, the motor starts on reduced voltage, determined by the tap selected, and after the motor accelerates to full or nearly full speed, the S contacts open and the R contacts close. When this happens, the compensator is completely disconnected from the circuit and the motor runs properly from the full voltage source.

Advantage The biggest advantage of this method is its "double barrelled" effect, i.e. using line resistance or line reactance, the line current and motor current are the same. With the compensator method, the motor is supplied with reduced voltage by transformer action, thus this reduced voltage draws a certain current but the line current is the same fraction of motor current as is the secondary to primary voltage ∴ with a starting voltage of 50 per cent, the line current will be 25 per cent.



(A) Direct-on-line starting

(B) Line resistance starting

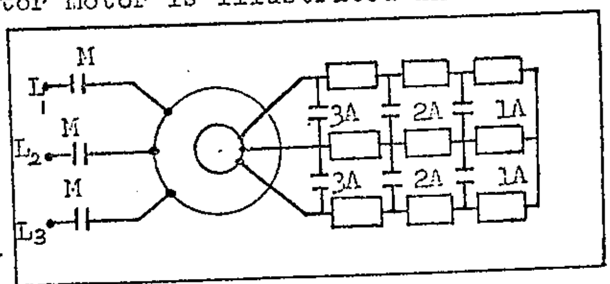
(C) Line reactance starting

(D) Auto transformer starting

(E) Star-delta starting

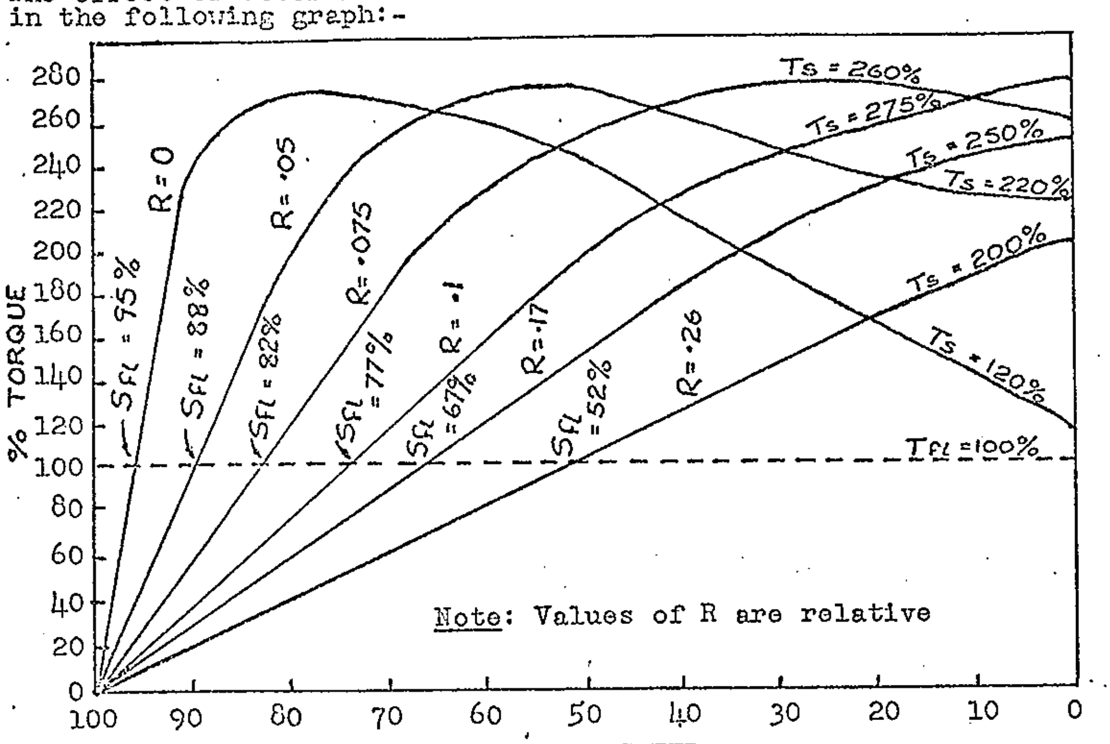
(4)
Star Delta Starter Fig. E represents the star/delta method. This method is interesting and economical in that no external equipment such as resistors, reactors, or transformers are needed to provide each phase with reduced voltage during the accelerating period. However, with this scheme, the motor must be designed to run in delta. Thus, when the M & S contacts close, the motor starts star connected with about 58 per cent voltage across each phase; then after reaching full speed, the S contacts are opened first, after which the R contacts close to connect the three winding phases in delta for full voltage operation. This system supplies about 1/3 starting torque of D.O.L. Motor must have six terminals.

(5) Wound Rotor Motor The ohmic value of the rotor resistance of a polyphase induction motor greatly affects three important operating characteristics. These are (1) starting torque (2) Starting current and (3) the speed under varying load conditions. The rotor resistance cannot be varied with a squirrel cage motor. For most applications this is not serious, but with some circuits, one or more of these characteristics must lend themselves to adjustment.
Induction motors with wound rotors fulfill these requirements. A simplified diagram showing how external resistors are connected in a rotor circuit of a wound rotor motor is illustrated in the following sketch.



In practice, the total external resistance is selected on the basis of the desired starting torque, and maximum permissable starting current. The number of steps is selected on the basis of the number of speed points and an acceptable smoothness of acceleration. The higher the external resistance, the lower will be the inrush current. This is because the rotor circuit is, in reality, the secondary of a transformer whose total impedence affects the magnitude of, not only the current in that circuit, but, by transformer action the current taken by the stator.

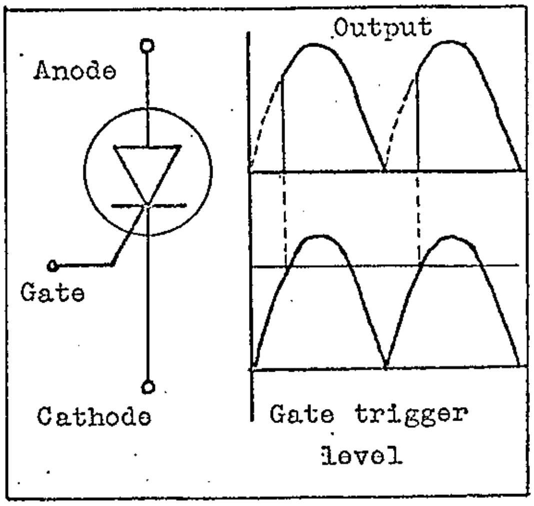
The effect of rotor resistance on a wound rotor motor is illustrated in the following graph:-



Unlike a D.C. motor which has rotor and stator fed from D.C. source, the A.C. induction motor is singly fed, i.e. currents are induced in the rotor by a synchronously rotating field. The speed of an induction motor is tied to the line frequency, the number of poles, and, for motors with phase wound rotors, to the resistance that is inserted in the secondary circuit. It follows, therefore, that speed control is possible by employing (1) a variable frequency source (2) one of several pole changing schemes, and (3) variable resistors in the rotor circuit of a phase wound rotor motor. However, the induction motor is essentially a constant speed energy converter, and under normal operating conditions the speed changes only slightly between no load and full load.

S.C.R. Speed Control

An electronic device which can be used to control the speeds of some A.C. motors incorporates a silicon controlled rectifier. An S.C.R. is basically a diode which can be switched on by a voltage applied to a gate.



An S.C.R. has high resistance in both directions until correct voltage is applied to the gate, it will then conduct in one direction only. Once conducting, the gate has no effect and can only be switched off by removal of anode voltage. On a speed control for motors, the S.C.R. is fired when and where desired on the sine wave. This effectively cuts the average voltage applied to the motor, so that it runs at a reduced rate. The back e.m.f. is also reduced as the motor has a high torque at low speeds. If the motor is replaced with a lamp, i.e. a purely resistive load, the lamp will dim as the average voltage is reduced.

TITLE:- SAFETY HANDBOOK

LECTURER:-

DATE:-

EQUIPMENT:- Safety Handbook

The Electrical Safety Handbook is compiled by the Electrical Engineering staff in Whyalla for issue to all new starters in the Electrical field.
The main purpose of the book is to outline potential hazards associated with electrical equipment, and to help protect electricians and others from coming into contact with LIVE conductors.
The main rules which the book covers are:-

1. Switches must be opened and/or fuses must be withdrawn before working on any equipment.
2. A switch must be locked out wherever provisions for doing so are made.
3. Danger tags must be employed.
4. All equipment must be earthed.

IF IN DOUBT - ASK !

The book also supplies a number of useful diagrams, tables, etc. which the electrician will need almost daily.

Special provisions have been set out dealing with the work of apprentices, and these regulations must be observed.

1. Apprentice electrical fitters and mechanics, during first and second years of their apprenticeship, must work under direct instruction of a foreman, leading hand, or journeyman.
2. During this period, they shall not be permitted to connect or disconnect circuits which have previously been "alive".
3. In the third year of apprenticeship, a boy may be permitted to operate fuses and switches, but he shall work under direct supervision.
4. In the fourth year of apprenticeship, a boy may work at all classes of work under general instructions and directions of his foreman, leading hand, or journeyman.

TITLE:- EFFECTS OF ELECTRIC SHOCK

LECTURER:-

DATE:-

EQUIPMENT:-

The effects of electric shock on a human being, is rather unpredictable and may manifest itself in a number of ways.

(a) Asphyxia:- Electric shock may cause a cessation of respiration (asphyxia). Current passing through the body may temporarily paralyse either the nerves, or the area of the brain which controls respiration.

(b) Burns (contact & flash):- Contact burns are a common result of electric current passing through the body; they vary in severity, the same as thermal burns. The burns can normally be seen at the points where the current entered and left the body; however, internal tissues along the path of the current are also damaged. Therefore, the seriousness of electric burns may not be immediately evident, because the appearance does not indicate the depth, or extent, of the internal injury.

In some accidents there is a flash, or electric arc, the rays and heat from which may damage the eyes, or result in thermal burns, to exposed parts of the body.

(c) Heart stoppage & fibrillation:- Electric shock may disturb the natural rhythm of the heart-beat. When this happens, the heart muscles may stop completely, or they may be thrown into a twitching, or trembling state known as "Ventricular fibrillation", in which the action of the individual muscle fibres are no longer co-ordinated. In either case (complete stoppage or ventricular fibrillation), the pulse disappears and circulation ceases.

(d) Muscle spasm:- A series of erratic movements of a limb or limbs may occur, owing to alternating contraction and relaxation of the muscles. This muscle spasm action on the muscles of respiration may be a factor in the stoppage of breathing.

Action of electric current:- In electric shock, the current may pass through the breathing centre at the base of the brain, and cause the centre to stop sending out the nerve impulses which act upon the muscles responsible for breathing. As a consequence, breathing stops abruptly. In such cases, starting artificial respiration immediately substitutes for the natural breathing of the victim. If the shock has not been severe, the breathing centre recovers after a time, and resumes its vital function; but the current may so paralyse the breathing centre, as to require several hours for recovery, and artificial respiration must be continued unceasingly, until there is recovery, or positive evidence of death. Under these conditions, victims of electric shock are unconscious, but heart action and blood circulation continue. Recovery depends on prompt and effective lung ventilation, until normal respiration is restored.

Current tolerance of the human body:- Alternating currents of high frequency produce little sensation, compared with alternating currents of low frequency and equal strength. Tests have been made to determine the "tolerance current" of typical individuals at several frequencies. The tolerance current was arbitrarily assumed, as the limiting current strength, which the subject could take through the arms and body, without marked discomfort or distress.

A man can tolerate only about 30 mA at 11,000 c/s, but can tolerate nearly .5 amps at 100,000 c/s. Although the tolerance current was found to increase very rapidly above 11,000 c/s, the increase between 60 and 11,000 c/s, was much less rapid, ranging from about 5mA at 60 c/s, to 30 mA at 11,000 c/s.

An investigation was made of the amount of 60 c/s current, which will produce mild shock, disclosed that the average current at which 42 persons first observed the sensation of shock, upon sudden contact, was 1.2 mA, and that the average of the maximum currents, which the persons could withstand without serious discomfort, was 8 mA.

Voltages as low as 12V - 25 to 60 c/s alternating current, have been shown by test, to be all that some individuals could withstand under conditions of good contact with the circuit. Other tests have shown that, when dry electrodes were held in both hands, a.c. voltages, ranging from 20 to 40, were all that were required to produce to maximum current, that individuals could withstand for a short time, and still have voluntary control of their muscles. In these tests, the currents ranged from 6, to 10 mA. Tests with direct current indicated that slightly higher current values could be withstood for a short time, until a hot spot occurred at the point of contact. The comparative immunity to injury, in handling circuits up to 120V with bare hands, is due to the high resistance of the dry, uninjured human skin. This resistance is greatly lowered by any thorough wetting of the skin, especially by perspiration and many chemicals, also by cuts and blisters. Under such conditions, 110 to 120V alternating current can produce a change in heart action, which may prove fatal. Furthermore, it requires only a few seconds contact, with a 50V standard frequency a.c. circuit, to produce blisters at the point of contact, thus destroying the dry-skin high resistance protection.

Factors determining seriousness of electric shock:-

(1) Body electrical resistance
(2) Path of current flow through the body
(3) Amount of current and duration of time.

(1) Body electrical resistance:-

a. Average body resistance approx. 5000 ohm (dry)
b. Average body resistance approx. 1000 ohm (damp)

Amount of current to cause death - approx. 0.1 amp

Voltage to produce fatal shock:-

a. $E = 0.1 \times 5000 = 500$ volts
b. $E = 0.1 \times 1000 = 100$ volts

(2) Path of current through body:-

Most electrocutions are due to "earth-fault" currents, i.e. current flowing from a "live" conductor or apparatus to earth, the current path being mainly between one hand and the feet. Most dangerous paths are those effecting the heart and brain, i.e. -

Current path from	Head	to Leg
" " "	Arm	" Arm
" " "	Arm	" Leg
" " "	Arm	" Chest

(3) Amount of current and duration of flow:-

Low current for a long time could be as dangerous as high current for a short time.

Current passing through the body is (ohms law) equal to applied voltage, divided by the resistance of the path taken by the current.

Effect of current passing through the body

1 Milliamp:- threshold of perception

10 - 15 Milliamps:- Tightening of muscles, and difficulty in releasing any object gripped - acute discomfort.

25 - 30 Milliamps:- Extension of muscular tightening to the Thoracic muscles, dangerous if not quickly stopped.

Over 50 Milliamps:- Fibrillation of the heart, which is generally fatal.

TITLE:- TESTING HAZARDS

LECTURER:-

DATE:-

EQUIPMENT:-

All work on an installation, or item of equipment, should be done with the circuit or equipment "dead". It is only necessary in theory to open a switch and/or remove a fuse to ensure safety. But even with such a simple operation, things can go wrong, i.e. labels may be incorrect or indistinct, a switch may be in the neutral wire, or, with a three phase bank or row of fuses, there may be a cross connection with an adjacent circuit, so that a "live" wire exists at a point of work. All too often the wrong circuit is isolated.

The safe working habit of TEST BEFORE TOUCH with a suitable testing instrument is essential. The series test lamp is NOT a suitable testing medium, and its use is forbidden, due to several serious accidents which have occurred to electricians while using them.

In many cases, particularly when investigating faults on such things as motor starters, complicated control circuits, and electronic apparatus, it is necessary to work with apparatus "live". Never work with, on or near live electrical equipment unless a second person is present. Such second person must know how to switch off the electricity supply and they should be conversant with resuscitation procedure.

Special care must be taken, by the use of correct test instruments and leads, insulated tools, and particularly strips of insulating material for the operation of contacts.

A further precaution often neglected, is to remove and replace apparatus covers, only whilst the apparatus is switched OFF. Serious accidents have happened when a cover (often heavier than expected) has dropped on "live" metal. Care must be taken, to check all equipment in a compartment, because control circuits often remain "live" when the main control switch is isolated.

Many commercial and industrial installations include very complicated control and safety circuits, e.g., air conditioning, lifts, process plant conveyors, diesel generating plant etc.

In many cases, trouble will occur in the control equipment, and to diagnose the fault it is common procedure, to operate or simulate operation of control circuits with drives isolated. As the systems vary so much, it is not possible to detail safety methods here, the following points should be noticed:-

(1) Make certain that you know what you are doing.
(2) Get a full circuit and sequence diagram, and study it.
(3) Depending on the layout, isolate circuit breaker, or withdraw fuses as necessary.
(4) TEST BEFORE TOUCH.
(5) Use insulated tools and devices as necessary.
(6) Remember that when a circuit breaker is isolated, control circuits may still be "alive".
(7) Never cut out an interlock if the device is faulty, replace or repair it.

Avoid working on conductors and/or apparatus from any position, from which a shock or slip will tend to bring your body towards exposed "live" parts.

When closing a switch or circuit breaker, keep your head turned. Do not look directly at the equipment if you can avoid it. Never work on electrical apparatus until you have been fully instructed of the hazard possibilities and how to obviate them. Radiation and induction heating cannot be seen and can be dangerous.

Micro-wave ovens, ultra-violet lamps, and X-ray equipment should be treated with respect. Learn what is required before you service and test.
Do not attempt to commence repairs on apparatus, until you are certain all safety procedures for isolating, tagging and locking off have been followed.

(1) SWITCH-OFF and ISOLATE before you start work or remove covers.

(2) Place a DANGER TAG on the source of supply to warn others that you are working on the circuit.

(3) TEST BEFORE YOU TOUCH, if in doubt ask.

TITLE:- SAFE PRACTICE

LECTURER:-

DATE:-

EQUIPMENT:- Nil

Accidents occur daily throughout the plant. Some are serious, but most are of a minor nature. Avoid becoming a statistic or causing someone else to become a statistic by remembering four basic causes of accidents.

1. LACK OF KNOWLEDGE
2. LACK OF FORETHOUGHT
3. CARELESSNESS
4. NEGLECT

Before carrying out ANY task think carefully about these four accident causing topics.

1. LACK OF KNOWLEDGE

Do not attempt any task unless you know EXACTLY what you are doing, and how your actions will affect others.
If you are unsure - ASK.
Don't allow your personal pride to prevent you asking questions - it is better to be safe at first than sorry later.
Read all notices displayed around the plant - get to know what they mean, why they are there, and most of all, you must REACT to notices, i.e. if the notice says "Wear safety glasses", then wear safety glasses.

2. LACK OF FORETHOUGHT

A person whose mind is pre-occupied with thoughts other than the job he is doing will be more susceptible to accidents than someone who CONCENTRATES on his job and THINKS about what he is doing.
Think before you act. Try to visualise what will, or could happen by your actions before you begin ANY task no matter how simple.
Everyone is equipped with a marvellour piece of equipment which when used properly, can make your life and work much easier and enjoyable - it is a thing called a BRAIN - USE IT TO THINK WITH. It will tell you what to do and how to do it by a simple thing called COMMON SENSE, which is again something which can prevent accidents when used.

3. CARELESSNESS

A number of factors can cause a person to be careless at what he or she is doing.

a. Anger
b. Haste
c. Pressure of time
d. Pressure of supervision
e. Fatigue
f. Lack of interest
g. Preoccupation.

A person who has no sense of responsibility towards himself, to others, or to equipment tends to be careless at most things he or she does. This type of person is dangerous in almost all situations and is one who frequently is the cause of accidents.
Study yourself; would you place yourself in this category, or would you judge yourself to be the CAREFUL type. If you are the latter, the chances are that you won't be the cause of accidents or the injured party provided that you don't allow the above factors to effect you.

4. NEGLECT
When you know that something should be done, and it is not done, then it is called NEGLECT. When injury or death is caused by another person's neglect, then the consequences can be extremely serious for the person who has been neglectful.
Safety is the responsibility of everyone, and anyone who sees anything which is unsafe and does not take the necessary steps to correct it is guilty of neglect. Obviously it is difficult to prove whether or not a person has seen something unsafe, but should an injury occur that you could have prevented by reporting what you had seen, then your neglect will disturb your conscience for a very long time especially if that injury was fatal.
A person who is lazy is more likely to neglect his duties and cause accidents than any other so if you see anything that you consider unsafe or dangerous, take steps to correct it. Either correct it yourself or inform your leading hand.

Safe Practice
The four topics described are the basis of what each person can contribute towards a successful safety programme regardless of what that person's job is. The electrician, however, has a much greater responsibility in his work as the results of what he or she does can endanger the lives of anyone handling electrical equipment. It is of extreme importance, then, that the electrician in particular must overcome the four factors described.
All safe practice is based upon these four important factors. Without them, no amount of effort on the part of the company in providing safety rules, equipment, or procedures will prevent accidents from occurring.
However, the company does make these safety rules, it does provide safety equipment, and it does lay down rules for certain dangerous procedures.
Most of the subjects are covered in lectures received in the Electrical ATS, other subjects will be covered by various departments during your training on the plant. These subjects may be summed up under the one heading of SAFE PRACTICE.

1. Listen carefully to instruction.
2. Don't exceed your instructions.
3. Obey all rules, regulations and notices.
4. Don't abuse tools and equipment.
5. Use tools and equipment in the proper manner.
6. Wear protective clothing and equipment.
7. Don't fool around on the plant.
8. Keep your workplace clean and tidy.
9. Don't interfere with electrical or other equipment unless you know exactly what you are doing.
10. Ask, if you are unsure or don't know.

TITLE:- WORKING ON LIVE CIRCUITS

LECTURER:-

DATE:-

EQUIPMENT:-

All employees are forbidden to work on live circuits, except the following:-

(a) Those employees authorized in writing by the Chief Electrical Engineer, to carry out running repairs, tests and adjustments, to control gear associated with continuous processes. Good quality, insulated tools, and approved rubber floor mats, must be used for such work.
The authorization to carry out such work will cease when the authorized employee is transferred away from the section of the plant specifically mentioned in the authorization, or if cancelled by the employee's foreman.

(b) Where permission is given by the Chief Electrical Engineer in writing, for other than work covered by (a).
Such permission shall apply only for the one occasion specified in the written order.
The written order shall specify the safety precautions to be taken, and will include the general precautions, besides any special ones necessary, to safely carry out the work mentioned in the order.
The person to whom the written order is given, must read the instructions contained in it, and sign a declaration at the end of the order, thereby indicating that he has read the instructions, is willing to carry out the work, and will observe the safety instructions embodied in the order.

Never work on a live circuit, unless absolutely unavoidable.
Never work alone on a live circuit - have at least one person standing by in case of accidents.
The standby man should be ready to deaden the circuit immediately a case of electric shock occurs, or if this is not possible, he should have suitable material handy to remove the victim from a live conductor.
He should advise you on the position of all parts of the material you are moving, particularly if it is a long length.
Be sure that you are insulated to withstand the full circuit voltage (maximum value).
Carry all your tools on your person; do not receive tools or material from persons at a different potential than yourself.
Be careful of removing leads from "negative", or "earth" bus-bars, unless they are disconnected at the higher potential end of the circuit, (e.g., meter leads). This precaution must be taken on all circuits, whose negative leads are held by the same bolt or clamp.
Do not use engineer's measuring tapes near live conductors, because they have a metallic thread, interwoven with the linen threads. Fatal accidents have occurred, through lack of this precaution.

General electrical maintenance:-

(1) Treat all electrical circuits and apparatus as ALIVE and DANGEROUS, until you are sure they are isolated and earthed.

(2) Switches, fuses and isolators, must be wired in the higher potential conductor.

(3) Rope off any temporary dangerous situation, and hang suitable warning notices from the rope.

(4) If working close to live conductors, place dry wooden barrier boards between the unsafe area and yourself.

Isolating:- (1) Before isolating a circuit for maintenance, notify all persons concerned with the circuit, and place danger tag at the isolating switch.
(2) Do not interrupt a conductor carrying current, except at apparatus designed for this duty.

TITLE:- S.A.A. RULES (EXTRA LOW VOLTAGE CIRCUITS)

LECTURER:-

DATE:-

EQUIPMENT:- S.A.A. Wiring Rules

S.A.A. 7.3.1. Source of supply - installations and portions of installations operating at extra-low voltage, shall be supplied from suitable generating, transforming, or converting equipment, or from batteries, having an output voltage not exceeding extra-low voltage at rated output, and not exceeding 40 volts A.C., or 145 volts D.C. at no-load.

S.A.A. 7.3.2. Isolation of transformer windings.

S.A.A. 7.3.4. Accessibility of any generator, transformer, converter or battery.

S.A.A. 7.4. Enclosure of live parts when used in a damp situation.

S.A.A. 7.5 & 7.6 Voltage rating of equipment and voltage drop in conductors.

S.A.A. 7.7 & 7.8 This section deals with main switches and general switches.

S.A.A. 7.9 Over-current protection of extra-low voltage circuits. Protection required - Protection not required and Fault level.

S.A.A. 7.10 Location of switchboards - distance from transformer.

S.A.A. 7.11 Determination of maximum demand - final sub-circuits - mains and sub-mains.

S.A.A. 7.12 Number of points per final sub-circuit - circuits protected by fuses - circuits protected by circuit-breakers.

S.A.A. 7.13 Final sub-circuits - reduction in current-carrying capacity.

S.A.A. 7.14 Plugs and Plug sockets - current rating - marking of voltage - preventing the insertion of an extra-low voltage plug, into a plug socket, connected to a circuit of higher than extra-low voltage.

S.A.A. 17.15 Conductors for extra-low voltage installations - Use of bare conductors - Use of bare busbars - Aerial conductors - Underground wiring - Earthing and where required.