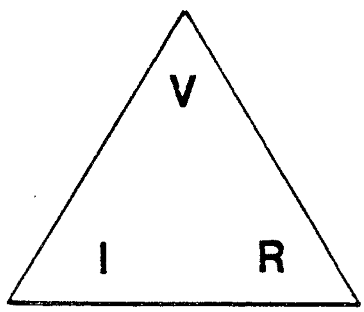
Basic Electricity



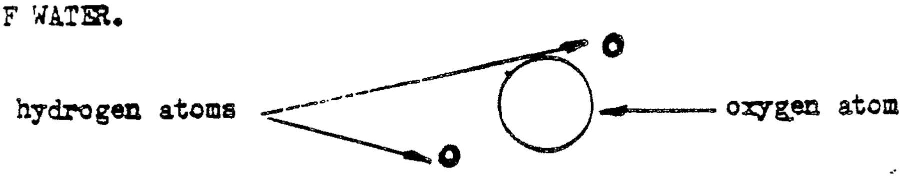
TRACTION TRAINING SCHOOL
BIRMINGHAM

THE BREAK DOWN OF MATTER

If we take a drop of water and divide it into two,divide one of the resultant two drops into two again and repeat this process thousands of times we would still have a minute particle which still retains the chemical characteristic of water. However sub - division of this minute particle will eventually result in a particle so small that any sub - division will cause it to lose it's chemical characteristic of water. This last droplet of WATER is termed a MOLECULE.

If it was possible to visually examine this water molecule it would be seen to exist of three particles closely bonded together. The two smaller of these would be identified as ATOMS of Hydrogen and the third larger one would be an ATOM of Oxygen.

WHEN ONE ATOM OF OXYGEN COMBINES WITH TWO ATOMS OF HYDROGEN THE RESULT IS A MOLECULE OF WATER.



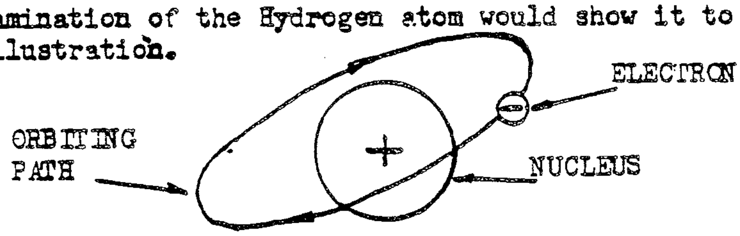
A MOLECULE OF WATER

Other materials are made up of differing types and numbers of atoms e.g.

A cellulose molecule (wood) consists carbon,hydrogen and oxygen atoms.
The human body consists of a total of 15 atoms in it's structure.

Thereis a total of approximately 100 different atoms, which are also known as elements, and all materials are made up of different combinations of atoms to form molecules of the materials.

A closer examination of the Hydrogen atom would show it to look like the following illustration.



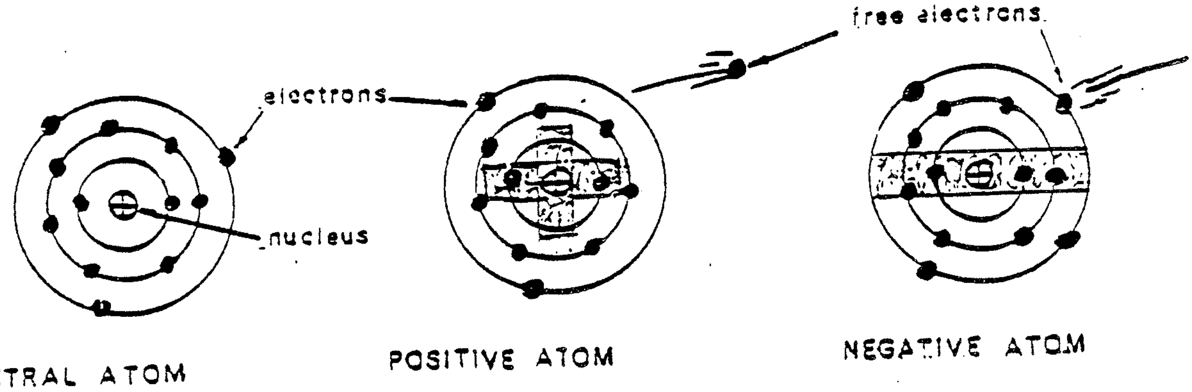
It can be observed to be like a sun with one planet spinning round it at an unbelievable speed. The sun represents the NUCLEUS of the ATOM and carries a PROTON which is POSITIVELY charged whilst the planet is an electron which is NEGATIVELY charged.

In normal conditions, in any atom, the POSITIVE charge of the PROTONS in the NUCLEUS exactly equals the NEGATIVE charge of the ELECTRONS in orbit around the NUCLEUS hence it is said to be ELECTRICALLY BALANCED.

THE ELECTRIC CURRENT

All atoms are bound together by powerful forces of attraction exsisting between the nucleus and it's electrons. If, however, a material has several electrons some of the outer ones are bound less powerfully to the nucleus and in certain materials such as copper and zinc these outer electrons are so weakly bound that they easily break away from their nucleus and wander among the other atoms at random. THESE MATERIALS AS KNOWN AS GOOD CONDUCTORS.

Such weakly bound electrons are termed FREE ELECTRONS and it is their random movement which causês an electric current.to flow.



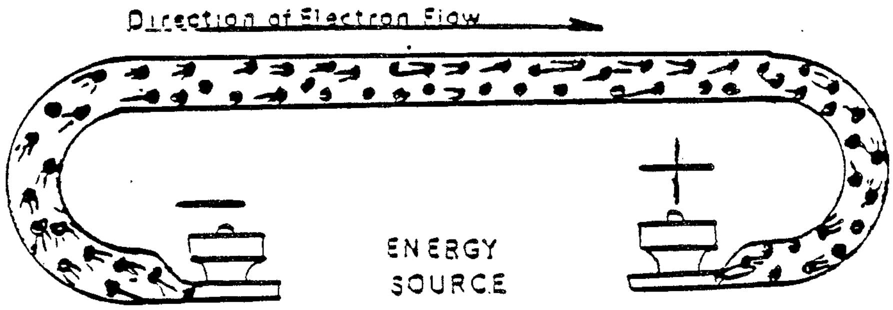
The unit of electric current is the AMPERE in honour of the physicist of that name

In some materials the electrons are very strongly bonded together and to their nucleus and therefore there are no free electrons,these materials are therefore poor conductors and are known as INSULATORS

GENERATING A CURRENT FLOW

It can be shown that UNLIKE charges ATTRACT each other and LIKE charges REPEL each other i.e.a negative and positive charge will be attracted to each other but two negative charges will repel each other as will two positive charges.

If we take a lenth of copper wire,which has an abundance of free electrons, and apply a negative charge to one end and a positive charge to the other, there are many ways in which this can be attained,e.g. a battery, the negatively charged electrons will be repelled by the negative charge to one end and attracted by the positive charge at the other end. In this way an electric current will be made to flow.



THE ELECTRIC CURRENT

GENERATION OF ELECTRICITY

It can be seen from the foregoing text that in order to make electrons flow i.e. produce an electric current,an external source of energy must be applied

There are six known sources of electrical energy which are capable of gener - ating an electric current and are as follows.

(1) HEAT

If heat is applied to a junction of two dissimilar metals an electric charge will result, e.g. a thermo-couple.

(2) FRICTION

If two different materials are rubbed together electrons can be transferred from one into the other so giving a positive charge to one material and a negative charge to the other, i.e. static electricity.

(3) LIGHT

A special type of photo-sensitive material has the property of developing an electric charge when exposed to light e.g. photo-electric cells as used in steam generators.

(4) PRESSURE

Certain crystals are capable of creating electric charges when subjected to pressure e.g. crystal microphones and in telephone mouth and ear pieces

(5) CHEMICALLY

Some metals, when immersed in certain chemicals, can become electrically charged. This is described in detail under "BATTERY".

(6) MAGNETISM

This is explained fully in the following text.

Although each of the above energy sources have different applications they all have one thing in common, they MOTIVATE THE FREE ELECTRONS IN AN ELECTRIC CIRCUIT AND THEREBY CREATE AN ELECTRIC CURRENT.

Referrig to the method of creating electricity by friction it was explained that by rubbing certain materials together e.g. a hard rubber rod and fur or silk and glass, a transfer of electrons takes place and the fur or the silk will lose electrons to the rubber rod or the glass. In other words we now have an excess of electrons which are negatively charged on one material which will be negatively charged and a deficiency of electrons on the other material which will therefore be positively charged. There is therefore a difference in the charge between these two materials which has an energy potential or, in other words, THERE IS A POTENTIAL DIFFERENCE BETWEEN THE TWO POINTS.

Each of the above six sources have the same ability to transfer electrons and therefore create a POTENTIAL DIFFERENCE across their terminals.

The POTENTIAL DIFFERENCE (p.d.) across a source of electricity is measured in VOLTS in honour of the physicist Voltair and the potential difference is also termed the VOLTAGE.

BECAUSE THE VOLTAGE IS THE FORCE WHICH MOTIVATES ELECTRONS IN THE CIRCUIT IT IS SOMETIMES TERMED THE ELECTRO MOTIVE FORCE (E.M.F.) OF THE SOURCE.

STUDENTS NOTES

THE BATTERY

A battery is two or more electric cells connected together.

An electric cell is a container in which two plates of dissimilar metals,with seperation between them,are immersed in a liquid,usually acid,which is known as the electrolyte. The chemical re-action between the two plates and the electrolyte results in a basic source of electricity. Refer to Fig 1.

The action of the electrolyte chemically transfers electrons from one plate to the other leaving one plate with a deficiency of electrons and the other with an excess of electrons.

This re - action therefore converts chemical energy into electrical energy in the form of electric charges on the plates i.e. there is a potential difference between the two plates.

With nothing connected to the plates,usually termed ELECTRODES,there would be a limit to the number of electrons which could be transferred due to the p.d. already generated,normally 1.5 volts.

Connecting a conductor between the two electrodes will initiate a flow of electrons through the wire from the negative electrode to the positive electrode Since this now leaves the negative electrode slightly deficient of electrons the electrolyte will resume transferring electrons from the positive electrode to the negative electrode.As long as the electrons transfer from the negative electrode to the positive via the conductor the electrolyte will transfer them back on to the negative electrode.

Whilst this action continues the negative electrode will gradually dissolve into the acid until there is insufficient left of it to transfer electrons, the cell will then become dead and unable to provide a charge.It cannot be recharged,the plate must be renewed,hence this type of cell is termed a PRIMARY CELL.

Almost any metals,acids or salts can be used in a primary cell and there are many types. Those used in the replacement battery of the Bardi lamp consists of a carbon rod for the positive electrode which is located in the centre of a zinc case which is the negative electrode. The electrolyte is ammonium chloride in a paste form which is packed between the rod and case. See Fig.2

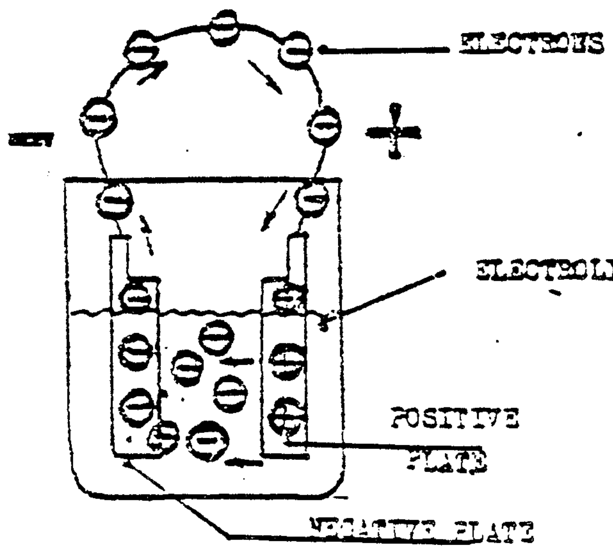
Three such cells are connected together in series to form a 4.5 volt battery.

SECONDARY CELLS

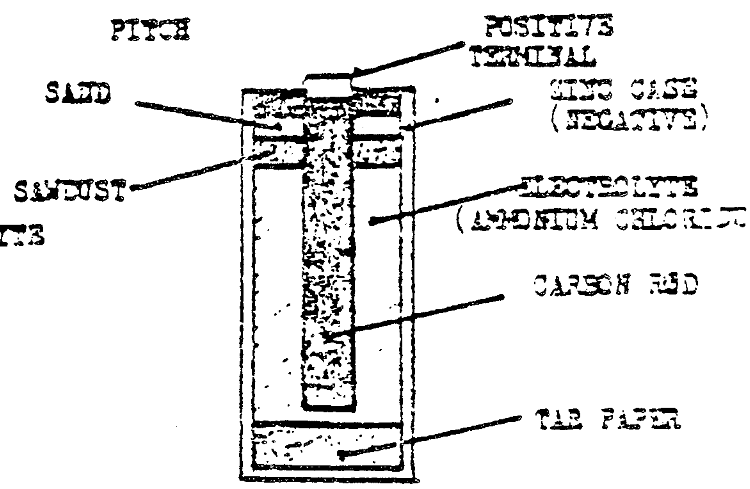
A battery of secondary cells can supply large amounts of power for a short time or small amounts of power for long periods and can be recharged.They are usually the lead - acid type i.e. the plates are lead and lead peroxide and the electrolyte is sulphuric acid.

During discharge the acid becomes weaker and the plates undergo a chemical change and change into lead sulphate and the p.d. between the plates becomes less. The battery is then recharged by connecting the two terminals to a suitable electrical D.C.supply.

It should be noted that the battery does not manufacture electrons for the circuit,the battery,or any source for that matter,merely provides the energy in the form of an E.M.F. (electro-motive force) to move the free electrons round the circuit.



SIMPLE CELL



PRIMARY CELL

NOTE

Before the discovery of electrons and their behaviour in the electric circuit physists of the day believed that the electric current flowed from points of high potential,positive, to points of low potential,negative,which is the opposite to the electron flow.

As most text books on electrical matters still perpetuate this original CONVENTIONAL CURRENT FLOW THEORY it will be used throughout the following text.

STUDENTS NOTES

ELECTRICAL CIRCUITS

(1) THE CLOSED CIRCUIT
A circuit is said to be closed when an electrical appliance(load) is connected to a source of electrical supply and current flows in the circuit.

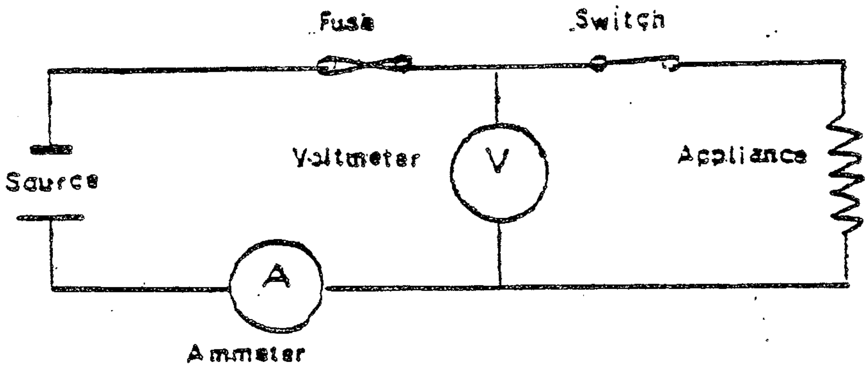
(2) THE OPEN CIRCUIT

A circuit is said to be open when the circuit beween the appliance or load is opened by a switch or by a broken wire.

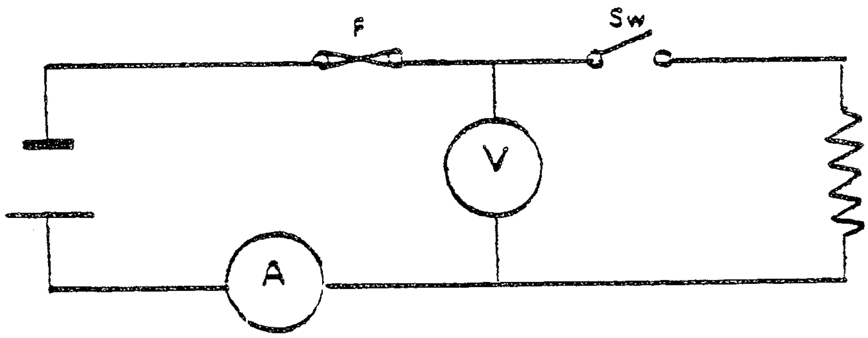
(3) THE SHORT CIRCUIT

A circuit is said to be shorted when the circuit between the appliance or load and the source is by-passed i.e.bared wires in contact or by bared wires touching earthed metalwork.

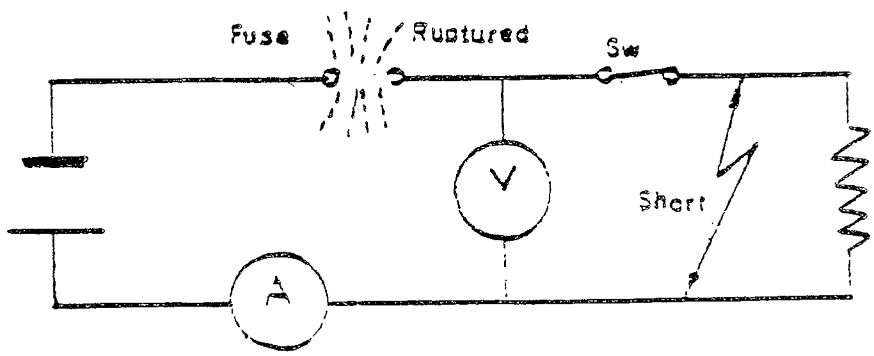
(1)
Closed Circuit



(2)
Open Circuit



(3)
Short



THE RELATIONSHIP BETWEEN THE VOLTAGE AND CURRENT

It has already been pointed out that if there is an excess of electrons at one point in a circuit and a deficiency at another a voltage or potential difference exists between the two points. This was referred to as the E.M.F. and is measured in VOLTS.

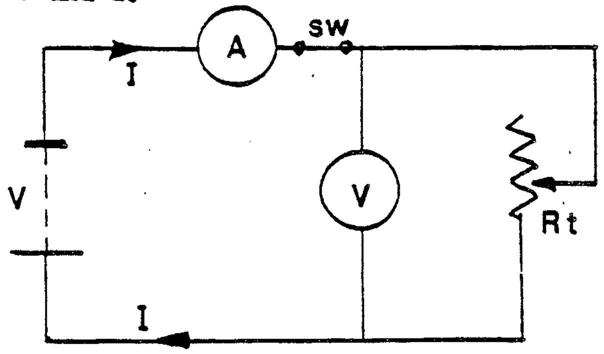
It was also shown that if a closed circuit is made between the two points where a potential difference exists a current will flow and will be measured in AMPERES or AMPS.

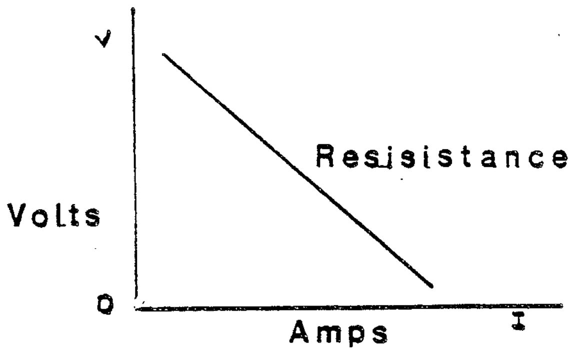
For example, on a diesel electric locomotive when the Driver opens the power cont roller the main generator generates a voltage or E.M.F. which causes a current to flow through the traction motors and the value of this current is shown on the ammeter.

Experimentally it can be shown that the potential difference across the ends of most conducting materials is directly proportional to the current flowing in the circuit.

The experimental circuit and the resultant graph are shown below where
V = voltage of the source
I = Current flowing in the circuit
Rv = variable resistance of the circuit.

Altering the value of the variable resistor in steps will result in changes of V and I.



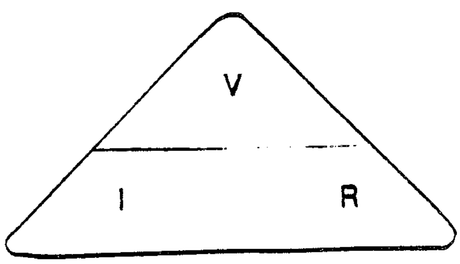


From this relationship we can derive the equasion $R = \frac{V}{I}$

This relationship is known as OHMS LAW and in honour of the phycisist who first discovered this relationship, the unit of measurement of resistance is the OHM symbolised by Ω.

By transposition we can also obtain the equasions V = IR or I = V/R.

These three equasions can be easily remembered by the following triangle.

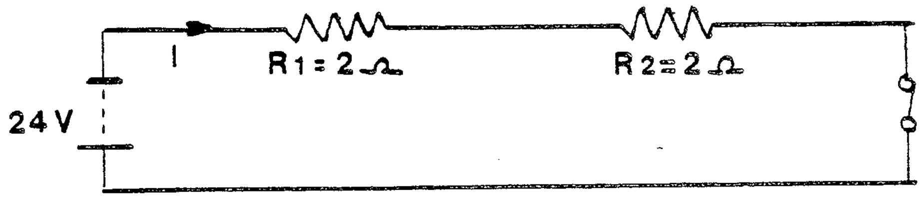


The following are examples of resistance of components on a locomotive and are only quoted to give an idea of magnitude.

Operating coil of a 110 volt relay................200 - 400 Ω
Traction motor armature winding..................0.031 Ω
Traction motor field coils.......................0.012 Ω
Traction generator armature winding..............0.00312 Ω

RESISTORS IN SERIES

In the following circuit two resistors are shown connected in SERIES so that the current must flow through each resistor in turn when the circuit is switched on.



It can be shown that the total resistance of Rt of such a connection is R1 + R2

i.e Rt = R1 + R2
For example if we substitute the values shown in the illustration we can calculate the following

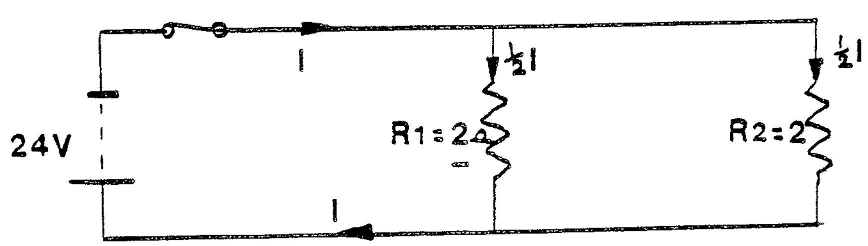
Rt = R1 + R2 Ω
Rt = 2 + 2 Ω
Rt = 4 Ω

If the battery voltage is 24 volts then the current flowing in the circuit can be found by applying Ohms Law

I = V/Rt

I = 24/4 = 6 Amps.

RESISTORS IN PARALLEL
In the following circuit the same two resistors are connected in parallel so that the current divides equally to flow through the two resistors when the switch is closed i.e. half the current flows through R1 the other half through R2.



It can be shown that the total resistance of such a circuit is

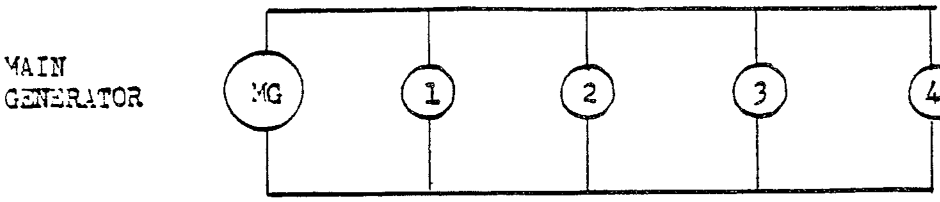
$$\frac{1}{Rt} = \frac{1}{R1} + \frac{1}{R2}$$ Thus substituting as before

$$\frac{1}{Rt} = \frac{1}{2} + \frac{1}{2} = 1$$ therefore where I = V/Rt

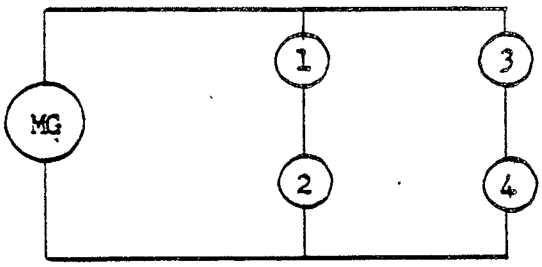
I = 24/1 = 24 Amps.

From the above it can be seen that if two resistors of equal value are connected in SERIES the total value of resistance is double the value of one resistor but if two of equal value are connected in PARALLEL the total resistance is a half of the value of one resistor. A similar relationship exists with any number of RESISTORS OF EQUAL VALUE.

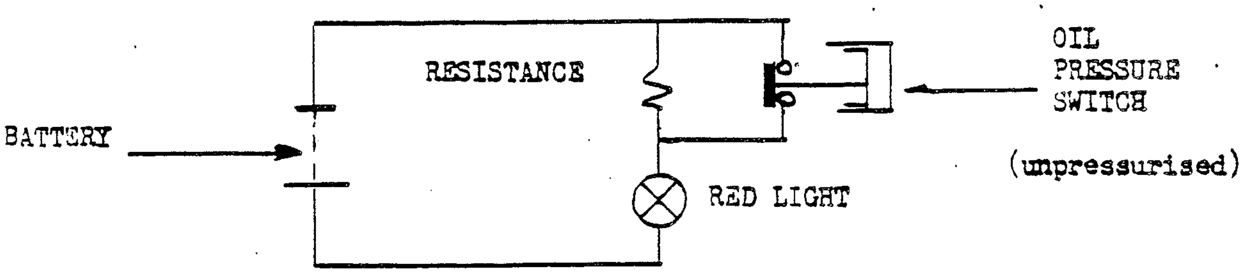
TYPICAL ARRANGEMENTS OF SERIES AND PARALLEL CONNECTED CIRCUITS



Parallel connected traction motors



Series/Parallel connected traction motors



Typical control of the Engine Stop Light

Typical examples of resistances connected in SERIES on diesel electric locos. are :-

(a) Control of current to the main generator field (Load Regulator)

(b) Control of current to the auxiliary generator field(Load Regulator)

(c) Dim/bright fault light control

Typical examples of resistances connected in parallel on locomotives are:-

(a) Traction motors connected across the Main Generator.

(b) Auxiliary machines,compressors etc.connected across the Auxiliary Generator.

(c) Resistances connected across the traction motor field for weak fielding.

STUDENTS NOTES

POWER

Power is regarded as the "rate of doing work". This involves two factors.

(1) The effort or the force required.

(2) The quantity moved in a given time.

In considering electrical power we take into account:-
(1) The force which is the volt

(2) The quantity moved per unit time which is the Ampere.

Therefore ELECTRIC POWER = VOLTS x AMPERES

The unit of electrical power is the WATT hence
1 WATT = 1 VOLT x 1 AMPERE

and 1 KILOWATT = $\frac{\text{1 VOLT x 1 AMPERE}}{1000}$

The HORSEPOWER is the British unit for the measurement of large units of power and 1 HORSEPOWER = 746 WATTS.

It can therefore be seen from the foregoing that the current reading on the ammeter of a locomotive is not a true reading of the power. The following is an example of how the horsepower of the locomotive is arrived at if the generator voltage is 800 volts.

Power = V x I Watts = 1600000

Horsepower = 1600000 Watts / 746

= 2145 H.P.

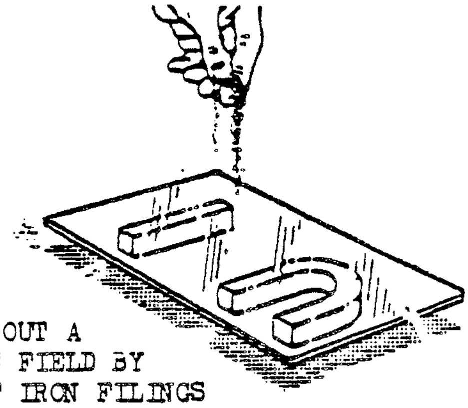
i.e. approximately the rating of an English Electric Class 40 locomotive.

STUDENTS NOTES

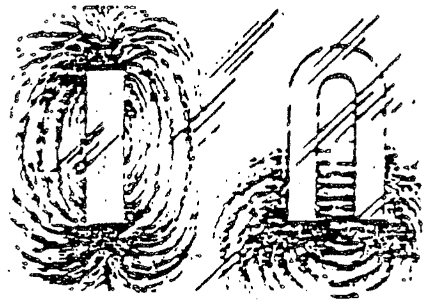
MAGNETISM

Magnetism is an invisible force and can only be seen in terms of the effects it produces.

The zone which is affected by magnetism is known as the magnetic field and it's shape can be plotted by placing a bar magnet below a sheet of transparent material and sprinkling cast iron dust over the sheet which will result in field patterns being formed as shown below.



TRACING OUT A MAGNETIC FIELD BY MEANS OF IRON FILINGS



HOW THE IRON FILINGS ARRANGE THEMSELVES.

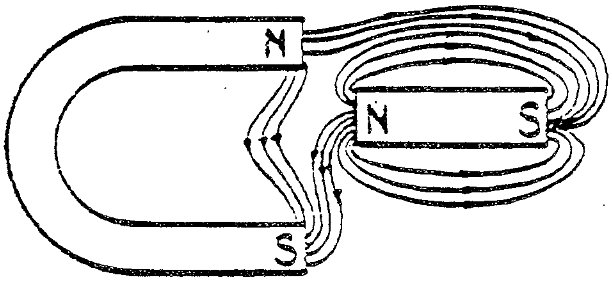
Observations of the patterns shows three important factors:-

(1) The direction of the lines of force, as they are termed, is from the North to the South outside the magnet and from South to North inside it.

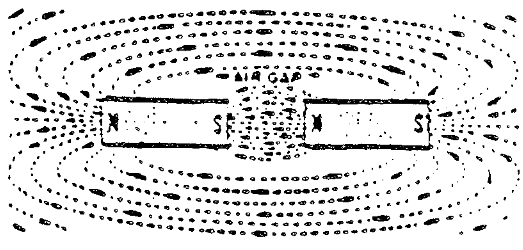
(2) The lines of force never cross each other.

(3) The nearer to the magnet the closer are the lines of force to each other, i.e The field is strongest near the magnet.

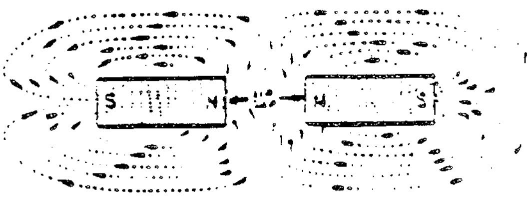
Unlike poles attract each other, like poles repel each other.



FLUX LINES NEVER CROSS



Unlike poles attract



Like poles repel

On diesel locomotives permanent magnets are not extensively used for the following reasons:-

(a) They cannot be switched off.

(b) The magnetic strength cannot be altered.

(c) The magnetic polarity cannot be reversed.

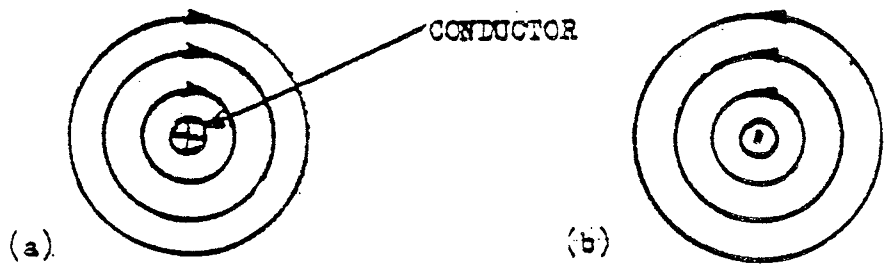
<u>The Magnetic Field About A Current Carrying Conductor</u>.

If an electrical current is passed through a straight conductor a magnetic field will be set up round the conductor in concentric lines of force as shown below.

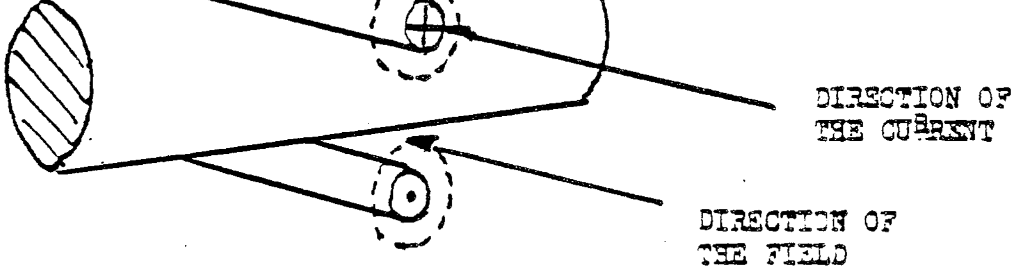
If this field is plotted by means of compasses it will show that the diredtion of the field is related to the direction of the current.

Figure (a) shows the current flowing away from the viewer into the paper,rather akin to a dart's flight feathers, and it can be seen that the magnetic field is clockwise in it's direction. If the current in the conductor is reversed as in (b)i.e. flowing from the paper towards the viewer,like the point of a dart, the field will be anti-clockwise in it's direction.

The relationship between the direction of the field and current can also be likened to the action of the corkscrew. If the corkscrew is turned clock - wise it will go into the cork,away from the operator. If it is turned anti - clockwise it will withdraw from the cork towards the operator.

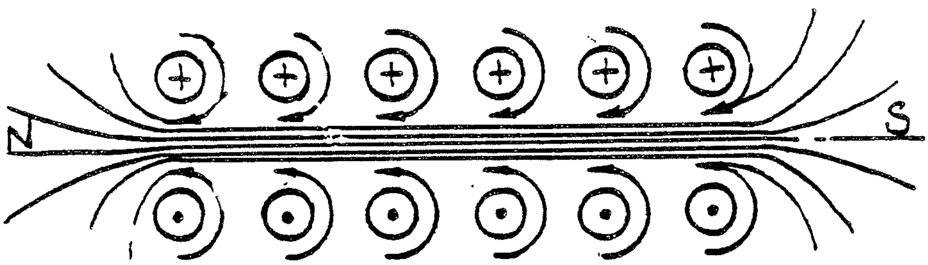


If the conductor is now taken over the top of a rod, round the rod and back underneath as shown in the illustration below the direction of the magnetic field and the current will be as shownn



If the conductor is now continually coiled round the rod and then cut in two along it's length the direction of the current will be as illustrated in the next figure. If the rule to determine the direction of the magnetic field is now applied i.e.current into the paper magnetic field clockwise, current out of the paper magnetic field anti - clockwise. It can be observed that the pattern of the total field generated is the same as that of the bar magnet.

ELECTRO - MAGNETIC COIL



The magnetic strength of such a coil will depend on the value of the current and the number of the turns on the coil.

By inserting a switch between the supply and the coil the magnetic field can be controlled

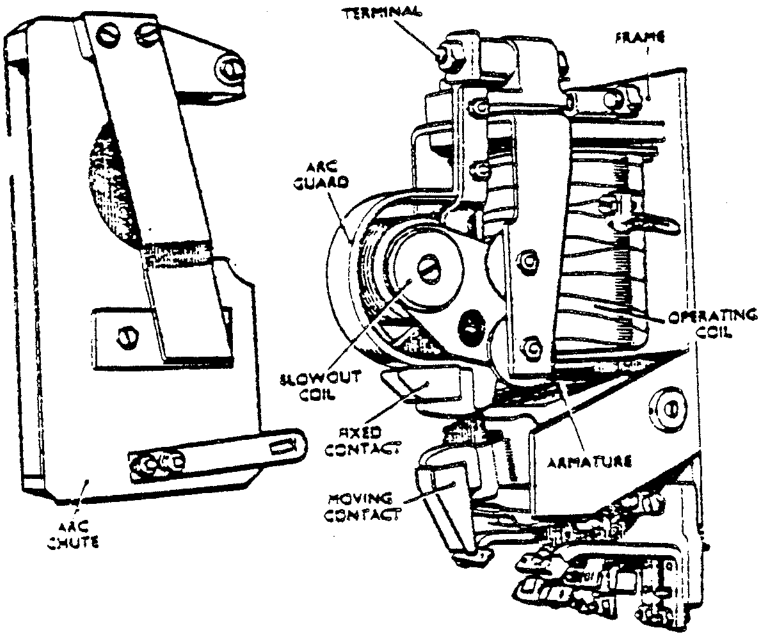
Similarly by inserting a variable resistor in the circuit the magnetic field strength can be varied

If the direction of the current is reversed then the magnetic field polarity will be reversed.

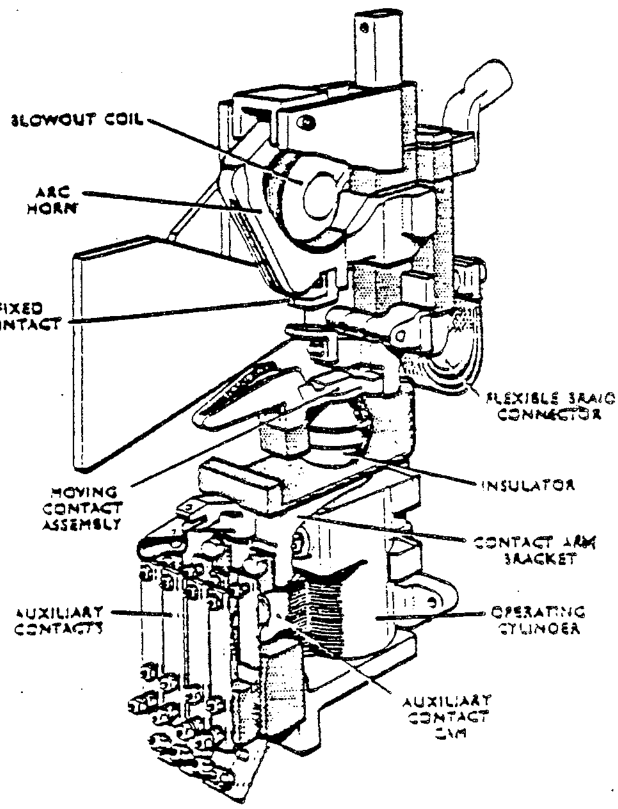
The electro - magnetic coil is extensively used on diesel electric locomotives. for operating SOLENOID VALVES e.g. Engine Run Solenoid (E.R.S.) Engine Speeder Valve (E.S.V.) and also ELECTRO- PNEUMATIC VALVES (E.P.). These valves have electro - magnetic coils which actuate air valves which,inturn, operate heavy duty type contactors and reversers.

A stronger magnetic field is obtained if an iron core is placed inside the coil inwhich case the devise is known as an ELECTRO - MAGNET.

Electro - magnets are used on locomotives for the operation of electrical contactors and relays and field and armature windings of motors and generators.



Electro Magnetic Contactor.



Electro Pneumatic Contactor

GENERATION OF ELECTRICITY

Gneration of a voltage

It has been seen in the preceding pages that an electric current in a conductor or a coil can produce a magnetic field. This process is also reversible.

To show this effect a length of wire, a simple bar magnet and a galvanometer can be used. A galvanometer is a very sensitive meter for measuring very minute values of current and voltage.

If the magnet is moved across the wire, near to but not touching, the needle of the galvanometer will be deflected and will then return to zero when the movement of the magnet ceases, i.e. an E.M.F. has been INDUCED in the wire. Fig 1

If the movement of the magnet is reversed the direction of deflection of the needle is also reversed. It can also be shown that the degree of deflection of the needle is proportional to the strength of the magnet and the speed at which the magnet passes the wire.

Movement of the wire past the magnet has the same effect (see Figs 1 & 2)

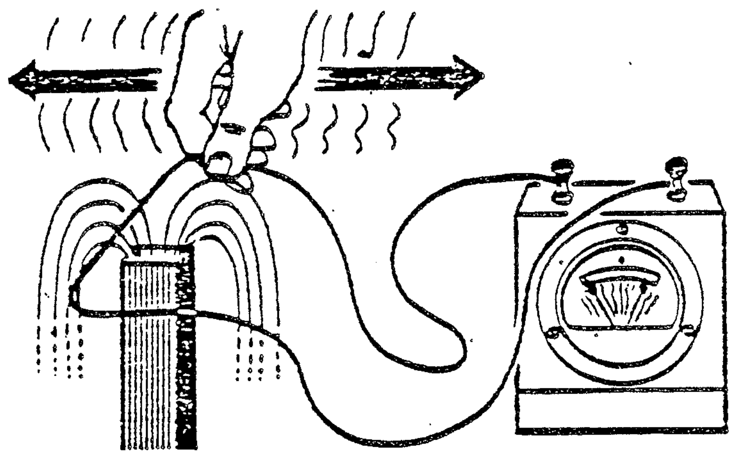


FIG 1.

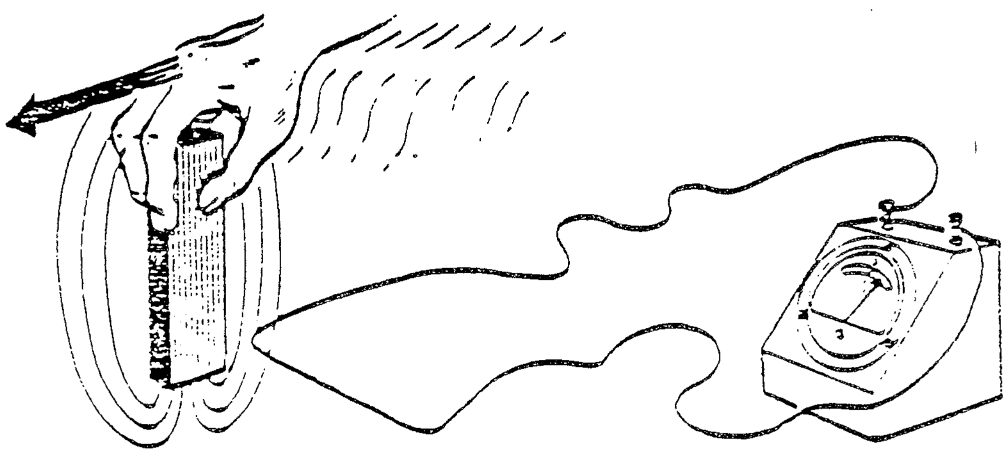


Fig. 2.

To obtain a more continuous supply of electricity a continuous movement of the wire or the magnet is required and this is best obtained by causing the wire to travel in a circle through the magnetic field. (see FIg.3)

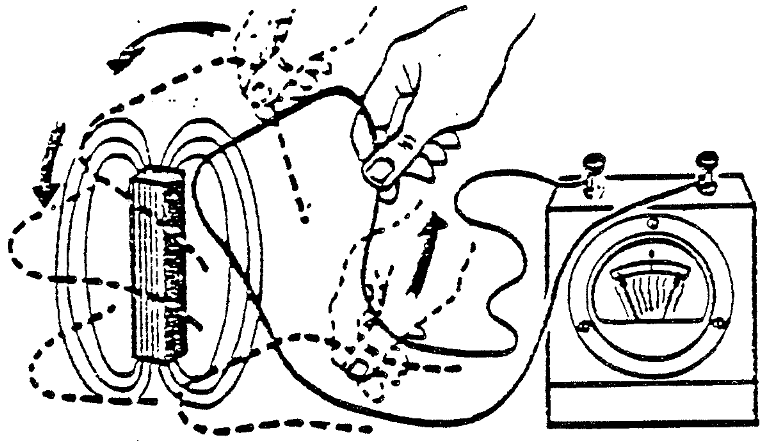


FIG. 3

This method of producing electricity i.e.rotating a wire or a number of wires round a magnet is the principle of the electric generator.

If the wire is wound into several loop to form a coil then the E.M.Fs. generated in each loop will be additive hence the deflection on the galvanometer will be much greater.(see Fig.4)

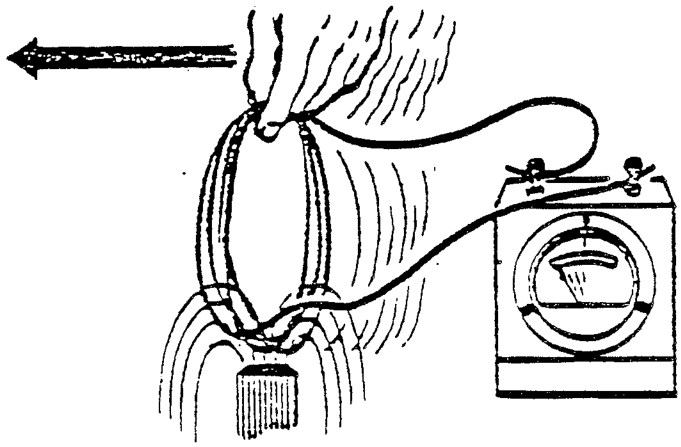


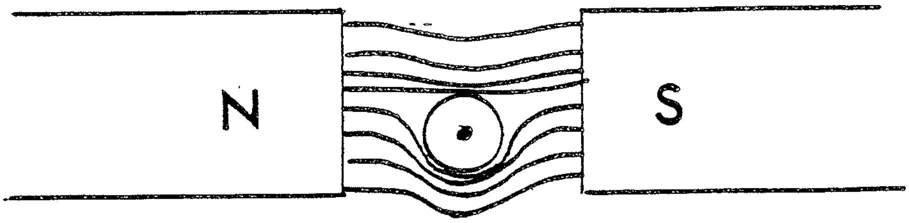
FIG 4.

The result of all these observations shows that :-

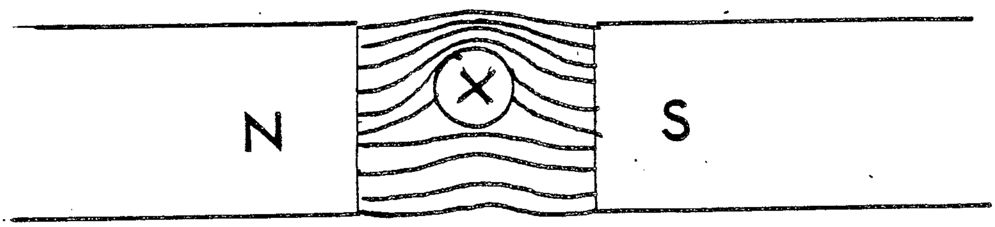
THE VOLTAGE OR E.M.F. GENERATED IS PROPORTIONAL TO THE STRENGTH OF THE MAGNET AND THE SPEED OF THE MOVEMENT AND THE NUMBER OF TURNS OF THE COIL.

THE DIRECTION OF THE INDUCED E.M.F.

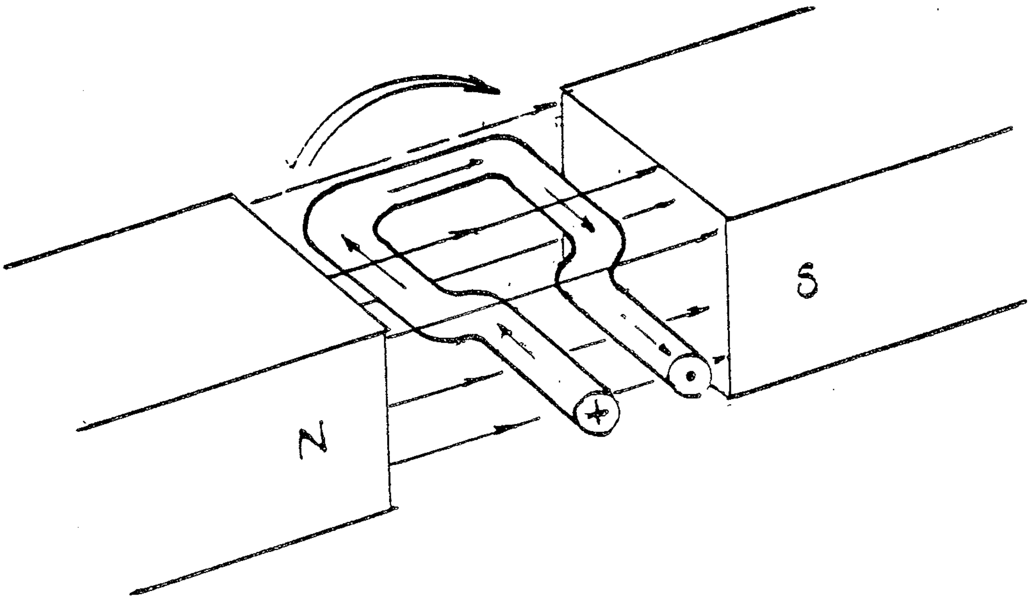
The following illustration shows a conductor being moved downward to cut the lines of force of a magnetic field. This movement can be thought as to distort the field such that the lines of force are now bent in an anti - clockwise direction and the current induced in the conductor is flowing out of the paper.



Conversely if the conductor is moved upwards to cut the lines of force the field will be bent upwards hence the lines of force will be clockwise and the current induced will be flowing into the page. Note the corkscrew rule.



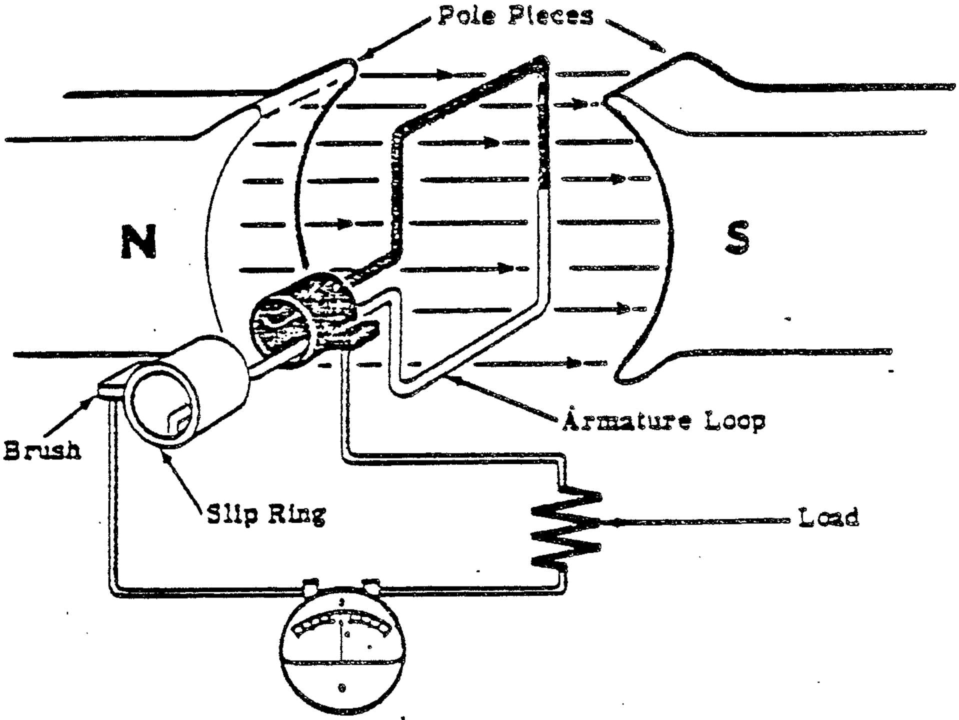
If the single conductor is now formed into a loop it can be observed from the illustration that when the loop is rotating the two conductors are cutting the magnetic field in the opposite direction and their respective E.M.Fs. will be cummulative.



STUDENTS NOTES

It now remains to collect the induced current from the coil and this is attained by the use of slip rings as shown in the following illustration.

The Elementary Generator.

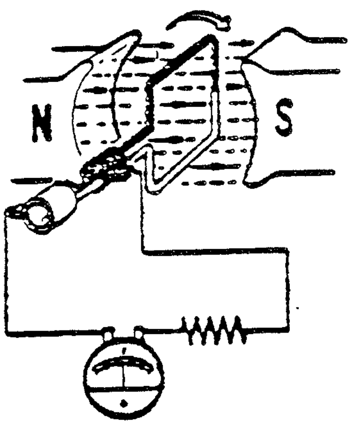


Elementary Generator Operation.

Assume that the armature loop is being rotated clockwise and the value of the is measured first at position "A". In this position the Conductors are travelling parallel to the lines of force and do not cut them hence no E.M.F. is generated.

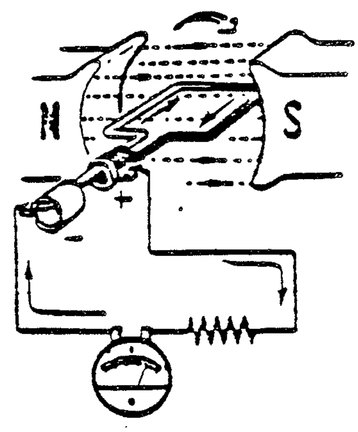
As the rotating loop begins to cut the field at an angle the value of the E.M.F. will gradually increase until, at 90° rotation the loop is cutting the field at right angles and the E.M.F. will be at a maximum - Position "B".

Observe that from 0 - 90° the black conductor cuts down through the field whilst the white conductor cuts upwards. The induced E.M.F.s are therefore in series and the resultant E.M.F across the brushes (The Terminal Voltage) is the sum of the two E.M.F.s.



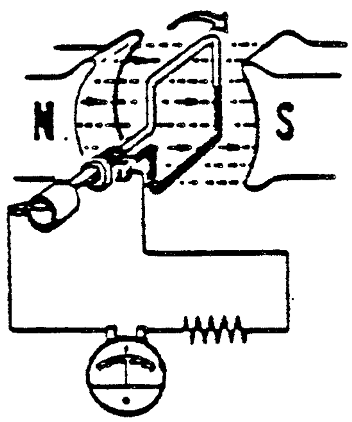
A Position
0°

FIG. 1



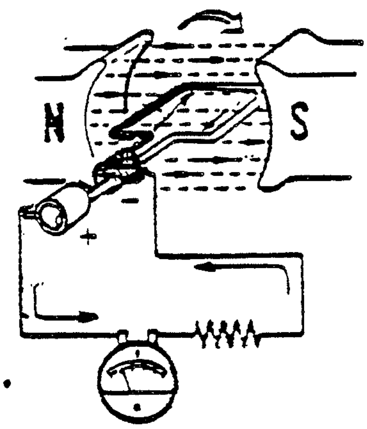
B Position
90°

FIG. 2.



C Position
180°

FIG.3.



D Position
270°

FIG. 4.

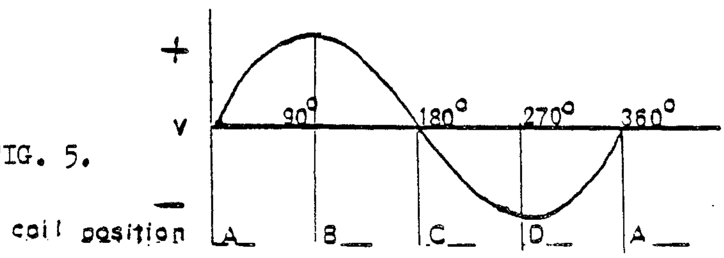


FIG. 5.

The electric current will vary in the same manner as the E.M.F. and the direction and the direction of the current and the polarity of the E.M.F. will depend on the direction of the field and the direction of rotation.

As the loop continues to rotate from 90° to 180° it's angularity with respect to the field will increase hence the value of the E.M.F. and the current will decrease to zero at 180°. (Fig.3 position"C")

When the loop rotates beyond 180° it will be observed that the black conductor now cuts the lines upwards and the white conductor downwards. As a result the polarity of the E.M.F. and the direction of the current reverses.

From 180° to 360° therefore the waveform will be opposite to the one generated from 0° to 180° and the waveform for the complete revolution will be an ALTERNATING E.M.F. which will cause an ALTERNATING CURRENT TO flow in the load. Refer Fig. 5.

STUDENTS NOTES

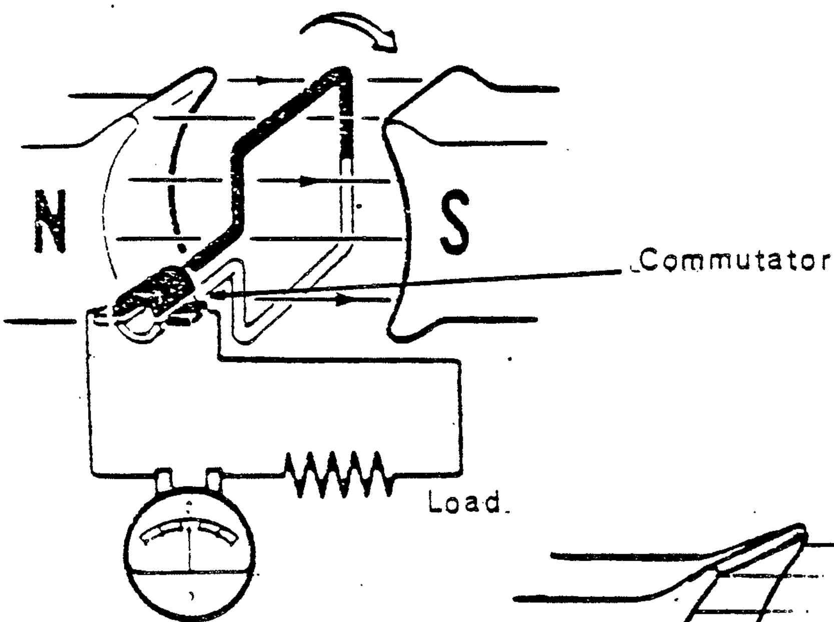
CONVERSION OF A.C. TO D.C. BY COMMUTATION.

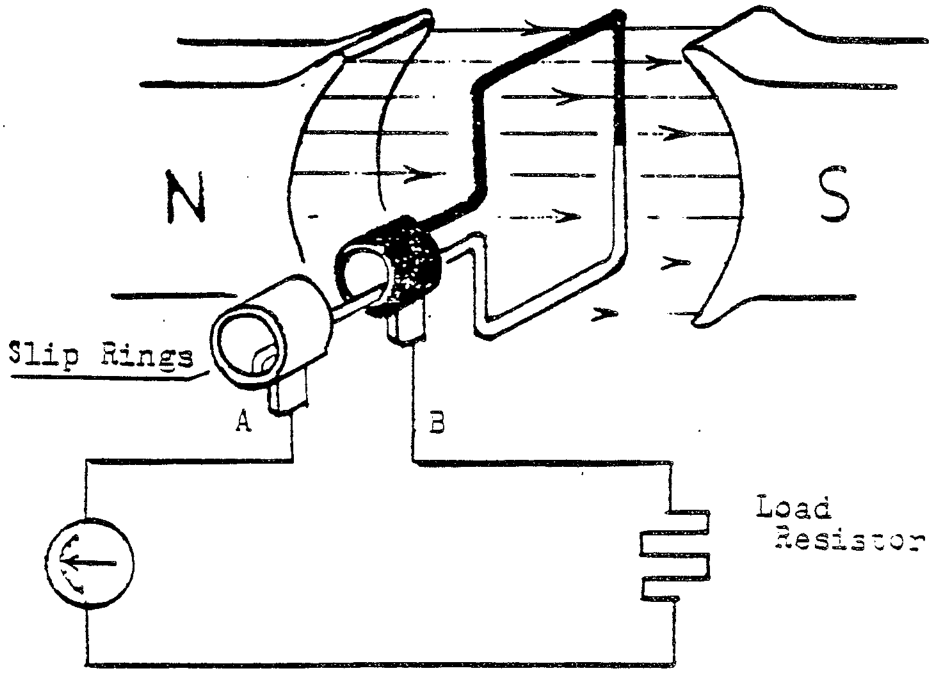
In order to convert the generated A.C. voltage to D.C. the negative portion of the waveform must be reversed to become a positive pulse. Some form of switch must therefore be used across the generator output in such a way that it will reverse the connections to the load every time the polarity of the induced E.M.F. changes.

The switch takes the form of one "SPLIT" slip - ring, the ends of the coil being then connected to each segment of the split slip-ring or, as it is normally termed, the commutator. The segments are insulated from each other so that there is no electrical connection between them, the shaft, or any other part of the armature.

The entire component is known as the commutator and it's action in converting A.C. to D.C. is known as COMMUTATION.

The illustrations below show the difference between slip-rings and a commutator.





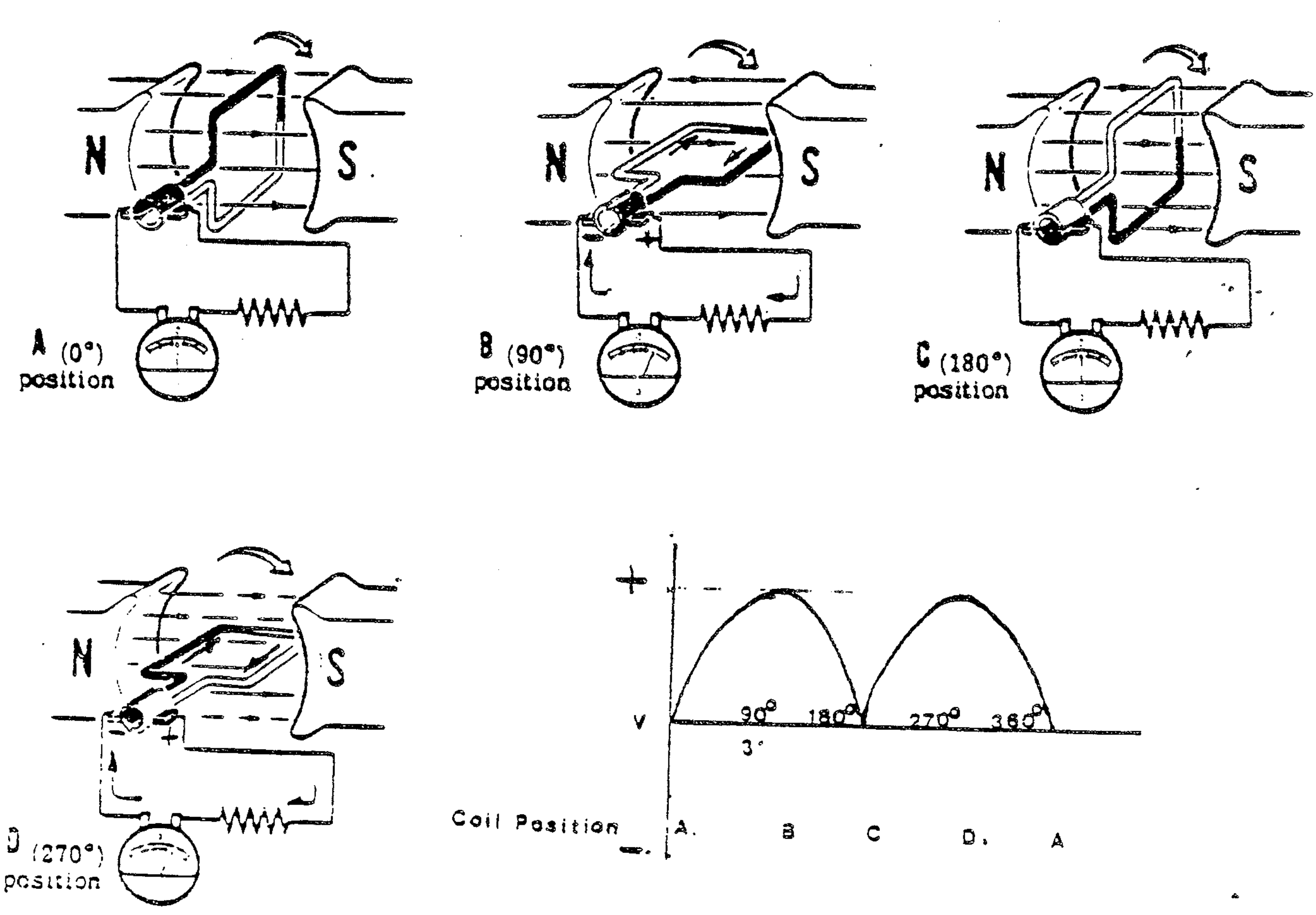
COMMUTATION.

In position "A", the loop is perpendicular to the magnetic field, no E.M.F. is generated in conductors of the loop, hence no current flow. Notice that the brushes are in contact with both segments of the commutator, short circuiting the loop, the short circuit does not create any problem since no current is flowing. The moment the loop moves slightly beyond position "A" (0 degrees), however, the short circuit no longer exists. The black brush is in contact with the black segment while the white brush is in contact with the white segment.

As the loop rotates clockwise from position "A" to position "B" the induced E.M.F. starts building up from zero to maximum at position "B". As the loop continues rotating clockwise from position "B" to "C" the induced E.M.F. decreases, until at position "C" (180°) it is zero once again.

In position "C" notice the black brush is slipping off the black segment onto the white segment, while at the same time the white brush is slipping off the white segment onto the black segment. In this way the black brush is always in contact with the conductor of the loop moving downwards, and the white brush is always in contact with the conductor moving upwards. As the loop continues rotating from position "C" (180°) through position "D" (270°) and back to position "A" (360° or 0°), the black brush is connected to the white wire which is moving down, and the white brush is connected to the black wire which is moving up. As a result, the same polarity voltage wave form is generated across the brushes from 180° to 360° degrees as was generated from 0 to 180 degrees. Notice that the current flows in the same direction through the ammeter even though it reverses in direction every half cycle in the loop itself. The voltage output then, has the same polarity at all times.

Converting A.C. to D.C. by Use of the Commutator



STUDENTS NOTES

IMPROVING THE D.C. OUTPUT.

It can be seen that the D.C. output of an elementary D.C. generator is very uneven, a pulsating voltage varying periodically from zero to a maximum. Although this pulsating voltage is D.C. it is not constant enough to operate D.C. equipment and appliances efficiently, hence, the generator must be improved so that it will minimise the pulse.

This is accomplished, in part, by adding more coils to the armature as illustrated in the following diagram. It can be observed that there is now two coils pos positioned at right angles to each other and that each coil has it's own pair of segments i.e. there is now four segments.

In the position shown the brushes are in contact with the segments of the white coil in which a maximum voltage is being generated, since it is moving at right angles to the field. As the armature rotates clockwise the output of the white coil starts dropping off and after revolving 45° the brushes slide off on to the black coil's segments in whose coil the E.M.F. is increasing. Note then that the E.M.F. of the white coil does not fall off to zero as it does in a single coil generator.

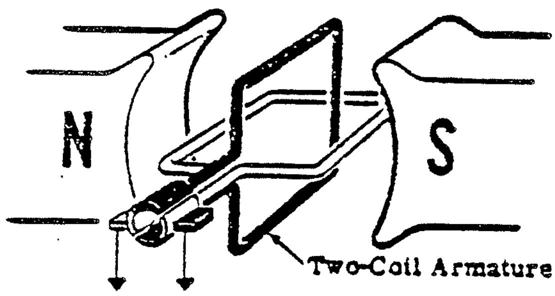
The E.M.F. increases in the black coil as it progresses in to the field reaching a peak at 90° whereupon it starts to decrease but will not fall to zero. At 135° commutation takes place once again and the white segments will once more be in contact with the brushes.

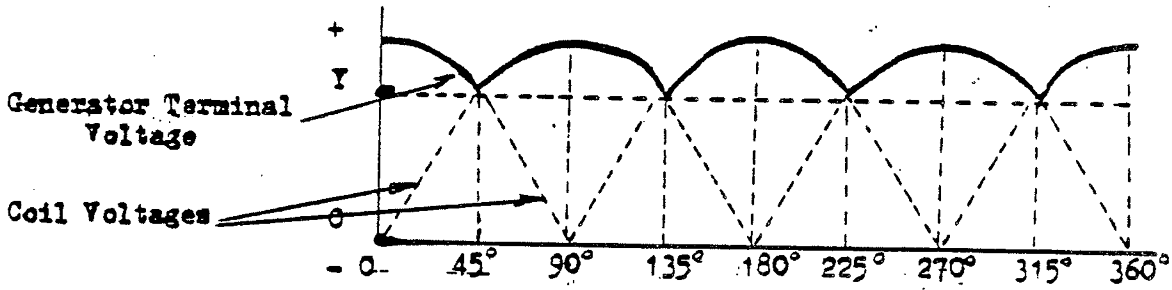
The output voltage waveform for the entire revolution is shown superimposed on the waveform of a single coil in fig.(b). Note that the output never drops below point Y. The rise and fall in voltage is therefore now limited between Y and the maximum. This small variation in the output voltage of a D.C. generator is termed "generator ripple".

It is apparent that the output of the two coil geanerator is much closer to constant D.C. than that of the single coil generator. It therefore follows that the addition of more coils will smooth the output or reduce the ripple further.

Graeter efficiency in terms of power output can be obtained by replacing the permanent magnets by electro-magnets. This gives an increase in the field strength. Increasing the number of pairs of poles also effects an increase in power output and typical traction generators have five pairs of poles.

Reduction of Generator Ripple





PRINCIPLES OF A D.C. MOTOR

FORCE ACTING ON A CONDUCTOR

The armature of the electric motor moves because there is a force acting on it. This force is the force of magnetism and it is produced whenever a conductor carrying current is placed in a magnetic field.

Fig (a) below shows a conductor lying in a magnetic field. As no current is flowing in the conductor the magnetic field exerts no force on the conductor.

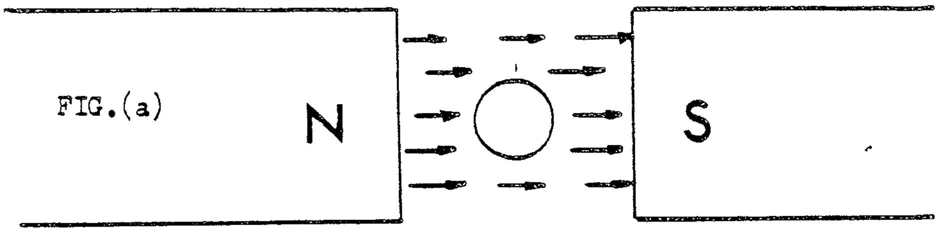


FIG.(a)

Consider the same conductor in fig.(b) below. this time carrying current into the page as indicated by the X symbol. In this case, in addition to the N - S magnetic field there is now the magnetic field produced round the conductor to the current flowing in it. It will be noted that the black and white arrows above the con conductor are aiding each other which indicates that the resultant field is stronger at this point whereas below the conductor the fields are in opposition thus indicating that the resultant field is weaker.

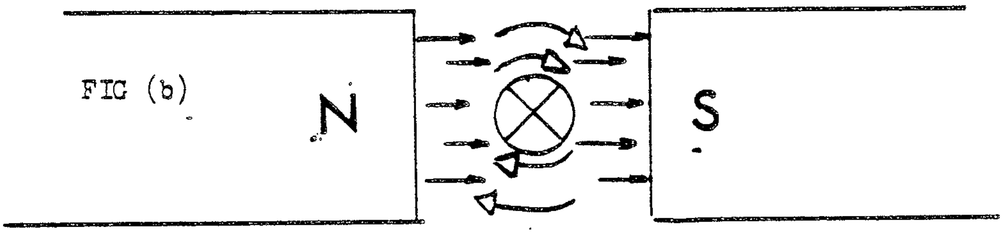


FIG (b)

The resulting effect of the two fields are shown in fig (c) below. Here the lines of force are shown to be more dense above the conductor and less dense below. It follows therefore that the resultant force on the conductor is downwards.

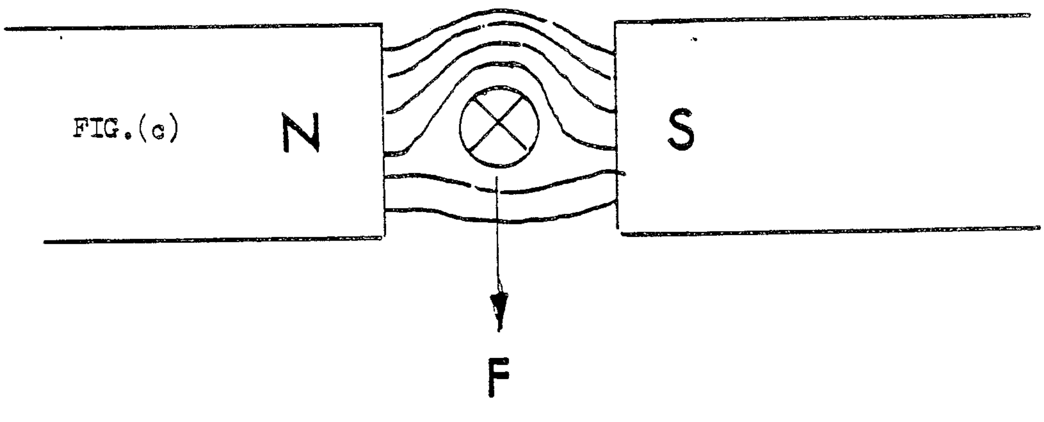


FIG.(c)

Factors Affecting The Amount Of The Force.

The force exerted on a current carrying conductor in a magnetic field depends on the following conditions:-

(a) The strength of the magnetic field

(b) The magnitude of the current.

(c) The length of the conductor in the field.

Reversal of Application Of The Force

If the direction of the current in the conductor remains unaltered Fig 1 & 2 but the FIELD POLARITY REVERSED is in Fig 2. then the resultant interaction of the polar fields and that about the conductor is also reversed, a stronger field being produced above the conductor and a weaker one below, hence the conductor is forced by the stronger field towards the weaker one i.e. in the doward direction.

FIG 1

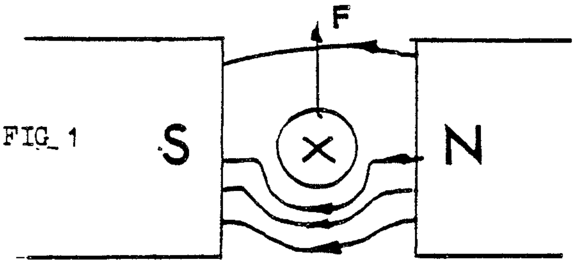
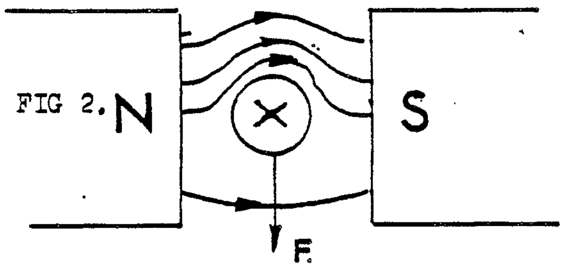
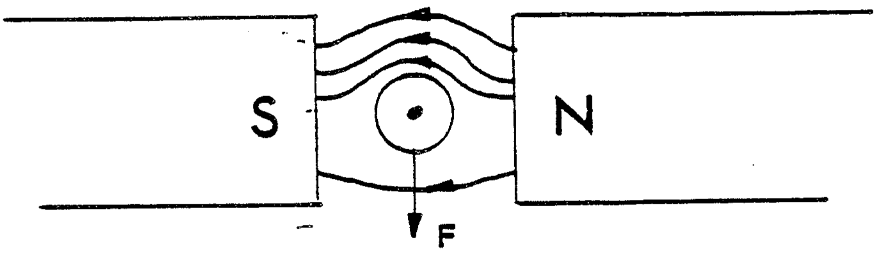


FIG 2.



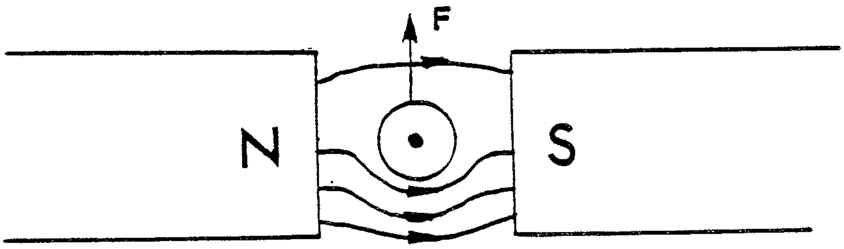
Similarly if the field polarity remains unaltered as in fig 1 & 3 but the direction of the current is reversed as in Fig. 3 , the resultant field interaction with that about the conductor is again reversed accomanied by the reversal of the force as shown.

FIG 3.



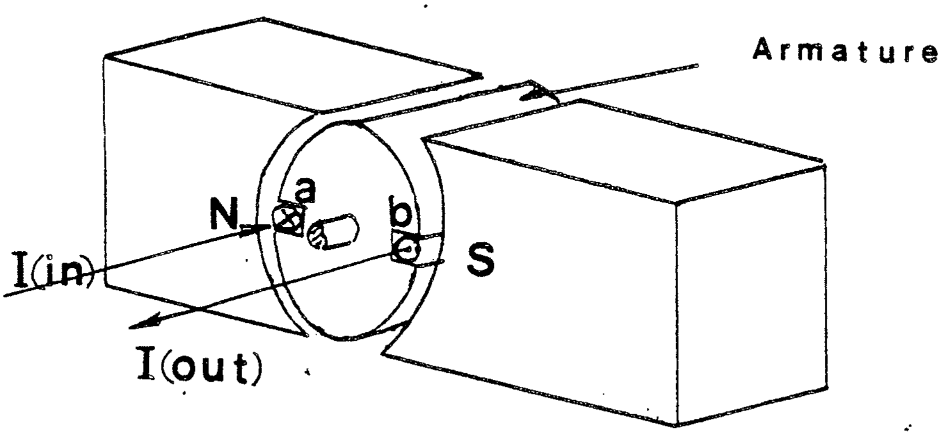
If, however the field polarity AND the direction of the current in the conductor were both changed, asiin Fig 4. then the direction of the force on the conductor will remain unchanged. Com pare Fig 4 with Fig. 1..

FIG.4.



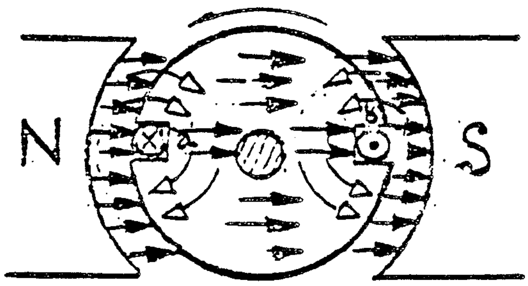
THE SIMPLE ELECTRIC MOTOR

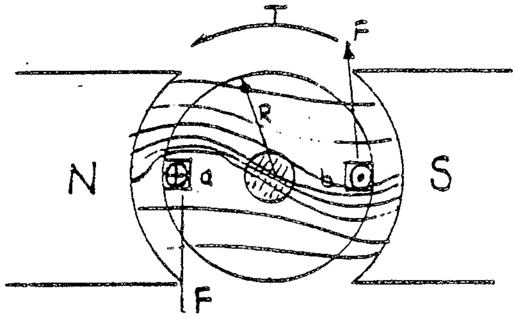
Next consider a conductor wound as aloop round a drum shaped,cast iron former (the armature) as shown in the illustration below.



Here the two sides of the loop 'a' and 'b' are shown placed in two diametrically opposite slots under the centres of the N & S pole pieces. If the current enters at side 'a' it must leave from side 'b' as shown.

Consider the above assembly as shown diagrammatically below. Here the current is depicted entering side 'a' left and leaving side 'b' right. The magnetic fields produced by the conductor is shown by the white arrows and the polar field being depicted by the black arrows.Diagram (1)





Using the same analysis of the resultant fields as previously used it can be observed that the inter-action of the two fields will produce a stronger field above the conductor at 'a' and a stronger field below the conductor at 'b',and a field pattern will be produced as in (2) above.

It can also be seen from (2) above that the magnetic forces exerted on each leg of the conductor will be transmitted to the sides of the slots in which they are placed and so transmit a turning moment to the armature shaft. From this reasoning a simple expression for torque can be derived.

Troque is the product of the applied force and the perpendicular distance from which it acts. In this case, the force(F) acting on one conductor at a distance (R) i.e. the radius. or

TORQUE = FORCE x RADIUS

This is the "MOTOR" principle as used in electrical machines.

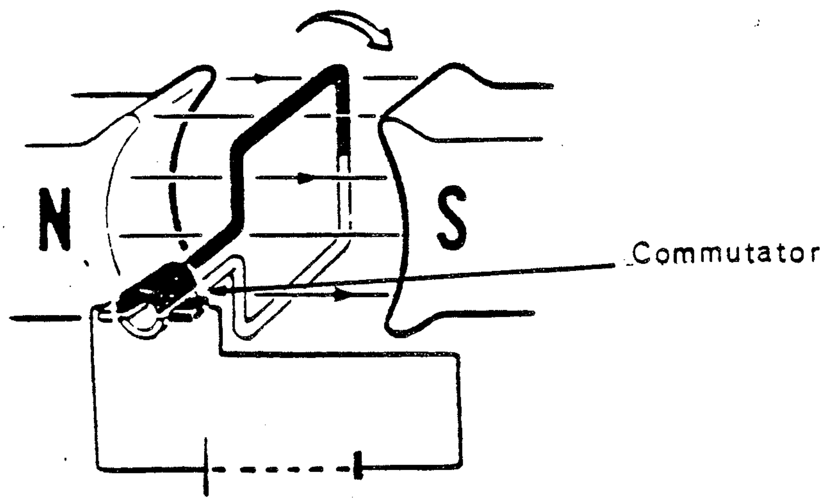
Refering to the output of the generator in the previous text it was shown that if a uni-directional or D.C.supply was required comutation was necessary i.e. the direction of the output E.M.F. was reversed under each alternative magnetic pole by means of a commutator.

A commutator is also required on a D.C. motor to reverse the applied E.M.F. to each coil of the armature as they pass each alternate pole so as to maintain a constant direction of force on each coil.

Referring to the next sketch,as the loop moves from the influence of one pole to the other the direction of the current flow is reversed by the action of the commutator which rotates with the loop and this ensures that the loop continues to rotate in the one direction.

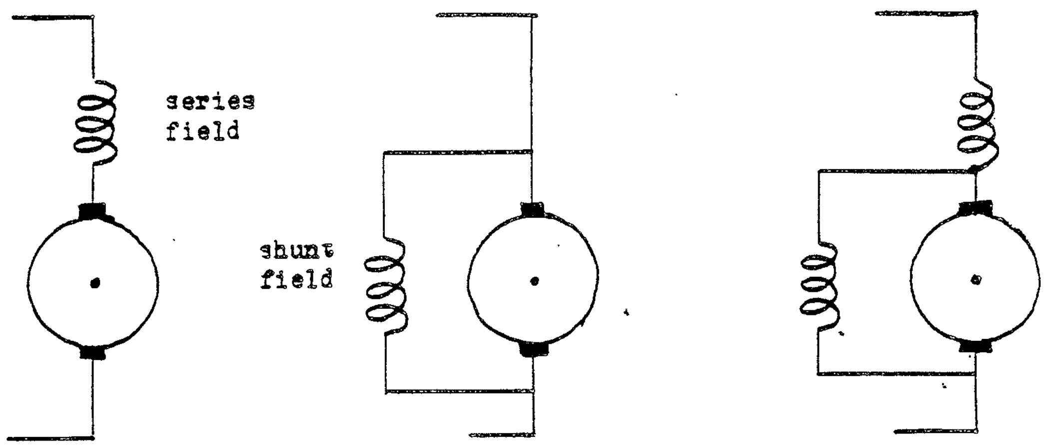
If this direction of rotation has to be reversed,then from the earlier text either the direction of the current in the loop has to be reversed or the polarity of the poles has to be reversed,but never both of them.

As with a generator the efficiency of the D.C. motor is increased by increasing the number of conductors on each coil,the number of coils,the number of pairs of poles which are also termed FIELDS.



The fields can be connected in several ways e.g. series,parallel or series/ paralell. On a Class 47 locomotive the series connection is used.

SERIES PARALLEL SERIES/PARALLEL or COMPOUND



STUDENTS NOTES

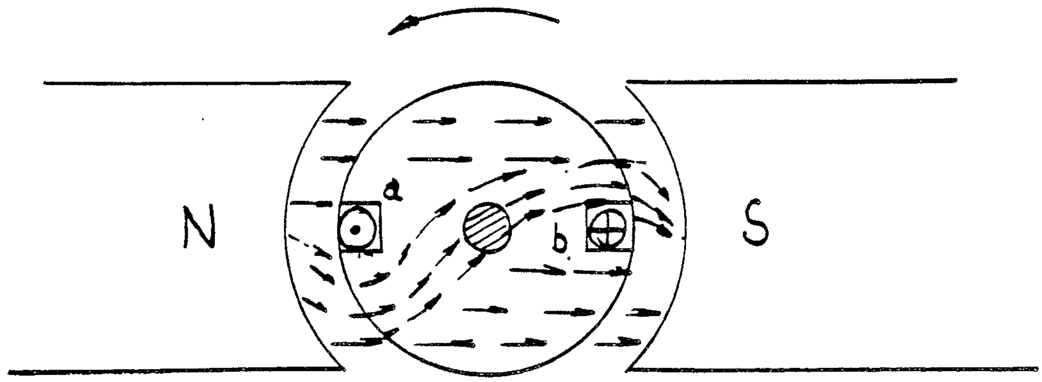
4.3. VOLTAGE GENERATED IN A MOTOR (BACK E.M.F)

The principles of electro-magnetic induction state that when a conductor moves through a magnetic field an e.m.f. is induced in the conductor, the direction of the induced e.m.f. depending on the direction of the magnetic field and the movement of the conductor.

A D.C. motor has a N - S field system, an armature, commutator and brush gear, i.e. it is basically similar in construction to a D.C. generator. The difference between the two machines is that the armature of the generator is rotated by som e prime mover to produce electrical energy at the terminals, whereas the motor receives electrical energy at the terminals to produce torque and rotation of its armature.

Because they are similar machines it is easily appreciated that as the armature of a motor rotates its conductors are moving through a magnetic field, hence an e.m.f. MUST be induced in them.

Comparing the diagram below with that on page it can be seen that the e.m.f's induced in the conductors are acting in opposition to the applied e.m.f. The induced e.m.f's are known as the BACK E.M.F. of a motor.



ARMATURE BEING ROTATED ANTI-CLOCKWISE BY 'MOTOR ACTION', SHOWING DIRECTION OF INDUCED E.M.F.

From the general equation for a generator the back e.m.f. of a motor when it is rotating is:-

Back e.m.f. (Eb) = Magnetic Flux X REV/MIN

The term "back e.m.f." is used to describe the e.m.f. which is generated in the armature of a motor when the armature is rotating in a magnetic field.

The back e.m.f. like all generated e.m.f. depends on the rate of rotation rev/min and the strength of the magnetic field consequently, the back e.m.f. is negligible at low revs/min but becomes proportional greater at the higher speed.

The practical effect of the back e.m.f. generated by the traction motor of a locomotive can be observed on the ammeter when starting a train.

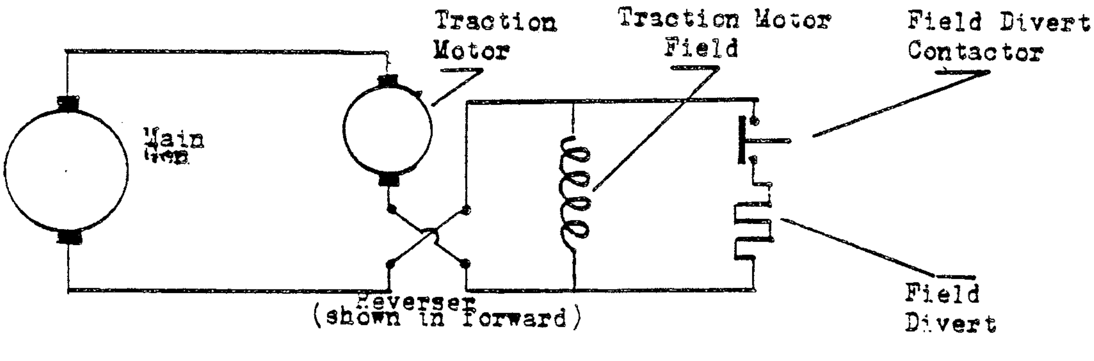
Initially, when the controller is opened, the ammeter moves rapidly to a very high value while the motors are at rest. As soon as the train moves i.e. the traction motor armatures revolve, a back e.m.f. is generated by the motors.

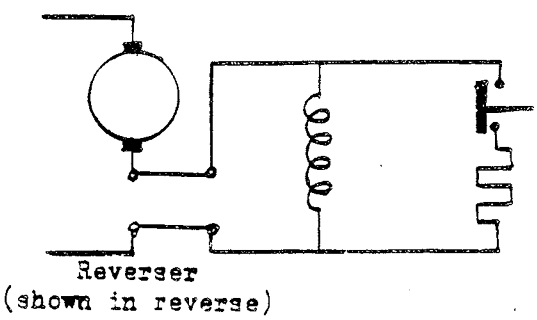
This causes a resistance to the current flowing from the Main Generator hence the current value on the ammeter decreases and therefore the maximum speed which can be attained by the motor, therefore the vehicle, will be limited. This is sometimes known as the "Balancing Speed".

Bearing in mind that the value of the back e.m.f. being generated by the motors is dependant on the armature speed and the field strength. In order to reduce the values of the back e.m.f to increase the speed the field strength must be reduced.

This is attained by <u>diverting</u> a portion of the <u>field current</u> into large resistors banks which are connected in parallel to the field coils. The following schematic diagram shows one stage of weak field but on most locomotives 3 stages are taken.

ELECTRICAL CONNECTION OF FIELD DIVERSION OF A SERIES TRACTION MOTOR





At a predetermined speed, 33 m.p.h. on a Cl.47 FDR1 is energised by a switch on the load regulator when it has wound to its minimum resistance value i.e. the generator field is at maximum excitation and cannot therefore increase its output to the traction motors.

FIELD DIVERSION

When F.D.R switch closes a proportion of the current passes through F1 resistor. There is therefore less current now passing through MI field coils hence the field strength is reduced resulting in a reduction of Back e.m.f. This then allows an increase in the generator current through the armature and results in an increase of speed.

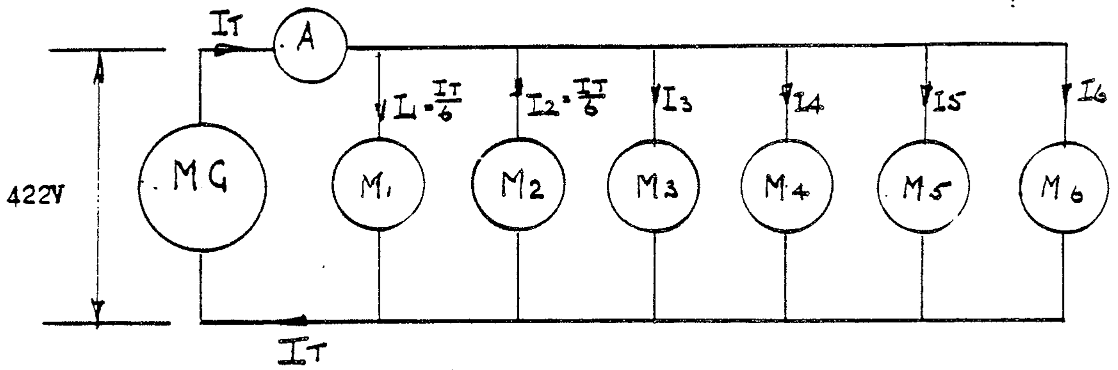
This operation is repeated at speeds of 45 and 61 m.p.h. on Class 47 locomotives.

MOTOR CONNECTION

On Cl.47 the traction motors can be connected in the parallel mode or series parallel mode as shown in the following sketches

PARALLEL MODE

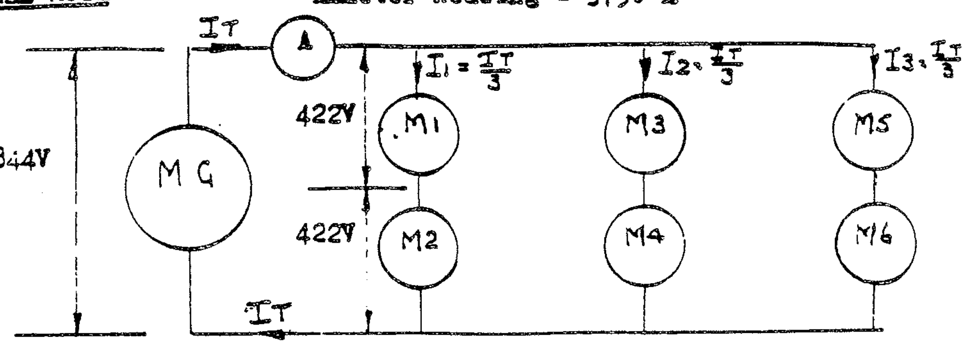
Ammeter reading = 7500A



Maximum starting current from main gen - 7500A.

Assuming the resistance of each motor is the same the current taken by each motor $= \frac{7500}{6} = 1250A$ Main Generator voltage across each motor = 422V

SERISS/ PARALLEL MODE



Maximum starting current from Main Gen = 3750A Assuming the resistance of each pair of motors is equal to the current taken by each motor

$$= \frac{3750}{3} = 1250 \text{ A}$$

Main generator voltage across each motor = 422V It can therefore be seen that whether the motors are connected in parallel or series-parallel the voltage across and the current taken by each motor is the same in both cases.

STUDENTS NOTES

STUDENTS NOTES

CONTACTORS

Contactors are switches which handle heavy currents and operate as a result of the action of other switches or relays. They fall into two main classes.

(1) Electro-Magnetic (E.M.) Types.

(2) Electro-Pneumatic (E.P.) Types.

Refer to page 12 for illustration.

The Resistance of Electrical Contacts.

Since the prime function of control equipment is carried out by contact, either making or breaking, it is essential that a good electrical contact is made.

A good electrical contact will be one where there is little opposition or resistance offered to the flow of current i.e. the "contact resistance" will be very low, and so, very little of the applied voltage will be lost or "dropped" across the contact faces.

The main factors affecting the resistance of electrical contacts are:-

(1) Material

Copper, silver and alloys of copper and silver.

(2) Surface Area Contact (large so as to minimise resistance.)

(3) Force applied to Contact.

(4) Condition of surfaces (free of dirt and pitting).

Operation of Power Contacts.

Power contacts are very robust and usually shaped so that there are two distinct areas, each having a different duty to perform. (Refer to figure 1).

(a) The Tip or Toe.

This area is the first to make and the last to break or part and so any arc formed by the current on being switched off takes place on this area and is directed then into the arc-chute. Because of the continual arcing in this area it is susceptable to burning and pitting.

(b) The Heel.

This area is the contact proper and is the final contact area when the contact action is completed. Because no arcing occurs in this area it is normally very clean and therefore offers no resistance to the current flow.

In order to contact the toe and heel in their proper sequence when opening and closing, these types of contacts may have a rolling action or a wiping action.

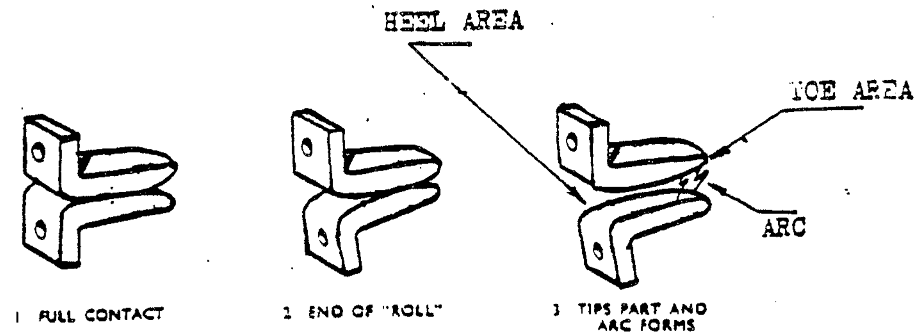
Cont'd........

The Rolling Action.

(1)

Consider the action of these contacts when opening. There is first a "rolling" action during which the tips remain closed but the heel portions separate. Then, as the gap at the heel increases the point of contact moves forwards until the tips part. If power current is being broken when the contacts part, an arc will form and be blown out beyond the tips by the magnetic blowout arrangements described later.

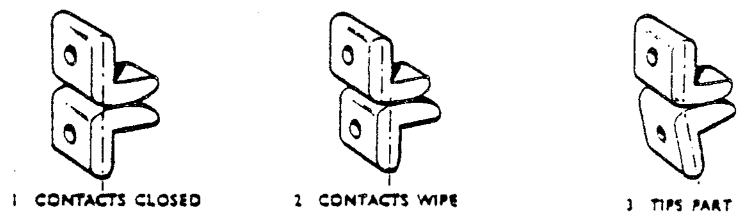
On closing the reverse action takes place, the tips touch first, the bottom contact rolls onto the full contact and the tips part as full contact is reached.



The Wiping Action.

(2)

The first action on opening is a sliding forward of the bottom contact, called the "wipe", this is followed by a slight knuckling action during which the contact rolls slightly and then parts. The principle is similar to that of the first type, the wiping action tends to bed in the bottom contact as it closes and offsets any tendancy to bad contact caused by the arc-roughened tips. i.e. there is a self-cleaning action.



"Welding" of Contacts. (On Making or Breaking the Circuit).

The possibility of "welding" of contacts has to be considered, especially in cases where a high current flows immediately on closing the circuit, as this leads readily to such severe local heating of the initial points of contact that welding of the surfaces may occur. Also when there is "contact bounce", i.e. in closing a circuit, the mechanical energy of the moving parts is arrested by the fixed contact, and in some cases the impact is so severe that the moving contact bounces once or twice before establishing continuous contact. This generates electrical arcs having a very high temperature.

Arc Dispersion.

This aims at minimising the destructive effects of the arc when it occurs. Although there are several methods of dispersing large electrical arcs the magnetic blow-out type is the one most utilised on diesel-electrical locomotives and therefore will be the only one to be described in this text.

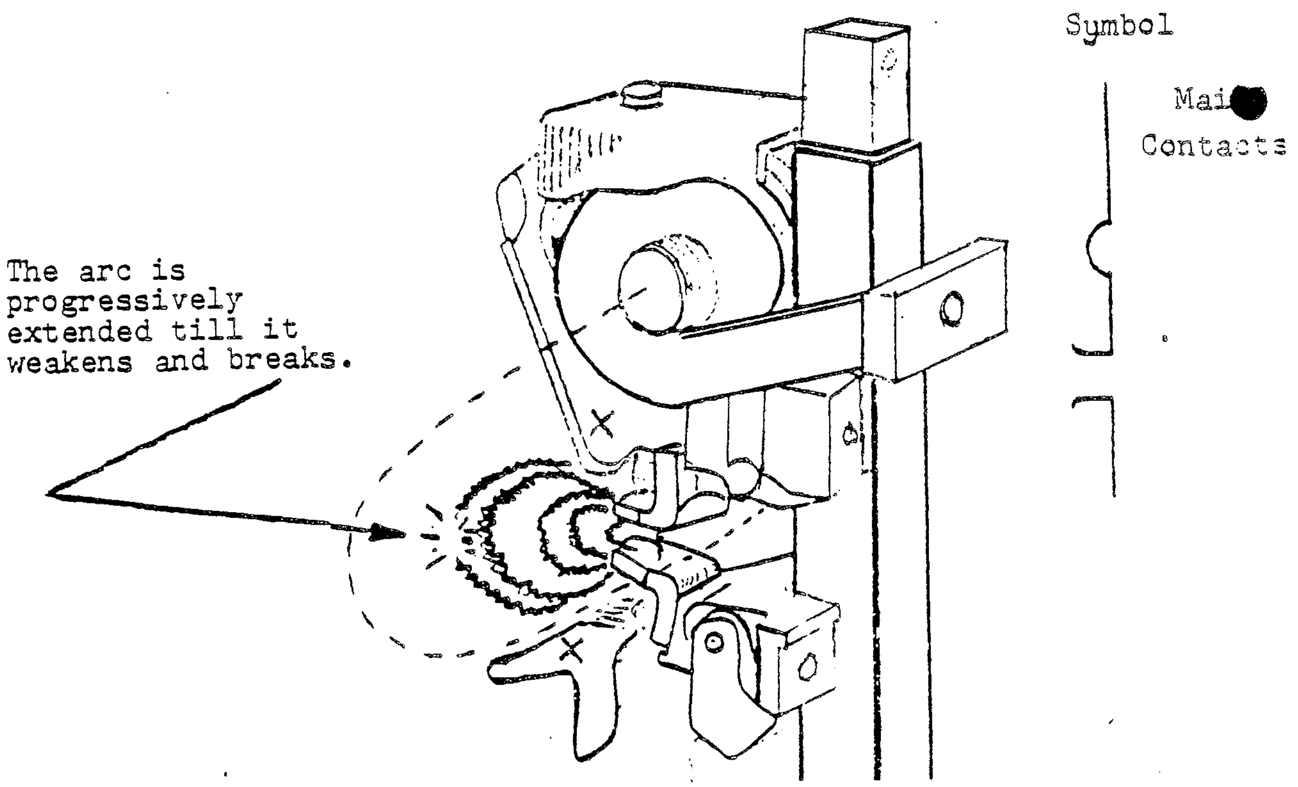
Magnetic Blow-Out Contactor.

This is usually a coil consisting of a few turns of copper strip connected in series with the power contacts, and is mounted on a magnetic core with side cheeks so shaped that the magnetic field created by current flowing in the blow-out coil is produced adjacent to the opening power contacts. The arc, which is a flow of current, is thus situated in a magnetic field, and so experiences a "motoring" force which blows the arc outwards into the fire-proof "arc-chute". The arc thus becomes an every-lengthening loop stretching between the fixed and moving contacts, and as the arc lengthens it is cooled in passing through the "arc-chute" and "splitters" until it is extingushed.

The magnetic blow-out field may also be provided by a permanent magnet.

Figure 3 below, shows the contacts parting. The drawing has been shown without the "arc-chute" but it is most important to remember that it should be in place at the time when the arc is drawn otherwise correct extinction will not take place.

Typical contactors, fitted with magnetic blow-out, are shown on page 12.



Alternating Current (A.C.)

A.C. power is being used to an ever increasing extent on Diesel Electric Locomotives. On Class 47 locomotives (except 47.401-47.420) the power for train heating is supplied from an A.C. Generator and then rectified to D.C. Furthermore on some non-E.T.H. locomotives, alternators are used to provide power for the excitation of the main generator field and wheel slip detection circuits, which again is rectified to D.C.

The main advantages of an alternator over a D.C. machine is their they do not require commutators and the brushes do not handle large voltages and currents, in fact some may have no brushes whatever.

The Alternator:

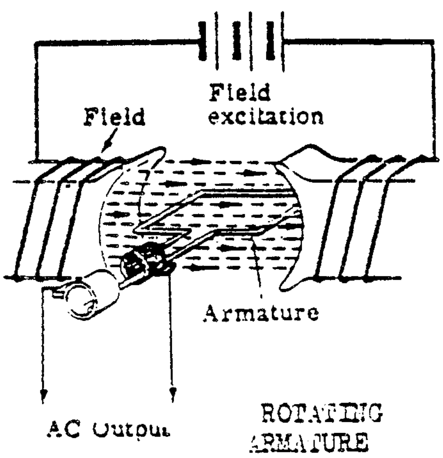
All electrical generators whether A.C. or D.C. depend for their operation on the action of a coil cutting a magnetic field or a magnetic field cutting through a coil. As long as there is relative motion between the coil and the magnetic field.

In order that relative motion may take place between a coil and a magnetic field, all generators are made up of two parts, a Rotor and a Stator.

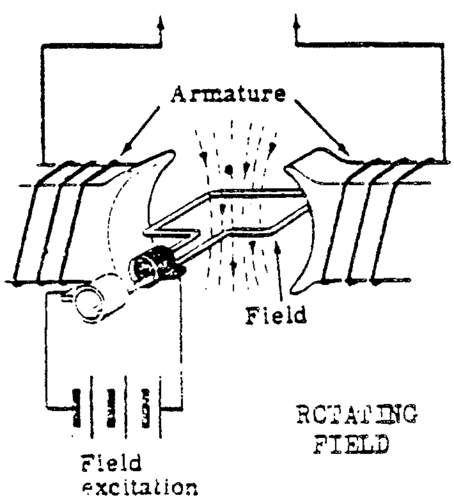
It was shown that in a D.C. generator the revolving part or ROTOR was always the armature but in an A.C. generator this is not usually true. There are two types of alternator, the revolving - armature type and the revolving field type. The revolving - armature type is similar in the construction to the D.C. genreator in that the armature or Rotor rotates through a stationary magnetic field, but in the D.C. generator the E.M.F. generated in the armature windings is converted into D.C. by means of the commutator, whereas in the alternator, the generated A.C. is brought to the load unchanged, by means of slip rings.

The revolving - armature alternator however, is only found in alternators of small power rating and is not generally used.

The revolving - field type of alternator has a stationary armature winding and a rotating field winding. The advantage of having a stationary armature winding or Stator is that the generated voltage can be connected directly to the load. Fixed connections are much more easily insulated than would be slip rings at very high voltages, so high voltage alternators are usually of the rotating field type, since the voltage applied to the rotating field is a low D.C. voltage, i.e. the Rotor. The problem of arc - over at the slip rings is not encountered.



ROTATING ARMATURE



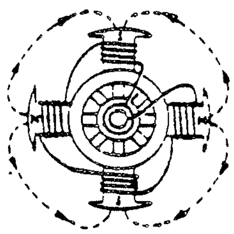
ROTATING FIELD

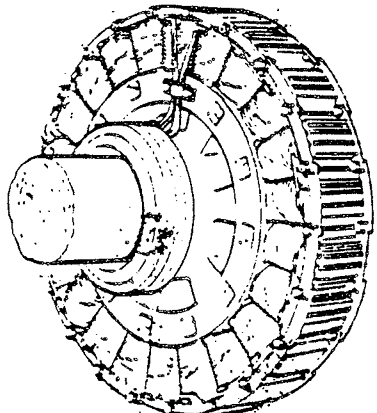
Types of Alternators:

The two main types of alternators are the high speed turbine alternator in which the Rotor is small in diameter and has the windings firmly embedded in its face to withstand high centrifugal forces. The second type is the SALIENT POLE alternator and its name is derived from the meaning of the word salient, i.e. jutting out. The salient pole alternator, because of its fabricated structure is a slow speed machine and is usually driven by engines, electric motors or even water power.

The E.T.H. alternator on the Class 47 is the salient pole type.

Schematic





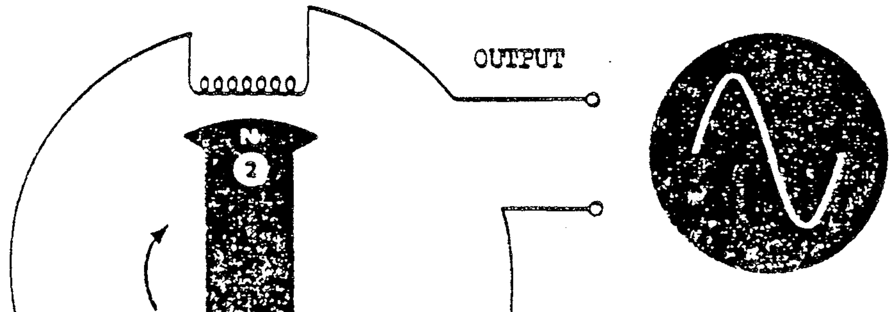
Regardless of the type of Rotor, its windings are separately excited with a D.C. supply, and the stationary armature or Stator completes the windings which are cut by the magnetic field.

Single Phase Alternator:

A single phase alternator has all the armature conductors connected in series as one winding across which an output voltage is generated. If you understand the principle of the single -phase, you will easily understand multi-phase operation.

The schematic diagram below illustrates a two-pole, single-phase alternator. Th stator winding is in two distinct coils, both being wound in the same direction round the stator frame. The rotor consists of two poles of opposite poraity.

As the rotor turns, its poles induce A.C. voltages in the stator windings. The two coils of the stator winding are connected to each other in such a way that the A.C. voltages induced in them are in phase, or 'series-aiding'.



SINGLE PHASE
ALTERNATOR

Two-phase Alternator:

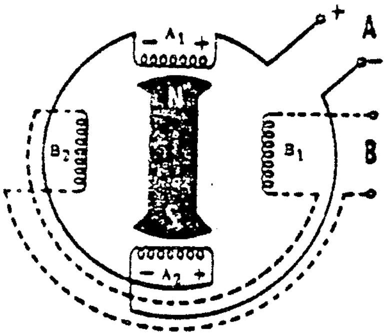
Multi-phase alternators have two or more single-phase windings symmetrically spaced around the stator. In a two-phase alternator there are two single-phase windings physically spaced so that the A.C. voltage induced in one is 90 degrees out of phase with the voltage induced in the other. The windings are electrically separate from each other. The only way to get a 90 degree phase difference is to space the two windings so that when one is being cut by macimum flux, the other is being cut by no flux at all.

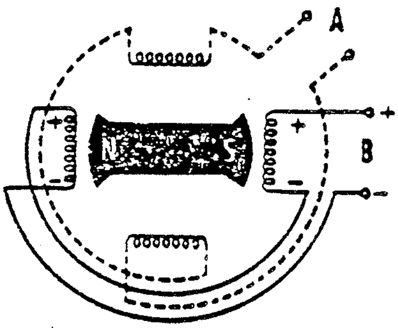
The diagram below illustrates a two-pole, two-phase alternator. The stator consists of two-single-phase windings completely separated from one another. Each winding is made up of two parts which are so connected that their voltages add. The rotor is identical to that used in the single-phase alternator.

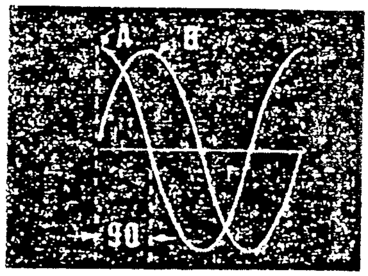
In (a), the roto poles are opposite the windings of phase A. Therefore, the voltage induced in phase A is maximum and the voltage induced in phase B is zero. As the rotor continues rotating, it moves away from the A windings and approaches the B windings. As a result, the voltage induced in phase A decreases from its maximum value, and the voltage induced in phase B increases from zero.

In (b), the rotor poles are opposite the windings of phase B. Now the voltage induced in phase B is maximum, whereas the voltage induced in phase A has dropped to zero. Notice that a 90-degree rotation of the rotor corresponds to one-quarter of a cycle, or 90 degrees.

The waveform picture shows the voltages induced in phase A and phase B for one cycle. The two voltages are 90 degrees out of phase as shown in (c).



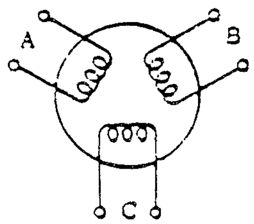


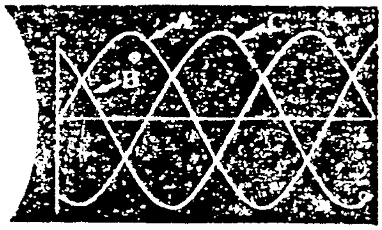


Three-Phase Alternator:

The three-phase alternator, as the name implies, has three single-phase windings so spaced that the voltage induced in any one is phase-displaced by 120 degrees from the other two. A schematic diagram of a three-phase stator showing all the coils becomes complex, and it is difficult to see what is actually happening. So the simplified schematic illustrated below shows the winding of each single-phase lumped together as one winding. The rotor is omitted for simplicity. The voltage waveforms generated across each phase are drawn on a graph, phase-displaced 120 degrees from each other.

The three-phase alternator shown in this schematic is essentially three single-phase alternators whose generated voltages are out of phase by 120 degrees. The three phases are independent of each other.

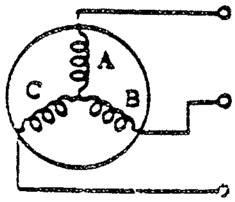




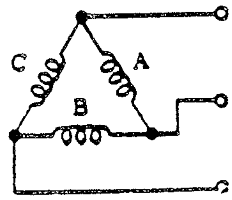
Instead of having six leads coming out of the three-phase alternator, three leads, one from each phase, are connected together to form what is called a 'star' connection. The point of connection is called the neutral, and the voltage from this point to any one of the line leads will be the phase voltage.

A three-phase stator can also be connected so that the phases are connected end-to-end; it is then called 'delta connected'. Both the 'star' and the 'delta' connections are used for alternators.

STAR CONNECTION



DELTA CONNECTION



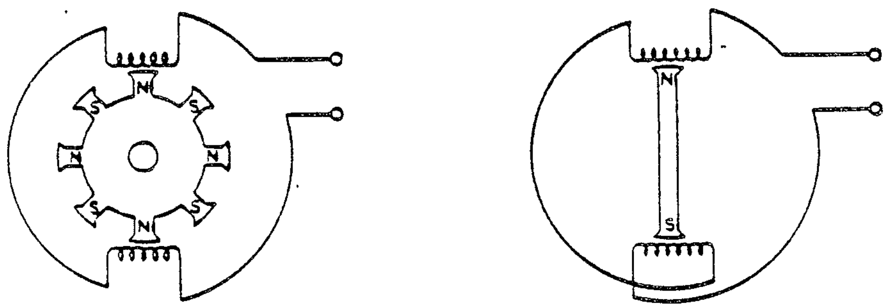
Frequency of Alternator Output:

The frequency of the A.C. generated by an alternator depends on the number of poles, and on the speed of the rotor. When a rotor has rotated through a sufficiently wide angle for two opposit poles - a North and a South - to have passed one stator winding, the voltage induced in the winding will have passed through a complete cycle of 360 electrical deegrees. So a single-phase, two-pole alternator rotating at 3,000 revolutions per minute will generate a 50-cycle-per-second voltage.

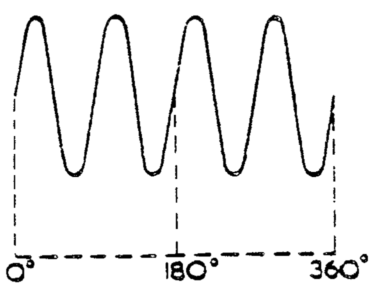
The more poles there are in the rotating field, the lower the speed of rotation will need to be for a given frequency. An eight-pole alternator, for example, will only have to rotate at 750 r.p.m. to generate a 50 c.p.s. output.

The relationship between generated frequency (F), expressed in cycles per second, the speed of the rotor (N), expressed in revolutions per minute, and the number of poles (P) is given by the formula: $F = \frac{NP}{120}$ HERTS

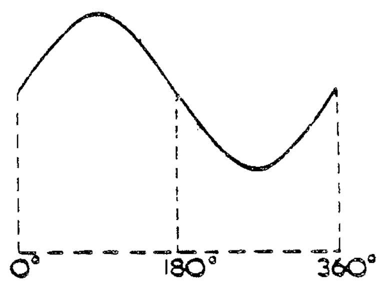
NOTE: One cycle per second is termed as 1 HERTZ in honour of a physicist of that name.



BOTH ALTERNATORS ARE ROTATING AT THE SAME SPEED



8 POLE



2 POLE

TRANSFORMER

TRANSFORMER ACTION

"Transformer Action" consists of two electro-magnetic principles which have already been examined.

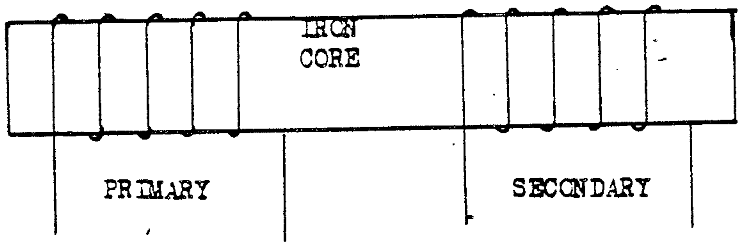
FIRST PRINCIPLE

When a current flows in a conductor a magnetic field is generated around the conductor and if the conductor is coiled round an iron core the magnetic field is much stronger

SECOND PRINCIPLE

When a magnetic field cuts the turns of a coil an e.m.f. is generated in the coil

A transformer consists of two coils a primary and a secondary, which are wound on a common iron core but electrically insulated from each other.



SIMPLE TRANSFORMER

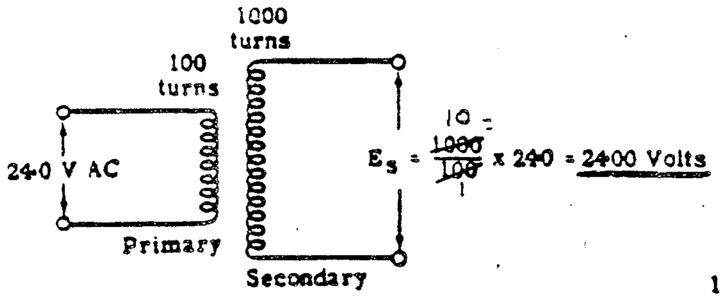
When an alternating e.m.f. is applied to the primary coil an alternating magnetic field is generated around the coil and in the iron core, (first principle).

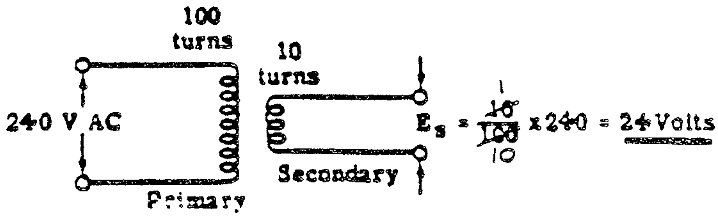
This alternating magnetic field cuts the turns of the secondary coils and therefore induces an alternating e.m.f. in that coil (second principle) Transformers are normally very efficient devices and the addition of the iron core can increase the efficiency to 98 or 99%. Assuming that all the magnetic lines of force generated by the primary cuts all the turns of the secondary the voltage induced in the secondary will depend on the ratio of the number of turns in the secondary to the number of turns in the primary.

For example if there are 1000 turns in the secondary and only 100 in the primary the voltage induced in the secondary will be 10 times the voltage applied to the primary (1000/100 = 10). Since the output of the secondary is greater than primary input this is termed a "step up" transformer.

If, on the other hand, the secondary had less turns than the primary, the secondary output would be less than the primary input and would be termed a "step down" transformer. These two types are shown in the following illustration.

Note, a transformer does not generate electric power it simply transfers power from one coil to another and, if necessary transforms the power from one level to another.





APPLICATION OF TRANSFORMERS

It has already been shown that the resistance of a conductor is proportional to its length i.e. the larger the conductor the greater its resistance.

It has also been shown that a voltage drop across a resistance is equal to the product of the current in the resistor and its resistance i.e. V = IR.

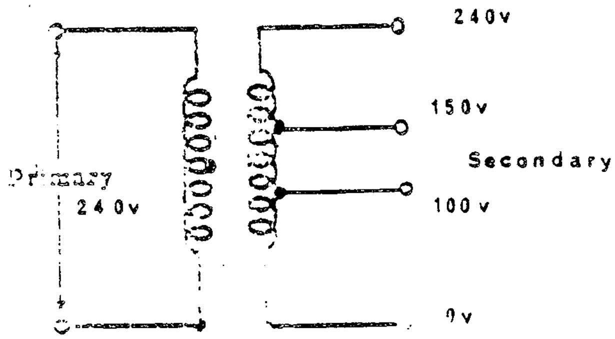
It can therefore be seen that if we transmit electrical power over long distances at a large current value there will be a large voltage drop between the transmitting and receiving points and therefore power losses.

This can be overcome by transmitting power having a very high voltage and a low current thus the IR losses or voltage drops are greatly reduced.

To transmit a.c. power at a high voltage, low current level the generated voltage of 6600 volts is stepped up by a thransformer to 66000 volts (66Kv) and distributed over long transmission lines then stepped down at different points to 6600 volts (6.6Kv) for local distribution and finally stepped down to 440 volts and 240 volts a.c. for local power and use. Further "specialised' supplies such as 25000 (25Kv) for railway traction can also be taken from the 66Kv lines.

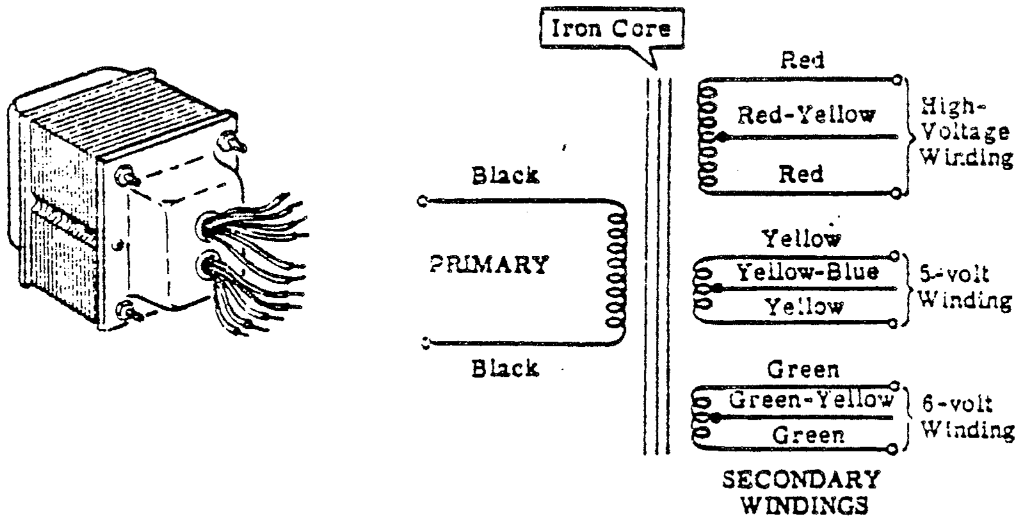
TRANSFORMER TAPPING

A further advantage of a transformer is that it can be 'tapped" to provide various voltage levels.



The following illustration shows a typical power supply transformer for radios etc in which each secondary winding supplies a different voltage. This arrangement eliminates the need for three separate transformers.

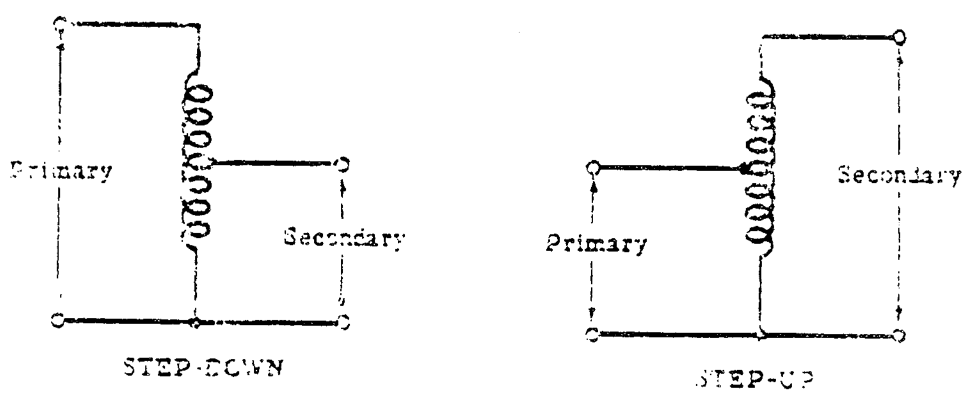
On the transformer illustration shown, the middle connections are termed the centre taps and the voltage between the centre taps and either connection is one half of the voltage across that winding. Taps can be taken from other than the centre position which will result in the voltages between the tap and the outer connection being different.



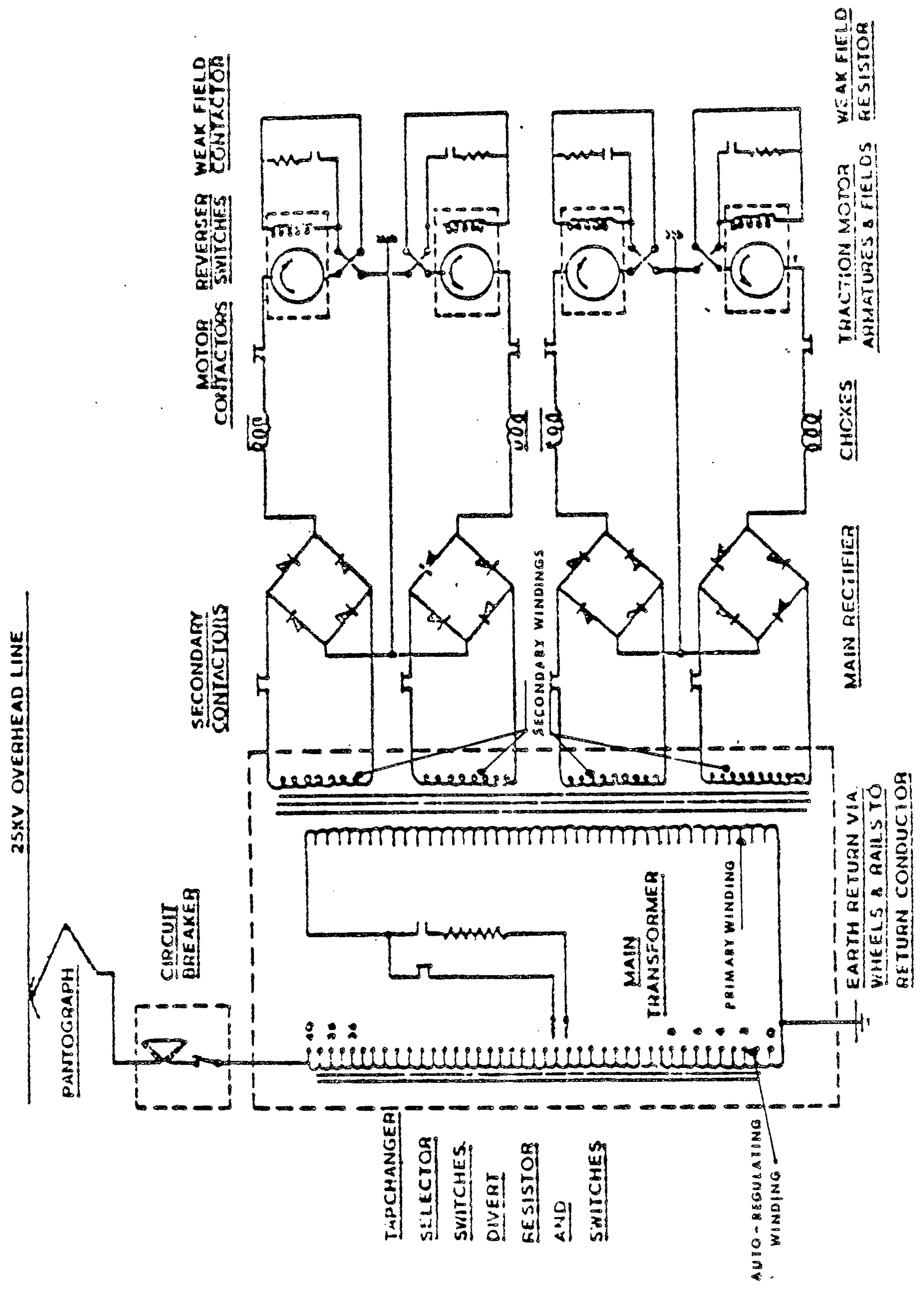
AUTOTRANSFORMERS

The autotransformer differs from other transformers in that it has only one winding instead of two. Part of this winding is used for both the primary and the secondary while the rest of the winding acts as either the primary or the secondary exclusively depending on whether the transformer is used to step the voltage up or down.

It can be seen from the illustration that, since there is only one coil autotransformers will require less wire and are therefore less expensive than two coil transformers. However they do not isolate the secondary and the primary circuits and therefore have a limited use.



The application of both types of transformers is shown in the illustration below which shows the power circuit of an A.C.Locomotive. It can be observed that the power from the over-head line is first taken to an <u>auto-transformer</u> which is a variable tap to step up or step down the voltage. The taps are then connected to the <u>primary winding</u> and the voltage stepped down by the <u>secondary windings</u> of the power packs.



A.C. LOCOMOTIVE - DIAGRAM OF TYPICAL POWER CIRCUIT CONNECTIONS

DIODES & RECTIFICATION

On pages one and two it was explained that materials having a large number of free electrons were grouped as good conductors of electricity but materials with a very small number or no electrons were grouped together as poor conductors or insulators.

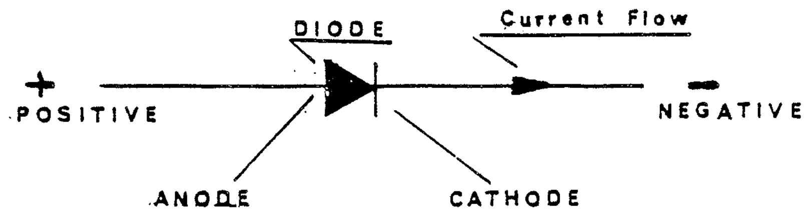
Certain materials however can be manufactured to form a third group known as semi-conductors or DIODES.

Principle of a Diode

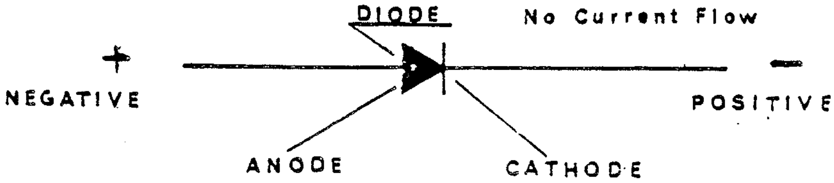
A diode is a device which will pass current easily in one direction, called the "forward" direction, i.e. presents no resistance to current flow, but will not pass current in the opposite direction termed the "reverse" direction, i.e. presents a very high resistance to the flow of current.

The following illustration No. 1 shows a diode connected in the forward direction (a) and the reverse direction (b) dependent on the polarity of the supply.

FIG 1



(a) FORWARD BIASED DIODE



(b) REVERSE BIASED DIODE

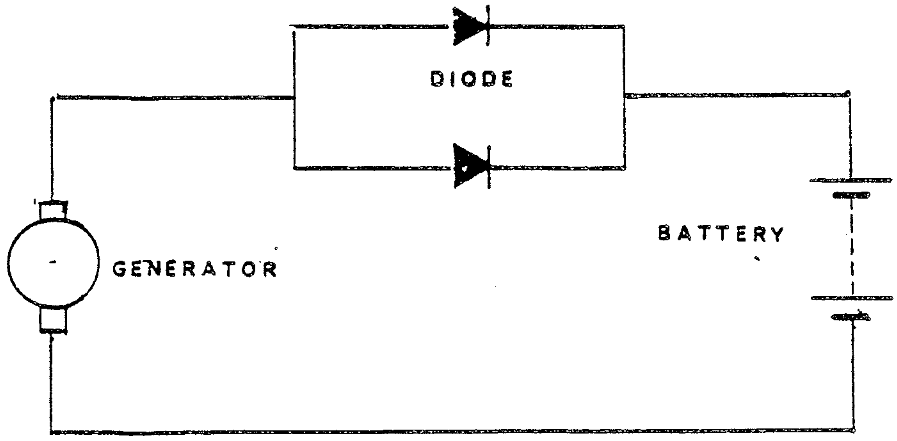
Note that the anode must always be positively biased for current to flow and that the arrow head of the diode symbol indicates the direction of conventional current flow which is opposite to the electron flow.

Continued ......

It is not intended to explain the complicated physics of a diode in this text, suffice to say that a diode in an electrical system acts in the same manner as a non-return or check valve in an air system.

Application of a Diode.

A typical application of a diode on locomotives is its use as a "blocking" device in the battery charging system as shown in figure 2.



BLOCKING DIODE (Battery Charging) FIG. 2

When the generator turns fast enough to generate a voltage greater than that of the battery the diodes permit battery - charging current to flow. If the generator slows or stops the battery voltage will exceed that of the generator and the battery would discharge through the generator. However the two diodes block the flow of discharge current.

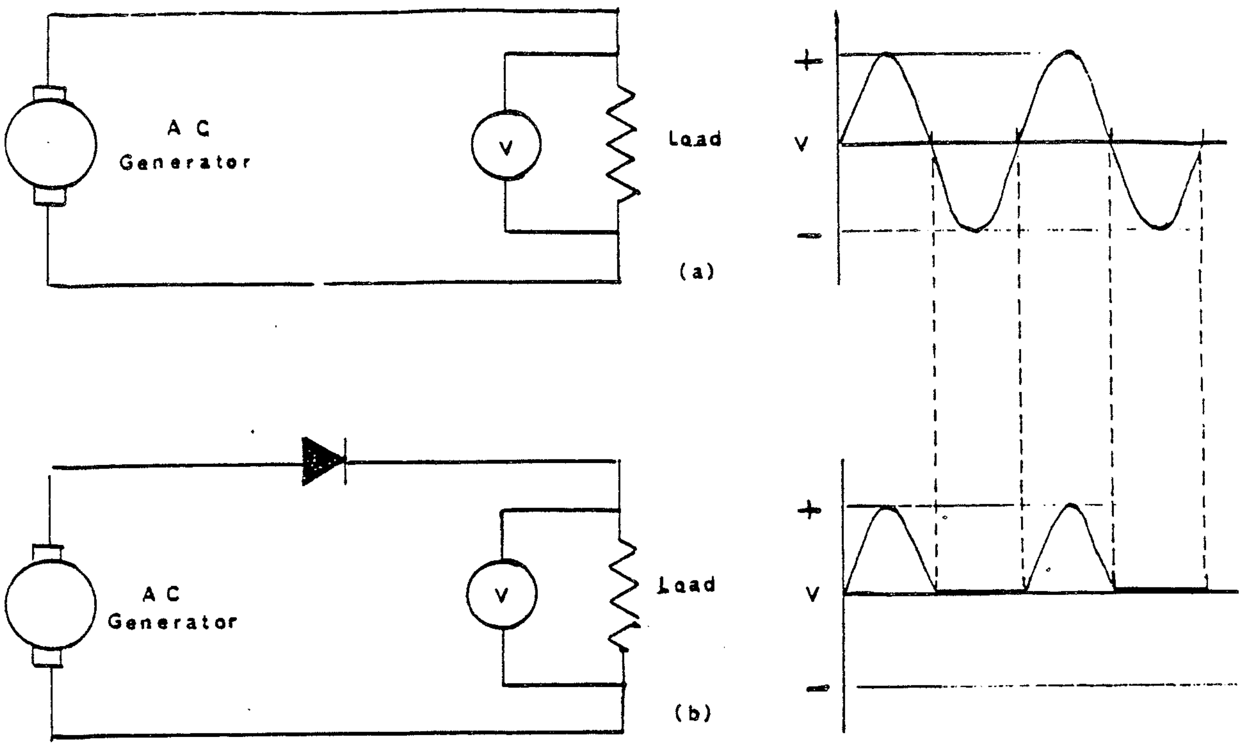
The purpose of two diodes in parallel is to prevent damage to the diodes under high current conditions, e.g. when the batteries are in a lower state of charge.

Another everyday use of diodes is in the rectification of A.C. power to D.C.

Half Wave Rectification.

As already been explained, an A.C. voltage wave is continually cycling from positive to negative to positive etc. and can be graphically shown as in figure 3 (a).

Continued......



HALF-WAVE RECTIFIER

FIG.3

If a diode is connected into the system, figure 3 (b) it will only pass current when the anode is positive in respect to the cathode hence the waveform generated is a pulsating D.C. voltage similar to that generated by generator fitted with a commutator as shown on page 19. This is known as a half wave rectifier.

It can be seen that each negative pulse is missing and therefore the power output is much less that the original A.C. waveform.

STUDENTS NOTES

FULL WAVE RECTIFICATION

Instead of chopping the negative cycle out. the efficiency of the output can be improved by "rectifying" the negative wave into a positive wave. i.e.

Full Wave Rectification.

There are several ways in which diodes can be connected to obtain full wave r rectification but the most common method is as shown in the following illustration.

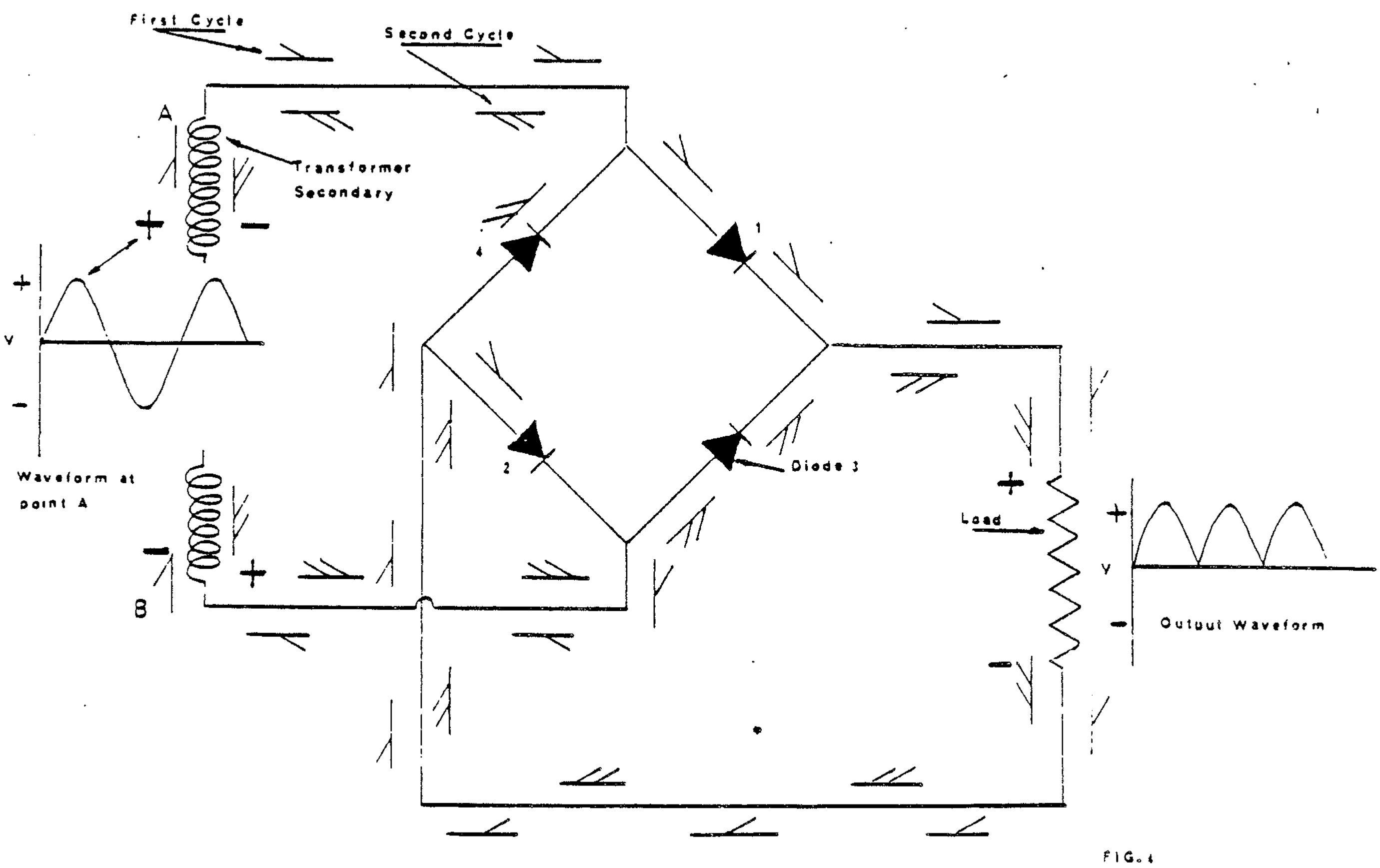
It can be observed that during the first cycle when the voltage at terminal A of the coil goes positive the anode of No1.diode will be positive and it will therefore pass current to the load then back to terminal B of the coil via diode 2. Note terminal B of the coil will now be negative.

During the second cycle terminal B of the coil will be positive hence the anode of diode No.3 will be positive with respect to the cathode hence it will pass current to the load in the same direction as before. After passing through the load the current will then pass through diode No.4. to terminal A of the coil.

It can be observed that during both cycles the direction of the current through the load is the same.

The practical use of the bridge rectifier is shown on page.

It is suggested that the trainee lines in between the single and double arrows with two different coloured pencils.



BRIDGE RECTIFIER (FULL WAVE RECTIFICATION)

STUDENTS NOTES