ENGINEDRIVERS CORRESPONDENCE COURSE

LESSON NO. 8

This lesson will give you an understanding of electricity and some of the equipment on a diesel electric locomotive.

FUNDAMENTAL PRINCIPLES OF ELECTRICITY

The movement of electricity through a conductor is known as an electric current and this flow of electricity may be likened to the flow of water in a pipe. In order that water may flow in a pipe there must be an open passage and also a pressure to cause the water to flow.

Although the manifestations of electricity are different from those of water, in many respects it is helpful to compare electrical phenomena with the actions which take place in hydraulic systems.

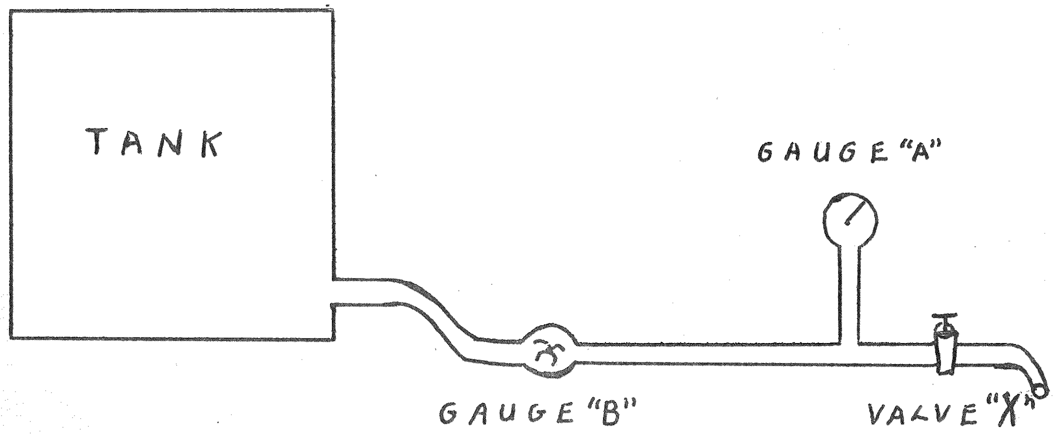


Fig. 1

Consider Figure 1 which shows an elevated tank to which is attached a pipe running to a lower level. A valve in the lower end of the pipe is represented by an "X" and "A" represents the gauge that indicates pressure. "B" is another gauge which indicates the movement of water through the pipe. This gauge could be some kind of vane mechanism which would turn when water moved through it. When the valve is closed there can be no movement of water through the pipe and the gauge at "B" will give no indication. Pressure will be indicated at "A" however, due to difference in level between the tank and the lower end of the pipe. There is, therefore, no flow of water in the pipe although there is a pressure tending to cause the water to flow.

If the valve is now opened, providing a free passage, there will be a movement of water through the pipe and the gauge at "B" will give an indication of this movement.

... ...

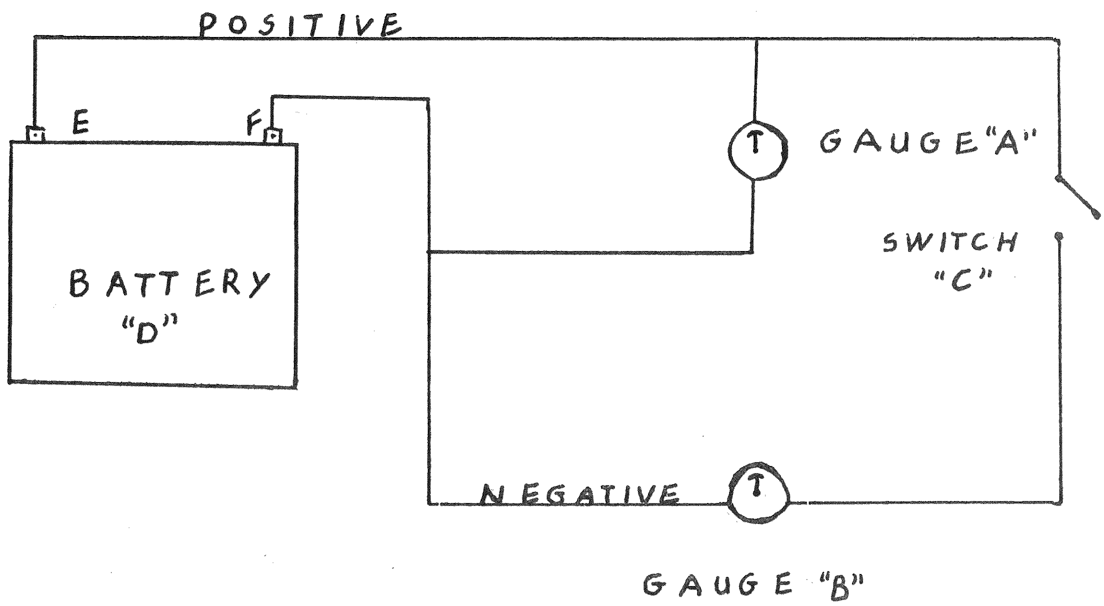


Fig. 2

In an electric system we have similar conditions. First the pressure, then the free passage and finally the movement of electricity called a current. In the electric system shown in Fig. 2 the battery "D" produces an electric pressure or tendency to cause current to flow. No current can flow however, until the switch "C" is closed, thus completing a circuit from a high to a low electric level. It is essential that there be a circuit between the terminals of the source of electricity before a current can flow. "E" is known as the positive terminal and "F" as the negative terminal.

In Fig. 2 a gauge for measuring electric pressure is shown at "A". This gauge will indicate pressure when the switch "C" is open and no current is flowing, just as the pressure gauge in the hydraulic system indicated pressure when the valve was closed and no water was flowing. At "B" is a gauge which measures the amount of current flowing in the circuit. This will give no indication until the switch is closed, (there is actually a small amount of current flowing through the meter at "A") but after the circuit is completed by the closing of the switch, the current meter will give an indication showing that current is flowing in the circuit.

In the hydraulic system, we would measure the rate of flow of water in gallons per second and the pressure tending to cause it to flow in pounds per square inch. There are also units used in measuring electric currents and pressures; these are the ampere for current and the volt for pressure. An electric current is measured in amperes and not in volts and it is just as incorrect to say that "a current of 600 volts flowed in a wire" as it would be to say "the water flowed in a pipe at the rate of 200 lbs per square inch".

The electrical pressure between two points is called **voltage** and is measured by a **voltmeter**.

Electrical current in a circuit is measured by an **ammeter**.

... ...

RESISTANCE

Returning to the hydraulic system, consisting of the elevated tank and the pipe leading from it, suppose we use a small pipe with a very rough interior and full of obstructions. The water would flow much more slowly through this pipe than it would through a large pipe having a smooth interior. Again suppose we use a long pipe instead of a short one. The water pressure would then have to overcome more friction along the walls of the pipe and consequently the water would flow less rapidly than in the short pipe.

In the same way conductors which are materials that allow the passage of an electrical current, offer varying degrees of opposition to the flow of electric currents.

This opposition which is known as resistance depends on the size and length of the conductor and on the material of which it is made.

The unit by which this resistance is measured is called the Ohm. If a conductor 5 feet long has a resistance of one Ohm, another conductor of the same thickness and same material, but 10 feet long would have a resistance of 2 Ohms.

Different materials have widely varying resistances. Copper has a very low resistance and for this reason it is widely used as an electrical conductor.

Some materials will not allow the passage of an electric current and are known as Insulators such as glass, porcelain or mica.

ELECTRICAL UNITS

The three fundamental units of electricity are :-

The Ampere (current, Symbol I)
The Volt (electrical pressure, or electromotive force (E.M.F.) Symbol E)
The Ohm (resistance, Symbol R)

These units are related to one another by Ohm's Law in such a way that

$$A \quad I = \frac{E}{R} \quad \frac{V}{O}$$

That is the current in a circuit (expressed in amps) is equal to the pressure (in volts) divided by the resistance in Ohms.

MAGNETISM

It is well known that iron can be made to attract other pieces of iron and when it does so, it is said to be magnetised.

A bar of iron which will attract pieces of iron is called a magnet and the property of attraction is called magnetism. There are two types of magnets, one is called a permanent magnet and can be made by taking a piece of hard steel and placing it in the centre of a coil of wire through which an electric current is flowing. After the current has been switched off the hard steel will retain magnetism. The other type of magnet is called an electro magnet and is basically a coil of wire with a soft iron core (Fig. 3) and when current is switched on, the core is powerfully magnetised, but when the current is switched off, the magnetism is quickly lost.

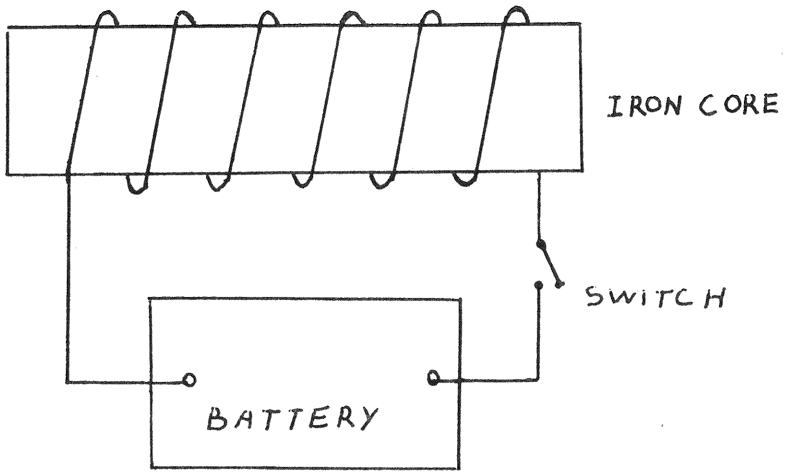


Fig. 3

BATTERY

This is often referred to as a storage place for electricity just as you would refer to a water tank as a storage place for water.

It consists of lead and lead peroxide plates placed in a diluted acid solution inside a suitable casing. The chemical reaction between the plates results in an electric pressure or voltage being created at the terminals which are named the positive marked with a + and the negative terminals marked with -. If we connect a suitable wire to each terminal as shown in Fig. 2 and thus form a circuit in which we place a resistance we will find that a current will flow from one terminal through the resistance to the other terminal. The resistance placed in the circuit can be referred to as the load and this load will generate heat. If we open the switch in the circuit the current will cease to flow. This condition is called an open circuit.

VOLTAGE AND CURRENT

We should have now learnt that voltage is an electrical pressure which will cause a current to flow but we have not learnt what an electric current is and how the voltage causes it to flow. To explain this we must understand what a conductor consists of and as we use copper wire as the conductor to form an electrical circuit we will endeavour to learn what the wire consists of and what current is.

If we had a very powerful microscope and directed its lens on a piece of copper wire, we would discover that it was comprised of millions of atom centres. These atom centres are not able to be moved. Around each atom centre we would observe electrons. These electrons are moving particles that circle the atom centres in a similar manner to the planets of the universe which encircle the sun. The only difference is that they have not a fixed orbit in which to travel. They move about from one atom centre to another in an aimless manner. When a copper wire is connected to the discharge side of a battery and to the device it intends to operate and then connected to the other terminal of the

... ...

battery, the battery voltage will force these electrons to flow around this wired circuit in one direction which is a direct current flow of electricity. A perusal of Fig. 4 will show what represents a piece of copper wire as seen through a microscope.

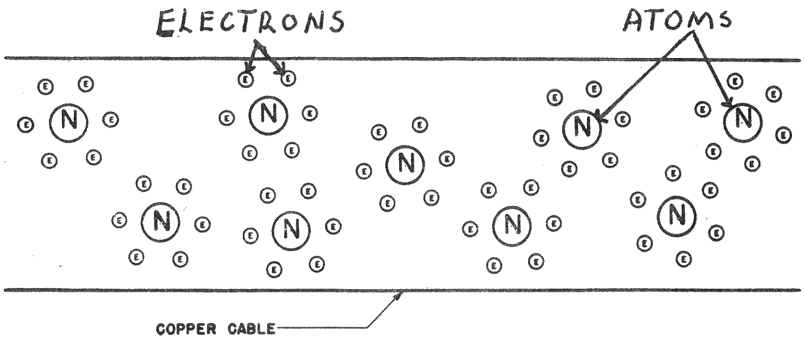


Fig. 4

We should have now learnt that :-

Amperage or Amps equal the flow of an electric current through a circuit.

Voltage or Volts equal the pressure of electricity in an electric circuit.

RESISTANCE

We have seen that in the water system it depends on the length of the pipe and the condition of the bore of the pipe on how much resistance is set up against the flow of the water. In other words if we use a pipe that has a rusty interior which has caused corrosion the corrosion will not only decrease the bore of the pipe but the water when passing through the pipe will hit against this corrosion and will be forced back against the normal direction of the flow, thus causing a resistance to the flow. If we desired to increase this flow of water we would do it in three ways.

(1) Substitute the rusty pipe for a non-corrosive one.

(2) Increase the pressure of the water by increasing the level of the water in the tank.

(3) Do both together. Use a non-corrosive pipe and increase the level of the water in the tank.

As we have stated we also have resistance in an electrical circuit and this is caused through the following :-

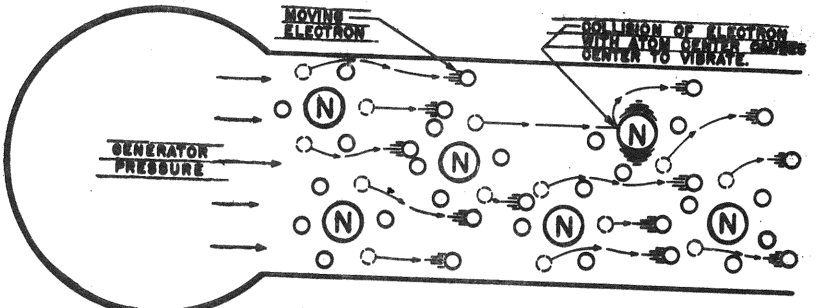


Fig. 5

... ...

Study Fig. 5. It represents a piece of copper cable which is coupled to a battery, the pressure voltage of which is forcing electrons to flow through the cable; in doing so they collide with the atom centres.

The collision of the electrons with the atom centres of a current-carrying cable produces the resistance in an electrical circuit. The collisions of the electrons and the atom centres causes the atom centres to vibrate. When the atom centre vibrates it creates heat. When the collisions are numerous, the heat becomes excessive, and in the case of copper wire would cause it to melt because copper has a low melting point.

It is sometimes necessary to have excessive heat in a circuit; as an example, we require heat for cooking and for our electric toaster and radiator. If we used copper wire in the element of these devices it would melt, if small in gauge, due to the excessive heat produced by the collisions between the electrons and atom centres. If it was of a large gauge, it would not produce any heat whatever because of the fact that copper has not so many atom centres as other materials and there would be insufficient collisions between the electrons and the atom centres; this is the reason copper is a good conductor of electricity.

Our electric cooking and heating devices are wired with nichrome wire. The collisions between the electrons and atom centres are numerous and the wire becomes red hot. Nichrome is durable enough to withstand the heat. Our electric light bulbs are wired with tungsten, a very tough metal that can withstand the high temperature of white heat. If we used nichrome wire in a light bulb it would melt as the copper wire would do in a cooking utensil.

Thus we learn :-

(a) That copper wire will allow a current to flow more freely as there are less atom centres.

(b) That the correct wire or material must be used for the circuit concerned otherwise damage can occur through excessive heat.

(c) That resistance in an electrical circuit has the same effect on amperage (flow) as the rust and corrosion had on the flow of water in a pipe.

(d) That resistance reduces amperage.

(e) That to increase amperage we must either increase the voltage or use a better conductor.

GENERATORS DIRECT CURRENT

It has already been explained that a battery can produce voltage but with the continual use of a battery such as placing a load on it and keeping it on continuously, the battery would become discharged and the voltage would drop to such a level that it would not be able to perform the work that is required of it. A generator can be used to recharge the battery. There are many types and sizes of generators in use but they all work on the same principle. What must be understood is that a generator must be

... ...

mechanically driven such as by belts or as in the case of the large generators on the diesel electric locomotives they are driven direct from the diesel engine crankshaft by means of drive shafts.

A generator will produce voltage or electrical pressure when its armature is rotated in a magnetic field. To understand the generator we must first return for a while to magnets. As has been explained there are two types of magnets, permanent magnets and temporary magnets. The temporary magnet is referred to as an Electro-magnet and must have a current passing through the coil of wire surrounding the iron core before it will become magnetised. If the current is cut off the core will quickly lose its magnetism. Figures 6 and 7 illustrate an iron bar which is being magnetised by a flow of current from a small generator.

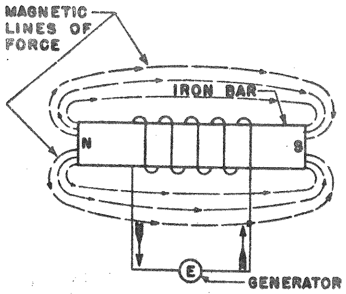


Fig. 6

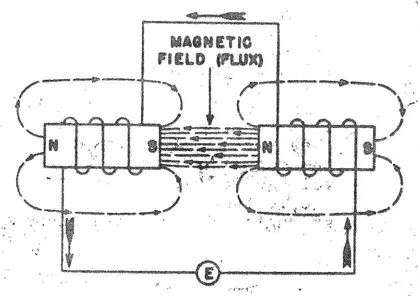


Fig. 7

You will note that the magnets have a north and south pole marked N and S. There are invisible lines of force leaving the north pole and are being attracted by the south pole. A basic rule of magnetism states: Unlike poles attract one another, like poles repel one another. We use the right hand rule to determine the position of the poles of a magnet. Assume that the fingers of the right hand are wrapped round the magnet as though they were representing the coil of wire. If the fingers point to the direction of current flow, the thumb points to the north pole.

Fig. 7 illustrates how these magnetic lines flow from the North pole of one magnet to the South pole of another magnet. Test the wiring with the Right hand rule and observe the flow of current in its right direction to cause the two opposite poles to face one another. The magnetic lines flowing between these two poles is called the Magnetic Field or Flux. It is in a field such as this that we rotate the generator armature of a diesel electric locomotive. The armature is coupled to the diesel engine crankshaft.

The armature is a cylindrically shaped device with slots cut lengthwise in its surface. Copper bars (conductors) are located in these slots and are secured by wooden wedges and bonding wire. These conductors are attached to Risers and to commutator bars. From the commutator bars the generator voltage is collected by carbon brushes and sent out to traction motors on a diesel electric locomotive. A perusal of Fig. 8 will show a simple generator. On a diesel electric locomotive this is referred to as the main generator.

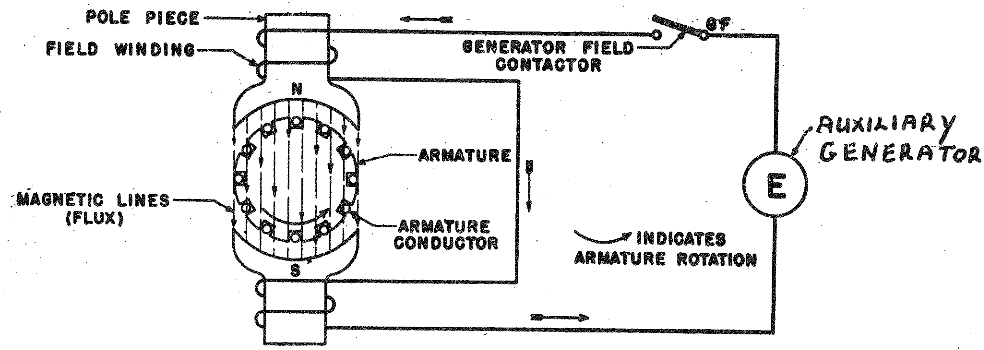


Fig. 8

The two pole pieces have an electric current being passed round them, by the way of field wiring from a small generator called an Auxiliary Generator. The pole pieces become magnets, the field current or flux flows from the north pole of the top magnet to the south pole of the bottom magnet. The armature of the generator is being rotated in this magnetic field by a diesel engine. The conductors of the armature are picking up electric voltage (pressure). The faster we rotate the armature, the more lines of force are cut by the conductors in a given length of time and the greater is the voltage produced. The more current that is sent from the auxiliary generator to the pole pieces the stronger they become magnetised; the stronger the magnets, the stronger the magnetic lines of force. When a current is allowed to flow through the fields of a generator it is known as exciting the fields.

We should have now learnt that to produce voltage we must rotate the generator armature and excite the fields. To change the voltage we change the speed of the armature or change the strength of the field current, or do both at the same time.

A perusal of Fig. 9 will show how the generator voltage is picked up from the commutator bars by the carbon brushes and delivered by cable and contactor to a traction motor. This flow of current flows from the positive side of the generator to the traction motor and after rotating the armatures of the traction motor returns to the negative side of the generator by the way of the cable, carbon brushes, commutator bars risers and conductors to be built up in pressure ready for delivery from the positive side of the generator.

... ...

We should now see that to cause current to flow we must :-

(1) Rotate the armature.

(2) Excite the fields.

(3) Give the current a complete circuit to flow through.

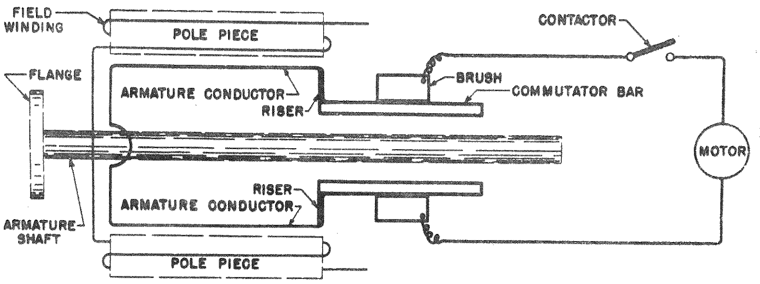


Fig. 9

DIRECT CURRENT TRACTION MOTORS

The main generator on a diesel electric locomotive is used to supply current to the traction motors and the traction motors turn this electrical energy into a mechanical force to rotate the driving wheels.

The traction motors are similar in construction to the generator. They have armatures and field windings. The armatures and field windings are smaller than that of the generator. However the actions of the two machines are different. We used the diesel engine to rotate the armature of the generator, but the armature of the traction motor is rotated by the passage of current through its armature and its pole pieces. As the current passes through the armature conductors, it sets up circular magnetic lines of force around the conductors. If you peruse Fig. 10 you will see these circular lines. The thick arrow indicates the direction of current flow through the conductors. After the current flows through the conductors it flows through the field windings (around the pole pieces). This magnetises the pole pieces just as the current from the auxiliary generator magnetised the pole pieces of the main generator.

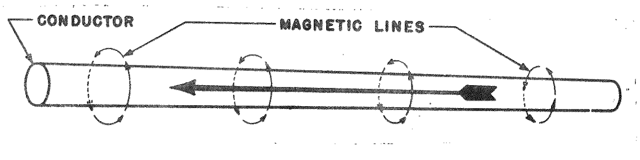


Fig. 10

... ...

From the north pole of one pole piece will flow magnetic lines of force to the south pole of the opposite pole piece. Thus we have two separate magnetic fields of equal power, one surrounding the conductors of the armature and one of straight lines of force between the pole pieces. Fig. 11 illustrates the end-on view of a traction motor. You will observe the pole pieces and the armature conductors. You will also observe the circular lines of force surrounding the armature conductors. The lines of magnetic force which run between the two pole pieces are bent round the armature conductor, due to the

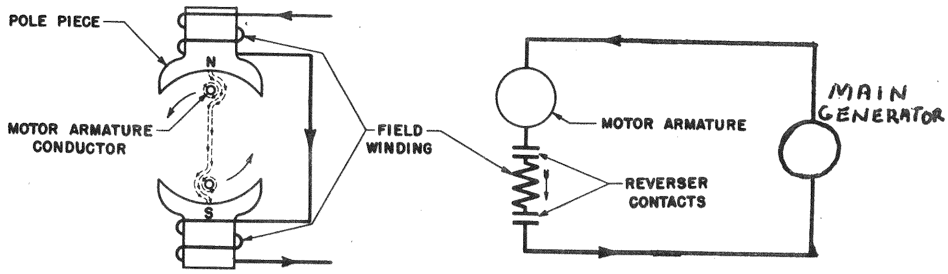


Fig. 11

pushing effect of the armature conductor's magnetic field which runs around the armature's top conductor in a clockwise direction and around the bottom conductor in a counter clockwise direction.

This pushing effect bends the straight lines of force between the pole pieces and stretches them like rubber bands. The conductors which are attached to the armature are then rotated.

The rule of motor rotation is: When a current-carrying conductor is in a magnetic field, it tends to move out of that field. Thus we see that it is the opposing or pushing action of these two fields of force that causes the armature to rotate.

You will note that the fields of force are set up from the same current. This current first passes through the armature conductors to create the circular lines of force and is then passed round the pole pieces to create the field windings to produce the straight lines of force.

Motors wound in this manner are called series motors because the armature winding is in series with the field winding. Series means current flowing through one or more devices which are connected together in such a manner that it flows first through one and then through the other.

Series motors are used on diesel electric locomotives because they are noted for their powerful starting torque or twisting effect. The powerful pushing effect between the armature conductor magnetic field and the field between the pole pieces enables the locomotive to lift heavy tonnages on steep grades.

... ...

TRACTION MOTOR BLOWERS

The traction motor blowers are for the purpose of providing ventilating air for the traction motors. The flow of an electric current through the traction motor results in increased temperature of the traction motor wiring, the ventilating air provided by the traction motor blowers reduces dust and other foreign matter entering the traction motors during the time the locomotive is in motion as well as keeping the motors at their correct operating temperature.

TRANSITION

This is the term used for the changing of the traction motor connections and takes place automatically depending on the speed of the locomotive. It is necessary to change and connect the electrical circuits at different speeds to enable the back voltage of traction motors to be controlled. Back voltage is the product of the traction motors after their armatures commence their rotation. There is very little difference in design of a traction motor and a generator. They both have pole pieces and their armatures rotate in the magnetic fields between them. As we produce voltage by rotating an armature in a magnetic field, it is only natural that the traction motor armatures will produce voltage when the ground speed of the locomotive has reached a speed necessitating the fast rotation of the traction motor armature. This product is of no use to the traction motors; in fact they try to force voltage along the cable that leads to the main generator, against the flow of current from the generator to the traction motors. This results in a falling off in power to the traction motors which will only obtain a certain speed and will not rotate any faster. To overcome this the back pressure must be reduced or the voltage to traction motors increased thus transition can be used.

Figs. 12, 13, 14 show what <u>Series</u>, <u>Series Parallel</u> and <u>Parallel Transitions</u> mean.

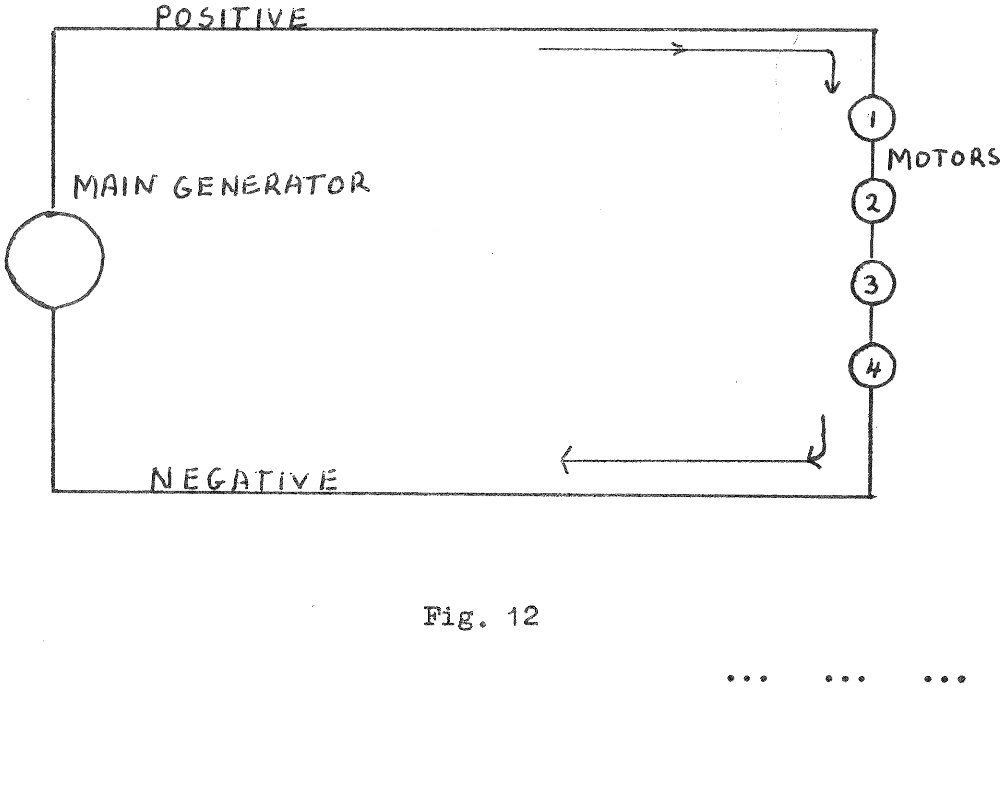


Fig. 12

... ...

Fig. 12 illustrates a Series circuit. You will observe that the current flowing from the generator to the four motors flows first through one and then through each other one in turn.

The voltage is divided equally between the four motors.

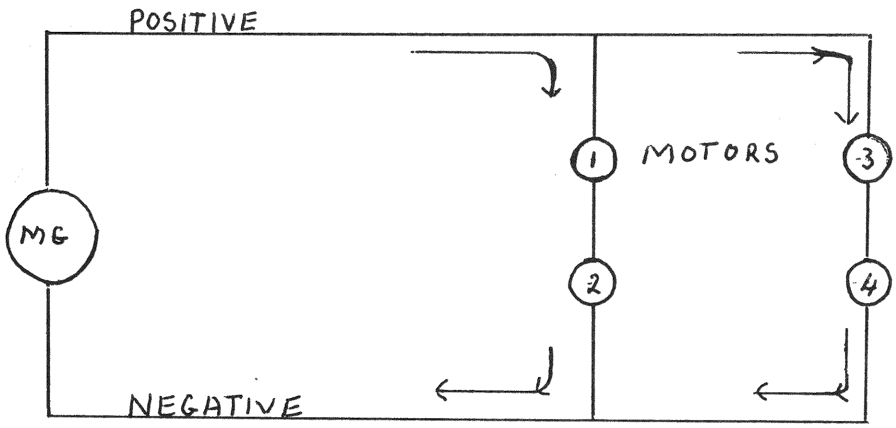


Fig. 13

Fig. 13 illustrates a Series Parallel circuit. You will note that there are two motors in Parallel and two motors in Series. In this type of circuit half the voltage and half the current reach each motor.

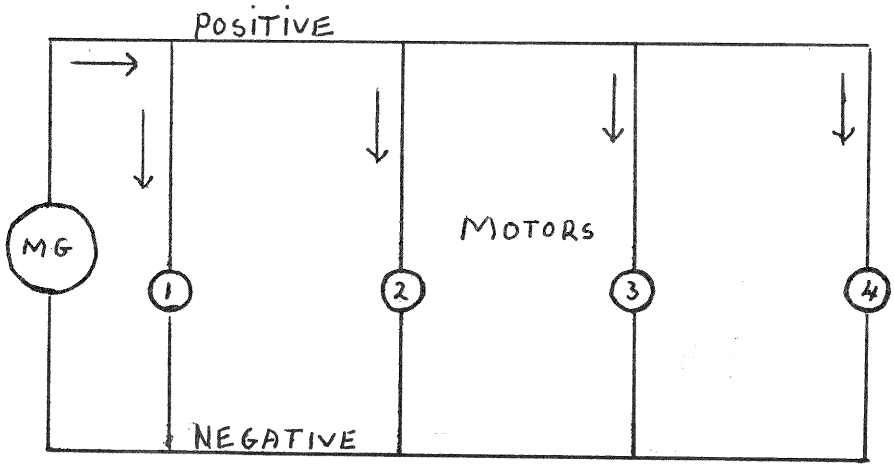


Fig. 14

Fig. 14 illustrates a parallel circuit. You will note that the motors are not on the one line. Each motor receives full voltage of the generator and the flow of current is equally divided between them.

... ...

CONTACTORS

Everyone knows that to stop a flow of water in a pipe or hose a tap has to be turned off. To restart the flow the tap is opened.

It is the same with an electric current. First we must have a complete circuit to allow a current to flow and to stop the flow of current we must break the circuit by some means. We refer to a circuit that is complete as a closed circuit and to a circuit that is not complete as an open circuit.

On diesel electric locomotives, high currents are carried by the traction motor power circuits. Traction power circuit means the circuit that carries the current from the main generator to the traction motors and back to the main generator. This circuit is known as a high voltage circuit as it carries a very high current. Main generators can produce up to 1000 volts and the current at times in the traction circuit can exceed 2000 amps. To open and close this type of circuit large switches called "contactors" are used.

These contactors are generally of two types :-

(a) Electric-pneumatic (E.P.) on which a small electro magnet is switched on and its energy operates an air valve which allows air from a control reservoir to push up a piston in a cylinder which closes the contactor contacts. The small electro-magnet is called a "magnet valve" which is only a remote controlled two position air cock controlled by electricity. When the current is cut off from the electro-magnet it allows the air valve to open a port which allows the air from the operating cylinder of the contactor to escape at the same time cutting off the supply of control air. A spring now opens the contactor's contacts with a snap action and opens the circuit.

(b) E.M. Electro magnetic on which a large electro-magnet is switched on and the powerful magnetism set up closes the contacts the closes the circuit. When power to the electro-magnet is cut off the magnetism is cut off and a spring causes the contact tips to open.

These contactors often break heavy currents and when opening form an arc or flame as it could be called. This arc if not controlled could cause the contact tips to be burnt and thus cause a failure by insulating the contactors tips and stopping the flow of an electric current. At times small pieces of molten metal will form beads on the tips and stop the contactor from closing properly. To decrease the arc magnetic blow out coils, arc chutes and arcing horns are used. When the contactor opens the arc which is drawn is forced outward and thereby transferred to the arcing horns. Finally the arc becomes so thin that it breaks. With the arc chute and blow out coils fitted a comparatively small opening of the contact tips is sufficient to break the arc and thus protect the tips from excessive heat.

... ...

The coil that is placed round a soft iron core to create an electro magnet is called the operating coil and when a current is allowed to flow through this coil it is known as energising the coil. Thus we have the terms : when the coil is energised the contactor's tips are closed. When the coil is de-energised the tips are open.

Figs. 15 and 16 show how these contactors would be shown in a schematic diagram. The operating coils on these contactors are energised by a low voltage current which is called a control circuit. H.V. High voltage. L.V. Low voltage.

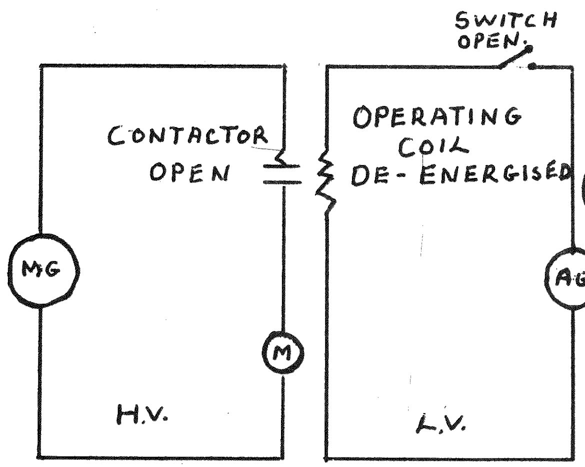


Fig. 15

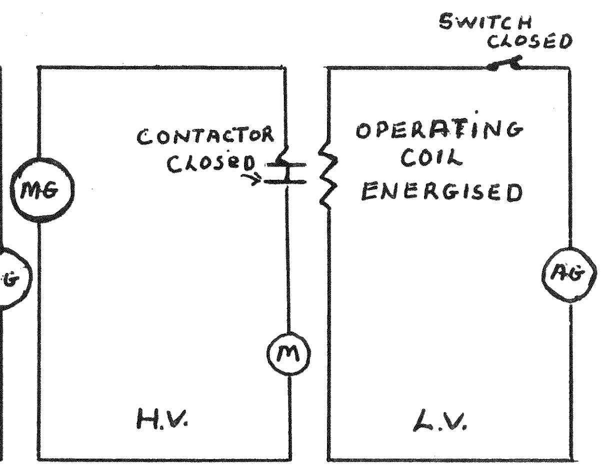


Fig. 16

RELAYS GENERAL PURPOSE

On diesel electric locomotives a low voltage electric system is provided. This system can either be supplied with power from the battery or from an auxiliary generator. To close and open circuits in this system a relay is often used. A relay is a device which when operated by the current in one circuit, automatically completes a second circuit and brings that into operation as shown in Fig. 17. In this case when the switch is closed it energises the coil of a relay which closes its contacts and energises the coil of a contactor which closes its contacts and allows a fuel pump motor to run.

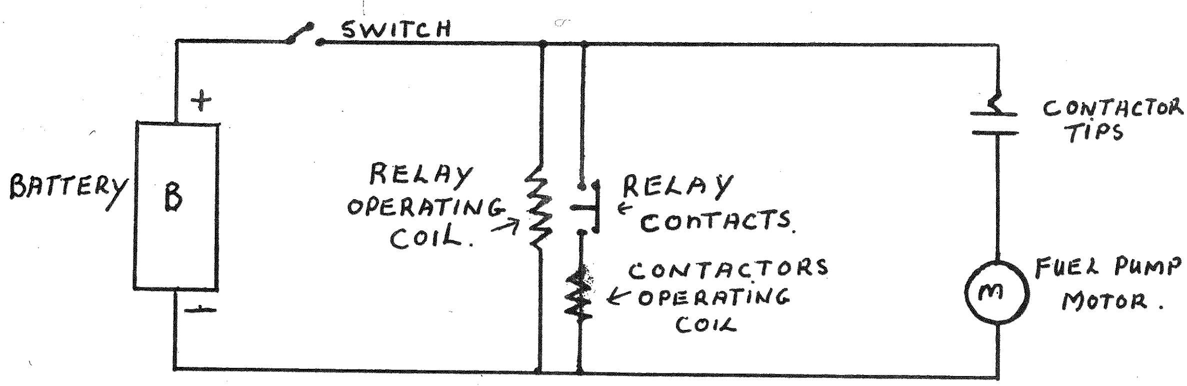


Fig. 17

... ...

A relay is an electro magnet which when energised causes magnetism to draw a small plate towards the iron core and thus closes contact tips and will allow the second circuit to be closed. When de-energised a spring or the weight of the plate opens the contact tips.

OVERLOAD AND EARTH RELAYS

These types of relays are called protective relays and although they work in the same manner as General Purpose relays they are operated by current in the traction motor circuit in the case of overload relays and by high voltage from the main generator in the case of earth relays. One relay can act as both an overload relay and an earth relay. In this case two coils are wound round the soft iron core, one is made of heavy gauge wire and operates with amperage and the other coil is made with fine wire and operates with voltage. The operating coil of an overload relay is placed in the traction motor circuit but the coil operates low voltage contacts in a control circuit as shown in Fig. 18.

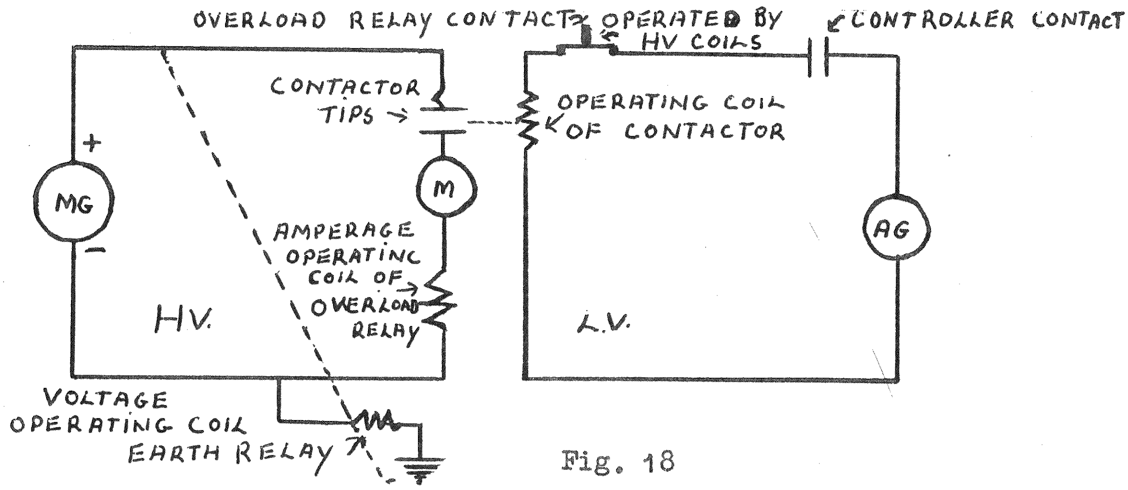


Fig. 18

This circuit shows that when the controller contacts are closed and the low voltage contacts of the overload relay are closed a current will flow and energise the coil of a contactor. The contactor closes and high voltage current will now flow to a motor and then through the operating coil of the overload relay back to the generator and the motor will run. The low voltage contacts of the overload relay are spring loaded so that when there is no current or a safe current flowing through its operating coil the contacts are closed but if the current should become excessive in the operating coil the magnetism will overcome the spring pressure and open the low voltage contacts which will de-energise the contactor's coil and cause the contactor to open disconnecting the generator from the motor. You will see by this that if the current becomes excessive and can cause damage, the motor and cables are protected against damage by the circuit being opened.

You will note that operating coil of the earth relay is placed off the negative side of the motor and its coil is attached to the frame of the locomotive. When the circuit is operating normally there is no current flowing through this coil, but if for any reason the current flow is allowed to go direct to the frame as

... ...

shown by the dotted line the current will flow through this coil and it will operate the overloads relays low voltage contacts and the power will be cut off the same as described before. When an overload relay operates the term generally used is "Overload Tripped".

CURRENT LIMIT RELAY

This relay is also a protective relay but is only in operation when the traction motor fields are shunted to decrease back voltage (pressure). It operates in the same manner as an overload relay except it does not suspend all power to the traction motors. The shunting of the traction motor fields will be fully explained later.

REVERSE CURRENT RELAY "RCR"

The R.C.R. is for the purpose of preventing a back flow of current. It works in conjunction with a battery charging contactor and controls the charging of the battery. As already has been stated if a battery is in continual use it will become discharged so after the engine has been started the auxiliary generator starts to rotate and when it reaches a certain speed it develops a voltage and a current will flow to the battery, when the battery charging circuit is completed by the action of the R.C.R. A simple battery charging circuit is shown in Fig. 19.

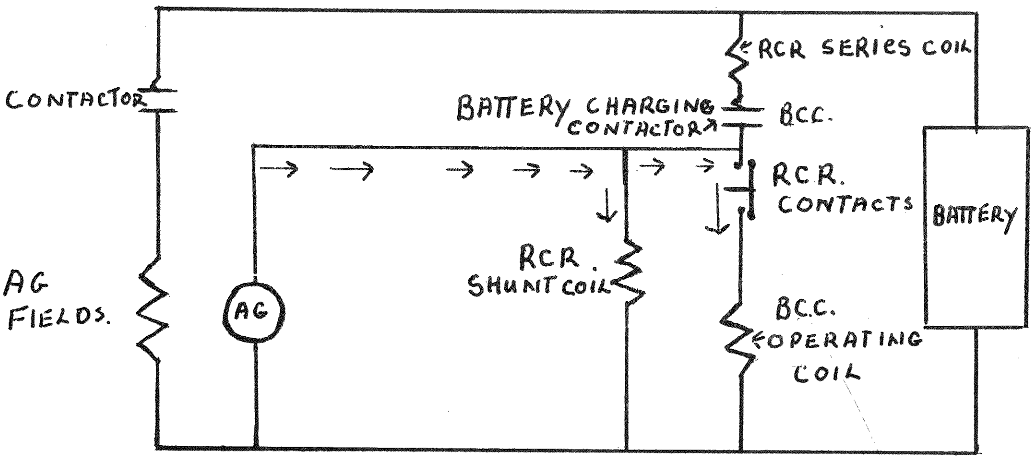


Fig. 19

When the engine is being started a current from the battery closes a contactor which excites the fields of the auxiliary generator and when the engine starts and the auxiliary generator runs up to speed the voltage from the generator operates the shunt coil of the R.C.R. This causes the R.C.R. contacts to close which in turn allows a flow of current to the operating coil of the battery charging contactor which closes and allows current to flow ~~from~~ to the battery, ~~to the fields of the auxiliary generator~~. It will be noticed that the R.C.R. has two coils when the battery is on charge; the magnetic pull of these two coils is the same and thus the R.C.R. contacts remain closed. If for any reason battery voltage reaches a higher voltage than the auxiliary generator a reversal of current would take place but when this occurs the current flow being reversed through the series coil of the R.C.R. alters the polarity of the coil

... ...

and causes a repelling action which opens the R.C.R. contacts which in turn de-energises the coil of the battery charging contactor causing the contactor to open and disconnect the battery from the generator. If a reversal of current was allowed to take place the battery current would attempt to drive the auxiliary generator as a motor and damage would take place.

REVERSERS

To allow a diesel electric locomotive to move in either direction a high current switch which is called a reverser is fitted. This switch can reverse the flow of current in the traction motor field coils to enable the traction motors to reverse the direction of rotation. Fig. 20 shows how this switch is set up in a circuit. The reverser itself is a cam operated switch consisting of two end frames carrying three support bars, to which contacts are secured. A shaft fitted with cams. Electro magnetic coils operating magnet valves on an air engine which is mounted on one of the frames.

The air engine is double acting with valve and piston at each end of the cylinder. The pistons are mounted on a common piston rod. The magnet valves are arranged so that only one magnet valve at a time is energised. When energised they allow compressed air to the operating cylinder. When de-energised they allow the compressed air to escape from the operating cylinder. Thus when a magnet valve is energised air enters the operating cylinder and forces the piston to the opposite end of the cylinder, and it depends on which magnet valve is energised as to which position the reverser moves either "Forward" or "Reverse".

The motion of the piston is transferred to a shaft by means of a fork ended cylinder lever. The shaft operates cams set at different angles. These cams operate rocker arms which close spring loaded contacts. The contacts carry the field current to the traction motors. It depends on which way the reverser is moved as to which contacts are closed. One set of contacts allows the locomotive to move forward and one set allows it to move in reverse. Whenever the cam pressure is taken off the rocker arms the spring loaded contacts will open by the action of the springs. A manual lever is provided to place the reverser in the centre position if required. When placed in this position all contacts are open and no circuit can be made to the traction motors.

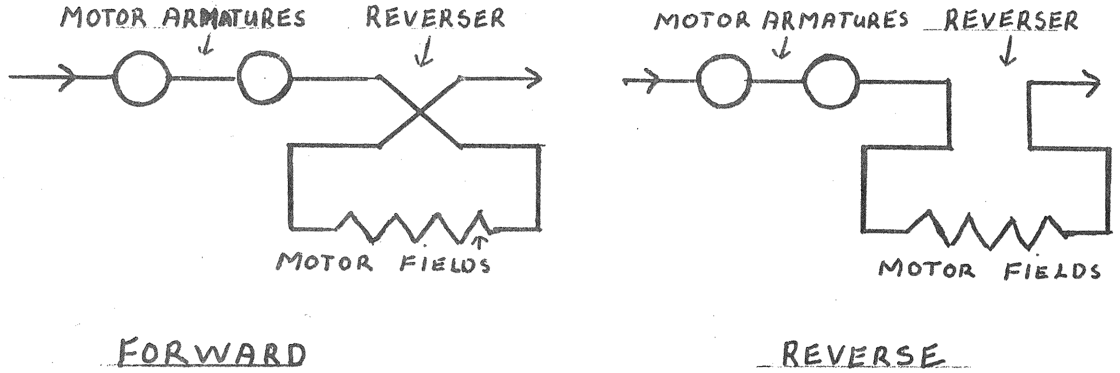


Fig. 20

...   .

MASTER CONTROLLER

The controller is used to control the supply of current to the traction motors and other equipment which is required to operate in a fixed sequence.

The controller contains cams of insulating material arranged in groups each of which is operated by a handle, the handles being mechanically interlocked to prevent incorrect use. The cams control the opening and closing of contacts which control the supply of low voltage current to the operating coils of solenoids, relays and contactors in the control circuits of a diesel electric locomotive.

FUSES

These are protective devices placed in electrical circuits to prevent excessive current from flowing under fault conditions. For instance, if a wire is called upon to carry more current than that for which it is designed, it will overheat and cause damage to other wiring and may create a fire. This is called overloading of a wire.

To prevent this occurring a fuse is placed in the circuit and this forms a weak link.

The rating of the fuse is such that it will only allow a safe current to be carried by the wiring. If the load is exceeded it will cause the fuse wire to melt and open the circuit, thus stopping the flow of current. If a fuse blows each time a new one is inserted, this can be taken as a danger signal that a fault has occurred in the circuit and the fuse is doing its job in protecting the wiring. It should be remembered that the rating of a fuse is marked on it and the correct fuse for each circuit must be used. On no account must a larger rated fuse be inserted. Some fuse wires are replaceable in the fuse holder, while with others the complete fuse must be replaced. "Dud" fuses must not be replaced in the fuse rack but a booking must be made in the repair book and the fuse left out for rewiring.

CIRCUIT BREAKERS

These are protective devices for the same reason as given above. A circuit breaker looks like a switch but has a tripping mechanism added to it. These are also designed to carry a certain current but above this current they will open the circuit automatically. These circuit breakers are thermal circuit breakers and when they trip the handle should move to approximately half way between "OFF" and "ON". To reset move the handle fully to "OFF" and then back to "ON" position. In some cases it may be necessary to wait a few minutes before the breaker can be reset; this is to allow the breaker to cool off. If a circuit breaker trips out each time it is reset, it is a sign that a fault has occurred in the circuit. Other types of circuit breakers fitted are called magnetic circuit breakers.

... ...

PURPOSE OF THE BATTERY

The battery on a diesel electric locomotive is provided to enable the engine to be started, to provide power for lighting, to the fuel transfer pump, control circuits, and excitation of main generator fields to enable the generator to give an output when the auxiliary generator is not operating. It also excites the fields of the auxiliary generator when engine is started. Power from the battery is used to enable the main generator to act as a starter motor to rotate the engine up to the speed at which it will fire and run. All circuits provided from the battery except in some cases lighting, can be isolated by a battery isolating switch.

This switch must be opened when the locomotive is left standing unattended with engine stopped.

When locomotive is put away, and when any electrical equipment not protected by other means is to be interfered with.

If this switch is not opened when the locomotive with engine stopped is left standing for long periods, it could result in a flat battery as some circuits would remain energised.

PURPOSE OF AUXILIARY GENERATOR

When the engine is running the auxiliary generator will give an output which provides low voltage power to charge the battery, to provide current for the control circuits, lighting, to run the auxiliary machines, and to excite the fields of the main generator. It also supplies current to excite its own fields.

PURPOSE OF MAIN GENERATOR AND TRACTION MOTORS

The main generator supplies high voltage current to the traction motors which turns the electrical energy into a mechanical force to turn the road wheels. The armature shaft of the traction motor is fitted with a pinion which engages a gear mounted on the axle, the pinion and gear both being enclosed by a case for retaining a lubricant and keeping out dirt.

The speed of rotation of the armature exceeds that of the wheel by the ratio of gear teeth to pinion teeth. That is, if there should be 16 teeth on the pinion and 63 teeth on the gear the motor armature would turn through $\frac{63}{16} = 3.94$ times as many revolutions per minute as the wheel. It must be remembered that the maximum speed of the locomotive must not be exceeded as damage can result to the traction motors by centrifugal force acting on the armature conductors.

SHORT CIRCUIT OR GROUND FAULTS

Electricity will follow the path of the least resistance. To prevent electricity from taking short cuts we use insulation which must always be kept in good order. This insulation confines the electricity to its proper path, that is, through its normal conductor. Motors and generators depend upon the flow of current through their

... ...

fields and armature coils where the work is done. Insulation keeps this current in the circuits leading to these coils. It also separates the turns of coils so that current must go round each turn. When the insulation fails, the current short cuts across the turns and it does not do its job, and we have what we call a short circuit. If the insulation fails in such a way that it lets current escape to the machine parts which are not in the regular electric circuit, we have what is called a ground fault. This means that current flows to parts connected with the earth or ground.

Careless handling of tools, bending of electrical wires, loose wires on terminals, dirty connections, dirt or dust allowed to enter where electrical equipment is housed, water or dampness allowed to come into contact with electrical equipment, carbon dust allowed to collect on electrical machines, and unauthorised interference with electrical equipment can cause short circuits or ground faults or in some cases fire and electrical burns to persons who interfere with equipment while it is alive.

FLASHOVERS

A flashover can either be a short circuit or a ground fault in a traction motor or generator and can be caused by a number of reasons, one of which is poor driving habits and another excessive wheel slip causing traction motor overspeed. A flashover is when electricity takes a short cut from one brush holder to another, that is from a positive brush to a negative bypassing the armature coils. It can also occur when electricity passes from the brush to the ground via the motor or generator frame. The damage caused by a flashover is generally very severe.

VOLTAGE REGULATOR

The auxiliary generator charges the battery and must be controlled to give a constant output at all times. This is made possible by the fitting of a voltage regulator. The generator also supplies other equipment as has been stated before and depending on the load placed on it by the number of items it has to supply current to; its voltage could rise when the load was taken off and decrease when a load was placed on it. Also when engine speed was increased or decreased, voltage value would change. To prevent this the voltage regulator controls a resistance placed in the auxiliary generator fields which can control the field strength or excitation and thus control output. The resistance is controlled by an electro-magnet so that when the load on the generator is increased or decreased or engine speed is altered, the electro-magnet increases or decreases its magnetism which alters the resistance in the generator field circuit to increase or decrease excitation and thus keep the generator at a constant output.

RHEOSTAT

A rheostat is a variable resistance which can be placed in a circuit to either increase the current flow when needed or decrease it when required. The rheostat can be operated by several means. A <u>Load Regulator</u> consists of a motor operated rheostat which controls the excitation of the main generator's battery field.

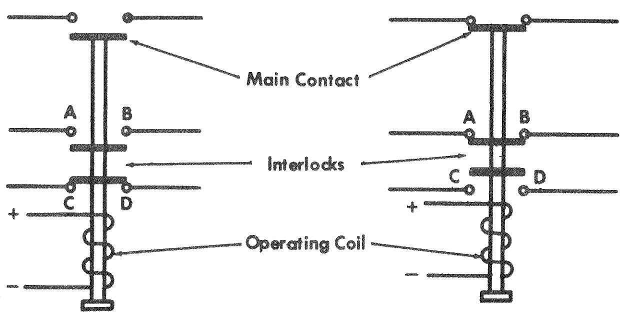
... ...

INTERLOCKS OR AUXILIARY CONTACTS

These are a mechanical devices operated in conjunction with another piece of equipment such as a contactor or reverser. They control circuits in the low voltage equipment and make the operation of one piece of apparatus dependant upon the opening or closing of a contactor or the positioning of a reverser. When closed they complete a circuit and when open they break a circuit. There are two types which are "NORMALLY CLOSED" or "NORMALLY OPEN" and they are often referred to as "IN" and "OUT" interlocks.

The normally "OPEN" or "IN" interlock is operated mechanically to close its contacts when the coil of the apparatus it is attached to is energised. Fig. 21.

The normally "CLOSED" or "OUT" interlock is closed when the coil of the apparatus it is attached to is de-energised. Fig. 22.



No Power To Coil

Main contact normally open
Interlock AB normally open
Interlock CD normally closed

Power Applied To Coil

Main contact now closed
Normally open AB interlock now closed
Normally closed CD interlock now open

Fig. 22 Fig. 21

FIELD WEAKENING OR FIELD DIVERSION

This is known as shunting the traction motor fields and the reason for it is to reduce back pressure "voltage" and allow the traction motor armatures to increase their speed and thus increase road speed. If a study of Figs. 23 and 24 is made it will be seen how this is done.

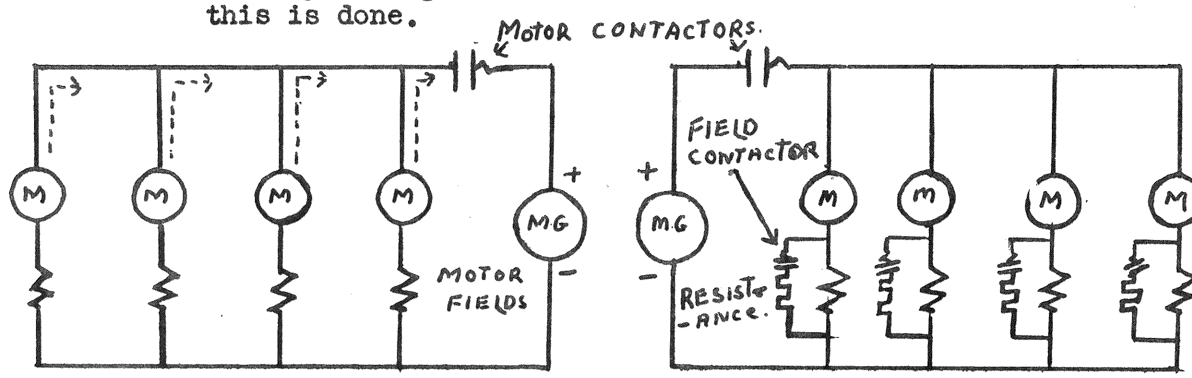


Fig. 23 Fig. 24

... ...

In Fig. 23 is shown a generator supplying four traction motors in parallel the current passing throug h two motor contactors and then being supplied to each traction motor off a different lead. When a certain speed is reached the traction motor back voltage shown by dotted lines stops the traction motor armatures from rotating any faster. When this stage is reached a transition relay "not shown" operates and closes the field contactors; this brings into force a resistance in parallel with each motor field, thus the current flow to the fields has to supply two sources. This of course weakens the motor fields and reduces the magnetic lines of force and this results in a loss of voltage production and decreases back pressure. The motor armature will now rotate more quickly and increase the speed of locomotive. This is only a high speed set-up and if the locomotive speed decreases through a grade, field diversion will be lost and the motors will revert to full field which is the set-up where the traction motors have their greatest torque or pulling power.

DYNAMIC BRAKE

This is a form of brake that operates only on the locomotive and is obtained by changing the traction motors into generators and by using up the generated power in resistances.

When the traction motors are acting as generators they retard the train, by tending to prevent the driving wheels from rotating. This is caused by the armatures of the traction motors having to rotate in a strong magnetic field.

The traction motors acting as generators, are given an electrical load to use up the power generated and this is done by connecting a resistance in the motor circuit. This resistance is called a braking resistance and it uses up the electricity generated by converting it into heat.

In doing so, the resistances get very hot. To prevent the resistance from burning out, resistance blowers are used to force cool air through the resistance grids to keep them at a safe temperature. This blower is driven by current supplied by the traction motors acting as generators.

The control of the dynamic brake is given to the driver so that he can increase and decrease the braking effort by increasing or decreasing the current in the traction motor field coils. A study of Figs. 25 and 26 will show the changes necessary in a power circuit to enable the brake circuit to be formed. In Fig. 25 it is shown that the battery is supplying current through a rheostat to excite the fields of the main generator and the output from the main generator is supplying the traction motors; this is a power circuit. Any movement of the rheostat can increase or decrease excitation of the main generator fields and thus increase or decrease output.

... ...

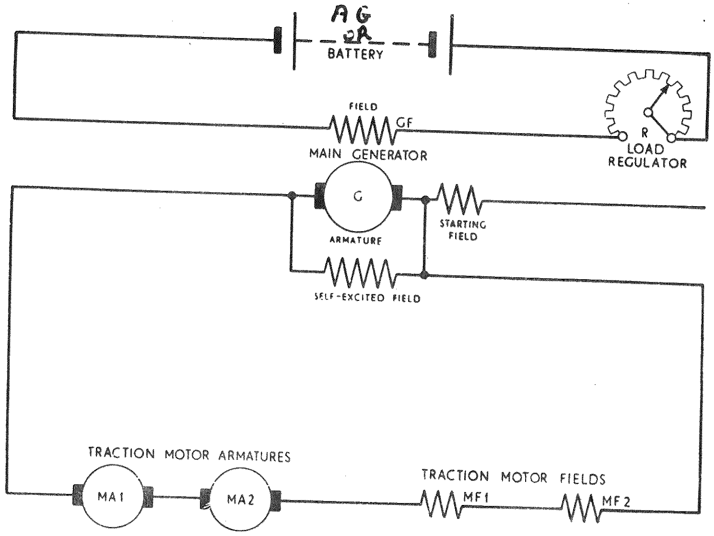


Fig. 25

Fig. 26 shows that the auxiliary generator is still exciting the main generator's fields but the main generator is being used now to excite the traction motor fields and any movement of the rheostat will not only affect main generator output but also the output of the traction motors working now as generators. By giving control of the rheostat to the driver he can control the braking effort of the locomotive. You will also note that the resistance grid blower is operated off traction motor current.

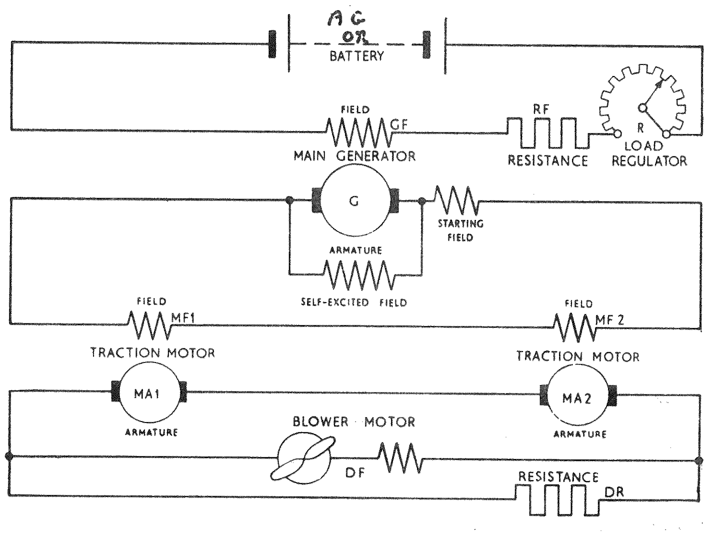


Fig. 26

MULTIPLE UNIT OPERATION

By the term "multiple unit operation" is meant that two or more units can be coupled together to operate as one, under the control of one driver. Thus, for instance two locomotives each having a driving cab at either end when coupled for multiple unit operation, are capable of being driven from any one of the four driving positions.

As the equipment in one locomotive, or the equipment in both locomotives can be operated from any one of the four driving positions it is obvious that some electrical connection has to exist between the controls. This wiring, which is arranged to be detachable between locomotives, is termed train line wires and these are carried between the locomotives by jumpers. These jumpers must be handled with care whenever they are inserted or taken out.

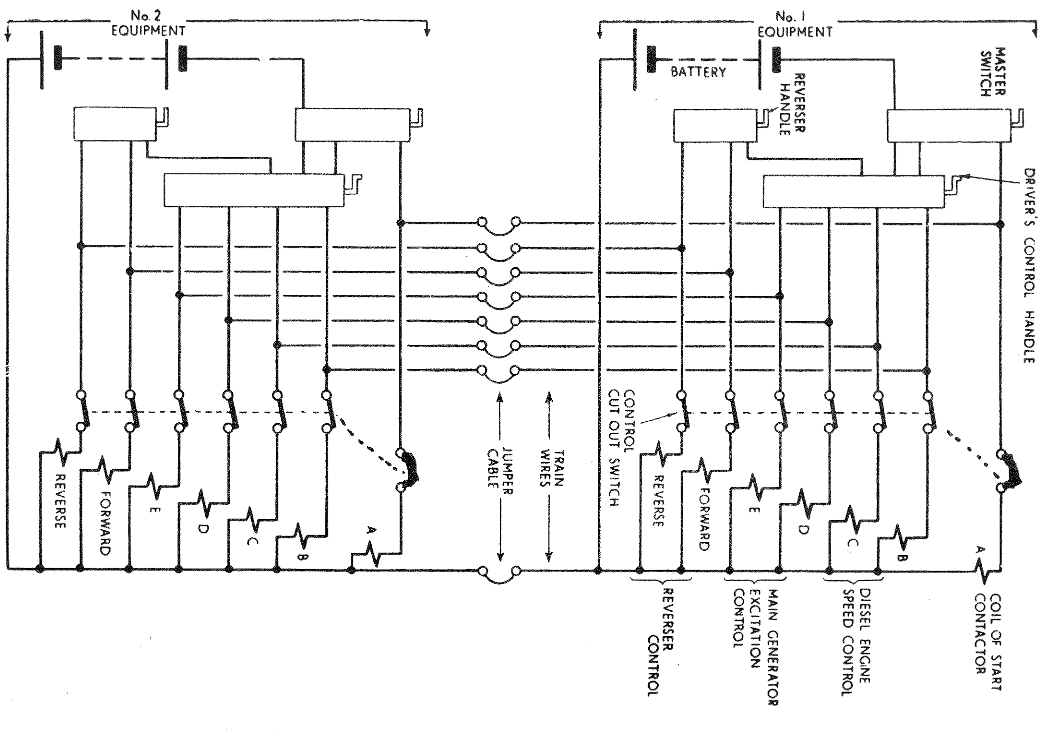


Fig. 27

By a study of Fig. 27 it will be seen when any wires are energised by one of the controllers a feed is sent to the operating coils on one locomotive and is also carried by train lines to the same operating coils on the other locomotive.

... ...

CONTROL CUT OUT SWITCH

This is a manually operated switch which when opened will isolate the control circuits of a locomotive. It is shown in Fig. 27 which shows that it isolates, engine start, engine speed, generator excitation and reverser control. When locomotives are coupled in multiple and the control cutout switch is opened on the locomotive that is controlling the operation of the equipment, the controller on this locomotive can still be used to operate the equipment on the other locomotive.

SOLENOID

This consists of a long uniform coil of wire placed round a hollow metal tube and acts in like manner to a bar magnet. An armature can be placed inside the hollow tube and when the coil is energised the armature which is only a thin round bar of metal will be caused to move up the metal tube and open ports to allow a fluid to flow. When the coil is de-energised the magnetic pull is lost and the armature will drop opening an outlet port and sealing off the inlet port. The term solenoid refers to the coil of wire. These are used on magnet valves, relays and EM contactors.

BASIC GENERATOR AND MOTOR PRINCIPLE

If we look at the diagram supplied with this lesson named as above we will see that we have a battery supplying a low voltage current through an 80 amp fuse, load regulator and to a contactor BF which can be remotely closed and opened by the master controller. When closed it allows a LV current to flow to the fields of a generator thus exciting the fields which become magnets. The polarity of these magnets or poles as they are called are so arranged that the north pole faces the south and thus lines of force or magnetic flux is set up between them in an air gap. The current after passing through the fields returns to the battery making a complete circuit. Placed between the poles is the armature which consists of a looped conductor; in fact, in an armature there are several of these loops. The ends of the conductor are attached to the commutator. The diesel engine turns the conductor in the magnetic field and thus cuts the lines of force which induces voltage which cause a HV current to flow out through the left hand brush on the commutator to the left hand brush on the commutator of the traction motor through the armature conductor and out through the right hand brush; this sets up a magnetic field around the armature - the current then passes through the fields or poles of the motor, thus forming another magnetic field. By the attraction and repulsion of the armature and pole magnetic fields the motor armature is forced to turn, which has a pinion attached to its shaft and which is engaged with another gear wheel pressed on to the axles and thus when the armature turns, the wheels turn. After the HV current passes through the traction motor fields it returns to the right hand brush placed on the generator's commutator and this completes the circuit. You will notice now that there are two circuits, one HV and one LV. To stop the generator from producing voltage the controller can be moved to off which opens the circuit to the generator's fields the magnetic flux is lost and the flow of current will stop.

The load regulator operates a brush arm on the rheostat which can insert or remove resistance from the fields of the generator thus increasing or decreasing output.

LESSON NO.8

In the first part of this lesson we learnt how a Direct current generator worked but as we also have locomotives fitted with Alternators which produce alternating current this part of the lesson will deal with alternators and alternating current.

What Alternating Current is:

Alternating current flows back and forth in a wire at regular intervals first going in one direction and then in the other. You know that direct current flows only in one direction and that current flowing is a measure of the number of electrons flowing past a point in the circuit in one second. Suppose a certain number of electrons pass a point in a wire in one second all the electrons flowing in the same direction, with result that current flow in the wire is one amp. If half this number of electrons move in one direction past a point in half a second, then reverse their direction and move back past the same point in the next half second, the total number of electrons passing that point in one second is the same as before and the current flow is one amp A.C. (Alternating Current)Refer to Fig. 1.

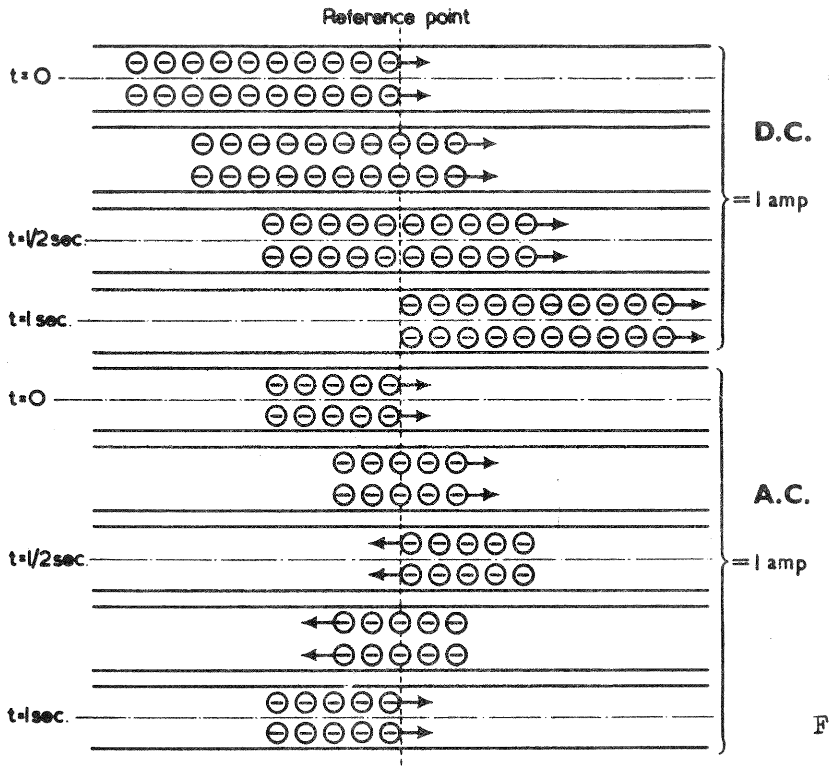


Fig.1.

If a single coil of wire is rotated in a fixed magnetic field as shown in Fig. 2, voltages are induced in the two sides of the coil. During one complete revolution each side of the coil travels in a circular path and passes alternately under the north and south poles of the magnetic field system, so that the direction and intensity of the field at a series of points round the path varies considerably. This can be shown diagrammatically on a graph where the vertical scale is field strength and the horizontal scale is distance around the cirumference. The voltage induced in the wire as it passes through this field follows the variation exactly, so that if we now consider the time taken to travel around the circumference at a fixed rotating speed, the voltage produced has a similar wave form.

Refer to Figs.2A and 2B. Since the voltages induced change direction, the terminal voltage of one end of the coil above the other is alternately positive and negative.

LESSON NO. 8

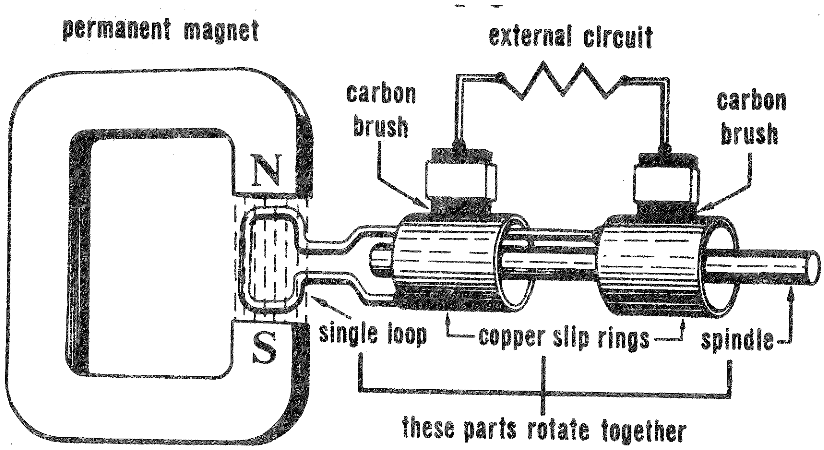


Fig.2.

If the two ends of the coil are connected to a pair of slip rings mounted on the armature shaft, the alternating voltage can be collected from a pair of carbon brushes bearing on the rings. This is the basic principle of a two pole alternator which would not be usually capable of producing such a smooth output as shown in Figs.2A and 2B. So most alternators have at least four poles.

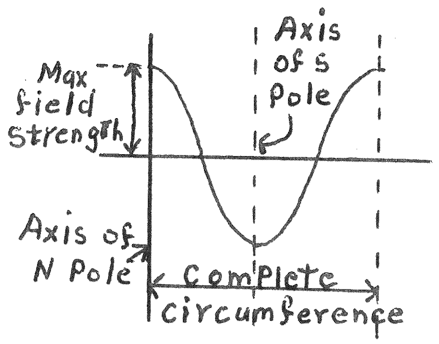


Fig. 2 A.

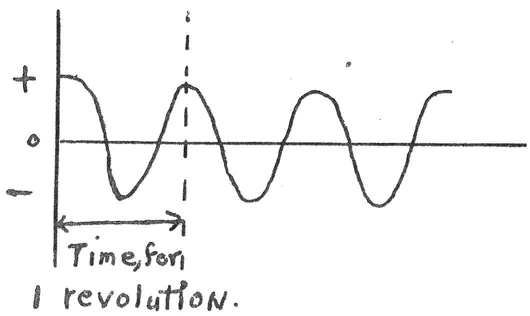


Fig. 2 B

Frequency

If the loop in Fig 3 rotates at a speed of 50 revolutions per second; the generated voltage will complete 50 cycles per second, it will then be said to have a "frequency" of 50 cycles per second, (50 c/s) thus frequency is the number of cycles per second.

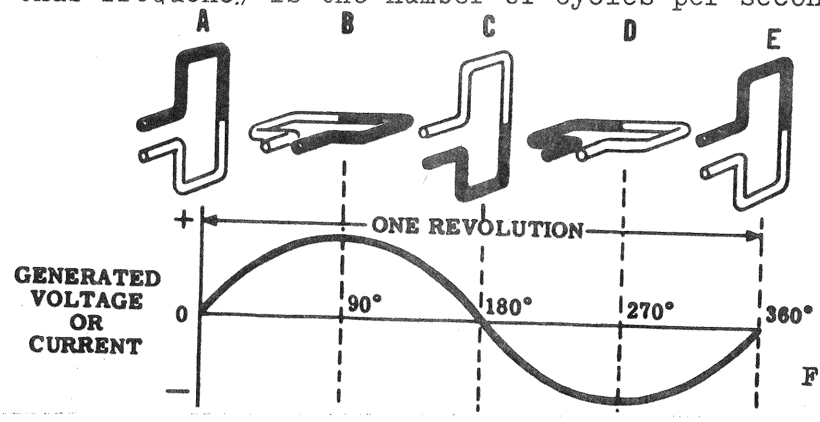


Fig.3.

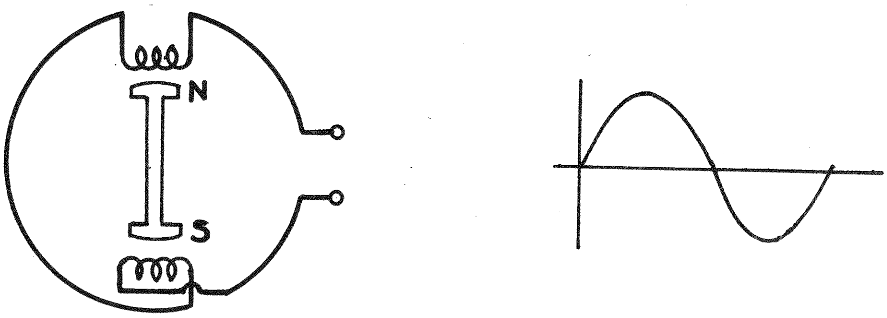


Fig.4. Single Phase Alternator.

Simple Single Phase and Three Phase Alternators

A single phase A.C. generator, often called a single phase "alternator" has all the amature windings connected in series as one winding, the output terminals or slip rings connected to the two ends.

You will remember in a D.C. generator the revolving part is the armature. There are two types of alternators, the rotating armature type and the rotating field type. The rotating armature type is similar to a D.C. machine but with slip rings instead of a commutator. The revolving field alternator has a electromagnet "Rotor" supplied with direct current through slip rings, and its magnetic field cuts through the fixed windings on the "Stator", inducing an alternating voltage in them. In either type of alternator the stationary part is called the "Stator" and the revolving part is called the "Rotor". There are both types fitted to a Dj locomotive.

Since the field current to produce the magnetic field is normally small compared with the output current from an alternator, it is preferable to mount the field poles on the Rotor which is done on most large alternators.

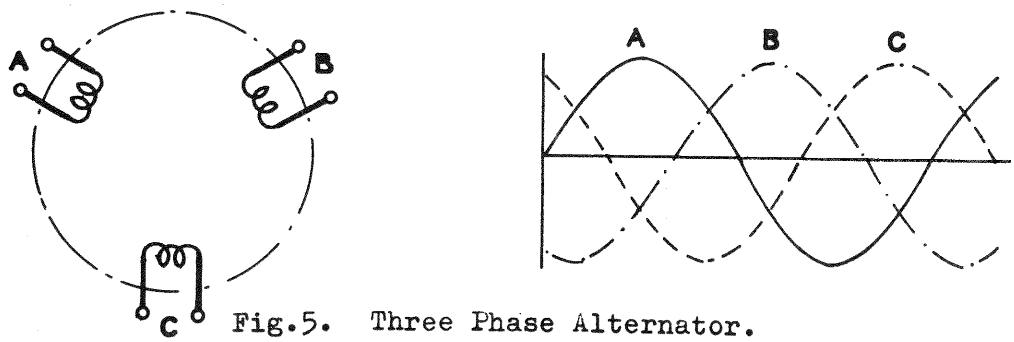


Fig.5. Three Phase Alternator.

Fig. 4 shows an elementary permanent magnet rotating field two pole alternator. The stator has two distinct poles, each with a coil wound on it, and connected in series in such a way as to produce opposite polarities.

LESSON NO. 8

Most modern alternators are three-phase-winding machines. This is because three phase alternators are much more efficient than single phase alternators. As its name implies, a three phase alternator has three single phase windings, arranged so that as the poles of the fields pass them their voltages reach a maximum one after another. A simplified diagram is shown in Fig. 5 with the windings lumped together and the rotor omitted for simplicity.

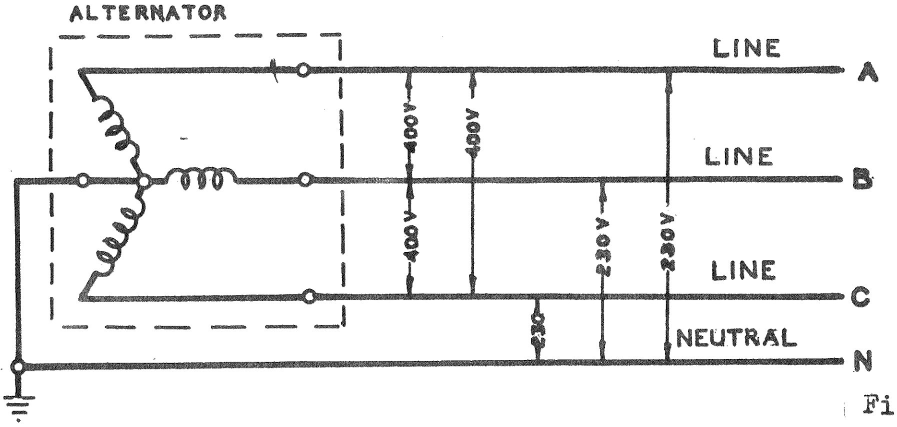


Fig.6.

We have already seen that the current and voltage produced by a generator varies from positive to negative in a uniform manner following what is known as a "sine Wave". You will see from Fig.5 that the "wave form" of a three phase machine consists of three equally spaced overlapping sine waves, each electrically independent of the others.

Instead of having six leads coming out of the three phase alternator, one end of each phase winding is usually brought out, the other ends of each three phases being connected together to form what is called a star connection. A fourth connection called a "neutral" is brought out from this point and is usually connected to earth. When a three phase alternator supplies a balanced load the neutral wire is usually omitted altogether (Refer to Fig. 6.)

Frequency is the Number of Cycles per Second.

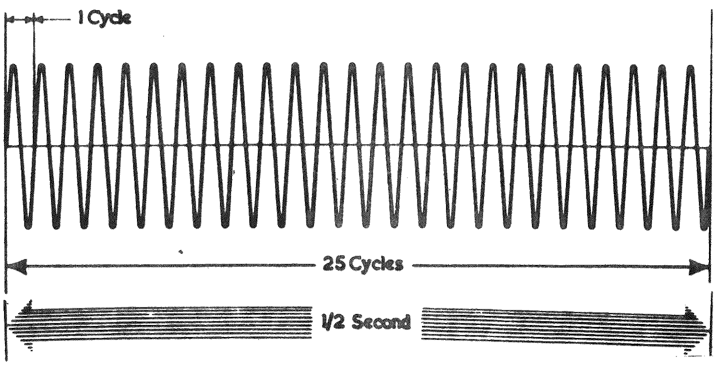


Fig.7.

It should be remembered that frequency is the number of cycles per second. You have already seen that the simple single phase two pole alternator generated one cycle each complete revolution, that is, when two opposite poles, a north and a south had passed one stator winding. To generate 50 cycles per second the machine must be driven at 50 revolutions a second, or 50 x 60 =3000 revolutions per minute. The more field poles a machine has the lower the speed necessary for any given frequency. A four pole machine for example, must be driven at 1500 R.P.M. to generate 50 cycles per second.

It must be remembered that for the alternators field excitation D.C.current is required. This can be obtained from some separate source such as an exciter. That is, a separately excited alternator, its output being rectified to D.C. by diodes (rectifiers).

On Dj locomotives there are three alternators all of which supply D.C. loads via "Rectifier bridges" which will be described below. These rectifier bridges ensure that the loads on the A.C. phases are equal, and hence each of the three alternators concerned has only three output terminals.

Bridge Rectification of Three Phase A.C.

Consider a single alternating voltage such as that in Fig.8. If such a voltage is supplied to a load through a switch as in Fig.9 and the switch is turned off every time the voltage goes negative, the voltage appearing at the load consists only of the positive portions of the applied voltage Fig.10.

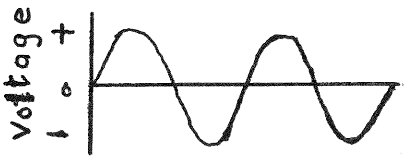


Fig.8

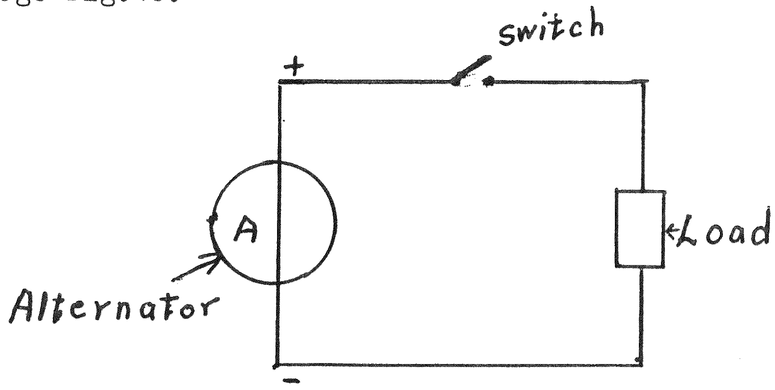


Fig.9

A diode (or rectifier) is an automatic switch which does exactly this, so that the switch in Fig.9 can be replaced by a single diode cell as in Fig.11 with the same result.

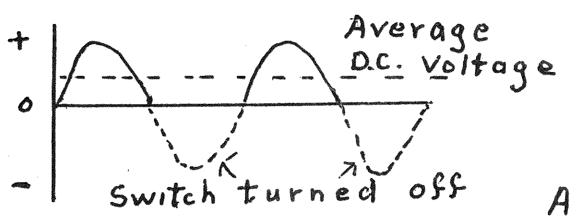


Fig. 10

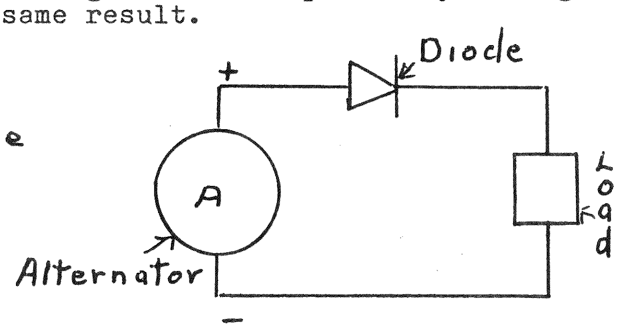


Fig.11

The original alternating voltage changed direction many times each second; and since only the positive portions are used the average voltage at the load would be direct current (D.C.) varying in magnitude many times each second but appearing as a steady current.

LESSON NO.8

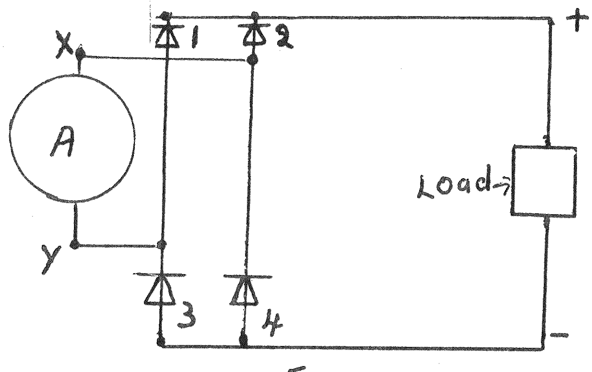


Fig.12

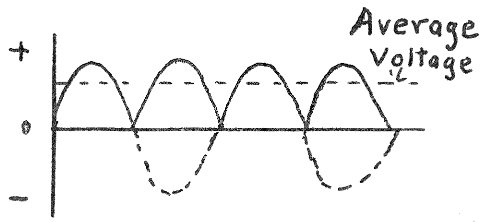


Fig. 13

If we use a more complex arrangement as shown in Fig.12 it is possible to make use of both portions of the alternating voltage. When the terminal X of the alternator is positive with respect to Y, current flows upwards, through diode 2, the load and back through diode 3.

When however terminal X is negative with respect to Y (on the negative portion of each cycle) current flows downwards through the alternator, up through diode 1, down through the load and up to X through diode 4.

The voltage at the load now appears as in Fig.13 and its average value is twice that of Fig.10 given the same input alternating voltage.

When we come to three-phase rectification a similar system is used; and the circuit is shown in Fig.14.

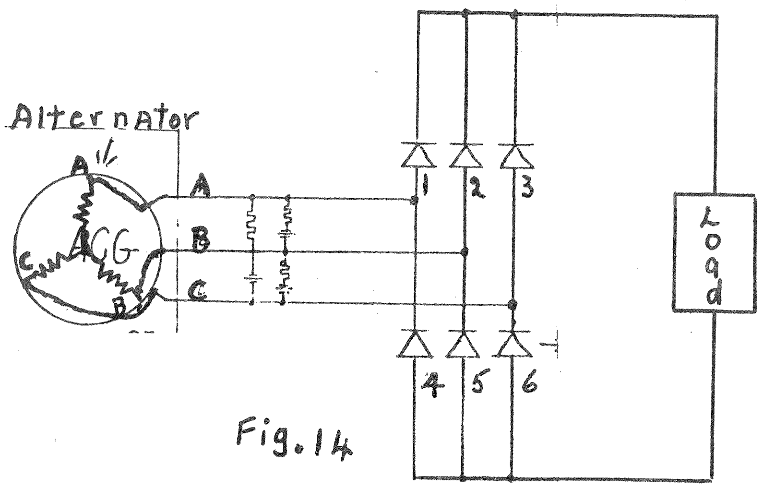


Fig.14

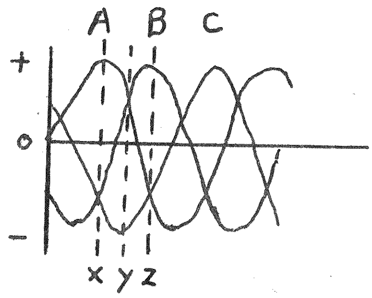


Fig.15

Comparing Figs.14 and 15 at point X when phase A is positive and phases B and C are both Negative, current flows out through diode 1, through load and back through diodes 5 and 6 to the alternator. At Y, current flows through diodes 1 and 2 to load; and back through diode 6. At Z, current flows out through diode 2 to load and back through diodes 4 and 6. At Z, current flows out through diode 2 to load and back through diodes 4 and 6, and so on. The net voltage available at the two output wires is that shown in Fig.16.

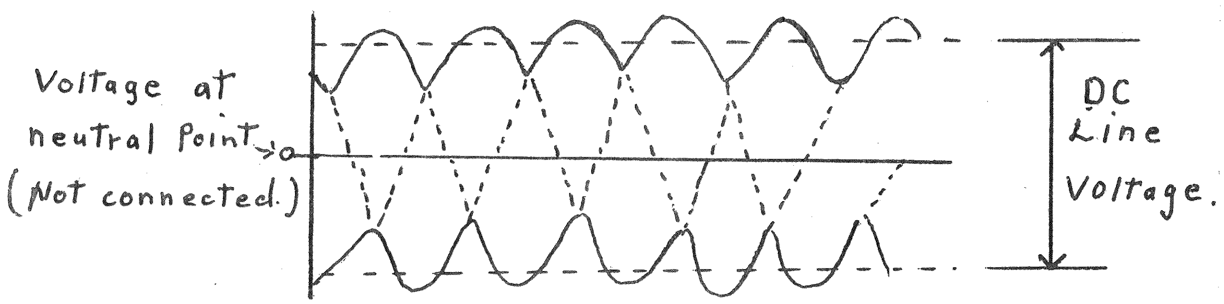


Fig. 16.

LESSON NO.8

Dj Locomotive Main Alternator(Brushless)

The main alternator assembly on this locomotive actually consists of two separate alternators in the one machine housing, the exciter and the main alternator. The exciter is a small three phase alternator mounted on the same shaft as the main alternator, and has field windings on the fixed portion and a rotating armature. The exciter field windings are connected to the 110 volt D.C. control circuits of the locomotive, and three phase A.C. is generated in the rotating exciter armature windings. The three exciter output leads are led along the armature shaft to a rotating rectifier assembly, which is a series of diodes bolted to a rotating ring and wire as shown in Fig.14. The exciter output is thereby converted to D.C , and the two D.C. output leads are again lead along the shaft to the rotating field of the main alternator.

The direct current from the rotating rectifier creates a rotating magnetic field in the main alternator dependent upon the original exciter field current.

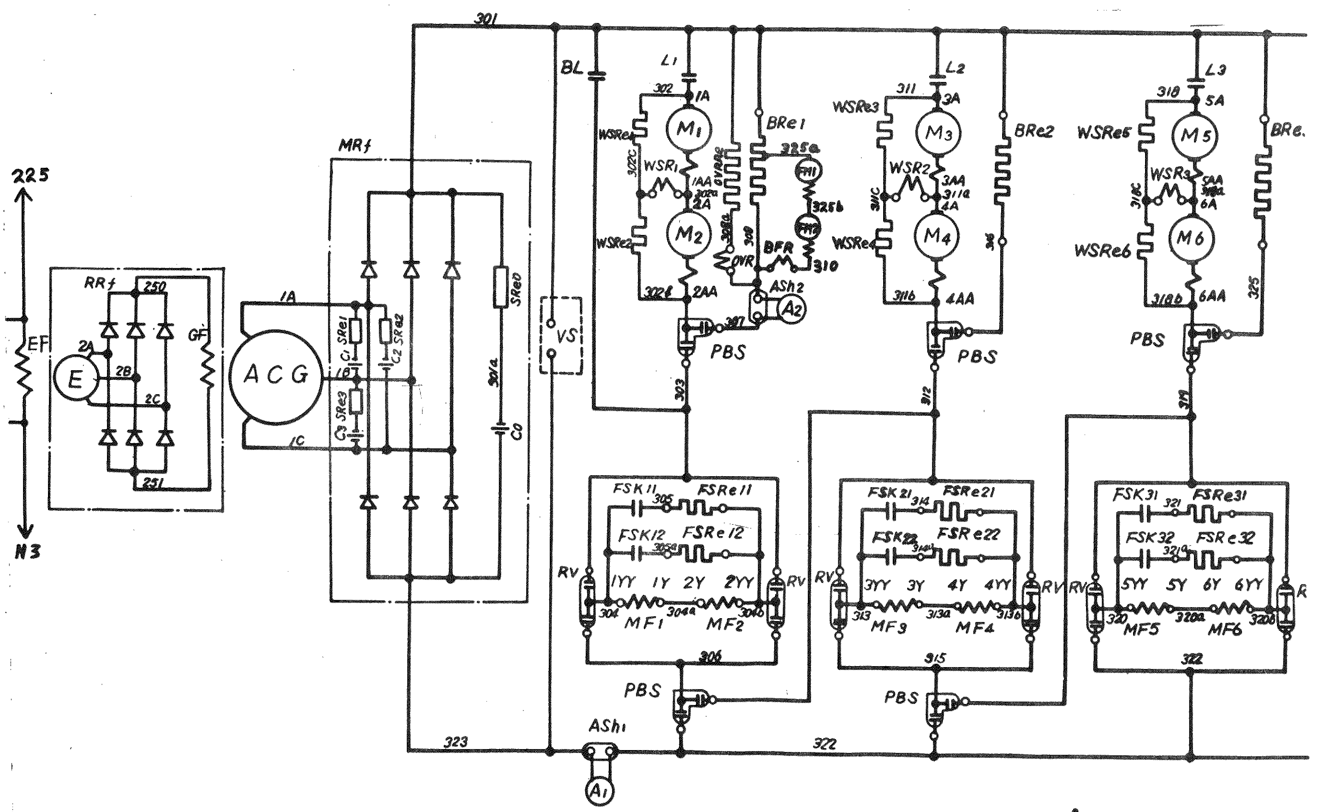
The rotating magnetic field induces three phase A.C. in the fixed stator windings of the main alternator, and the three main output leads run out of the machine housing to the main silicon rectifier which is in a separate cubicle.

The exciter, rotating rectifier and main alternator form a compact unit with no electrical connections between stationary and rotating parts, all communication being magnetic.

Electron Flow

In this lesson and all other lessons of the course we use the conventional method of learning current flow that is we follow from positive to negative.

The direction of electron flow is opposite to what is always conventionally accepted as the direction of current. The electron flow being Negative to Positive.



SCHEMATIC DIAGRAM OF POWER CIRCUIT Dj

AKR

LESSON NO. 8.

LIST OF QUESTIONS

1. What is voltage, what does it do and how is it measured?

2. What is current, how is it made to flow and how is it measured?

3. How do we make: (a) A permanent magnet.
   (b) An electro magnet.

4. (a) What does a battery consist of? (b) Name the two terminals fitted to a battery and state how they can be marked.

5. How does a generator work?

6. How do we change the generator voltage?

7. What must we do to cause a current to flow from a generator?

8. How does a traction motor work?

9. Would the magnets of the main generator and traction motors on a diesel electric locomotive be of the temporary or permanent type and explain why?

10. What are the traction motor blowers provided for and explain why they are necessary?

11. Describe the operation of :-
    (a) An E.P. contactor
    (b) An E.M. contactor
    (c) State the purpose for which they are used.

12. There are two different types of circuits on a diesel electric locomotive - name them.

13. Why are general purpose relays provided and in what circuits are they used?

14. What is (a) an overload relay provided for
    (b) a ground relay provided for
    (c) how do they operate?

15. What is the reverse current relay (RCR) placed in a battery charging circuit for?

16. How are: (a) The traction motors reversed.
    (b) The traction motors coupled to the driving wheels.

17. (a) Why are fuses and circuit breakers provided.
    (b) What must be done; if a fuse blows.
    (c) If a circuit breaker trips.

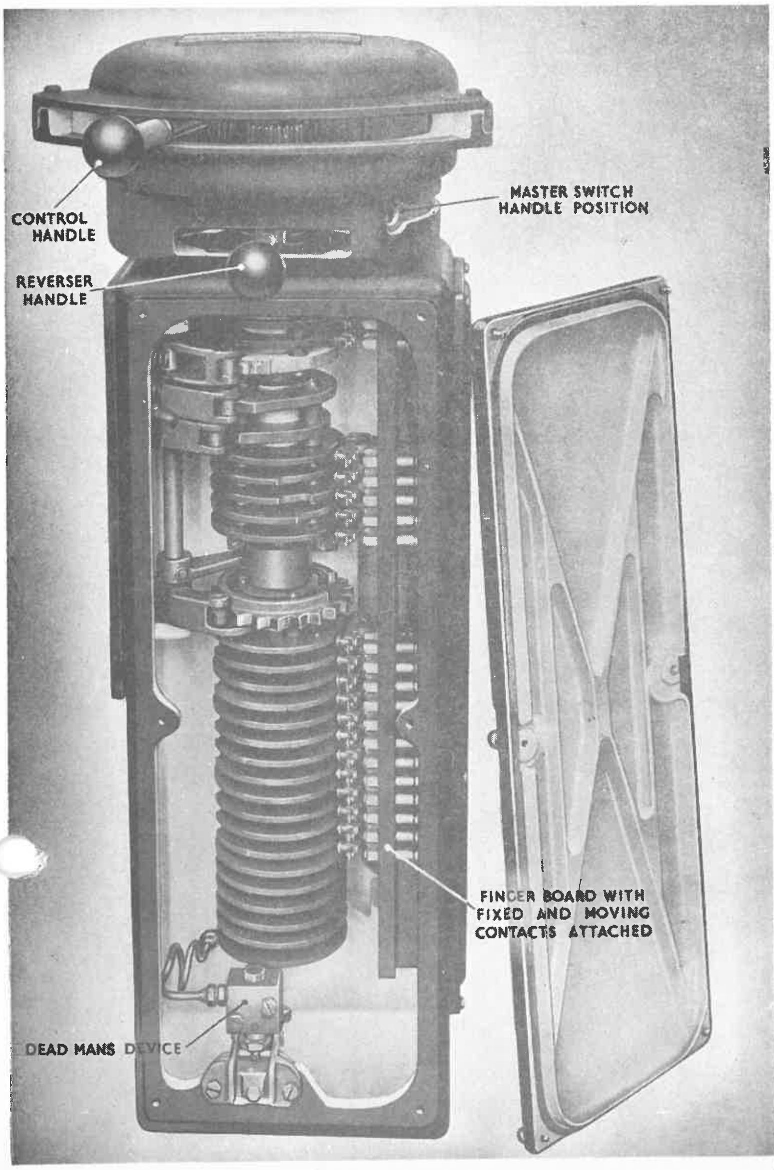
18. What is the purpose of:-
    (a) The auxiliary generator.
    (b) The main generator.
    (c) The traction motors.

... ...

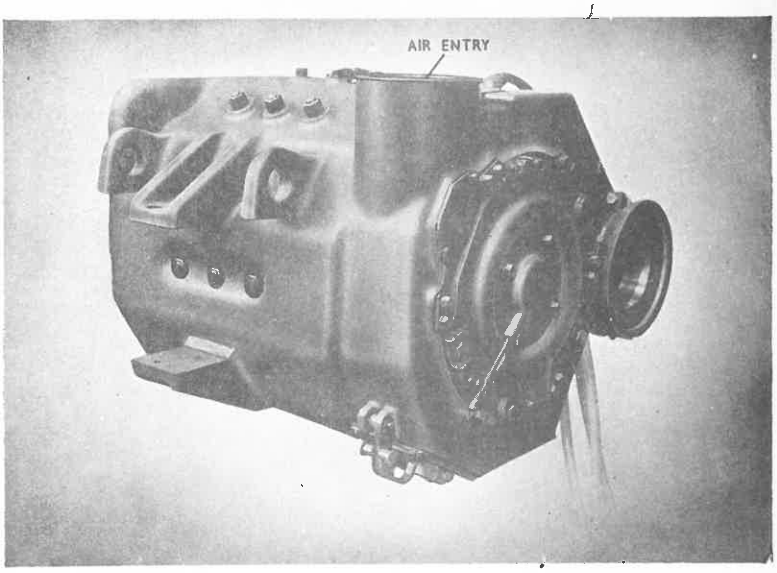
19. What will cause:-
    (a) A short circuit
    (b) A flashover.

20. What is dynamic braking and how does it operate?

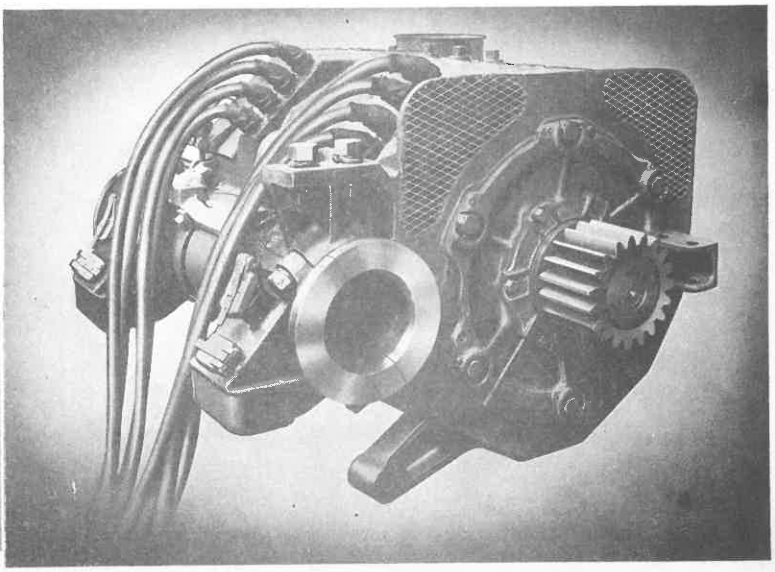
21. For what purpose do we use the shunted field connection.?



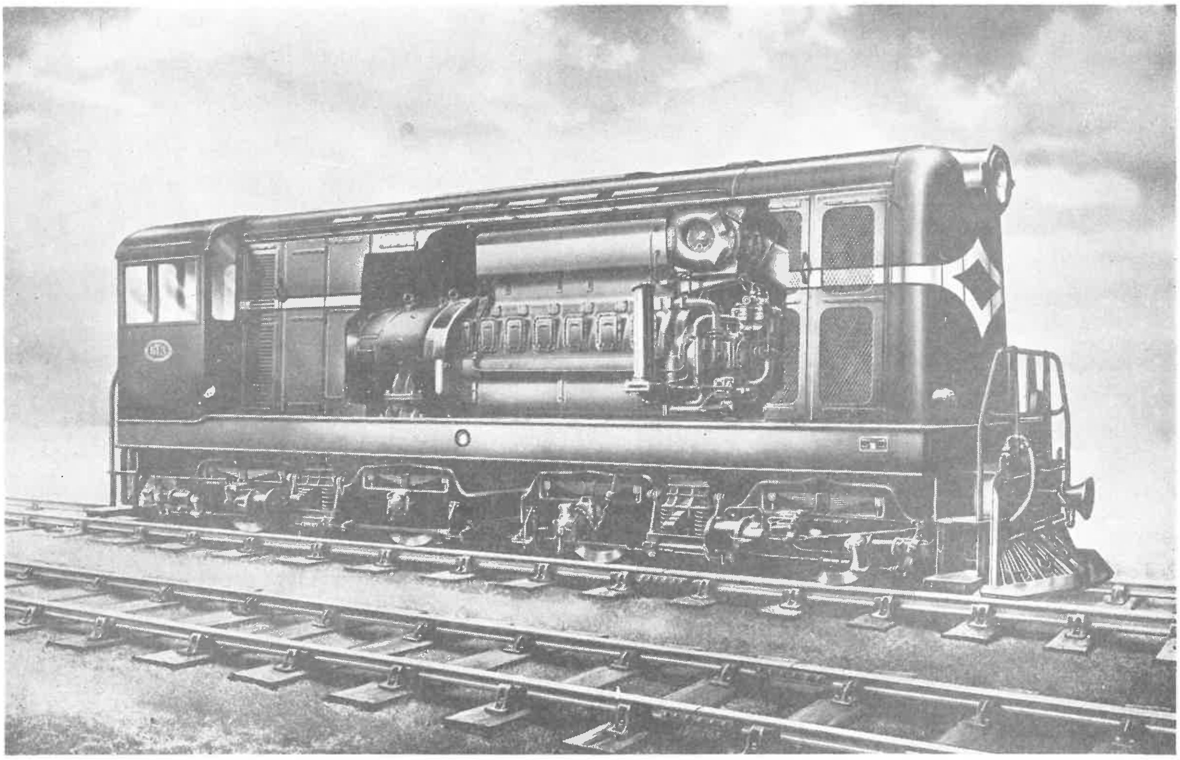
Controller



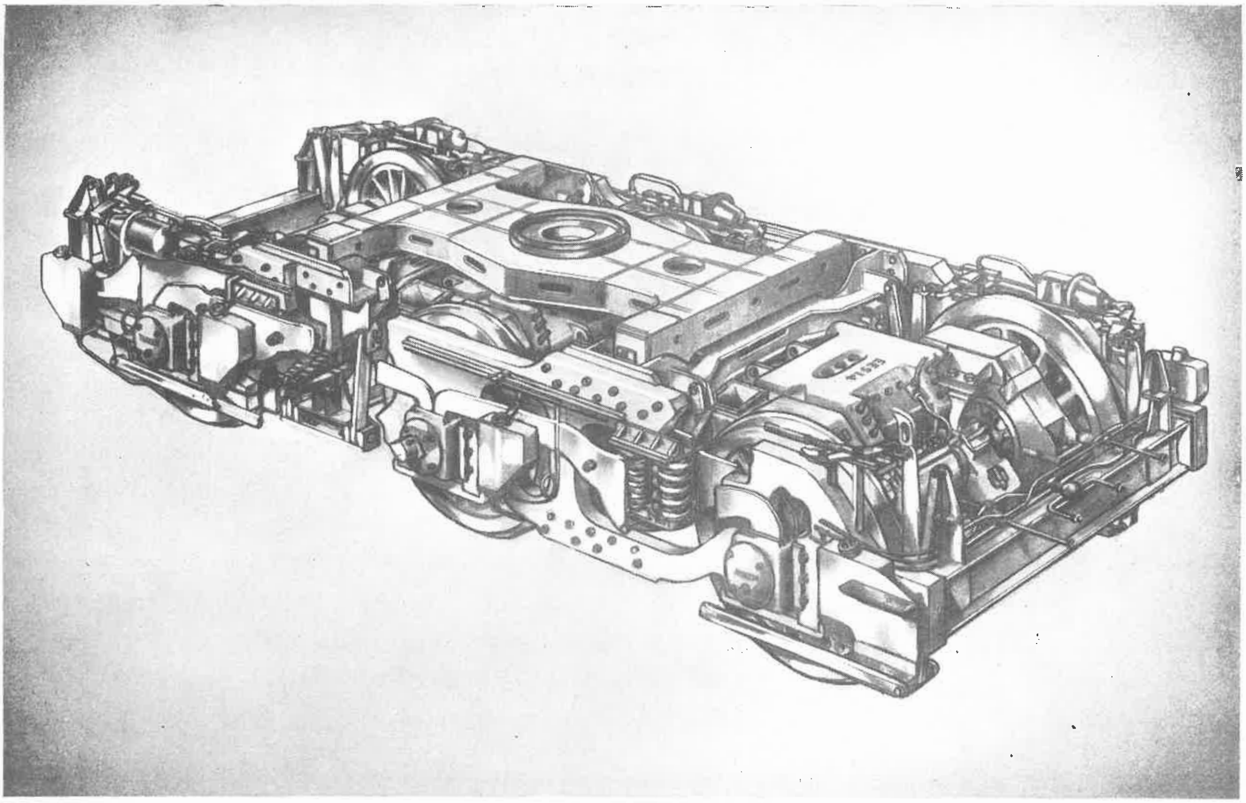
[redacted] Traction motor showing nose suspension bracket



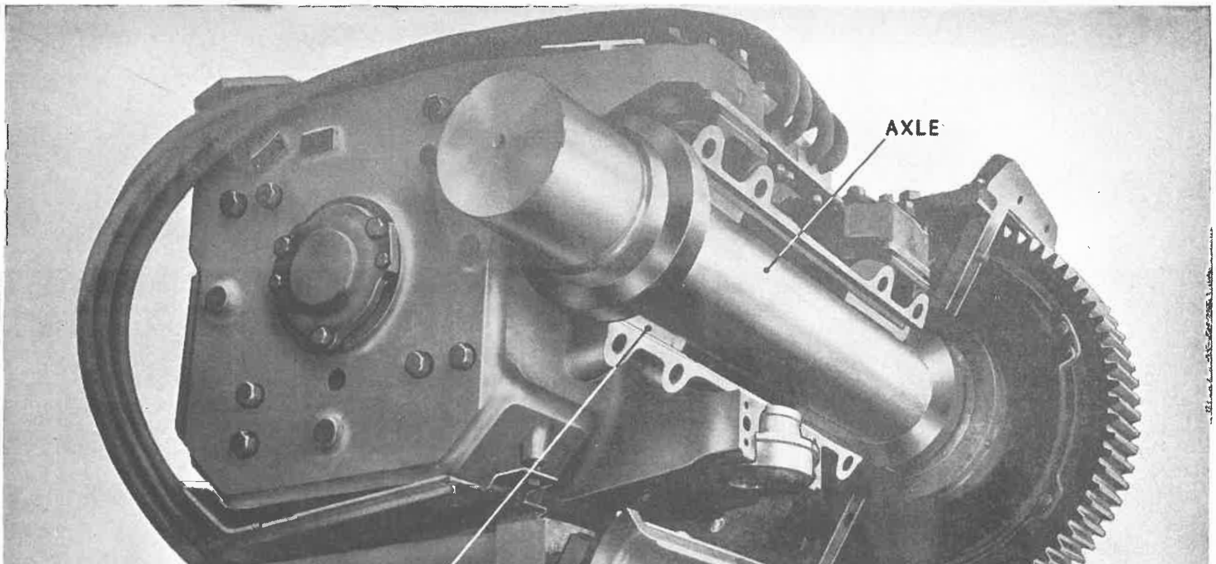
Traction motor showing driving pinion



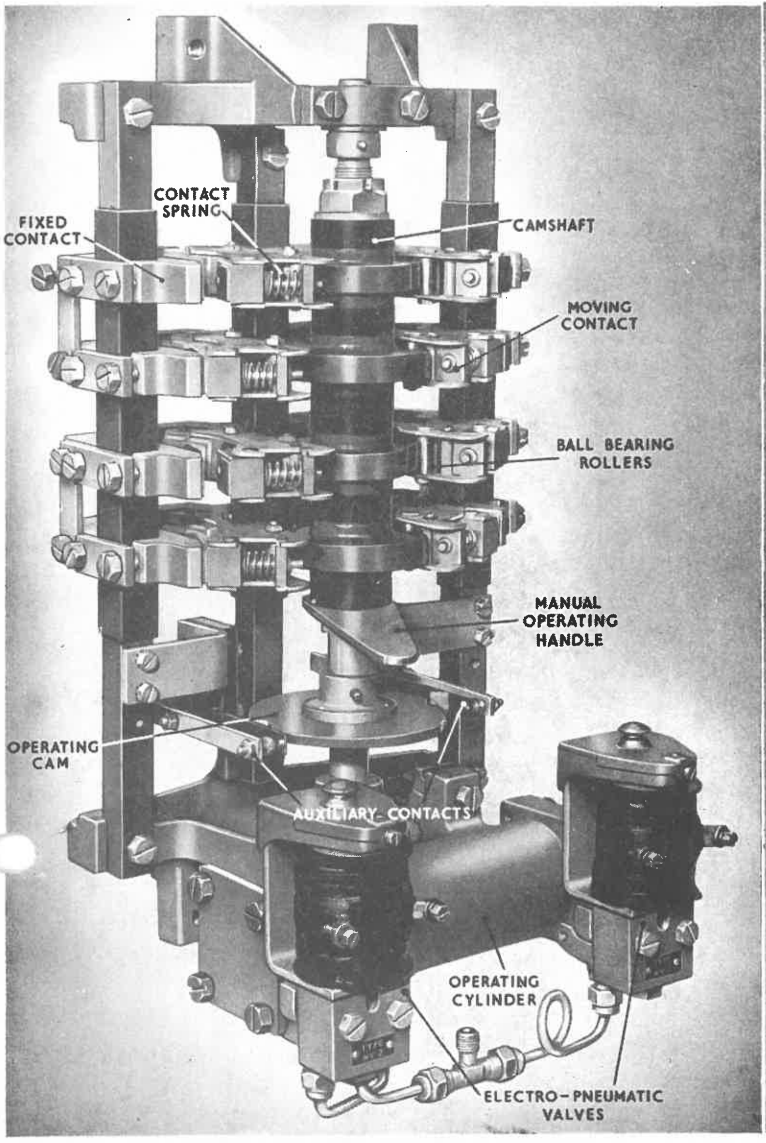
Mixed traffic locomotive with 6-cylinder pressure-charged " in-line " diesel engine



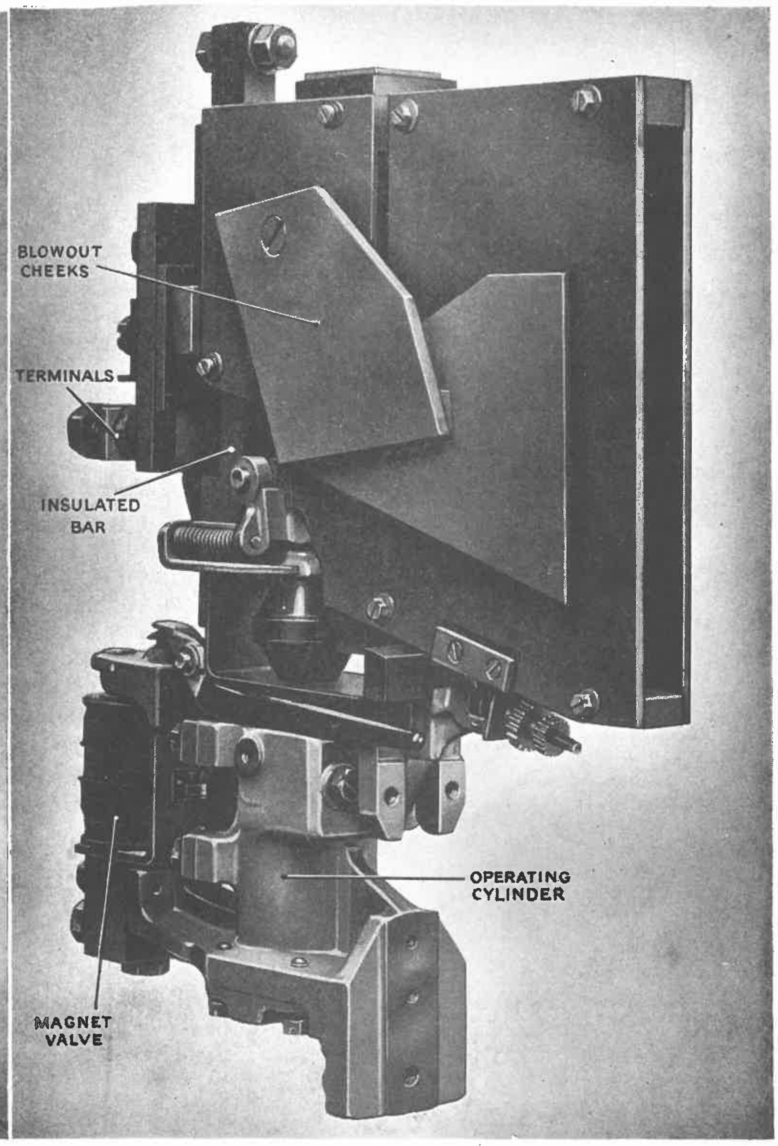
Typical motored bogie



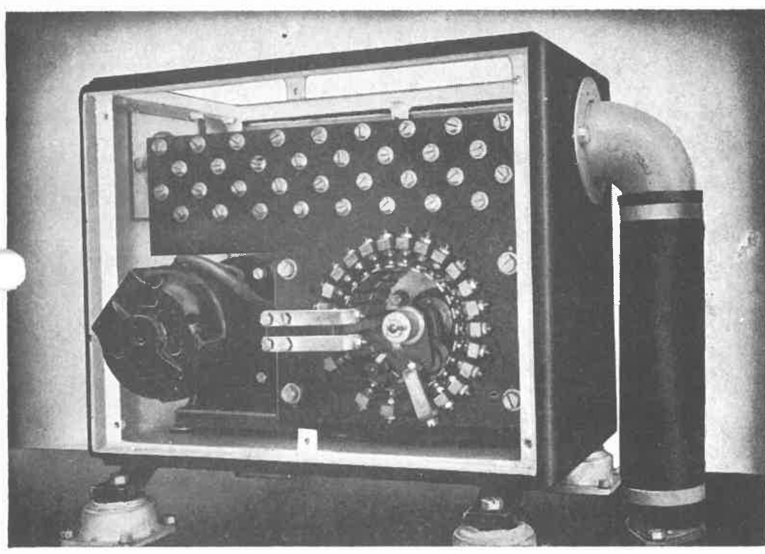
Axle and axle bearing



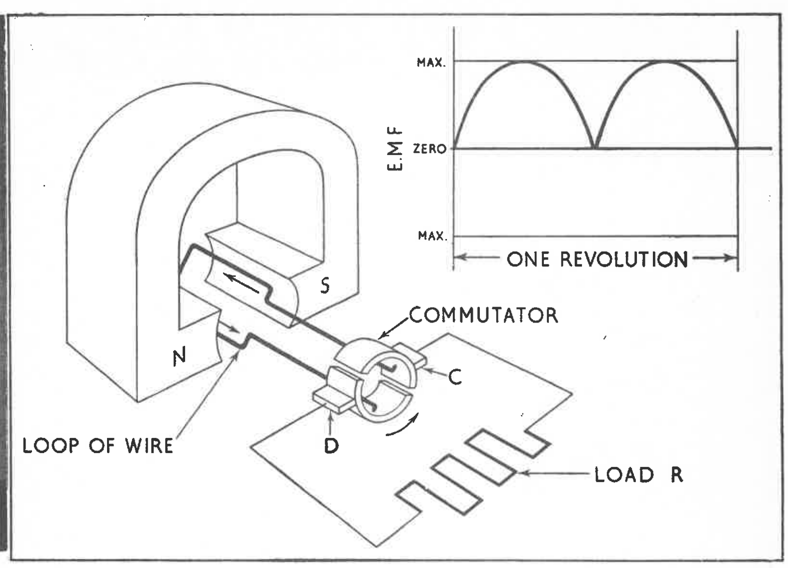
Reverser switch



Electro-pneumatic contactor

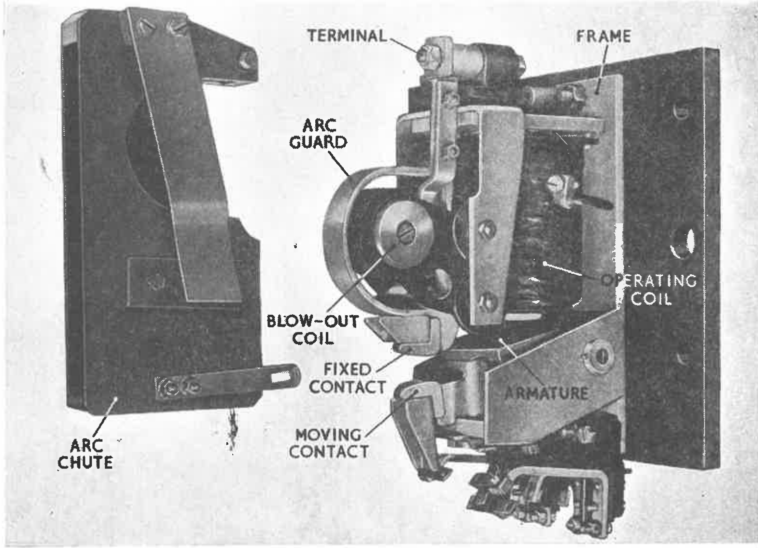


Load regulator

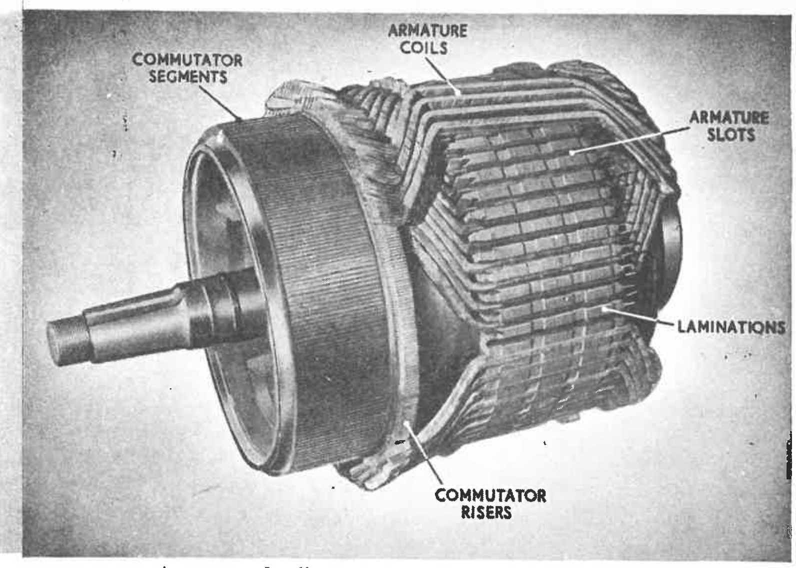


Principle of a direct current generator

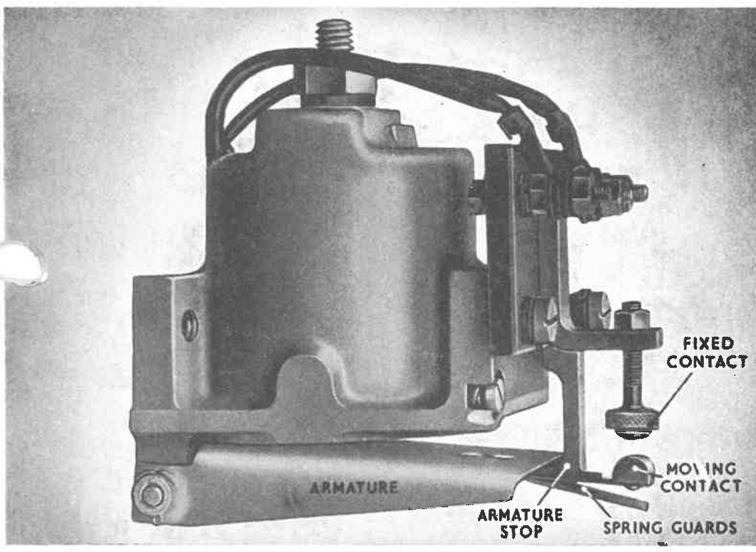
66/11



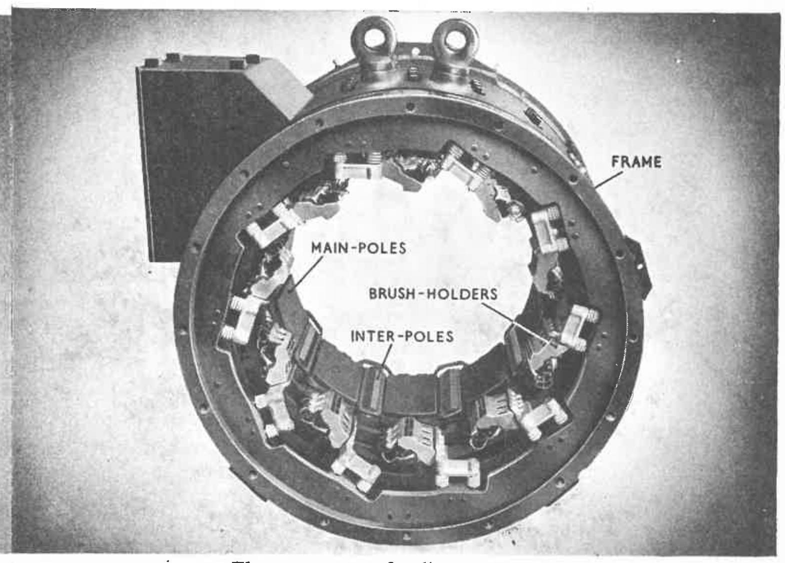
Electro-magnetic contactor



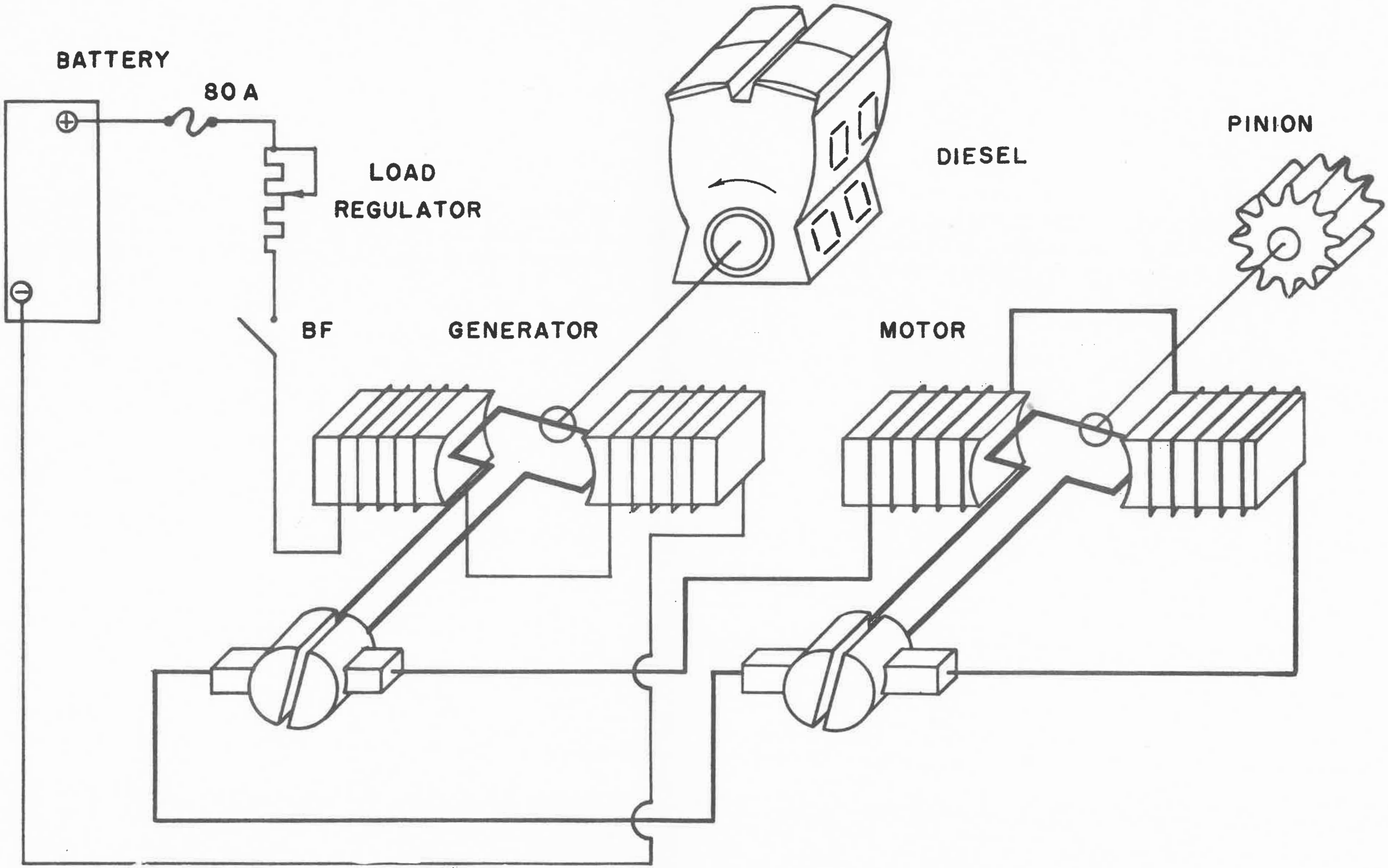
Armature of a direct current generator in course of construction



General purpose relay

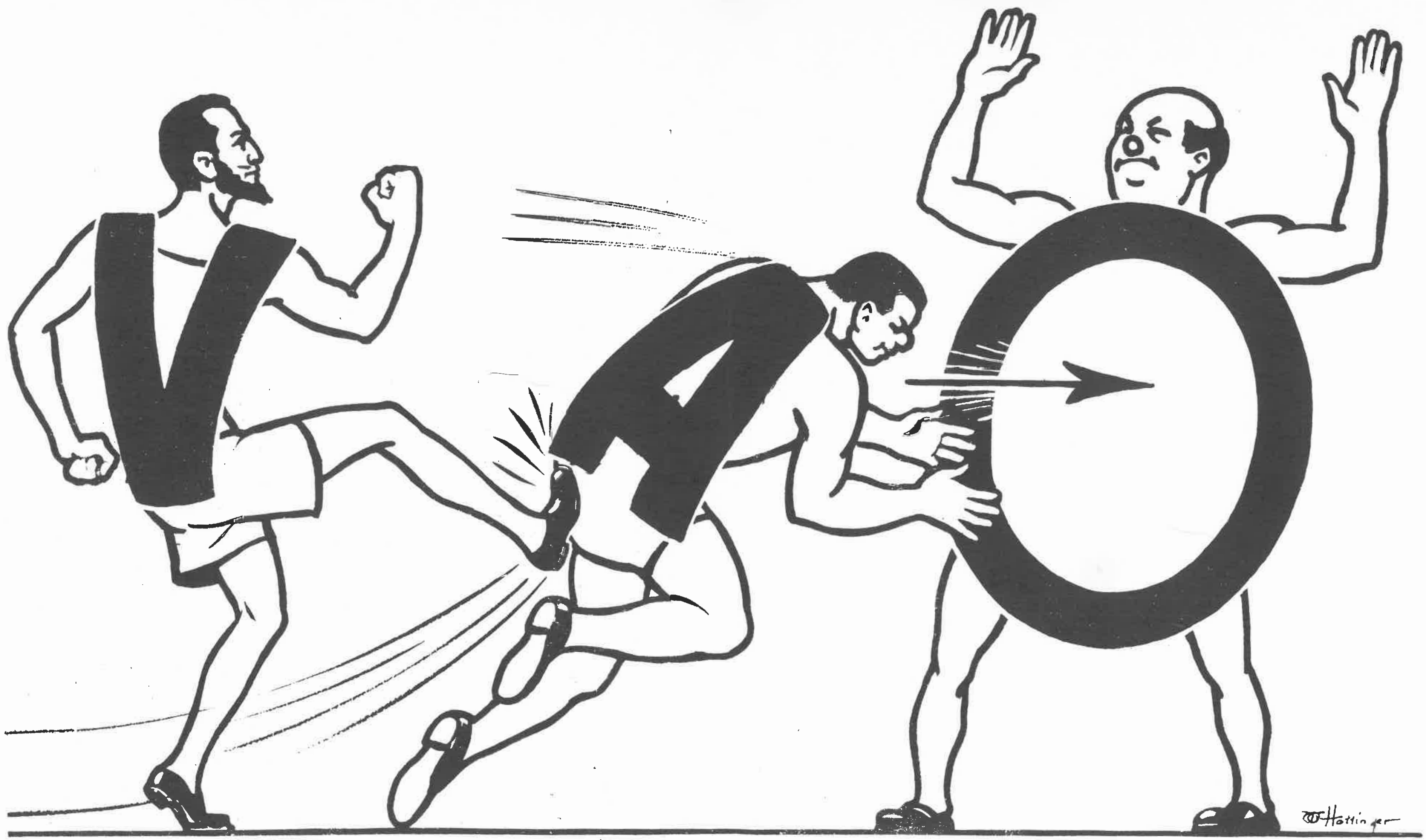


Electro-magnet of a direct current generator



BASIC GENERATOR AND
MOTOR PRINCIPLE

66/11



OHM'S LAW

$V = A \times O$ $\qquad$ $A = \frac{V}{O}$ $\qquad$ $O = \frac{V}{A}$

AMPERAGE – IS TORQUE – IS TRACTIVE EFFORT – IS DRAWBAR PULL – WILL MOVE BOX CARS OR ELSE!