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AUTOMOTIVE DIESEL MAINTENANCE 2. UNIT XIV, UNDERSTANDING DC GENERATOR PRINCIPLES.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

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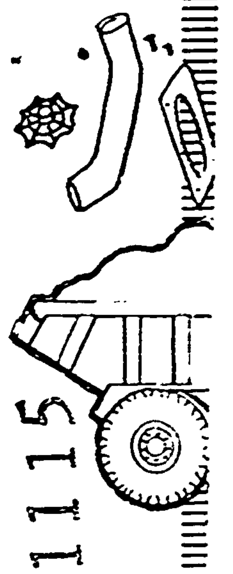
THIS MODULE OF A 25-MODULE COURSE IS DESIGNED TO DEVELOP AN UNDERSTANDING OF THE OPERATING PRINCIPLES OF DIRECT CURRENT GENERATORS USED ON DIESEL POWERED EQUIPMENT. TOPICS ARE (1) WHAT IS A GENERATOR AND ITS USE, (2) SHUNT GENERATOR PRINCIPLES, (3) POWER AND RATINGS OF A GENERATOR, (4) ARMATURE REACTION, (5) WHAT IS POLARITY, (6) TWO GENERATOR CIRCUITS, AND (7) APPLICATION OF GENERATORS ON THE JOB. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL PROGRAMED TRAINING FILM "DC GENERATORS I--INTRODUCTION TO DC GENERATOR PINCIPLES" AND OTHER MATERIALS. SEE VT 005 685 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 685 - VT 005 709. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 1" ARE AVAILABLE AS VT 005 655 - VT 005 684. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

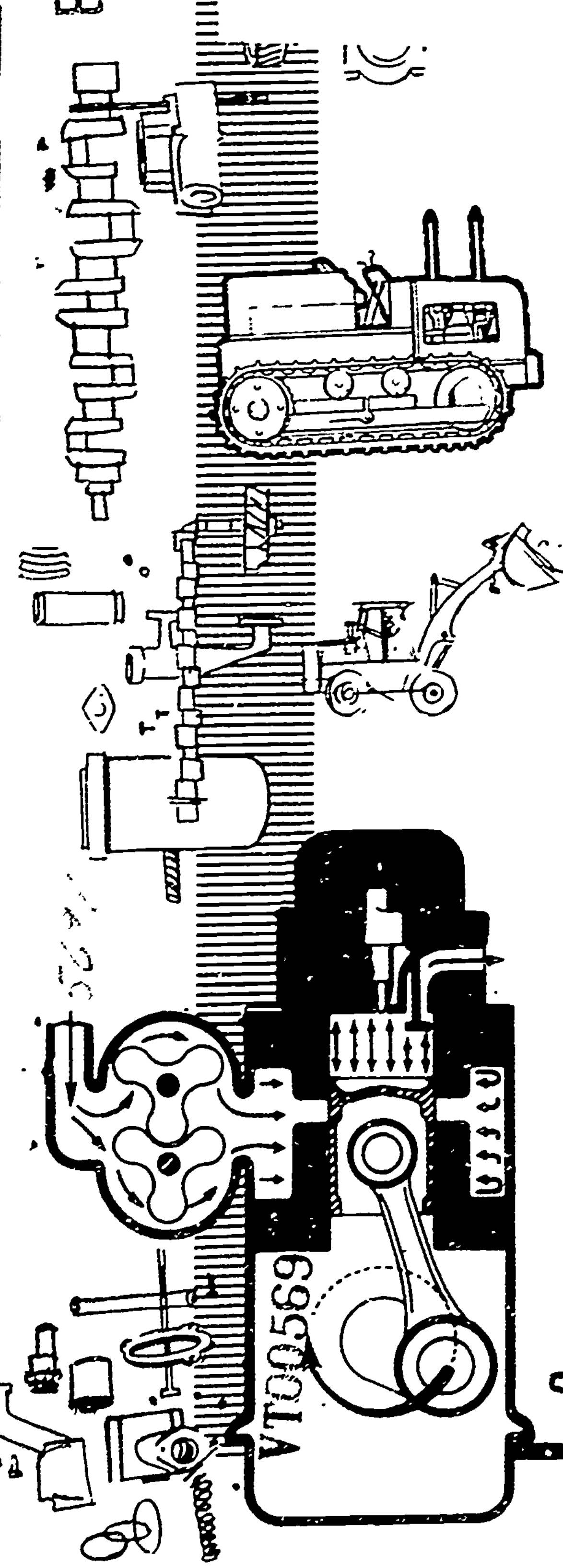
STUDY AND READING MATERIALS



AUTOMOTIVE DIESEL 2 MAINTENANCE

UNDERSTANDING DC GENERATOR PRINCIPLES — UNIT XIV

SECTION A	WHAT IS A GENERATOR AND ITS USE
SECTION B	SHUNT GENERATOR PRINCIPLES
SECTION C	POWER AND RATINGS OF A GENERATOR
SECTION D	ARMATURE REACTION
SECTION E	WHAT IS POLARITY
SECTION F	TWO GENERATOR CIRCUITS
SECTION G	APPLICATION OF GENERATORS ON THE JOB



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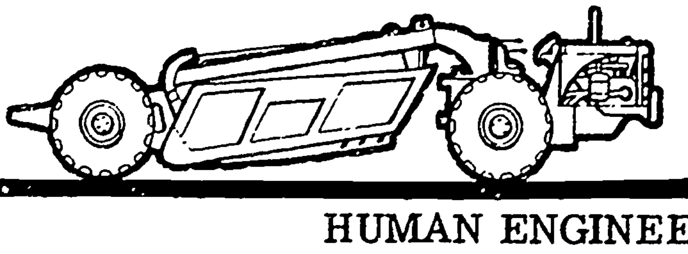

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SECTION A -- WHAT IS A GENERATOR AND ITS USE?

An automotive type generator is a machine that converts mechanical energy, supplied by the engine, into electrical energy used either for recharging the battery or for supplying power to the electrical system.

Whether the energy required for the electrical system is supplied directly by the generator or by the battery, or by a combination of the generator and battery, depends on the conditions under which the generator operates.

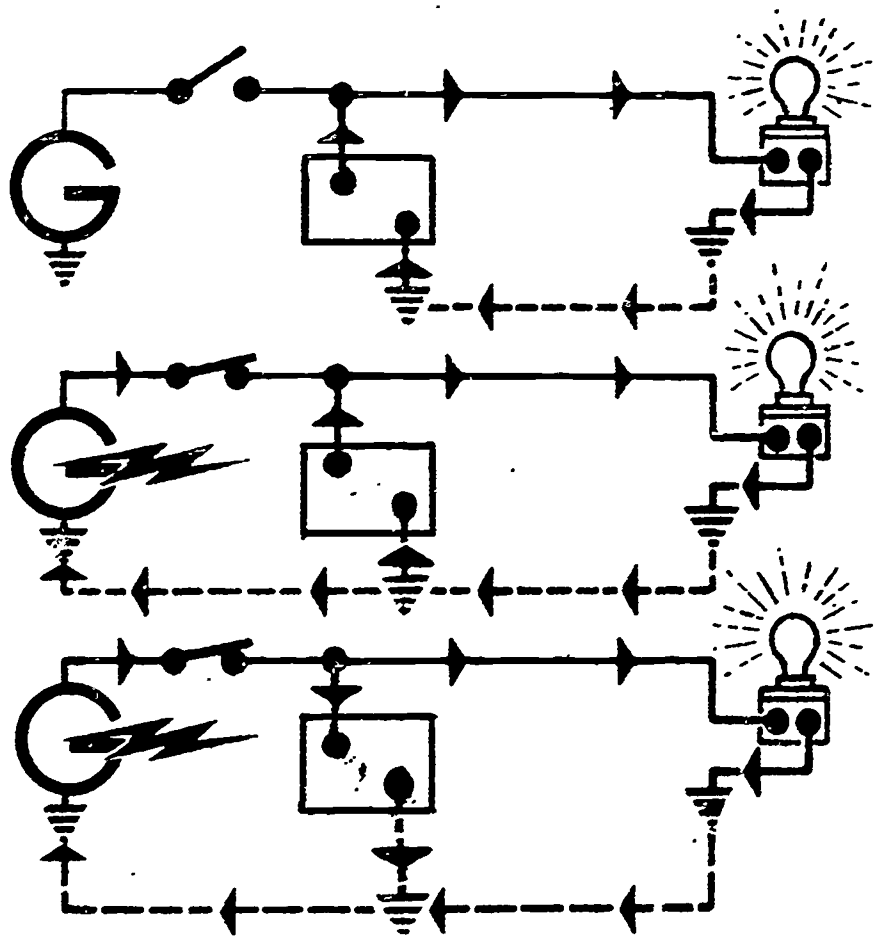


Fig. 1 Generator and battery power

When the standard automotive generator is either at rest or is operating at an extremely low speed such as at engine idle, or when operating at low engine speed, lights and accessories are supplied by the battery only, not by the generator. At medium speeds, energy is supplied to the electrical system by both the generator and the battery. At high speed, the generator alone supplies electrical energy -- to recharge the battery and to power the electrical system. See Figure 1.

SECTION B -- SHUNT GENERATOR PRINCIPLES

Generator operation is based on the principle of electromagnetic induction. Electrical pressure, known as voltage, is generated when any conductor is moved at right angles through a magnetic field. Voltage produced in this manner will cause current to flow in the conductor if it is part of a complete circuit.

Figure 2 shows the relationship between the magnetic field of a permanent magnet, the direction of motion of a conductor cutting through this magnetic field, and the direction of current flow from the voltage induced from this motion.

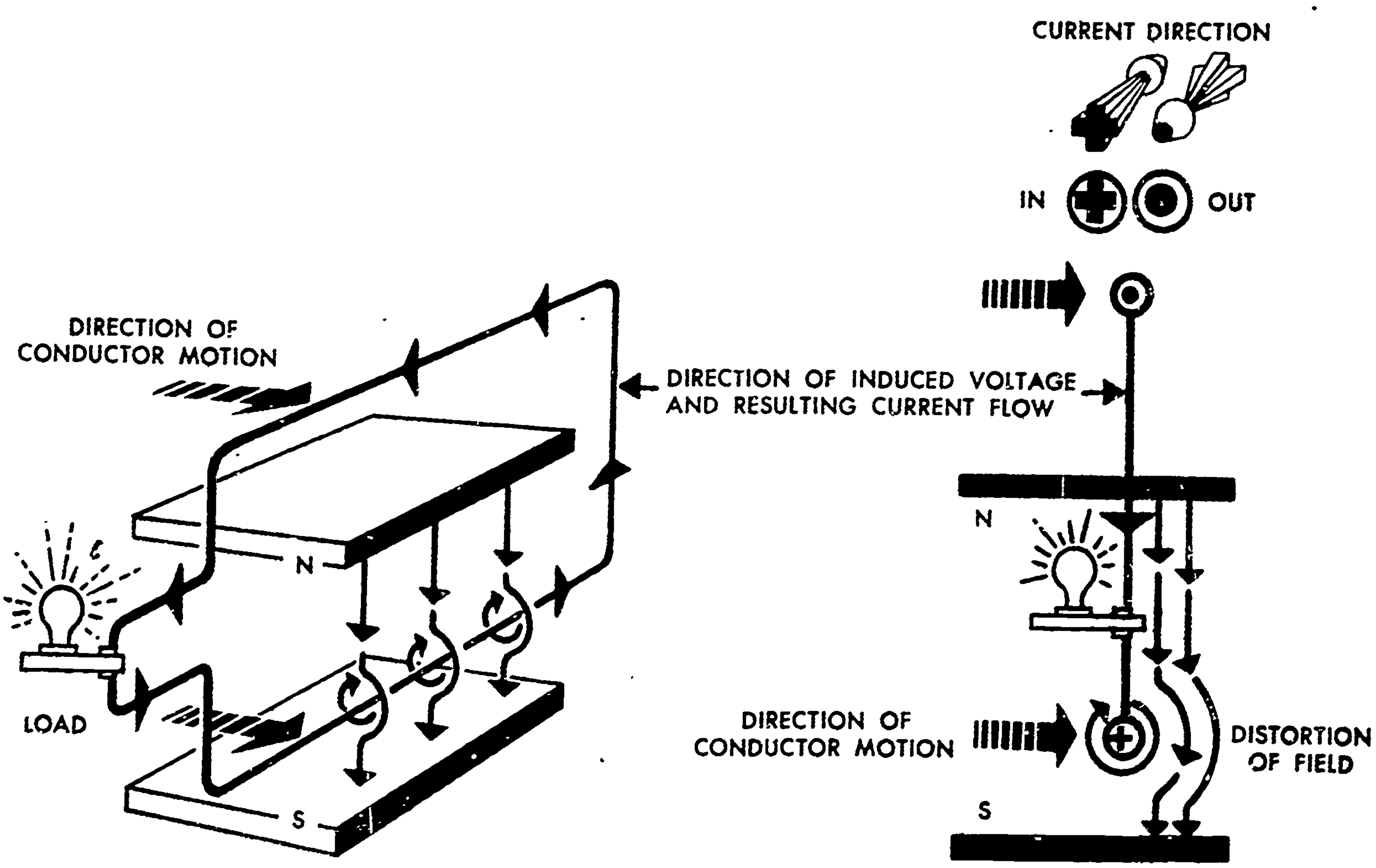


Fig. 2 How voltage is developed

A simple generator, with an armature having only one turn or loop of wire and two iron pole pieces, is illustrated in Figure 3. These pole pieces retain some magnetism, known as residual magnetism, from their last use. They are very weak permanent magnets with a magnetic field between them. If the armature is rotated in a clockwise direction through the magnetic field, a weak voltage is built up or induced in the left hand side of the loop away from the reader, and in the right hand side of the loop toward the reader. This induced voltage causes a flow of current in any conductor that completes the circuit by closing the two ends of the loop.

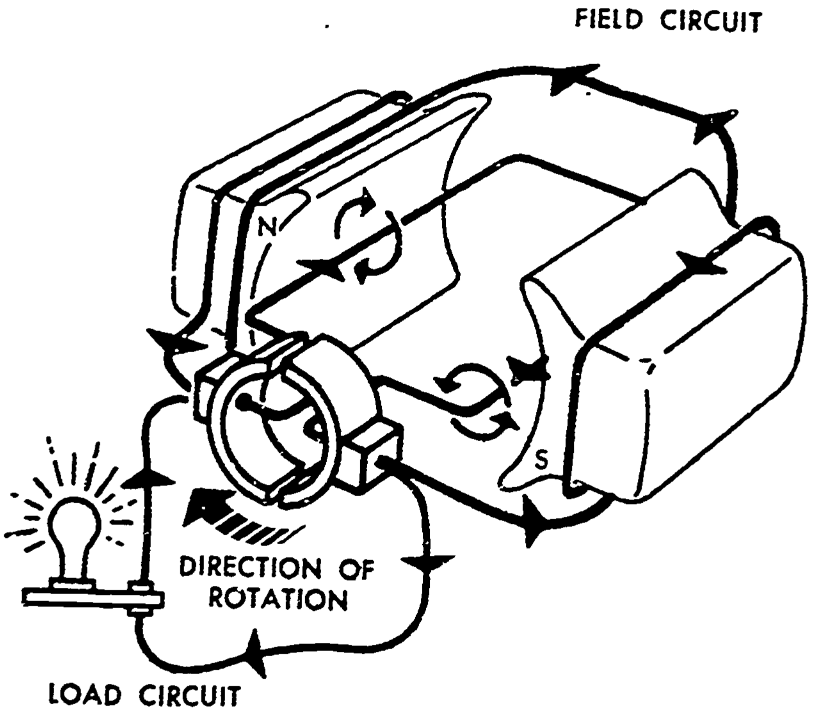


Fig. 3 Generator circuits

Joining the two ends of the loop through a conductor is commonly called "hooking across the generator". Two circuits are shown. One is called the field circuit and the other the load circuit.

The difference in voltage developed between the two ends of the armature loop when it is rotated through the magnetic field causes current to flow through the field coils. This flow of current through the field coils, which are wrapped around the pole pieces, causes the poles to become electromagnets. The magnetic field developed by these electromagnets strengthens the residual magnetic field of the pole pieces and greatly increases the total field strength between the poles.

The rotating armature loop, cutting through the stronger magnetic field, increases the induced voltage in the loop which, in turn, forces more current through the field coils. This creates an even stronger magnetic field with more lines of force. The armature cutting through this stronger magnetic field develops still more voltage. In this manner, the voltage of a generator is built up. The voltage between the two ends of the armature loop also causes a flow of current through the load circuit, as indicated when a light bulb is placed in the external circuit.

The ends of the armature loop are securely attached to a split ring called a commutator. Riding on the commutator are brushes. It is from these brushes that the voltage and the resulting current is transmitted to both the field and the load circuits. This is called commutation.

As can be seen in Figure 4, the armature loop -- when located in a vertical position -- cuts no magnetic lines of force. Therefore, no voltage is generated at this point. When the armature is in this position, the split in the commutator ring is passing under the brushes. The split in the commutator ring makes the direction of voltage and current the same with respect to the brushes. Since no voltage is present in the loop at this particular instant, there will be no current flow. Consequently, no arc or spark will occur when one commutator bar moves from under the brush and the adjacent bar replaces it. This halfway point is called the neutral point.

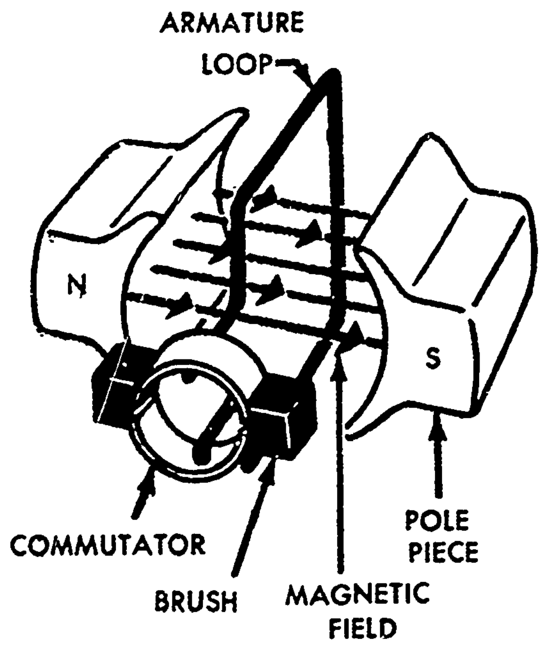


Fig. 4 Armature loop and magnetic field

Notice that Figure 5 shows the magnitude and direction of voltage during one complete revolution of the armature.

Just as electrical circuits must be complete, there must also be a complete magnetic circuit. The illustration in Figure 3 deals primarily with the electrical circuit, whereas Figure 6 shows the magnetic circuit of a two pole generator. It is important to remember that all air gaps in the

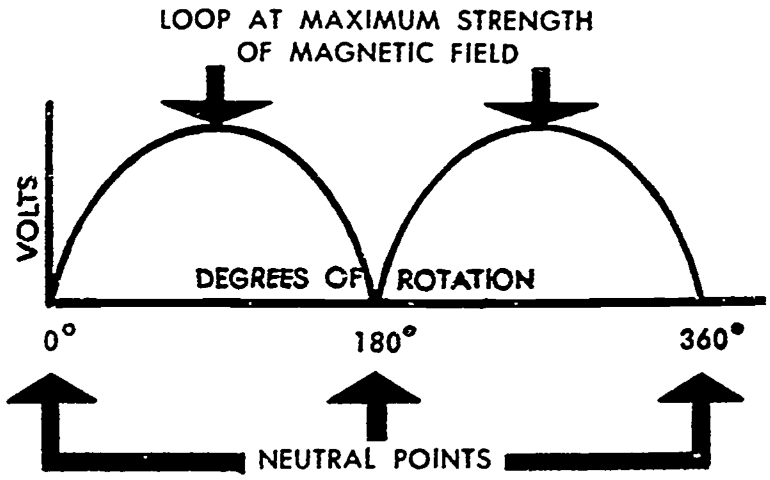


Fig. 5 Magnetic field and neutral points

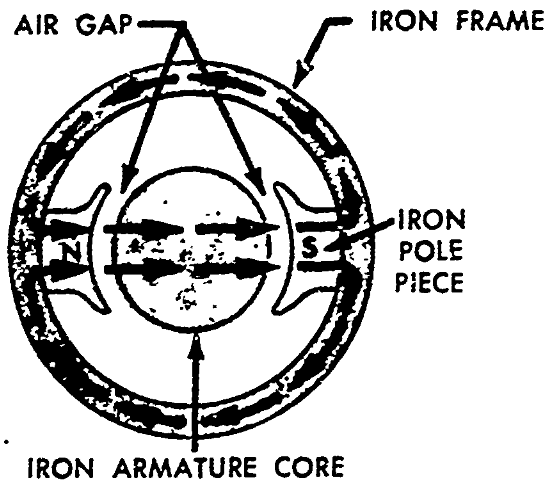


Fig. 6 Magnetic circuit

magnetic circuit act as high resistance and cut down the strength and effectiveness of the magnetic field.

For a more realistic picture of an actual generator, see Figure 7. Here is a more complete armature containing additional loops of wire embedded in the slots of an iron core. Note also that the loops are connected together at the commutator. Any voltage developed in one loop is added to the voltage developed in the other loops since they are connected in series. Voltage is increased by adding conductors to the armature. When more conductors and more commutator bars are used, the voltage waves overlap producing an almost constant value of DC voltage at a given speed and load.

Thus, the three basic fundamentals for developing current and voltage have been discussed. The strength of the magnetic field, the number of conductors on the armature, and the speed of the armature are the interrelated ingredients necessary to obtain electrical power from a generator.

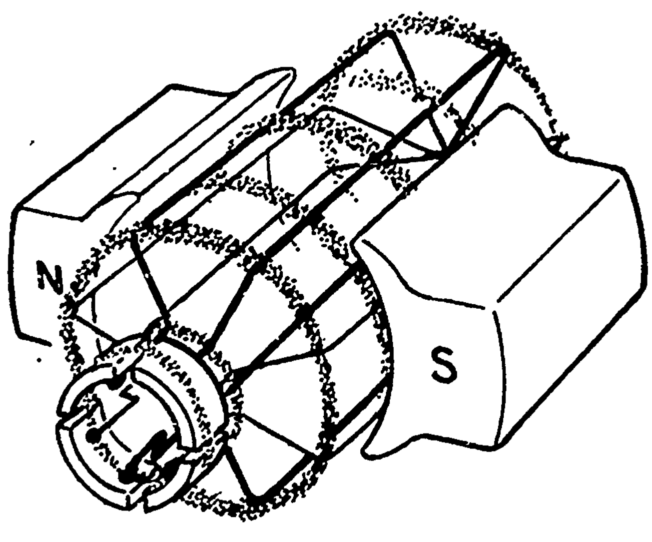


Fig. 7 Armature windings

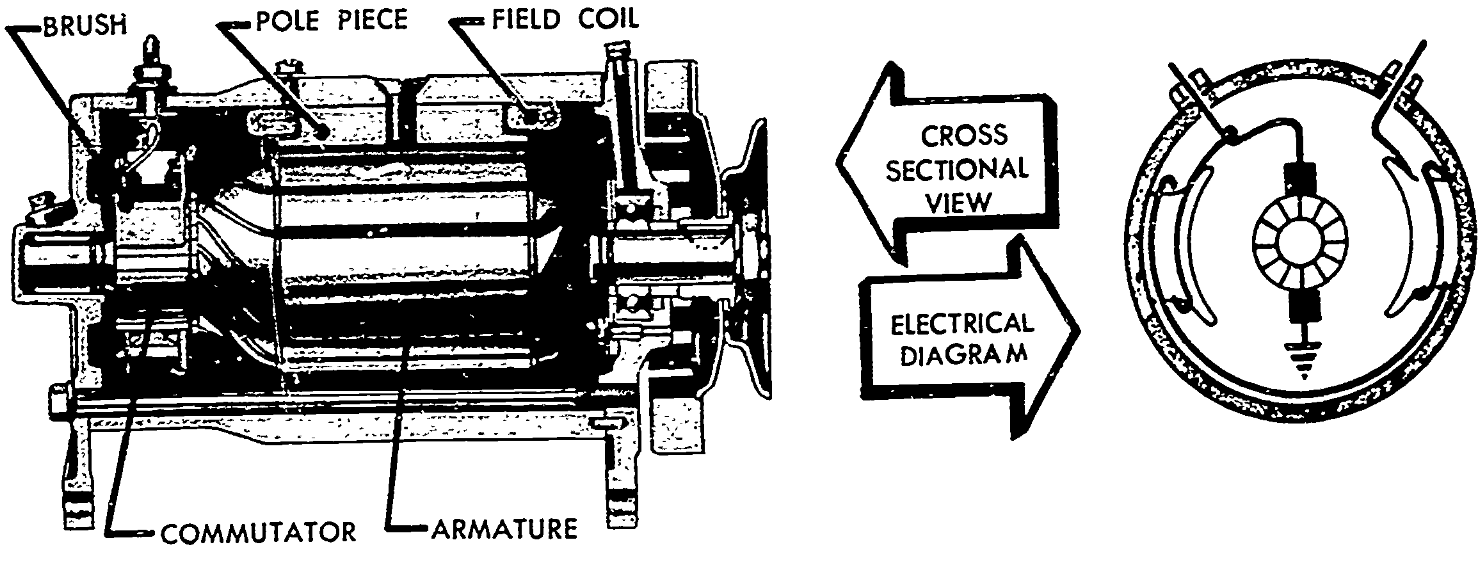


Fig. 8 Generator cross sectional view and diagram

SECTION C -- POWER AND RATINGS OF A GENERATOR

The physical strength of a generator must be great enough to withstand the electrical power it is designed to produce. Electrical power is the mathematical product of volts and amperes expressed in watts.

$$P = E \times I$$

where: P is watts or watt hours
E is voltage or electrical pressure
I is current or intensity of current flow

P = E x I

watts voltage current

Fig. 9 Power ratings (formula)

Voltage or electrical pressure induced in the coils of the armature causes current to flow through the field coils and load circuits. The voltage developed within the generator will climb to any value necessary to overcome the resistance in the attached circuits, providing the speed of armature rotation is sufficient. If the total resistance of the attached circuits is low, generator voltage will be low; if the attached circuits' total resistance is high, generator voltage will be high.

Since the field coils in the generator and many of the external loads can be damaged by excessively high voltage, some method of voltage control is necessary. To safeguard these components, an external unit called the voltage regulator is employed to limit the voltage developed in the generator. The voltage rating of the generator denotes the system voltage in which it is used. The generator is designed to withstand this voltage for any length of time under normal vehicle operating conditions.

Current flow is the result of the voltage developed in the armature coils.

The amount of current flow in the armature and in the attached circuits depends upon the voltage developed and the resistance in these circuits. If the total resistance of the attached circuits is high, generator voltage will be as high as the voltage regulator setting permits and current flow will be low. If the attached circuits' total resistance is extremely low, the current flow will be extremely high, providing the generator speed is sufficient.

Armature overheating can result from high current flow. Excessive heat can damage the insulation and the varnish used to bind the conductors in the armature slots. The soldered connections of the armature coils and commutator bars can also be melted by excessive heat. Consequently, open, grounded and short circuits could occur within the generator due to the heat caused principally by too high a current flow.

To prevent this condition, an external unit called a current regulator is employed to limit the amount of current flow in the generator. The current rating of the generator denotes the amount of current the generator can supply continuously without damage to its structure, under normal operating conditions.

Another source of heat, called iron loss, is present in the armature of all generators. The iron core of the armature acts as one large conductor which cuts magnetic lines of force as it revolves, generating voltage within the core itself. This action results in current flow called eddy currents. These currents produce heat, which is added to the heat developed by current flow in the conductors. To reduce the effects of eddy currents as much as possible, the iron core of the armature is laminated. The thin laminated sections prevent large voltages from developing, and the eddy currents are kept small. Therefore, less heat is developed in the armature. See Figure 10.

The heat produced during the operation of many generators is carried away by forcing air through the generator. This permits greater output without overheating the unit. Force ventilated generators carry a higher current rating than non-ventilated units of the same size. Air can be forced through a generator by placing a fan on the generator drive pulley, by passing the engine intake air through the generator, and by cooling with pressurized air through a blast tube. See Figure 11.

In summary, the power output or wattage of the generator is the product of its rated current times its regulated voltage. Heat is an enemy of all electrical equipment and must be taken into account when designing generators. The output of the generator must not be allowed to exceed its specified rating, otherwise damage to it or the electrical system will result.

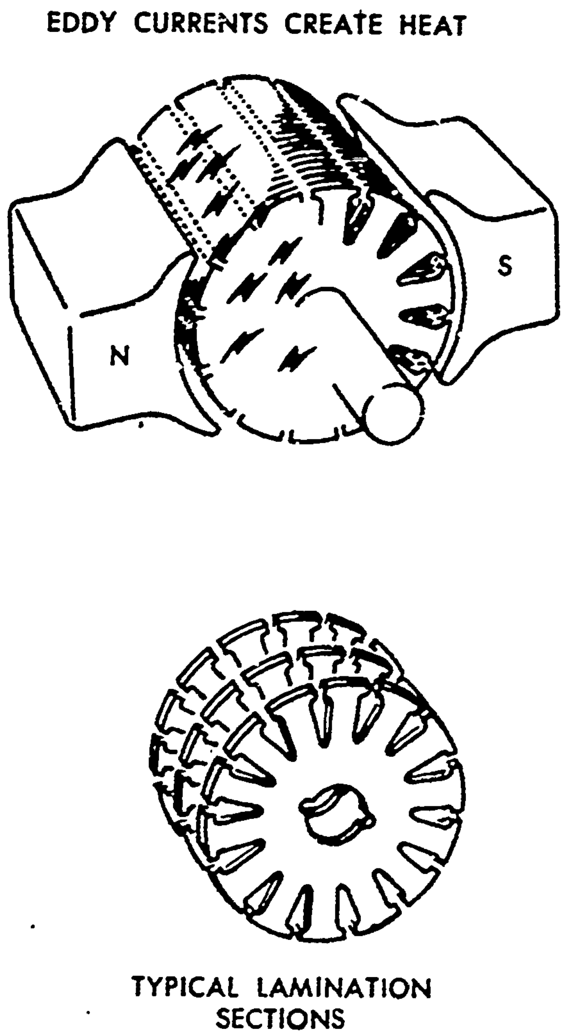


Fig. 10 Eddy currents and armature laminations

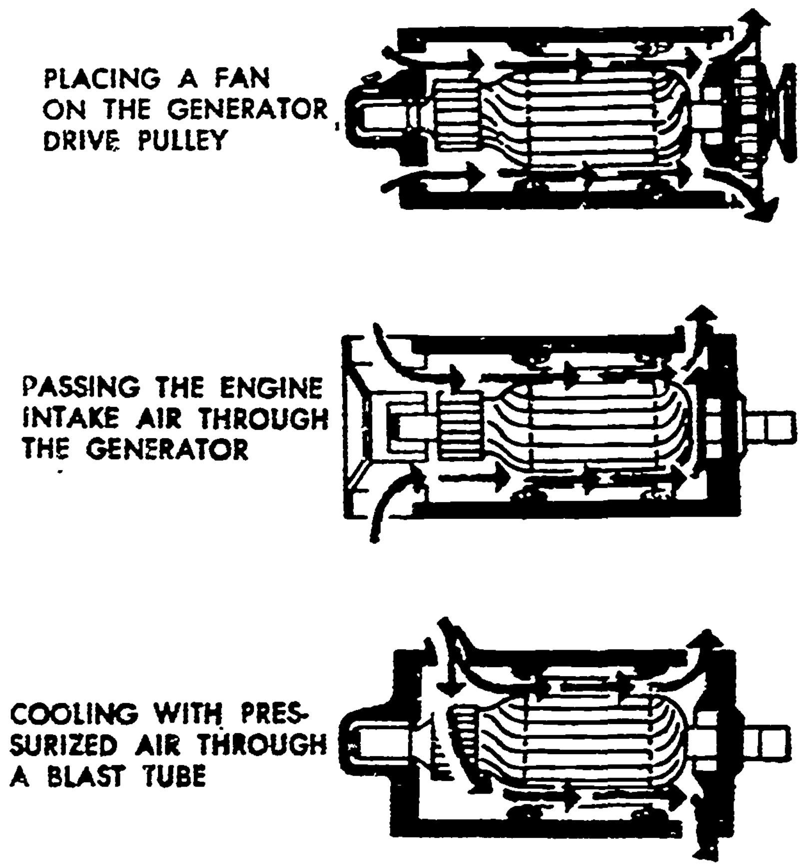


Fig. 11 Cooling generators

SECTION D -- ARMATURE REACTION

Armature reaction has an effect on brush location and neutral point. In explaining generation of electrical power, Figures 4 and 5 illustrated a conductor in the form of a loop rotating through a magnetic field, cutting lines of force. As the loop rotated, it arrived at a point where each side was traveling parallel with the magnetic lines of force for an instant, before cutting back across them in the opposite direction. This position was called the neutral point. At this point, no voltage was created, and there was no current flow in the loop, as indicated in Figure 12.

Direct current is obtained by switching the connections of the conductors with a commutator and brushes during the time the conductor is between the poles. This region is known as the commutating zone, and lies at the neutral point; see Figure 13 (a).

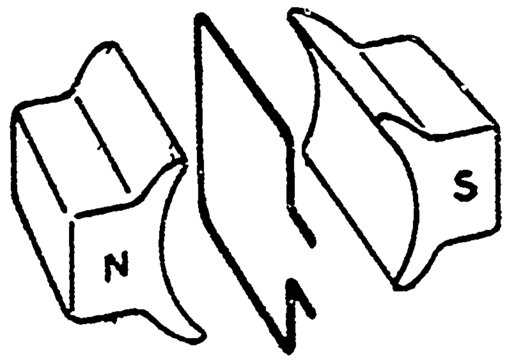


Fig. 12 Neutral position

In an armature wound for a two pole generator, there are two neutral points, one located approximately half way between each of the poles. All the armature conductors on one side of the neutral point have voltage generated in the same direction, whereas all the conductors on the opposite side have voltage generated in the opposite direction. Generators with more than two poles have one neutral point for each pole. As an example, for a four pole generator, there are four neutral points, one between each two adjacent poles. See Figure 13 (b).

In the previous discussion it has been assumed that the magnetic field between the poles was made up of straight lines.

Figure 13 (c) shows not only this magnetic path, but also the position of the brushes relative to the armature loop in that field. If, by some manner, the magnetic field between the poles were to become shifted, a change in the neutral position would result. With a change in the neutral position, a new location for the brushes becomes necessary. Otherwise, the armature loop being commutated would be generating voltage, and a high current would be short circuited between the commutator bars and the brush. This would display itself in the form of an arc, causing burning and rapid wear of the brush.

Therefore, a new location of the brushes makes it possible for commutation with neither voltage nor current present in the loop. See Figure 13 (d). Such a distortion of the magnetic field as shown actually exists. This distortion is caused by the magnetic field set up around the armature conductors acting with the magnetic field of the poles. It is called armature reaction. Figure 14 shows the normal magnetic field between the poles.

Figure 15 (a) shows the magnetic field surrounding the coils of the armature that results when current flow is established in the coils. It must be remembered that all the load current flows through the conductors of the armature, and the greater the current flow the greater will be the strength of the surrounding magnetic field.

The magnetic field formed after combining the magnetic field of the armature and the field of the pole pieces is shown in Figure 15 (b). The change in the magnetic field changes the neutral position and necessitates a change in brush location to insure maximum brush life and smooth commutation as described above.

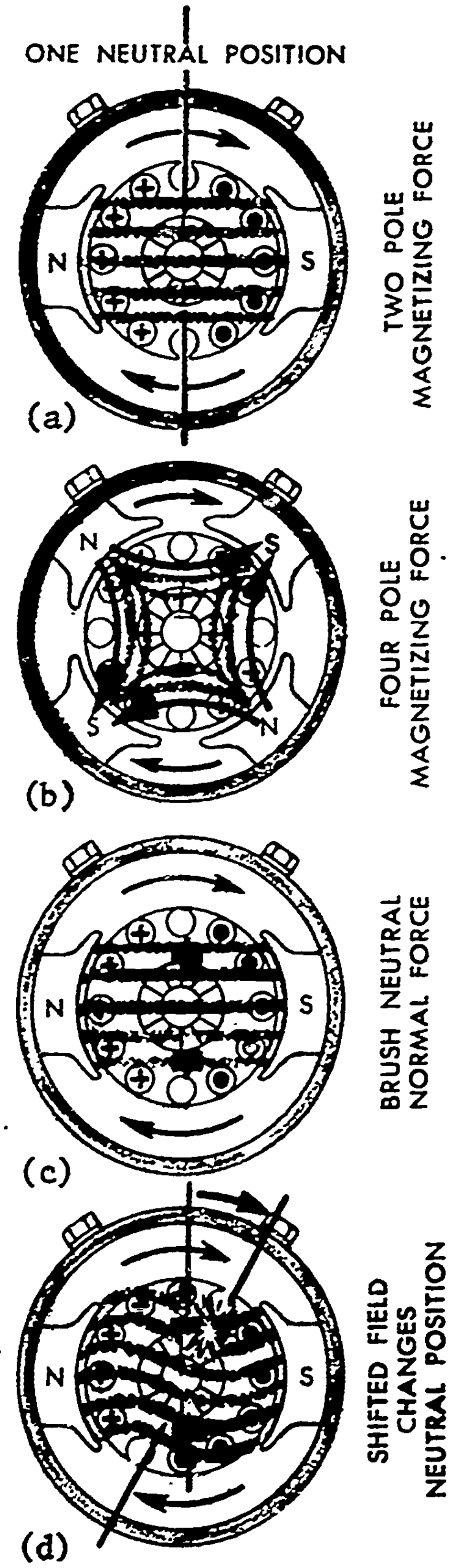


Fig. 13 Magnetic force

All conductors in the armature are connected in series through the commutator so that load current flows through all of them. To obtain best commutation, it is necessary to locate the brushes at the load neutral rather than at

Fig. 14 Magnetic lines of force

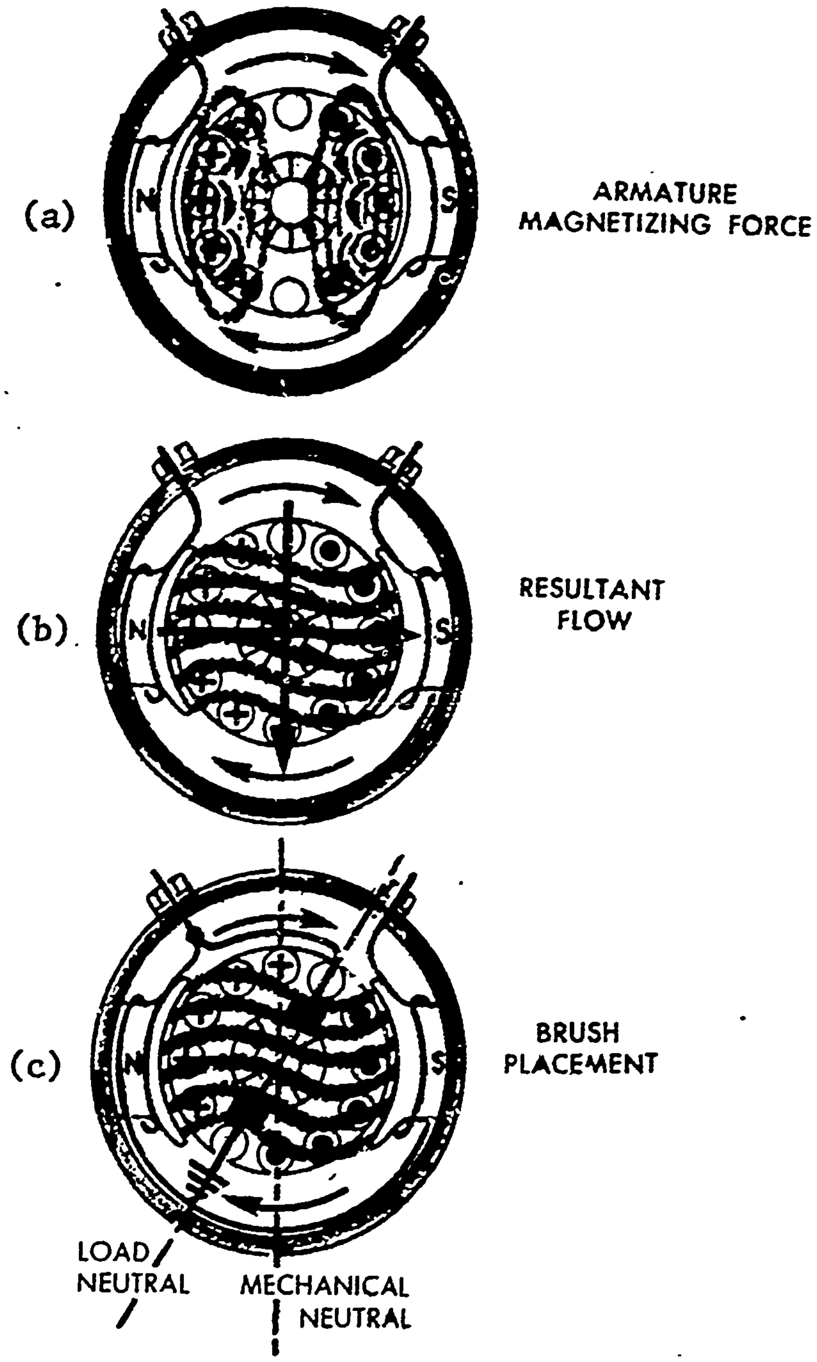


Fig. 15 Magnetic field and brush position

the mechanical neutral. The load neutral is located ahead of the mechanical neutral in the direction of rotation as shown in Figure 15 (c).

At a constant speed and load there is an ideal commutating point. However, with varying speeds and loads, as encountered with automotive type generators, the ideal commutating point is constantly changing. For this reason, a brush position is selected which will be the best average location that will create the least arcing at the brush under the most usual conditions of operation.

SECTION E -- WHAT IS POLARITY ?

Polarity is the direction of current flow from the generator to the external circuits. As can be seen in Figure 16, the direction of current flow in the conductors depends upon the polarity of the poles. If the polarity of the pole shoes is reversed, all other conditions remaining the same, the direction of current in the conductors also is reversed. Therefore, a generator is capable of supplying current in either direction, depending upon the polarity of the poles.

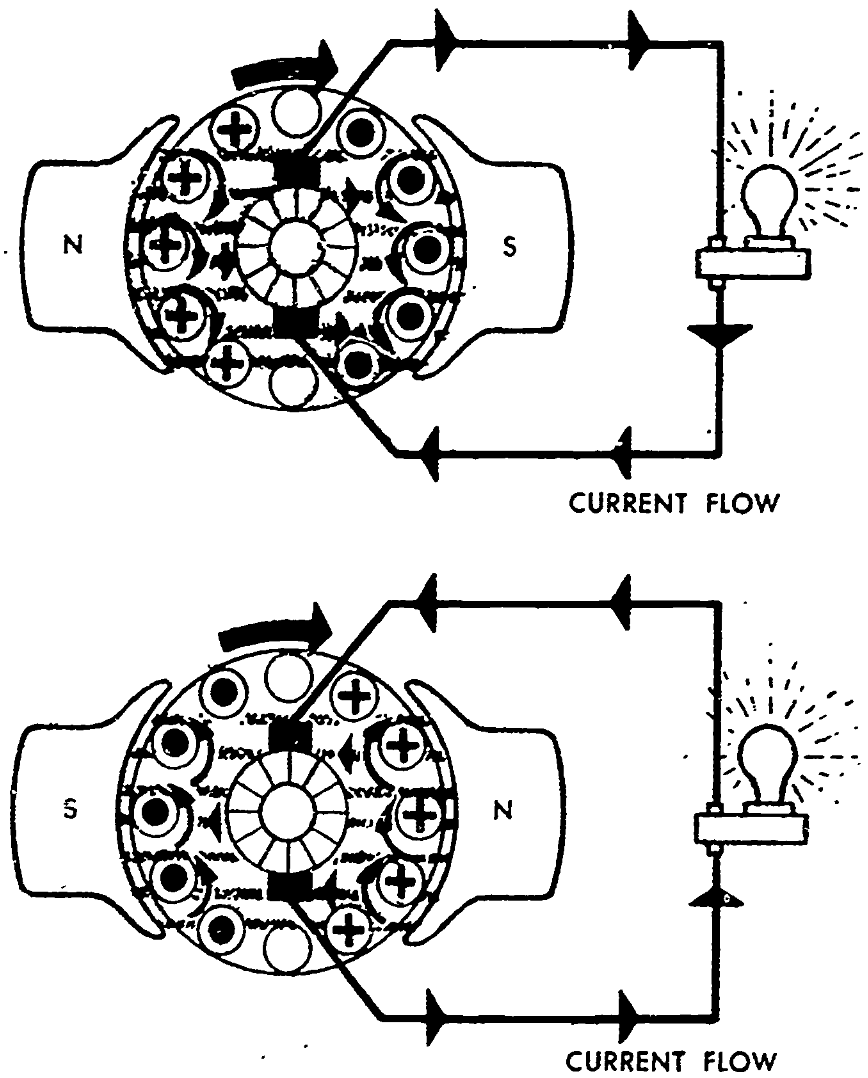


Fig. 16 Generator polarity

SECTION F -- TWO GENERATOR CIRCUITS

"A" CIRCUITS AND "B" CIRCUITS-- As has been pointed out in the discussion of power and ratings of generators, the output of a generator must be controlled. Voltage control is needed to protect not only the generator, but also the electrical system of the vehicle. Without voltage control, light bulbs, external wiring, relay coils, contact points and all other electrical components of the vehicle would be endangered by the high voltage, resulting in short life or damaged accessories. Even the battery would be subjected to too high voltage and an excessive overcharge and short life would result.

The three basic fundamentals that determine a generator's output are the speed of armature rotation, the number of armature conductors and the strength of the magnetic field. Any one of these basic fundamentals could be used to control the generator voltage and current. However, the simplest method controls the strength of the magnetic field. to limit the voltage and current output of the generator.

The voltage regulator and current regulator are units in the external circuit used to sense either high voltage supplied to the electrical system or high current supplied to the external loads. These two units automatically decrease the current flow in the field coils. This, in turn, decreases the magnetic strength of the generator and limits its ability to continue generating high voltage or voltage sufficient to cause high current flow. Generator control, therefore, is the function of the generator regulator. Its method of controlling the generator output is by adjusting the strength of the generator's magnetic field. The amount of generator field coil current is adjusted automatically by the regulator to meet all conditions of speed and load.

The simplified illustration in Figure 17 shows the various factors involved in voltage regulation and the manner in which it is done.

Full generator voltage lies between the two brushes. Any circuit connected between these brushes will have full generator voltage impressed upon it. The flow of current in any circuit connected in this manner will depend, therefore, on the generator voltage and the amount of resistance in the circuit.

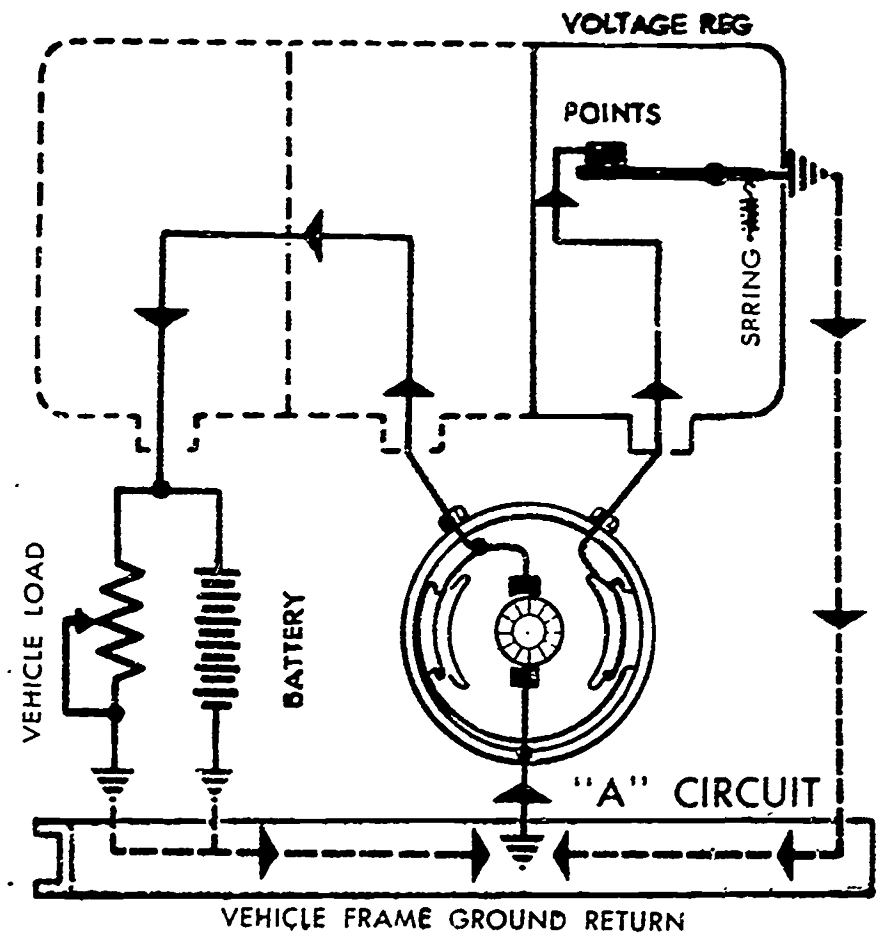


Fig. 17 "A" circuit generator

The field circuit in the generator is shown connected across the generator brushes. The ground symbol indicates that the ground brush and the field coils are connected together through a common conductor, usually the vehicle frame. Since the field coils are connected between the generator brushes, full generator voltage will cause current to flow from the insulated brush of the generator, through the field coils, through a set of contact points located in the voltage regulator, through the ground conductor, and back to the ground brush of the generator.

The load circuit of the generator can be traced from the insulated brush to the battery and load resistance, through the battery and load resistance to ground, through the ground conductor, and back to the ground brush of the generator.

As stated previously, if the resistance in the load circuit is high, the generator will build up a high voltage to overcome it. High generator voltage causes high current to flow in the field circuit. This intensifies the magnetic field between the poles. Additional voltage is developed within the armature windings which is commutated to the field coils for even more field current. When this happens the danger of high voltage becomes evident.

As seen in Figure 18, a set of contact points is placed in series with the field coil circuit and all the field coil current passes through them. If these points were to open (as indicated), current would no longer pass through the points but travel through a resistance to ground and then through the ground conductor back to the ground brush of the generator. Inserting resistance in series with the field coil greatly decreases the field coil current, thereby decreasing the magnetic strength between the poles and the voltage developed in the generator.

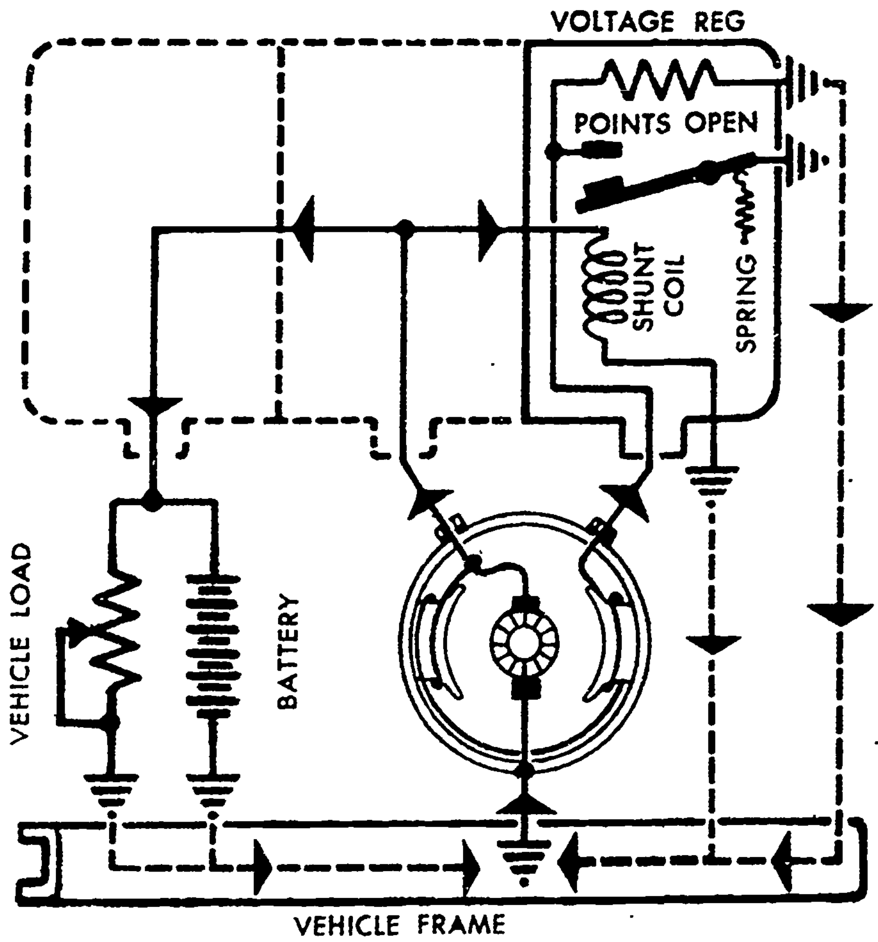


Fig. 18 Field control circuit

A shunt coil is also connected across the generator brushes. Generator voltage will cause current to flow through the winding of this coil. The coil, which carries current, has a magnetic field surrounding it which attracts the armature to which the lower contact point is attached. When generator voltage becomes sufficiently high, the spring pressure holding the points closed will be overcome by the attraction of the magnetic field surrounding the coil and the points will open. The greater the generator voltage, the greater the current flow will be through this coil and the stronger its magnetic pull.

The shunt coil is the sensing unit that operates a set of contact points to reduce the generator voltage and prevent high system voltage. When the generator voltage drops as the result of inserting resistance in the circuit, the magnetic pull of the shunt coil weakens, and spring tension closes the points, allowing the generator voltage to build up again until it is sufficiently high to open the points. Due to the rapid opening and closing of the regulator contact points, they are said to vibrate. Generator voltage is at its peak when the points are closed and at a minimum when the points are open. The vibration action of the contact points is so rapid that a voltmeter will register only the average voltage developed.

Figure 19 shows the various factors involved in current regulation and the manner in which it is done. This diagram shows the same field and load circuits as described in the discussion on voltage regulation. It should be remembered that when there is low resistance in the load circuit, voltage will not climb to a high value, although the current will increase. Therefore, current control must be provided for.

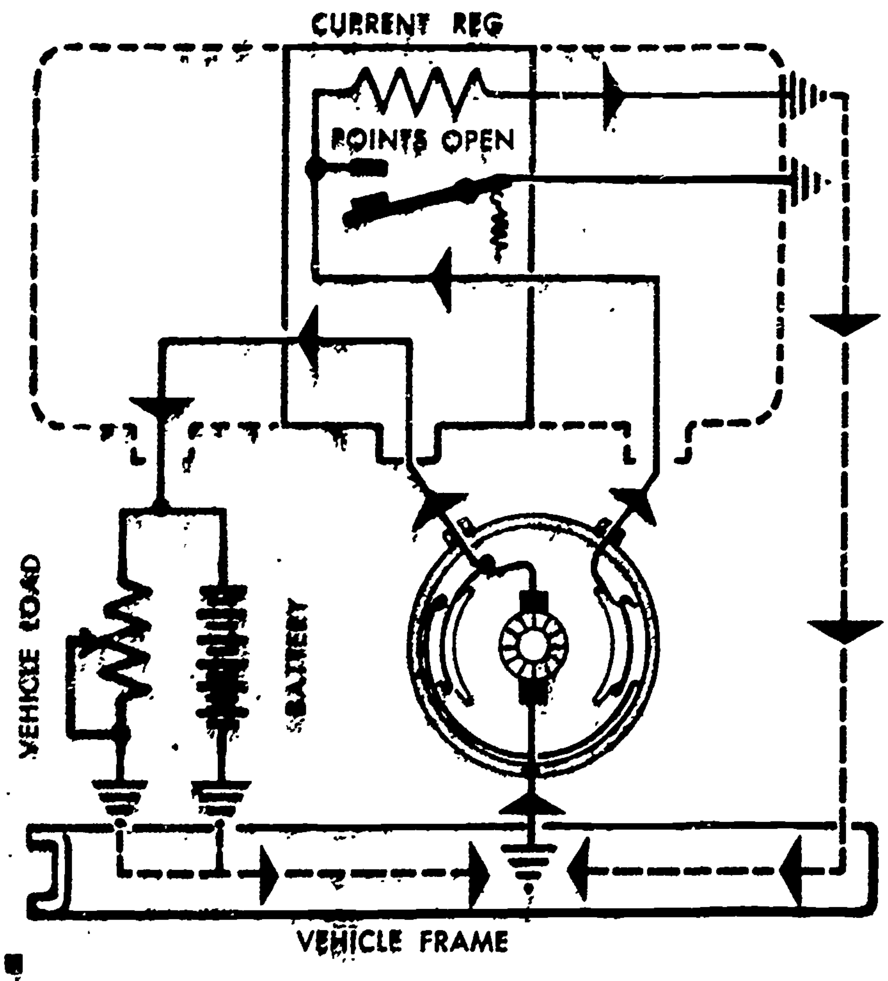


Fig. 19 Current control circuit

Since the current flow in any circuit depends upon the voltage or pressure causing it to flow, any reduction in voltage will result in a reduction in current. As seen in the diagram, a set of contact points is placed in series with the field coil circuit and all field coil current passes through it. If these points were to open, (as shown), current would no longer pass through them but would, instead, travel through a resistance to ground and then through the ground conductor back to the ground brush of the generator. Inserting this resistance in series with the field coil not only greatly decreases the amount of field coil current but also decreases the magnetic strength between the poles and decreases the voltage developed in the generator. The decrease of voltage, therefore, decreases the amount of current flow to the load circuit.

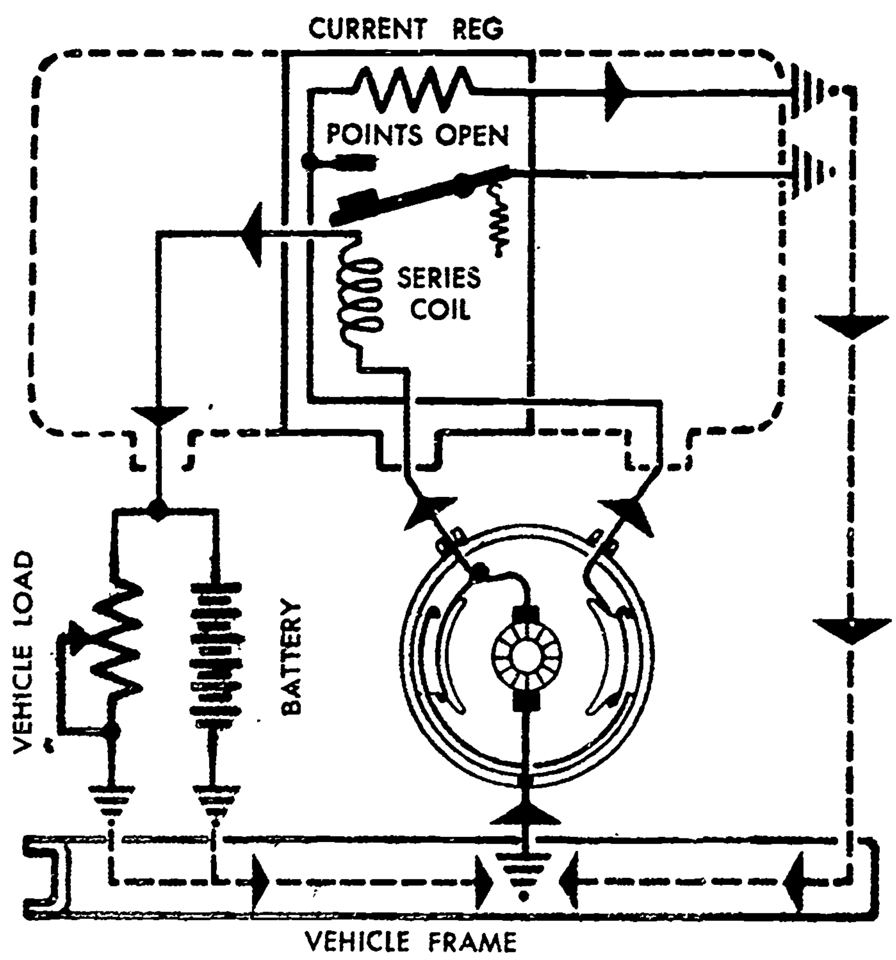


Fig. 20 Load circuit and series coil

Figure 20 illustrates a coil placed in series with the load circuit, permitting all the load current to pass through it. A magnetic field is developed surrounding it, which attracts the armature to which the lower point is attached. When current of sufficient magnitude passes through the circuit, the spring pressure is overcome by the attraction of the magnetic field surrounding the coil, and the points open. Opening of the points places the resistance in series with the field coils, and generator voltage is decreased.

This decrease in generator voltage will not force as much current to flow. Thus, current control is obtained. The series coil may be called the sensing unit that operates a set of points to reduce generator voltage and current and prevent high current that endangers the life of the generator. When resistance is inserted in the circuit, the load current drops. The magnetic pull from the series coil becomes less than the pull of the spring,

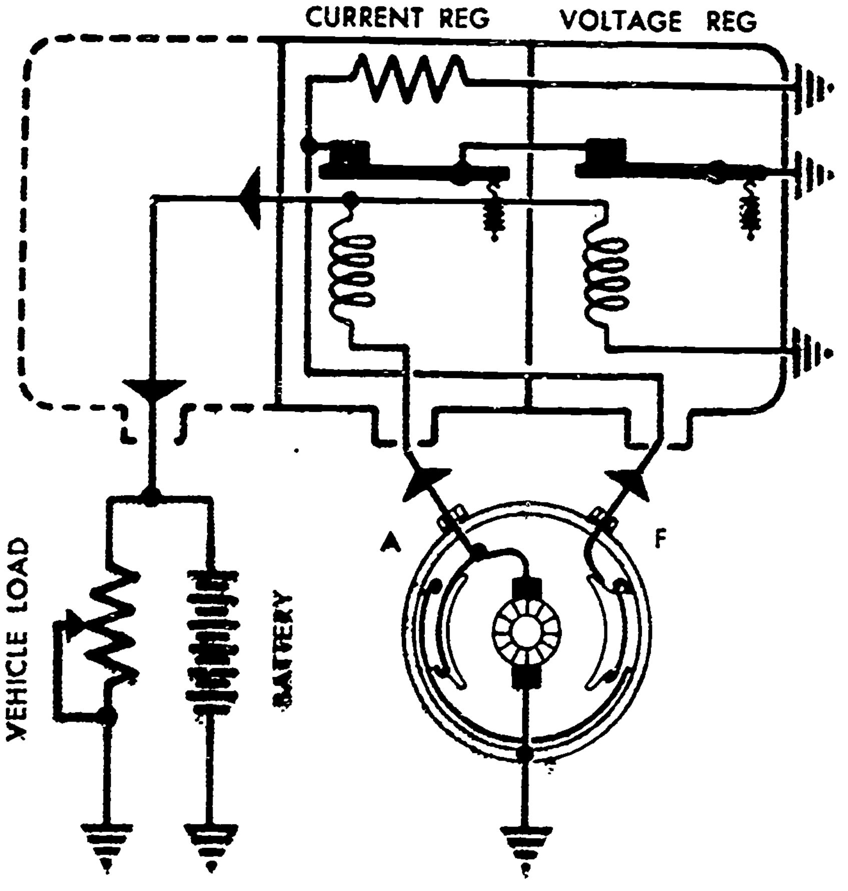


Fig. 21 "A" circuit generator

and the points close. This allows the generator voltage to again build up until sufficiently high current is forced through the series coil to open the points.

A simplified circuit employing both current and voltage regulators is illustrated in Figure 21. The resistance in the load circuit determines which regulating unit will operate, providing the generator is at sufficient speed. If the load resistance is large, as would be encountered with all electrical appliances turned off and with a battery fully charged, the generator voltage will be high, and only the voltage regulator will operate. If load resistance is low, as would be encountered when many of the appliances are turned on and with a battery low in charge, the generator voltage will be low. Under these conditions, high current will flow and the current regulator will operate. Either the voltage unit or the current unit will operate, never both at the same time.

Thus far the discussion concerns the location of the regulator points, which are a part of the field circuit, and are located after the field coils. The field circuit, grounded outside the generator at the generator regulator, is attached to the insulated brush inside the generator. This type of a field hook-up is called an "A" type circuit. See Figure 21.

Another method of connecting the regulator points into the field circuit is accomplished by placing the points before the field coils. This is called a "B" type circuit. Regulating the current and voltage is accomplished in exactly the same manner as for the "A" circuit. The only difference between the two circuits is in the connections of the field coils. The field circuit in the "B" type hook-up is attached to the insulated brush outside the generator through the generator regulator and is grounded inside the generator ground brush. See Figure 22.

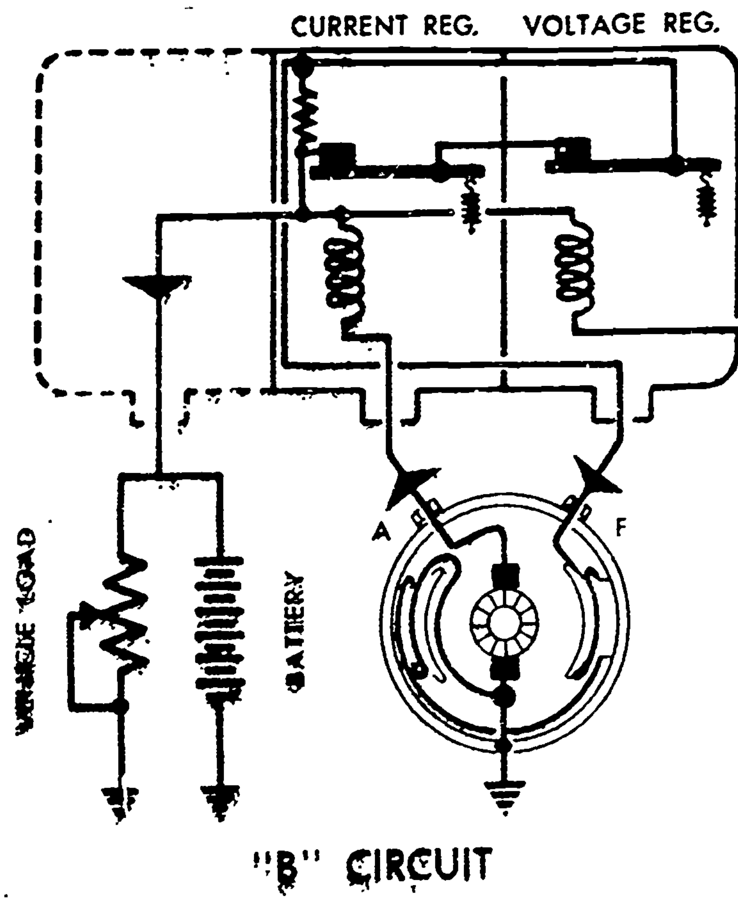


Fig. 22 "B" circuit generator

A simple way of stating the difference is; An "A" circuit has externally grounded field coils and a "B" circuit has internally grounded field coils; one is grounded at the regulator and the other at the generator. A simple illustration is shown in Figure 23.

There is no particular advantage to using one circuit or the other. Both circuits do exactly the same job. The output of any given generator connected either way will be the same. The designer and engineer, however, should decide which circuit they plan to use and then design the regulator and generator to correspond.

Since the two systems require different procedures for checking, and adjusting, it is necessary to first determine which type unit is being checked. This may be done by inspecting the connections at the brushes and fields. If the generator field coil lead is connected to the insulated brush inside the generator, the generator is an "A" type circuit. If the generator field coil lead is connected to the grounded brush inside the generator or to the generator frame, the generator is a "B" type circuit.

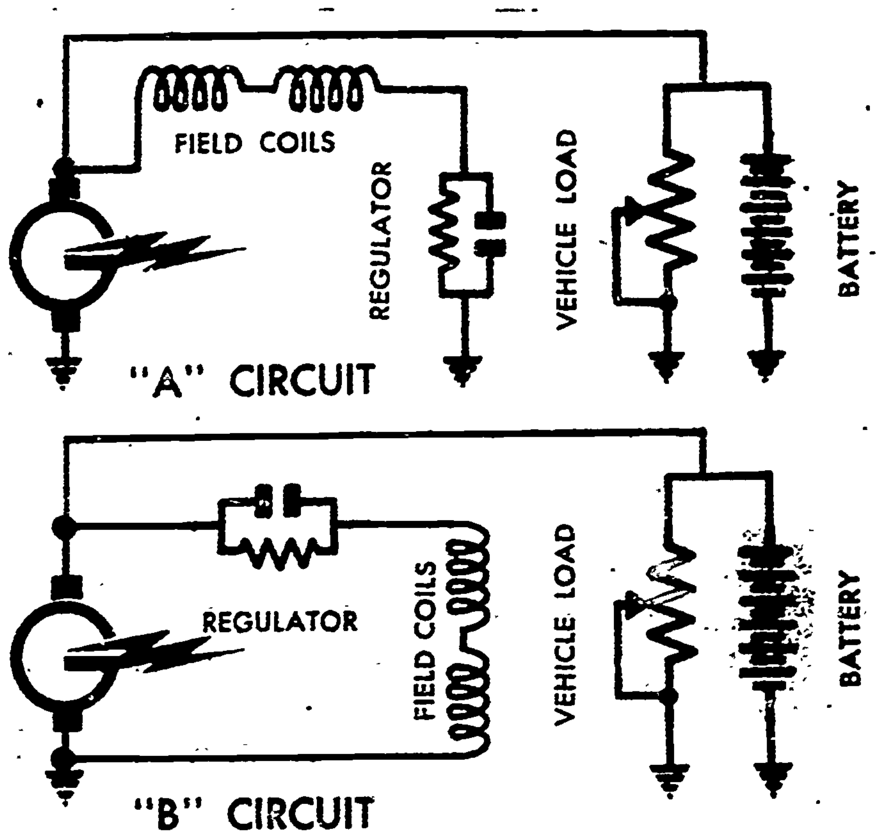


Fig. 23 "A" and "B" circuit generators

Sometimes a wire is used for a return circuit in place of the vehicle frame. This is called an insulated circuit. Generators connected in this manner may have either an "A" or "B" circuit. Care must be taken that the connections are properly made for the regulator used with the generator.

SECTION G -- APPLICATION OF GENERATORS TO THE JOB

The normal electrical load on a vehicle determines the capacity of the generator to be used. A satisfactory application requires that a generator be used which can produce 10 to 20 percent more output than is required by the total connected load. This additional output is required to replace the electrical energy used from the battery when the generator is not at operating speed. Momentary electrical loads, such as the cranking motor, are not considered in determining the total load.

Extremely dirty, dusty, muddy or wet operating conditions often make it necessary that the generator be totally enclosed, to prevent entry of foreign material. Total enclosure does not allow ventilation through the generator; consequently the build-up of internal heat is high. The output of an enclosed generator, therefore, must be less than a ventilated unit of the same size.

The ambient or surrounding temperature in which a generator must operate may also be an important factor in generator design. High temperature surrounding the generator adds to the heat developed by current passing through the armature conductors and by eddy currents. The generator must be designed to withstand the total heat of operation. The length of service that is to be expected of the generator also must be a part of the generator design. Ease of replacement of parts is another factor in the design of such units.

The speed at which the armature turns is a very critical factor in generator design and application. The drive ratio of an automotive generator (generator speed with reference to engine speed) may vary from 2 to 1, to as high as 3 to 1.

Illustrated in Figure 24 is the load circuit only. If the connections between the generator and the battery were joined as shown and the generator voltage is lower than battery voltage, the battery would discharge through the generator to ground and back to the battery. Due to low resistance in such a circuit, high discharge current would produce rapid deterioration inside the generator in the form of burned insulation and wiring. This would also result in a discharged battery.

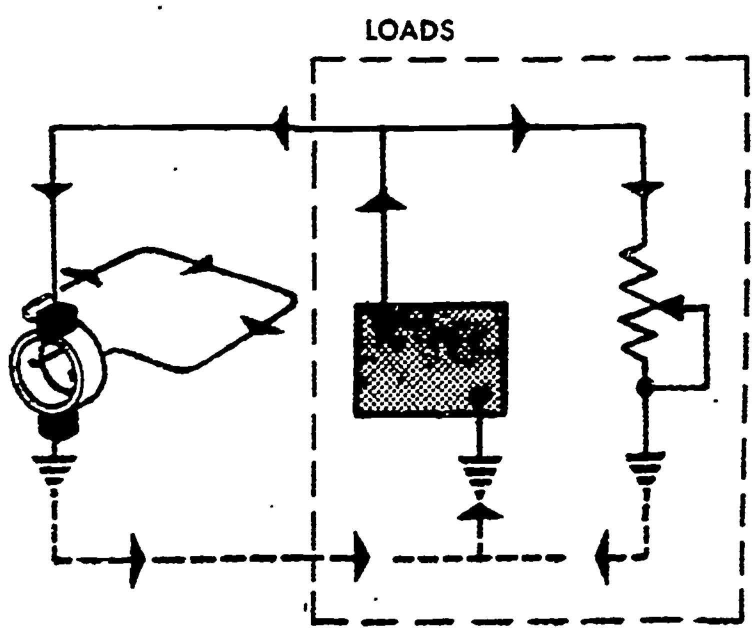


Fig. 24 Load circuit only

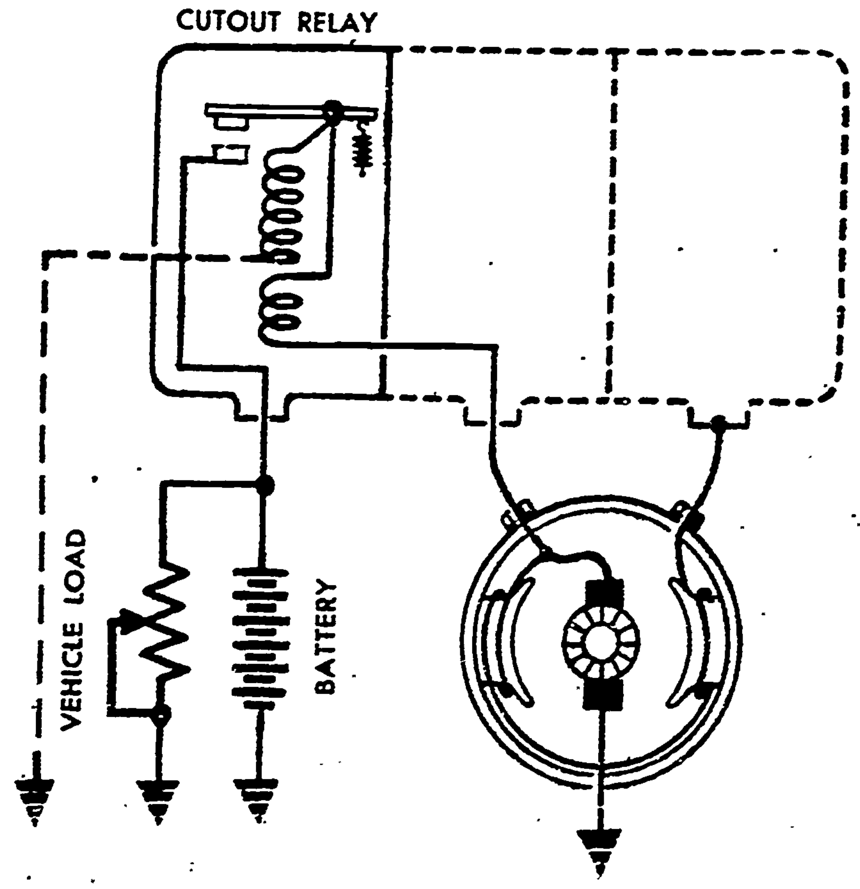


Fig. 25 Load circuit and cut-out relay

Figure 25 shows how the load circuit is broken by an electrical switch to prevent the battery discharge. The normal position of the switch, called the cut-out relay, is shown. It functions to close the circuit between the generator and battery when the generator has developed sufficient voltage to overcome battery voltage. The cut-out relay also functions to open the circuit between the battery and the generator when the battery voltage is greater than generator voltage. This condition exists only when the speed of the armature is not sufficient to develop enough voltage to overcome battery voltage. The engine in an at-rest position with the vehicle parked, the engine at idle speeds, or at low operating speeds, are all conditions where the cut-out relay is open (unless the generator is designed to develop voltage greater than battery voltage under these conditions.)

The contact points of the cut-out relay are closed and opened by magnetic attraction. When the voltage of the generator is great enough to cause current to flow in the operating coils of the relay, a magnetic field of sufficient strength is set up around the coils. This attracts the armature, which overcomes spring tension and closes the points and allows the generator to supply current to the load circuit.

Adjustment of spring pressure on the armature of the relay must be such that the generator voltage required to close the points is equal to or slightly greater than battery voltage. The speed at which the generator armature must be turning to develop enough voltage to close the relay points is called the cut-in speed of the generator.

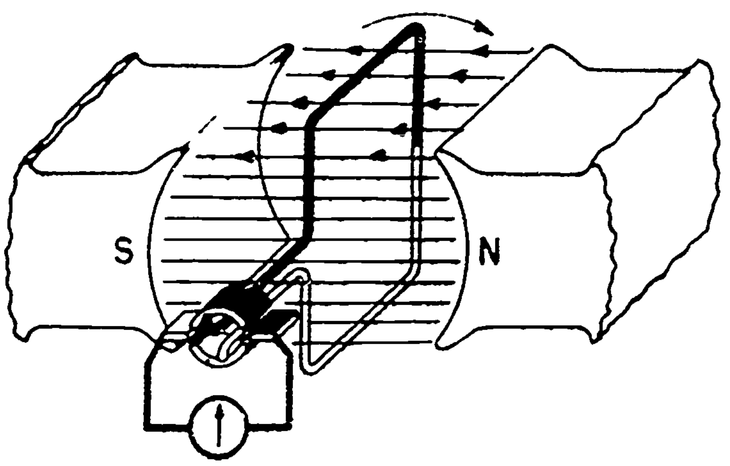
When the voltage of the generator drops, because of a reduction in speed, to a value less than battery voltage, the higher voltage of the battery will force current back through the series coil of the regulator and the generator. Reversing the direction of current in the series coil causes the magnetic field of the relay to weaken, allowing spring tension to open the relay. The generator and battery are then disconnected so that current discharge from the battery will not flow back through the generator and damage it.

It is important that the speed at which the generator cuts in should be at least 100 rpm above or below the engine idle speed. The drive ratio chosen must assure that this condition exists; otherwise, burned out relay points caused by rapid vibration (opening and closing) of the contact points will result. Since no engine idles at a constant speed, it has a certain variance in speed when idling. If the cut-in speed of the generator occurs at the exact speed of idling, the points of the relay will close when idle speed is reached. When the engine speed decreases, the generator speed will also decrease. Insufficient voltage will be developed to hold the relay points closed and the points will open. Thus, the change in generator speed at this critical point will cause the relay to open and close and the points will be burnt from breaking the circuit repeatedly.

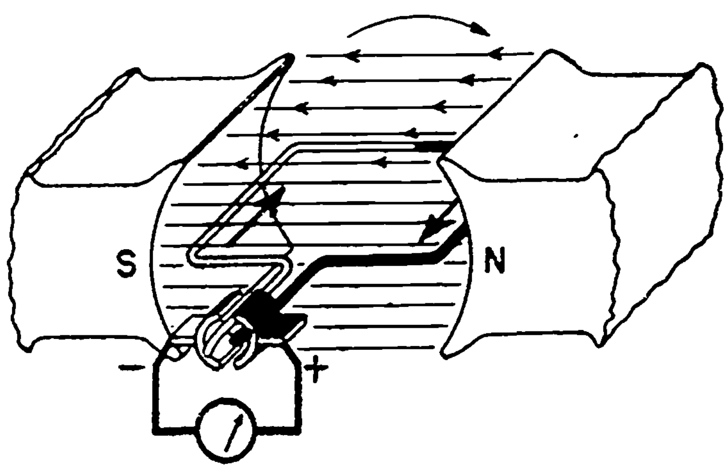
Changing pulleys to speed up the generator, in an attempt to get a charge rate at engine idle, often causes this condition. A smaller drive pulley on the generator may cause trouble by driving the generator so fast at high engine speeds that the regulator cannot control the voltage. A generator driven at excessively high speeds also may develop bearing failure, or the armature windings may be thrown from the core by excessive centrifugal force.

The drive ratio between the pulley and the generator, therefore, is quite critical. Generators must be designed for certain speed and load characteristics. Vehicles operating at slow engine speeds, with high electrical loads, require a generator with low cut-in to keep the battery in a charged condition. Vehicles operating at high engine speeds, and high electrical loads, do not require a low cut-in generator. Vehicles operating normally at low engine speeds, but with periods of high speed operation, require a low cut-in generator capable of withstanding high speeds.

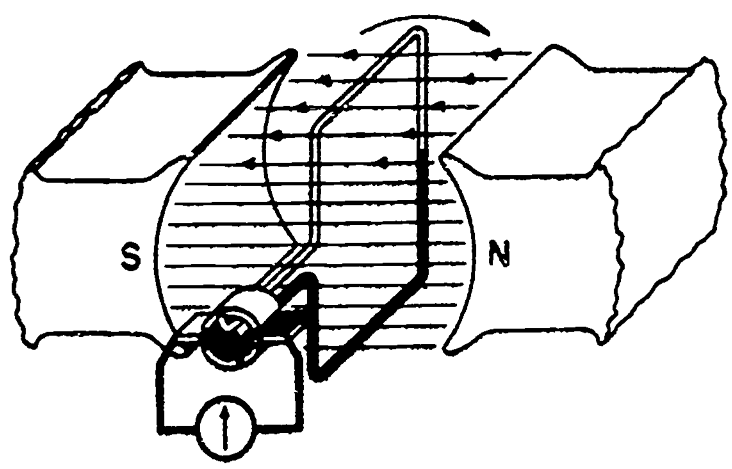
DIDACTOR PLATES FOR AM 2-14D



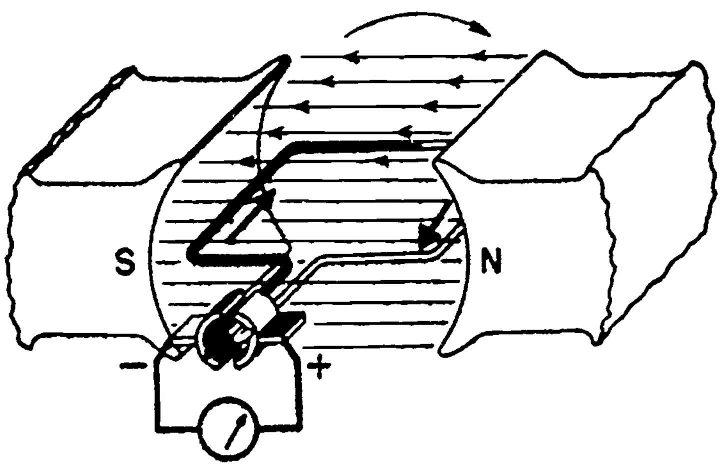
(a) position 1



(b) position 2

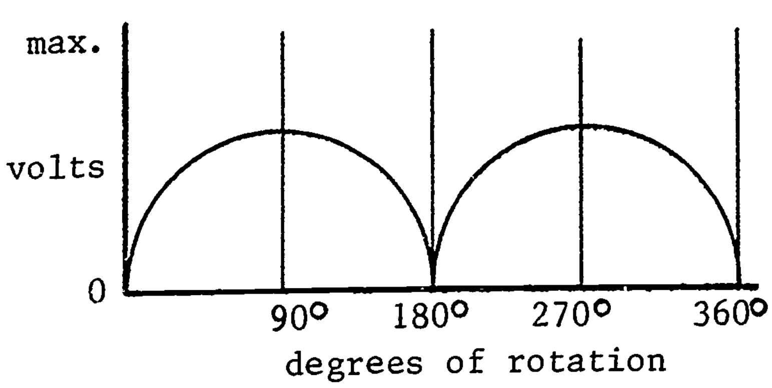


(c) position 3

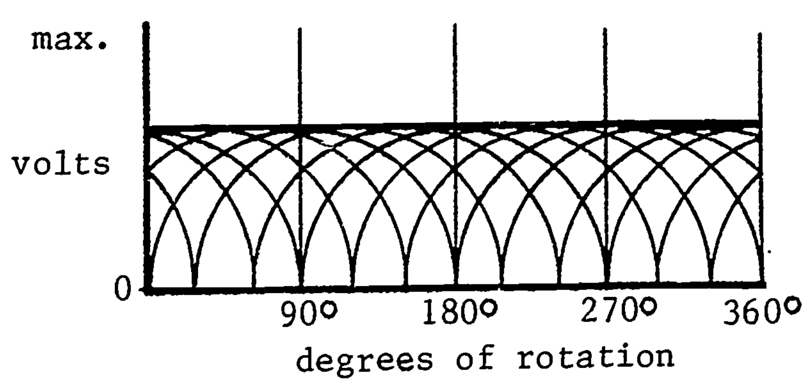


(d) position 4

Plate I

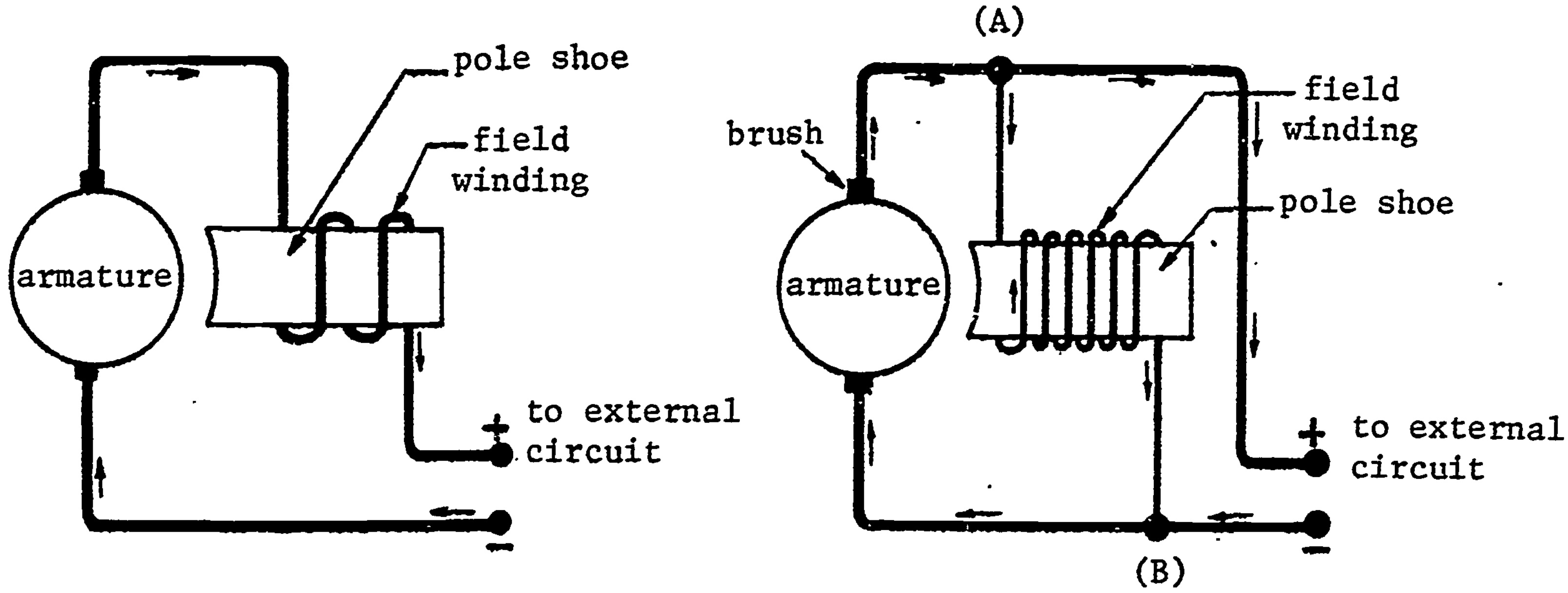


(a) pulsating DC voltage in single armature coil generator



(b) smooth DC voltage in multiple armature coil generator

Plate II



(a) series generator (b) shunt (parallel) generator

(For simplicity only one pole is shown in each diagram. In actual generators, the armature is surrounded by two, four or more pole shoes.)

Plate III

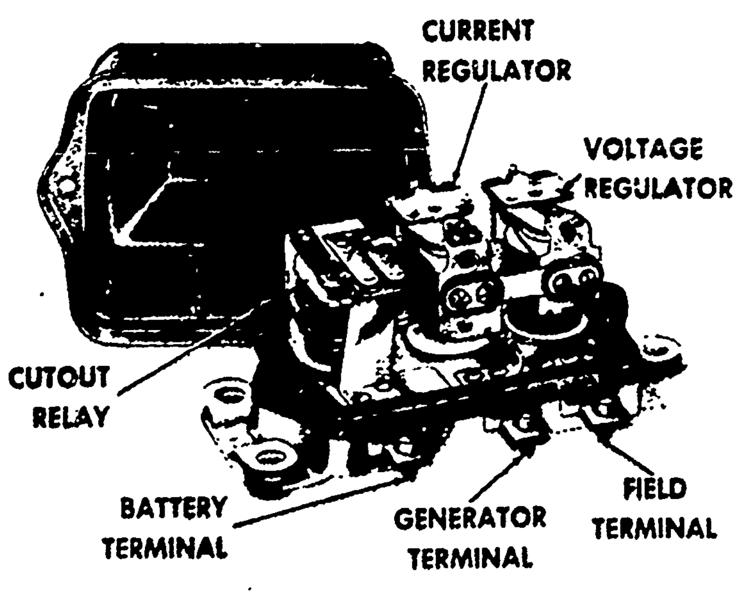


Plate IV Typical three unit "A" circuit type generator regulator

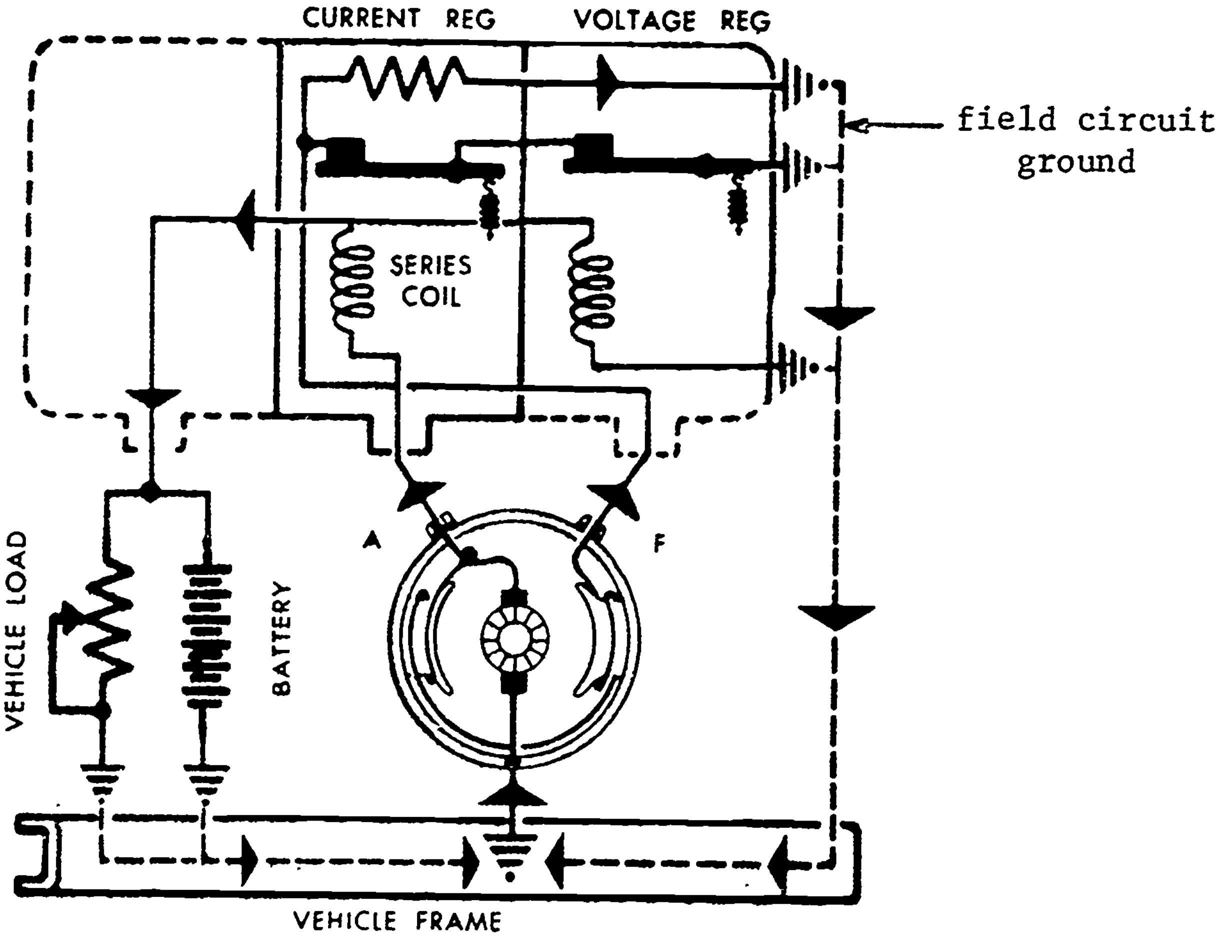


Plate V "A" circuit

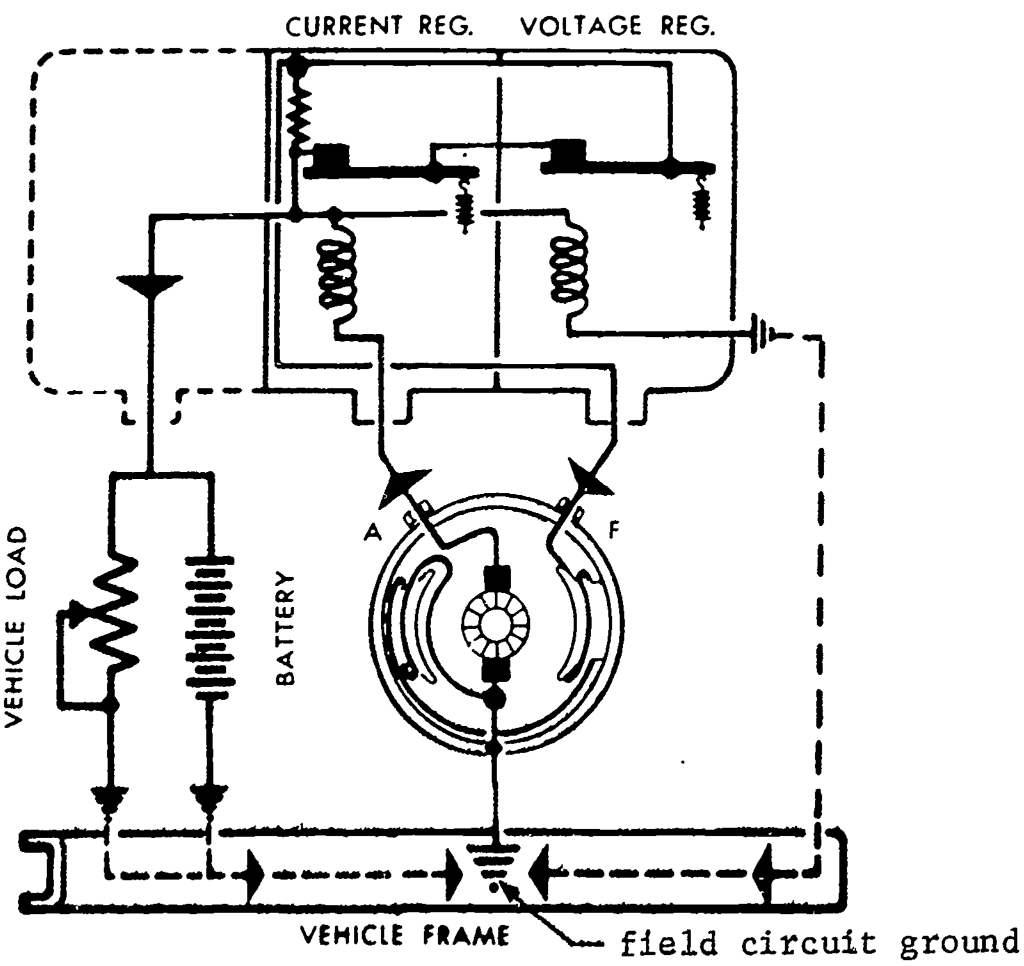


Plate VI "B" circuit

0

AM 2-14D
10/14/67

DC GENERATORS I --

INTRODUCTION TO DC GENERATOR PRINCIPLES

Human Engineering Institute

Minn. State Dept. of Ed. Vocational Education

Press A -1

Check to see that timer and index are OFF

1

This film is the first of two in which we will discuss DC generators. The next film will cover DC generator testing and servicing.

In this film we will discuss basic principles -- how DC generators develop current and voltage, the factors which determine generator output, current and voltage regulation, and generator power and ratings.

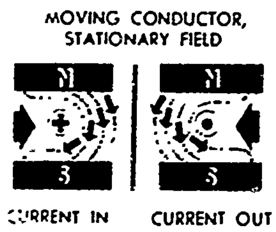
You will also be introduced to "A" circuits and "B" circuits.

Press A -2

1-1

2

Current will be produced in a conductor if the conductor is moved through a stationary magnetic field. This is one of the three ways of producing current by ELECTROMAGNETIC INDUCTION. This fundamental principle is the basis of operation for all DC generators.



Press A -3

1-2

3

If a means is provided for rotating many series-connected conductors through a magnetic field, and if an external circuit is provided, we can put the current that is produced to work. That is what happens in a DC generator.

A DC generator converts ___(1)___ energy into ___(2)___ energy.

A. (1) electrical (2) mechanical -4
B. (1) mechanical (2) chemical -4
C. (1) mechanical (2) electrical -5

1-3

4

Incorrect.

A DC generator converts the MECHANICAL energy of rotation into ELECTRICAL energy, which causes current to flow in the generator armature windings and in the external circuits.

Press A -5

1-4

5

OK. See Plate I.

This series of diagrams shows what happens when a steadily rotating conductor moves through a magnetic field. Let's follow one side of the conductor loop through one complete rotation. Take the blackened side of the loop.

In Plate I (a), the loop is moving roughly parallel to the lines of force and none of them are being cut.

Is a current being produced in Plate I (a)?

A. Yes -6
B. No -7

1-5

6

You are incorrect.

See Plate I (a). In Position 1, the conductor is moving roughly parallel to the lines of force between the pole pieces. Momentarily at least, NO lines of force are being cut. This means that NO CURRENT is being induced in the conductor at this moment.

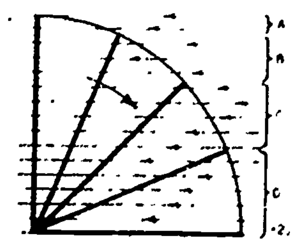
Press A -7

1-6

7

OK.

See Plate I (b). As the loop rotates from Position 1 to Position 2, it cuts through lines of force at an increasing rate. The speed of rotation remains constant, but more lines are cut for each equal time interval.



A, B, C and D in the diagram at left show how many lines are cut during each equal time interval between Position 1 and Position 2. Count them.

Press A -8

1-7

8

(See Plate I (b).)

As the loop moves toward Position 2 at constant speed, the current induced in the conductor ______________.

A. is constant throughout the quarter-rotation —9

B. builds up during the quarter-rotation —10

1-8

9

Your answer is incorrect.

One principle of electromagnetic induction is that the more lines of force that are cut during a given time period, the HIGHER will be the induced current in the conductor.

What happens to the rate at which lines are cut as the loop moves from Position 1 to Position 2?

Press A—8

1-9

10

OK. The current builds up to a peak as the loop approaches Position 2. At that point the lines of force are being cut at the maximum rate for that particular speed of rotation.

If the loop were rotating faster, the induced current at Position 2 would be ______________.

A. higher —12

B. lower —11

1-10

11

No.

Remember that the amount of induced current depends on the RATE at which the lines of force are cut (how many per second, for example).

If the loop were rotating faster, it would cut through more lines of force per second and the induced current would be HIGHER.

Press A —12

1-11

12

OK. The SPEED OF ROTATION is one of the factors that helps to determine the output of an automotive generator.

As the loop continues through its rotation, it again reaches a point of NO induced current. See Plate I (c). Then it moves on to Position 4. See Plate I (d).

In moving from Position 3 to Position 4, the current induced in the conductor moves in the OPPOSITE direction from what it did between Position 1 and Position 2. Thus, an alternating current is produced in the rotating conductor.

Press A —13

1-12

13

In order to be useful in automotive applications the current must be made to flow in ONE DIRECTION ONLY in the external circuits. This is accomplished by a COMMUTATOR.

In the diagrams in Plate I, note that the commutator is a ring split into two parts. One end of the conductor is attached to each half of the commutator.

The current in the external circuit flows from ______________.

A. positive to negative —15

B. negative to positive —14

1-13

14

Incorrect. See Plate I (b) and (d).

Note that in each of these diagrams the current is flowing toward the half of the commutator on the right. (Note the arrows.) That side is the POSITIVE side.

Press A — 15

1-14

15

OK. (See Plate I (b) and (d).)

In each of these figures, current is flowing out through the commutator half that is on the righthand side. (Note the direction of the arrows.) The current is picked up by the positive generator BRUSH and is conducted through the external circuit, back to the lefthand commutator half through the negative generator brush.

The commutator acts as a sort of one way gate for the current flowing from the conductor.

______________ flows in the external circuit.

A. Alternating current —16

B. Direct current — 17

1-15

16

You are incorrect.

The commutator permits the current to flow in ONE DIRECTION ONLY in the external circuit. Current that flows in only one direction is called DIRECT CURRENT.

Press A -17

1-16

17

OK. Automotive DC generators contain many more conductor loops (ARMATURE WINDINGS) than the simple generator illustrated in Plate I. But each armature winding serves only one pair of COMMUTATOR BARS, which allows current to flow from that winding in one direction only.

If you would like to review what we have covered so far, press A. — 2

Otherwise, press B. — 19

X(C) — 18

2-17

18

OK. An automotive DC generator produces current that moves in one direction only in the external circuits. Each loop (armature winding) is connected to only one pair of commutator bars that acts in the same way as the commutator halves illustrated in Plate I.

Let's review quickly since you made an error or two on the questions. When you answer them all correctly we'll talk more about the armature windings.

Press A — 2

1-15

19

The simple DC generator illustrated in Plate I is not capable of producing usable current levels.

With additional loops of wire and more commutator sections, however, the generator will be capable of producing more voltage. Any voltage developed in one loop will be added to the voltage produced in all other loops, because they are connected in series.

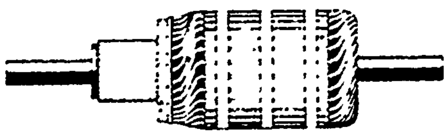
Press A -20

2-19

20

Placing more loops (coils) around the rotating iron core will produce smoother and steadier voltage and current.

We already know that at certain instants during rotation the voltage generated in each coil drops to ZERO. But other coils will be producing high enough voltage so that the overall voltage output will be fairly constant.



Press A — 21

2-20

21

See Plate II. Plate II (a) illustrates the pulsating DC current produced by a single armature winding as it rotates through a full 360 degrees. The voltage rises to a peak twice, and falls to zero twice during one complete revolution.

Plate II (b) illustrates the effect produced by a multiple coil armature. Each individual winding produces its own pulsating current, but the overall effect is a fairly smooth, steady output of voltage and current.

Press A -22

2-21

22

A generator with 100 turns of armature winding can produce about ________________ as much current as one with only 50 turns, if the speed of rotation is the same for each.

A. one-half -23

B. twice — 25

C. I don't know -24

2-22

23

Your answer is incorrect.

A generator with 100 turns of armature winding will cut lines of force at a rate TWICE as high (per each equal time interval) as one with only 50 turns, if rotation speed is the same for each.

Therefore, the 100 turn generator will produce TWICE the induced current.

Press A -25

2-23

24

A generator with a 50 turn armature will cut each line of force 50 times for each revolution it makes. Similarly, a 100 turn generator armature will cut each line of force 100 times per revolution.

Since the 100 turn armature cuts each line of force twice as many times for each revolution, it will produce TWICE as much current as the 50 turn armature if rotation speeds are the same for each.

Press A -22

2-24

25

OK. The number of CONDUCTORS (turns) in the armature is another factor that helps to determine the output of an automotive generator.

In order to produce a steady emf (electromotive force) of ONE VOLT, the armature windings must cut through the lines of force at a rate of 100 MILLION PER SECOND!

This is one reason why a generator must contain so many turns of wire in its armature and must rotate at such high speeds, even though the magnetic field consists of hundreds of thousands of lines of force. Press A -26

2-25

26

If a generator armature contains 100 turns of wire and is rotating at 20 revolutions per second (1200 rpm), each line of force will be cut 2000 times per second.

At that rate it would take a magnetic field of 600,000 lines of force to produce 12 volts.

Press A - 27

2-26

27

The POLE SHOES in an automotive generator retain some of the magnetism created during their last use. This is known as a residual magnetism. At this time they are very weak permanent magnets with a weak magnetic field between them.

Is the residual magnetic field strong enough to supply enough lines of force to provide normal operating voltages for the electrical system?

A. Yes - 28
B. No - 29

2-27

28

You are incorrect.

The residual magnetic field between the generator pole shoes is NOT strong enough to provide enough lines of force to generate the voltages needed by the electrical system.

The field must be strengthened in some way.

Press A -29

2-28

29

OK. In order to create a magnetic field of sufficient strength, the pole shoes are wound with coils called FIELD WINDINGS. Current for these windings is provided by the generator itself. A complete FIELD CIRCUIT is provided when the field windings are connected either in series or in parallel with the generator brushes. (See Plate III.)

Press A - 30

2-29

30

Diagrams of simple series-wound and shunt-wound generators are shown in Plate III. In Plate III (b), you can easily see the field circuit. Start with the top armature brush; continue to connection (A). Proceed downward through the field winding to connection (B), then back to the bottom brush. You have traced the field circuit.

When current passes through the field circuit, the field magnetism is ______________ .

A. strengthened - 32 B. weakened - 31

2-30

31

Incorrect.

Passing current through the field winding turns the pole shoes into powerful ELECTROMAGNETS. The strengthened magnetic field increases the concentration of lines of force between the pole shoes.

Press A - 32

2-31

32

OK. As current flows in the field circuit, the magnetic field between the pole shoes is strengthened. Each pole shoe is turned into a powerful ELECTROMAGNET. More lines of force are provided for the rotating armature windings to act on.

As the strength of the field magnetism increases, the generator output will ________________, if the speed of armature rotation remains constant.

A. increase — 34
B. decrease — 33

2-32

33

You are incorrect.

As the field current increases, the magnetism of the pole shoes is strengthened, due to the magnetic field that is induced around the field winding.

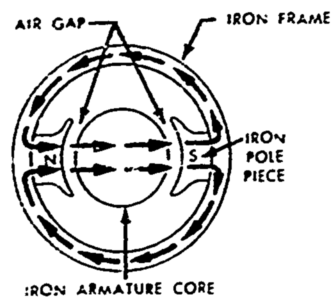
Increasing the magnetic strength of each pole shoe will increase the number of lines of force between them. With more lines of force to cut the generator output will INcrease.

Press A — 34

2-33

34

OK. The STRENGTH OF THE MAGNETIC FIELD is the third factor that helps to determine the output of an automotive generator.



Magnetic circuit

The iron core of the armature acts to concentrate the lines of force so that a powerful field is provided. Just as a complete circuit is required in electrical systems, a complete magnetic circuit must also exist in the generator. Press A — 35

2-34

35

We have mentioned three factors which contribute to the output of an automotive generator. They are:

1. The speed of rotation of the armature
2. The number of conductors (turns) in the armature
3. The strength of the magnetic field

We discussed SPEED OF ROTATION in the previous section. If you would like to review the NUMBER OF CONDUCTORS and the STRENGTH OF THE MAGNETIC FIELD, press A. Otherwise, press B.

19 37

3-35

X(C) — 36

36

We have discussed three factors which contribute to the output of an automotive generator. They are:

1. The speed of rotation of the armature
2. The number of conductors (turns) in the armature
3. The strength of the magnetic field

We covered SPEED OF ROTATION in the previous section. But let's have a quick review of NUMBER OF CONDUCTORS and STRENGTH OF THE MAGNETIC FIELD, since you made an error or two on the questions in this section.

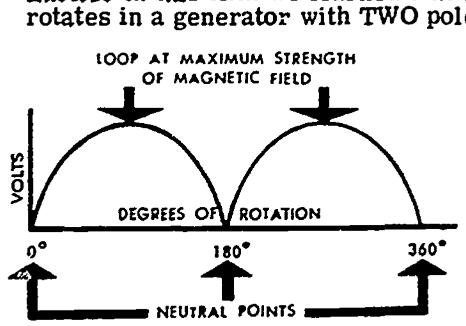
Press A — 19

2-36

37

ARMATURE REACTION AND BRUSH POSITIONING

Earlier in this film we learned that as the armature rotates in a generator with TWO pole pieces, the voltage drops to ZERO twice during each complete revolution.



The points in armature rotation where the voltage is ZERO are known as NEUTRAL POINTS.

Press A — 38

3-37

38

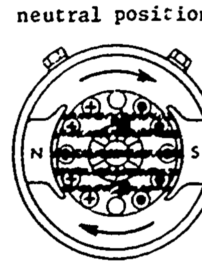
This illustration shows the normal magnetic field that exists between the pole shoes of a two pole generator. Note that the lines of force are assumed to flow straight across from the N shoe to the S shoe. We will call this the MAIN FIELD.

Press A — 39

3-38

39

mechanical neutral position



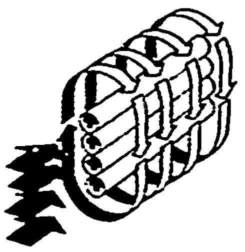
In this illustration the armature and the brushes are shown in place. The brushes are located in the MECHANICAL NEUTRAL position -- the point at which no current is induced in the armature windings if the magnetic field remains undistorted as shown.

Press A — 40

3-39

40

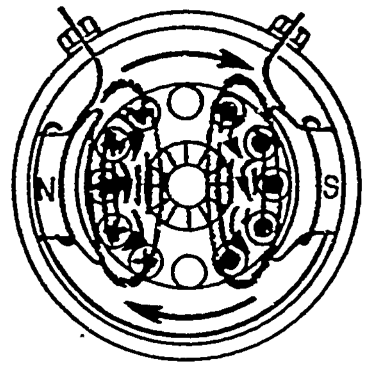
Under actual operating conditions, however, the path of the field between the pole shoes is NOT straight as illustrated previously.



The field becomes DISTORTED due to a reaction between the main field and the magnetic field created around the armature windings as current passes through them. The magnetic field created around each winding combines with those of adjacent windings to form a strong field around all the armature windings, as illustrated here.

Press A — 41 3-40

41



In this illustration, the magnetic field that surrounds the armature windings is shown. We will call this the ARMATURE FIELD.

During generator operation this field tends to ______.

A. remain stationary — 42
B. rotate in the same direction as the armature — 43

3-41

42

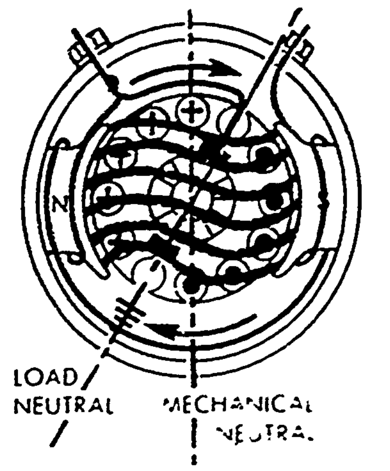
Your answer is incorrect.

During generator operation, the magnetic field created around the armature windings tends to be dragged along slightly in the same direction that the armature is rotating.

Instead of remaining stationary, the armature field tends to rotate slightly in the direction of armature rotation.

Press A — 43 3-42

43



OK. The tendency for the armature field to rotate slightly is responsible for two effects in an operating generator:

1. It causes the normal magnetic field between the pole shoes to DISTORT as shown in the illustration at left.
2. It causes the neutral points to SHIFT in the direction of armature rotation from the mechanical neutral position to the LOAD NEUTRAL position.

Press A — 44 3-43

44

The distortion of the main field, and the resulting shift of the neutral points is called ARMATURE REACTION. This effect takes place in all operating DC generators.

In order to insure maximum generator output, the brushes should be placed at the ______ points.

A. mechanical neutral — 45
B. load neutral — 46

3-44

45

No.

The ideal position for the brushes in most generators is the LOAD NEUTRAL position -- located somewhere beyond the mechanical neutral points, in the direction of armature rotation.

Press A — 46 3-45

46

OK. The brushes should be placed in the LOAD NEUTRAL position. (The one exception to this general rule is the INTERPOLE type generator. The interpole generator is designed to cancel out the effects of armature reaction automatically. The brushes can be placed in the mechanical neutral position.)

Placing the brushes at the LOAD NEUTRAL points improves commutation in the generator.

Press A — 47 3-46

47

We already know that when the magnetic field between the pole shoes becomes distorted, a shift in the neutral position occurs. This means that the position of the brushes must be changed also.

If the brushes were left in the mechanical neutral position, the armature loops would be generating voltage at the same time they were being commutated.

The generated current would be short-circuited between the commutator bars and the brushes. The short circuit occurs in the form of an ARC, which causes burning and rapid wear of the brushes and damage to the commutator bars.

Press A — 48 3-47

48

Armature reaction occurs when the rotating ___(1)___ field causes the ___(2)___ field between the pole shoes to distort in the direction of armature rotation.

A. (1) armature (2) main — 50
B. (i) main (2) armature — 49
C. I cannot answer this question — 38

3-48

49

You are incorrect. (The correct answers are reversed.)

The rotation of the armature and the slight dragging along of the ARMATURE field causes the MAIN field between the pole shoes to distort in the direction of armature rotation.

Press A — 50

3-49

50

OK. The main field becomes distorted during armature reaction.

Another effect that occurs during armature reaction is that the ideal commutating points shift TO the ___(1)___ position FROM the ___(2)___ position.

A. (1) mechanical neutral (2) load neutral — 51
B. (1) load neutral (2) mechanical neutral — 53
C. I cannot answer this question — 52

3-50

51

You are incorrect.

Are you sure you read the question correctly?

Take another look at it. Note that we are asking which position the neutral points shift TO during armature reaction.

Press A (You won't be penalized for this incorrect answer.) — 50

3-51

52

To repeat from an earlier frame:

The tendency for the armature field to rotate slightly is responsible for two effects in an operating generator:

1. It causes the normal magnetic field between the pole shoes to distort in the direction of armature rotation.
2. It causes the neutral points to shift in the direction of armature rotation. FROM the mechanical neutral position TO the load neutral position.

Press A — 50

3-52

53

OK.

It is the ___ ___ position that dictates the approximate ideal position for the brushes in most automotive generators.

A. load neutral — 55
B. mechanical neutral — 54

3-53

54

You are incorrect.

If the brushes were placed in the mechanical neutral position (in all except interpole generators), severe arcing would take place between the brushes and the commutator bars. Generator output would be seriously hampered. Frequent brush replacement and commutator service would also be needed.

Press A — 55

3-54

55

OK.

At constant speed and load there is an ideal commutating point. Automotive applications call for varying speeds and loads, however. This means that the ideal position for the brushes will change with varying conditions.

Under such conditions, a brush location must be selected that will cause the least arcing under the widest range of typical operating conditions.

If you would like to review ARMATURE REACTION AND BRUSH POSITIONING, press A. Otherwise, press B. — 57

3-55

37

X(C) — 56

56

OK.

Since you've had some trouble with at least one or two questions in this section, let's review ARMATURE REACTION AND BRUSH POSITIONING.

When you answer all the questions correctly, we'll talk about Generator Power and Ratings.

Press A – 37 3-56

57

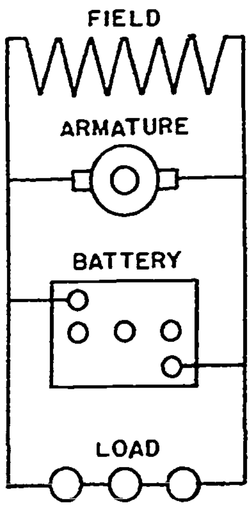
GENERATOR POWER AND RATINGS

An automotive generator must be designed and built to withstand all the electrical power it is capable of producing. Electrical POWER is expressed in WATTS, and is the product of electrical pressure (VOLTS) times current (AMPS). P = E x I.

$$P(\text{watts}) = EMF(\text{volts}) \times CURRENT(\text{amps})$$

Press A – 58 4-57

58



Every automotive generator serves two circuits -- the FIELD CIRCUIT and the LOAD CIRCUIT (the battery charging circuit may be considered part of the LOAD CIRCUIT).

The two circuits may vary in how they are connected. but they are found in all automotive generator applications.

Press A – 59 4-58

59

VOLTAGE (electrical pressure) induced in the generator armature windings causes current to flow in the field circuit and in the load circuit. As long as the speed of armature rotation is sufficient. the voltage will climb to whatever value is necessary to overcome any resistance in either of the connected circuits.

Press A – 60 4-59

60

The field coils in the generator, and many components in the load circuit can be damaged by high voltage. so some means of voltage control is needed.

An external unit called a VOLTAGE REGULATOR is used to limit the voltage (electrical pressure) developed in the generator. (See Plate IV.)

If no voltage regulator is used, the voltage produced by the generator will ____________________.

A. decrease as it meets resistance in the field and load circuits – 61
B. increase to overcome any resistance it meets in the field and load circuits – 62

4-60

61

Your answer is incorrect. If voltage acted in that way the generator would be self-regulating and no external regulator would be needed.

The reason a voltage regulator is needed is that otherwise. the voltage would INcrease to overcome any resistance that occurs in the field and load circuits. no matter how HIGH that resistance. The resulting high voltage could damage the generator or the components in the external circuits.

Press A – 62 4-61

62

OK. The VOLTAGE RATING of a generator indicates the system voltage that the generator is designed to deliver.

An automotive generator is designed to withstand its rated voltage for any length of time under normal vehicle operating conditions.

Press A – 63 4-62

63

As stated previously, voltage induced in the armature windings causes current to flow in the field and load circuits.

CURRENT flow (amperage) in the field and load circuits depends on the developed voltage and the resistance in the circuits.

If the resistance is HIGH in a circuit, the circuit voltage will be __(1)__ and the current flow will be __(2)__.

A. (1) high (2) low – 65
B. (1) low (2) high – 64

4-63

64

You are incorrect.

Remember what we said about voltage -- it will climb as high as necessary to overcome any resistance it meets, provided that the armature speed is sufficient.

If the resistance is high, voltage will also be HIGH -- attempting to overcome the high resistance.

Current flow on the other hand is RETARDED by high resistance. The higher the resistance, the LOWER the current flow will be.

Press A — 65

4-64

65

OK. High resistance means high voltage and low current flow.

If the resistance in the attached circuits is extremely LOW and armature rotation speed is sufficient, current flow will be HIGH. High current produces heat.

Damage to the insulation and to the varnish used to hold the armature windings in place can result. Soldered connections in the windings and at the commutator bars can melt.

As a result, short, open and grounded circuits can occur in the generator.

Press A — 66

4-65

66

To prevent the damage that can be caused by excessively high current and the resulting high HEAT, some means of current control is needed.

Just as a voltage regulator is used to limit the voltage developed in the generator, an external CURRENT REGULATOR is used to limit the current flow. (See Plate IV.)

If no current regulator is used, the current flow will be abnormally high and the components will be damaged, primarily by excessive ____________ .

A. amperage — 67 B. voltage — 68 C. heat — 69

4-66

67

That is not the answer we were looking for.

Amperage IS current flow.

What effect does high current flow (high amperage) have on the components of the electrical system? Read the last frame again carefully and then answer the question.

Press A — 66

4-67

68

You are incorrect. You said that if current is too high, damage will result because of excessive voltage. This is not the case.

We already know that current and resistance are related -- when one is low, the other is high. LOW resistance then, means HIGH current.

We also know that resistance and voltage are related -- the higher the resistance, the higher the voltage will be. LOW resistance then, means LOW voltage. So, high current means low voltage.

Since excessive voltage is not the answer, what DOES cause component damage when current is too high?

Press A — 66

4-68

69

OK. The current regulator acts to prevent overheating caused by excessive current.

The CURRENT RATING of a generator indicates the amount of current that the generator can supply continuously without internal damage, or damage to components in the external circuits.

Press A — 70

4-69

70

Another source of generator heat is EDDY CURRENTS flowing in the iron core of the armature. Voltage is generated in the iron core itself, because it acts as one large conductor as it rotates through the magnetic field between the pole shoes. These eddy currents produced cause heat, known as iron loss.

To keep the eddy currents small, the core is made of laminated sections instead of one solid piece of iron. This prevents large eddy currents from building up and reduces iron loss (heat) in the armature.

Press A — 71

4-70

71

Most automotive generators are designed so that air will be forced through the generator housing by some means. The forced air acts as a cooling medium for the rotating armature.

A force-ventilated generator will probably carry a ________ current rating than a non-ventilated unit of the same size.

A. lower — 72

B. higher — 73

4-71

72

No. The current rating of a generator depends on its ability to produce current without danger of damage due to heat.

The normal operating temperature of a non-ventilated generator will be somewhat higher than that of a force-ventilated model of the same size, because force-ventilation removes heat more efficiently and lowers the operating temperature.

The force-ventilated generator can carry a HIGHER current rating without danger of over-heating. Press A-73

4-72

73

OK. A force-ventilated generator can safely carry a higher current rating than a non-ventilated unit of the same size.

Heat is an enemy of all electrical equipment.

If you would like to review GENERATOR POWER AND RATINGS, press A.-57

Otherwise, press B.-75

A(C)-74

5-73

74

OK. A force-ventilated generator can carry a higher current rating because heat build-up will be less of a problem.

Since you have made an error or two on the questions in this section, let's have a quick review of GENERATOR POWER AND RATINGS.

Press A-57

4-74

75

We learned earlier in this film that one of the factors that helps to determine generator output is the STRENGTH OF THE MAGNETIC FIELD between the pole shoes.

Varying the strength of the field will cause variations in generator output. This fact serves as the basis for generator voltage and current CONTROL.

Press A -76

5-75

76

The generator regulator is connected in series with the generator FIELD CIRCUIT. This circuit supplies current to the FIELD COILS, which are wound around the generator pole shoes.

Varying the field current will cause changes in the magnetic field between the pole shoes.

If something acts to lower the field current, the main field will have ___(1)___ lines of force to be cut, and the voltage will ___(2)___ if armature speed remains the same.

A. (1) more (2) increase - 77

B. (1) fewer (2) decrease-78

5-76

77

Incorrect.

Lowering the field current will cause the main field between the pole shoes to weaken. A weaker magnetic field contains FEWER lines of force.

With fewer lines of force for the rotating armature windings to cut, the generator voltage will DECREASE, if rotation speed remains constant.

Press A -78

5-77

78

OK. By controlling the strength of the magnetic field between the pole shoes we can control generator voltage -- we can obtain VOLTAGE REGULATION.

The VOLTAGE REGULATOR unit contains two windings:

A shunt winding (in parallel with the load circuit) is made up of many turns of fine wire.

A field series winding (in series with the field circuit) is made up of fewer turns of heavier wire. Both windings are VOLTAGE SENSITIVE.

Press A-79

5-78

79

As generator voltage increases, current through the voltage regulator windings creates a magnetic field which pulls OPEN a set of spring loaded contact points.

Opening these points channels the field current through a resistance, which reduces the current flow through the field coils.

This causes the main field to weaken and results in lower generator voltage.

When the voltage regulator points are open, the resistance in the field circuit is __________ than when the points are closed.

A. higher -81

B. lower -80

5-79

80

You are incorrect.

When the generator voltage climbs to the limit of the voltage regulator setting, the field current becomes strong enough to open the voltage regulator contact points. Opening the points channels the current through a resistance.

When the voltage regulator points are OPEN, field circuit resistance is HIGHER.

Press A - 81

5-80

81

OK. Increased field circuit resistance means LOWER field current.

Once the generator voltage drops to the lower limit of the voltage regulator setting, the contact points close to allow voltage to build up once more.

This cycle of opening and closing the points is repeated 50 to 100 times per second in order to limit the voltage to the predetermined value.

A voltmeter reads ______________.

A. each voltage fluctuation as the points open and close - 82
B. the overall average voltage created across the points - 83

5-81

82

No.

Automotive voltmeters are not mechanically capable of keeping up with voltages that rise and fall 50 to 100 times per second. The voltmeter reads the overall average of the voltages created across the points during point vibration.

Press A - 83

5-82

83

OK.

The CURRENT REGULATOR unit is constructed much the same as the voltage regulator unit, except that it consists of only one winding -- a series winding (in series with the load circuit) with relatively few turns of heavy wire. This winding is CURRENT SENSITIVE. The entire generator output current flows through it.

As current flow builds up in the load circuit, a ______________ is formed at the current regulator winding.

A. short circuit - 84
B. magnetic field - 85

5-83

84

Incorrect.

A malfunction elsewhere in the system could cause a short circuit in the current regulator.

But we are talking about normal operation. Remember the fundamentals of electricity and magnetism -- when current is passed through a conductor, a MAGNETIC FIELD is created around it.

Press A - 85

5-84

85

OK. The magnetic field (created around the series winding in the current regulator) causes a set of spring loaded contact points to OPEN when the current reaches the limit of the regulator setting.

This causes the field current to pass through a resistance, which reduces the current flow through the field coils.

Lowering the field current causes the generator output to ________.

A. decrease - 87
B. increase - 86

5-85

86

Your answer is incorrect.

In our discussion of the voltage regulator we learned that a decrease in the field current causes a weaker main field and a resulting drop in generator voltage.

Remember that voltage is electrical pressure -- it pushes current through conductors. What will happen to the rate of current flow if the electrical pressure (voltage) is DEcreased?

Press A - 85

5-86

87

OK.

When the generator output drops to the lower limit of the current regulator setting, the magnetic field around the series winding weakens. Spring tension overcomes the force of the magnetic field and the contact points close again.

This opening-closing cycle is repeated 50 to 200 times per second in order to limit the current flow to the rate for which the current regulator is set.

Press A - 88

5-87

88

Thus we have both the generator voltage and output (current) under control.

An important point to remember is that when two regulators are used -- a voltage regulator and a current regulator -- only one of them operates at a time. In normal service they DO NOT operate simultaneously.

Press A – 89

5-88

89

If the vehicle's electrical load requirements are heavy, and the battery is low, the system voltage will not have a chance to build up enough to activate the voltage regulator. The voltage regulator points will remain closed.

Under heavy load however, the demand for CURRENT will be high. To protect against overloading and overheating, the current regulator points will ________ when the current reaches the maximum regulator setting.

A. close – 90
B. open – 91

5-89

90

You are incorrect. You said the current regulator points would CLOSE.

Keep in mind that under heavy load conditions and low battery charge, the system voltage is low. When voltage is low, the voltage regulator points remain closed.

If both sets of points remain closed, the system will have no protection against excess voltage or current when the generator is operating.

Press A – 89

5-90

91

OK.

When the load requirements for the vehicle are relatively light and the battery is nearly in a full state of charge, the system voltage will increase (attempting to overcome the high counter-electromotive force (CEMF) of the highly charged battery). Due to this high resistance, generator output (current) will be reduced. The current regulator points will be closed.

Press A – 92

5-91

92

The VOLTAGE regulator points will OPEN, however, due to the increased system voltage. The system will then be totally dependent on the voltage regulator.

If the vehicle battery is well-maintained and in a reasonably high state of charge, the ____________ will do most of the work to protect the vehicle's electrical system.

A. voltage regulator – 94
B. current regulator – 93

5-92

93

Incorrect.

A battery in a relatively high state of charge has high CEMF. CEMF acts as a resistance to battery charging voltage. The increased resistance causes the charging voltage to rise, in an attempt to overcome the high CEMF.

This brings the VOLTAGE REGULATOR into action.

Press A – 94

5-93

94

OK. The voltage regulator has to work harder than the current regulator as the vehicle battery comes nearer to full charge.

This is one reason why voltage regulator points often wear out faster and must be serviced more often than current regulator points.

If you would like to review this section on GENERATOR CURRENT AND VOLTAGE REGULATION, press A. – 75

Otherwise, press B. – 96

6-94

95

OK. The voltage regulator works harder than the current regulator when the electrical load is light, and when the battery nears full charge.

You have had some trouble with a question or two in this section, so let's review GENERATOR VOLTAGE AND CURRENT REGULATION. When you answer all the questions correctly we'll discuss "A" and "B" circuits.

Press A – 75

5-95

96

There are two major types of automotive DC generator circuits -- the "A" circuit and the "B" circuit. See Plates V and VI.

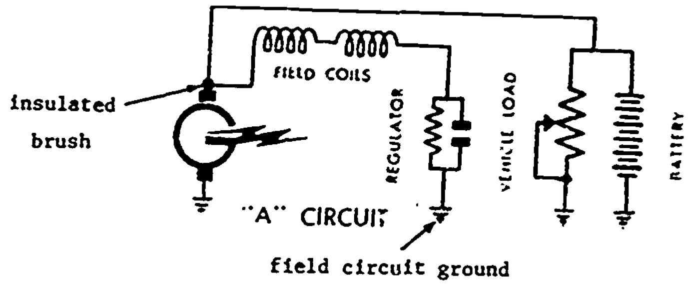
Both types of circuits do exactly the same job. The output for a given generator will be the same no matter which circuit design is used.

The only significant difference between the two is the location of the field circuit GROUND.

Press A — 97

6-96

97



In an "A" circuit system, the field circuit is grounded OUTSIDE the generator at the generator regulator. It is connected to the INSULATED brush inside the generator. Press A. —98

6-97

98

An "A" circuit generator has ____(1)____ grounded field coils. The field circuit is connected to the ____(2)____ brush inside the generator.

A. (1) internally (2) insulated — 99
B. (1) externally (2) insulated — 101
C. (1) internally (2) grounded — 100
D. (1) externally (2) grounded — 99

6-98

99

Only part of your answer is correct.

The field coils in an "A" circuit generator are grounded EXTERNALLY at the generator regulator -- outside the generator.

The field circuit is connected to the INSULATED brush inside the generator in the "A" circuit system.

Press A — 101

6-99

100

Your answers are incorrect.

We said that in an "A" circuit system, the field circuit is grounded outside the generator. The field coils are part of the field circuit. Since the field circuit is grounded outside the generator, the field coils are grounded EXTERNALLY.

Inside the generator, the field circuit is connected to the INSULATED brush. A circuit cannot be grounded at both ends if current is to flow.

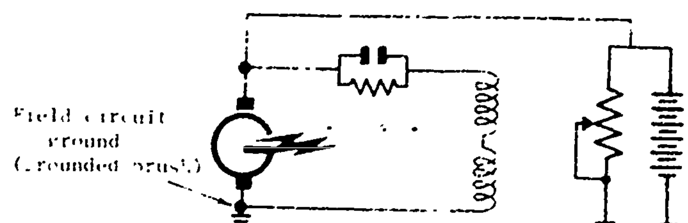
Press A — 98

6-100

101

OK.

In a "B" circuit system, the field circuit is grounded INSIDE the generator at the GROUNDED brush. It is attached to the insulated side of the generator at the generator regulator.



Press A — 102

B CIRCUIT

6-101

102

A "B" circuit generator has ____(1)____ grounded field coils: the field circuit is connected to the ____(2)____ side of the generator at the generator regulator.

A. (1) internally (2) grounded — 103
B. (1) externally (2) insulated — 103
C. (1) internally (2) insulated — 105
D. (1) externally (2) grounded — 104

6-102

103

Only part of your answer is correct.

A "B" circuit generator has INTERNALLY grounded field coils. The field circuit is grounded inside the generator -- at the grounded brush.

The field circuit is connected to the INSULATED side of the generator at the generator regulator.

Press A — 105

6-103

104

Your answers are incorrect.

A "B" circuit generator has INTERNALLY grounded field coils -- the field circuit is grounded inside the generator at the grounded brush.

Since a circuit cannot be grounded at both ends if current is to flow, the field circuit is connected at the generator regulator to the INSULATED side of the generator.

Press A -102 6-104

105

OK. In both "A" circuit and "B" circuit systems, the field circuit has one connection at the generator and one at the generator regulator.

In a "B" circuit system the field circuit is ___(1)___ at the regulator, and ___(2)___ in the generator.

A. (1) insulated (2) grounded -107

B. (1) grounded (2) insulated -106

6-105

106

Incorrect.

The rule to keep in mind is that a "B" circuit generator has INTERNALLY grounded field coils. This means that the "B" type field circuit is GROUNDED in the generator.

Since the circuit cannot be grounded at both ends. the "B" circuit must be insulated at the regulator.

Press A -107 6-106

107

OK.

A generator field circuit which is grounded at the regulator and connected to the insulated generator brush is ______________.

A. an "A" circuit -109

B. a "B" circuit -108

6-107

108

No.

We said that the field circuit is grounded at the regulator. This means that the generator field coils are grounded EXTERNALLY -- outside the generator.

When the field coils are grounded externally and the field circuit is connected to the insulated brush. we have an "A" CIRCUIT.

Press A -109 6-108

109

OK.

If you are inspecting a generator regulator and you find that the "F" terminal is grounded under normal conditions. the regulator is part of ________ system.

A. an "A" circuit -111

B. a "B" circuit -110 6-109

110

You are incorrect.

This situation is really the same as in the preceding question.

The regulator "F" terminal is the connecting point for the field circuit. If the regulator "F" terminal is grounded, you have EXTERNALLY grounded field coils. or an "A" CIRCUIT system.

Press A -111 6-110

111

OK.

If you are inspecting a generator and find that a bare wire is connected to the "F" terminal. and the "F" terminal is connected to the grounded brush. you are inspecting ____________ generator.

A. an "A" circuit -112

B. a "B" circuit -113

6-111

112

Incorrect.

The "F" terminal of the generator is the point of attachment for the field circuit. If the "F" terminal of a generator is connected to the GROUNDED BRUSH, this means that the field coils are grounded INTERNALLY (inside the generator).

Internally grounded field coils mean that this is a "B" circuit generator.

Press A -113

6-112

113

OK. If the generator "F" terminal is connected to the grounded brush, you have a "B" circuit system.

An insulated generator "F" terminal means an "A" circuit system.

It is important for the automotive service technician to be able to determine what type system he is dealing with.

If you would like to review "A" circuits and "B" circuits, press A. Otherwise, press B. -115

96

6-113

114

OK. If the "F" terminal of the generator is GROUNDED, you are dealing with a "B" circuit system.

Since you made an error on one or two questions in this section, let's have a brief review of "A" circuits and "B" circuits. Take your time and think carefully before answering the questions.

Press A -96

6-114

115

Congratulations!

You have successfully completed this film, "Introduction to DC Generator Principles."

What we have discussed here should prove to be an important addition to your overall understanding of automotive electrical systems.

Press REWIND

6-115

INSTRUCTOR'S GUIDE

Title of Unit: UNDERSTANDING DC GENERATOR PRINCIPLES

AM 2-14
9/6/67

OBJECTIVES for this Unit:

1. To review shunt generator principles, how they are constructed, "A" and "B" circuit designs, generator power ratings and application of generators on the job.
2. Review the three basic fundamentals for developing current and voltage and the regulating of current and voltage for the protection of the generator and the connected circuits.

LEARNING AIDS suggested:

Visual Aids:
Delco-Remy Training Charts and Manual
No. 5133-E;Generators

Models:
Any generator components, armatures, pole shoes, field coils, voltage regulators etc., that could be brought into a classroom for discussion and demonstration.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. What is the source of energy for a automotive type generator?
2. What effect does magnetism have on generator output?
3. How is generator output controlled in relation to magnetism?
4. What is residual magnetism?
5. What is meant by induced voltage?
6. What are the two circuits within the generator?
7. How is voltage built up within the generator?
8. What part does the commutator play in a generator?
9. Why are the brushes necessary in a generator?
10. What is meant by the term air gap?
11. What effect would increased or decreased air gap have on the generator field strength?

12. Why are armature cores made of laminated sections instead of solid iron?

13. What are the three basic fundamentals necessary to generate electricity?

14. What external unit acts to safeguard the generator, its components, and the externally connected circuits?

15. What are some of the methods used in cooling generators?

16. What is meant by the neutral point of an armature loop?

17. How does armature reaction affect the location of the brushes?

18. What is meant by load neutral and mechanical neutral position of the brushes?

19. How does pole shoe polarity effect current flow from the generator?

20. What is the primary difference between an "A" circuit generator and a "B" circuit generator?

21. What is the function of the cut-out relay?

22. What is meant by the cut-in speed of the generator in relation to the cut-out relay?

23. Why is it important that the speed of the generator cut-in be at least 100 rpm above or below the engine idle speed?