training chart manual

SECTION e

GENERATORS

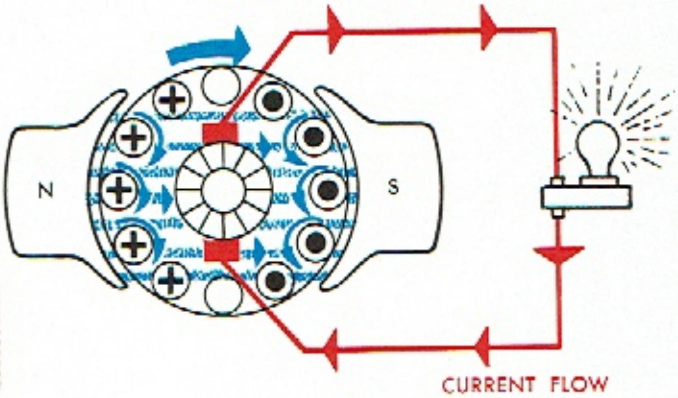
DELCO-REMY · ANDERSON, INDIANA, U.S.A.
DIVISION OF GENERAL MOTORS CORPORATION

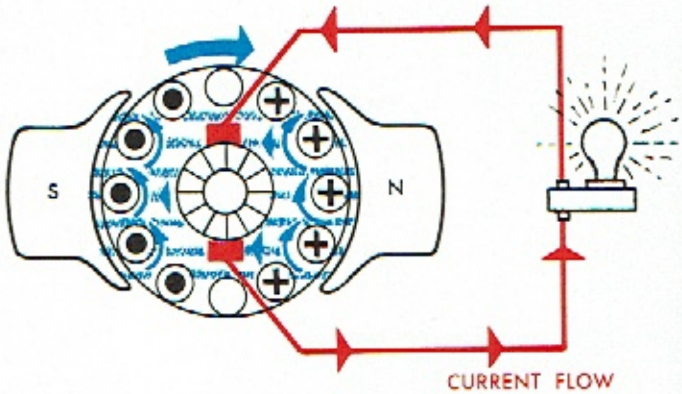
WHAT IS POLARITY?

Polarity is the direction of current flow from the generator to the external circuits.

As can be seen in the illustrations, 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 is also reversed. Therefore, a generator is capable of supplying current in either direction, depending upon the polarity of the poles.





TWO GENERATOR CIRCUITS

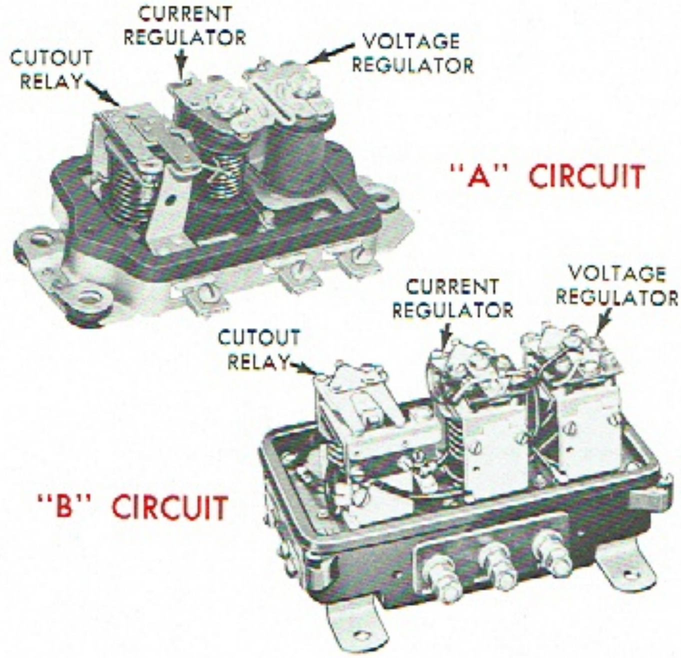
"A" CIRCUITS AND "B" CIRCUITS

As has been pointed out in the discussion of "Power and Ratings of Generators", the output of a generator must be regulated or 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 the 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 subject to too high voltage and an excessive overcharge and short life would result.

Under the discussion of "How a Generator Develops Voltage", 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 to 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.

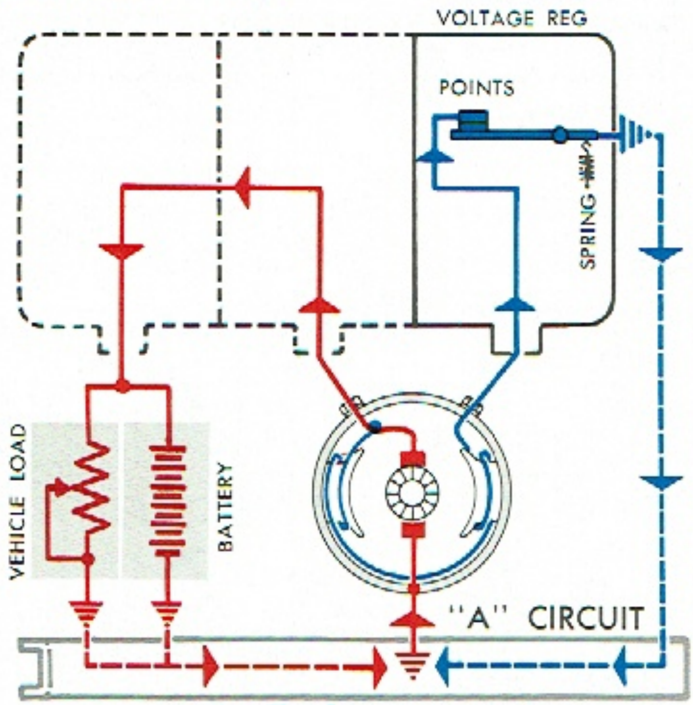


The simplified illustration below shows the various factors involved in voltage regulation and the manner in which it is done.

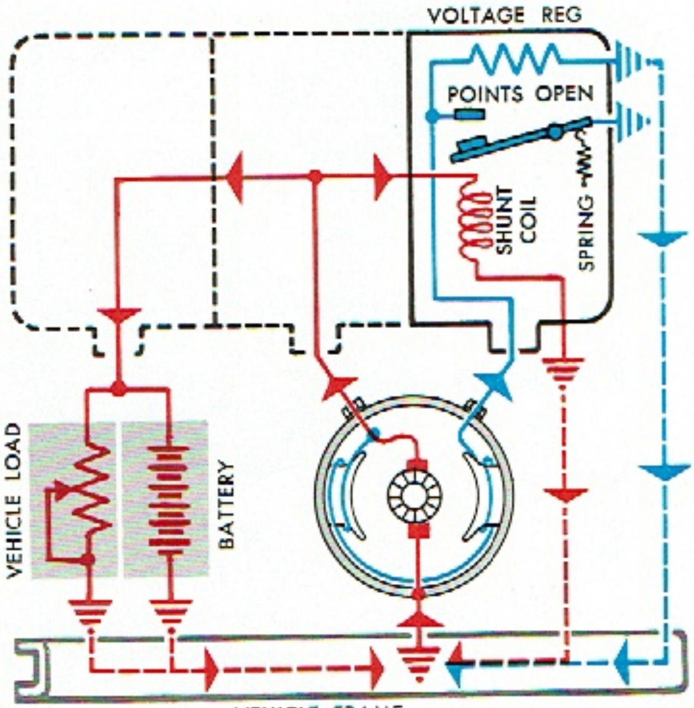
Full generator voltage lies between the two brushes. Any circuit connected between these brushes will have full generator voltage impressed upon it. The flow of current in any circuit connected in this manner will depend, therefore, on the generator voltage and the amount of resistance in the circuit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

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 resistance to ground, through the ground conductor, and back to the ground brush of the generator.

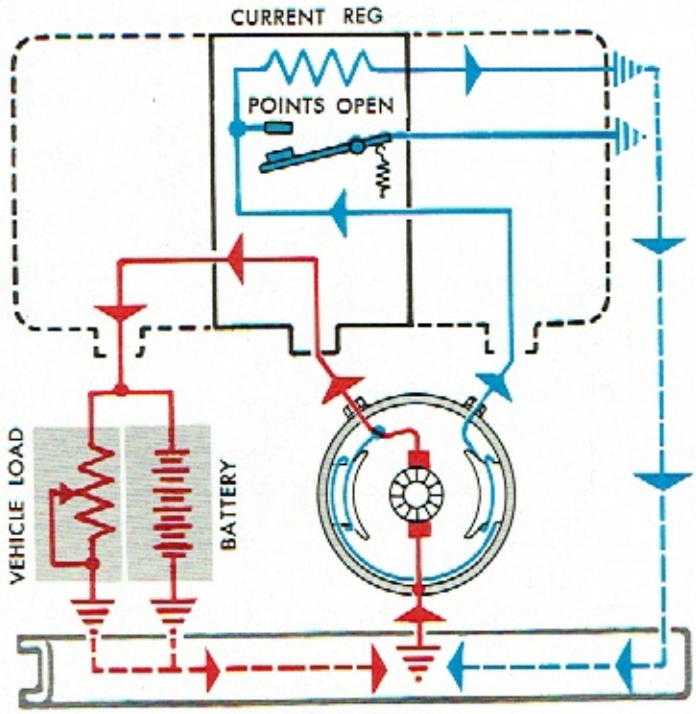


As stated previously, if the resistance in the load circuit is high, the generator will build up a high voltage to overcome it. High generator voltage causes high current to flow in the field circuit. This intensifies the magnetic field between the poles. Additional voltage is developed within the armature 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 the diagrams, a set of contact points is placed in series with the field coil circuit and all field coil current passes through them. If these points were to open, 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 coils greatly decreases the field coil current, thereby decreasing the magnetic strength between the poles and the voltage developed in the generator.

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 through this coil and the stronger its magnetic pull. The shunt coil can be called the "sensing unit" that operates a set of contact points to reduce the generator voltage and prevent high system voltage. When 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 points are open. The vibrating action of the contact points is so rapid that a voltmeter will only register the average voltage developed.



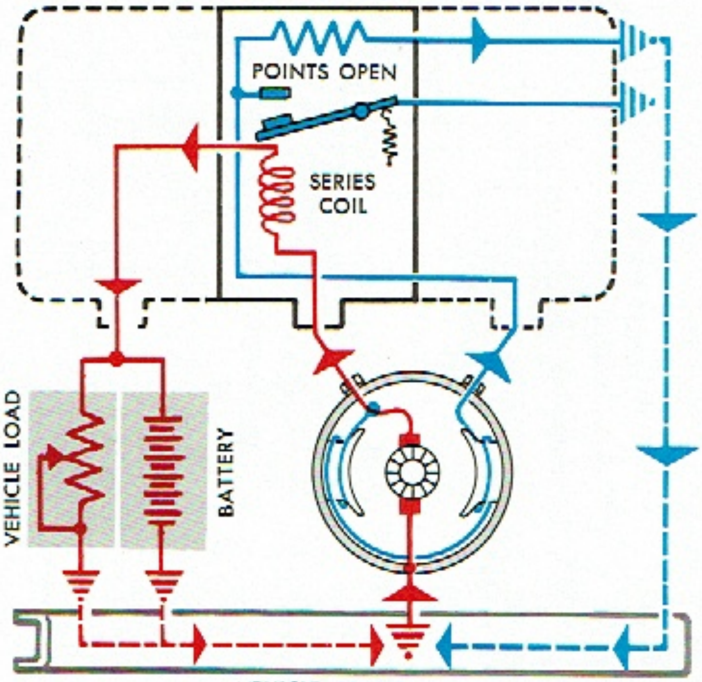
The illustration at the left shows the various factors involved in current regulation and the manner in which it is done.

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 obtained.

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.

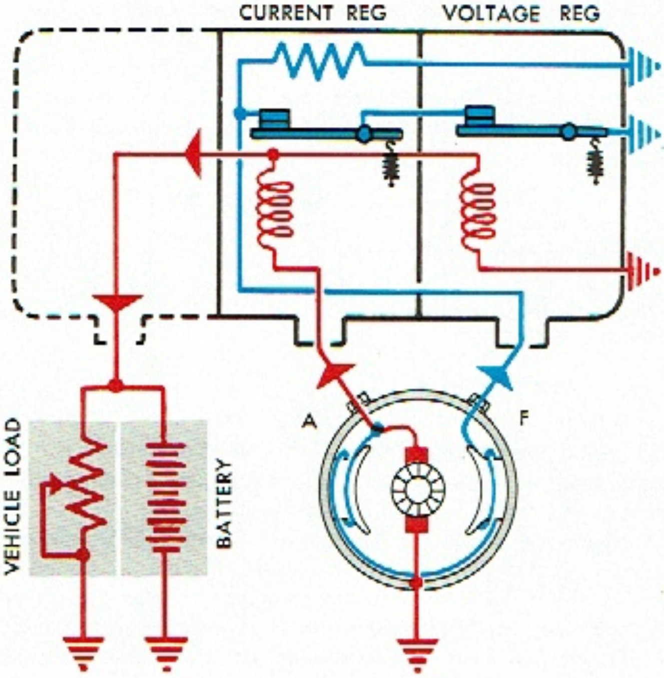
As seen in the diagram, a set of contact points is placed in series with the field coil circuit and all field coil current passes through it. If these points were to open, current would no longer pass through them but would, instead, travel through a resistance to ground and then through the ground conductor back to the ground brush of the generator. Inserting this resistance in series with the field coils 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.

A coil placed in series with the *load circuit* permits 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 this circuit, the spring pressure holding the points closed 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 load 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, 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. The resistance in the load circuit determines which regulating unit will operate, providing the generator is at a 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.



"A" CIRCUIT

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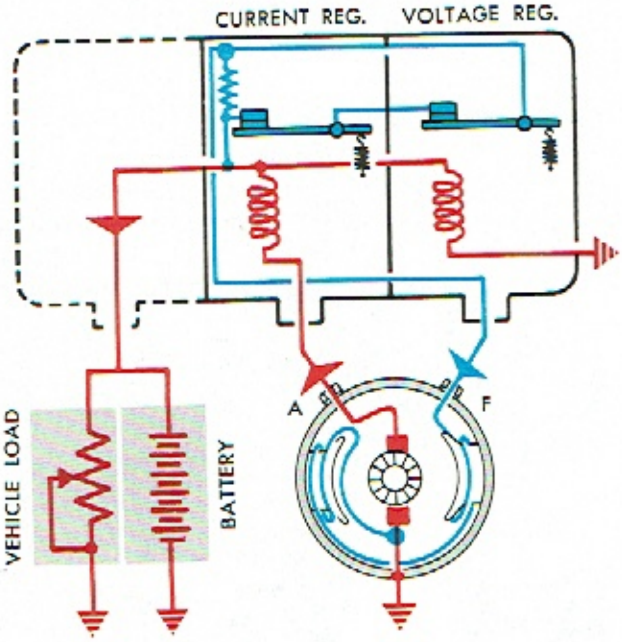
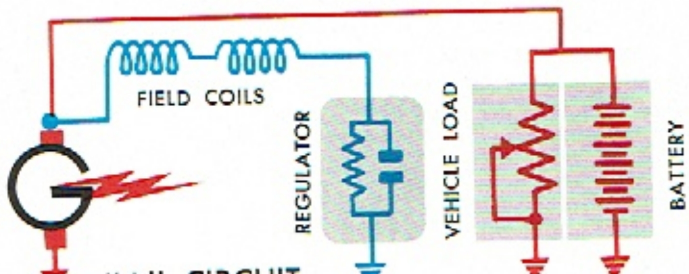


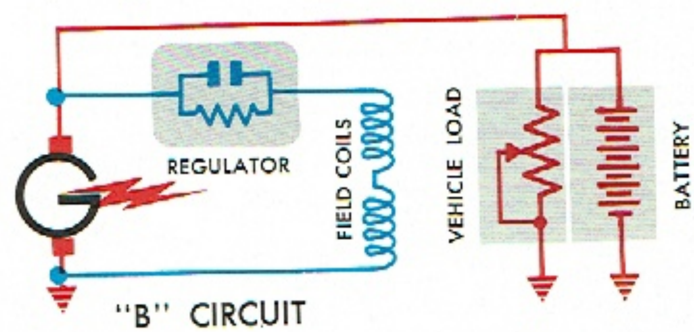
"B" CIRCUIT

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 at the generator ground brush.



"A" CIRCUIT

There is no particular advantage of 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.



"B" CIRCUIT

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. 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.

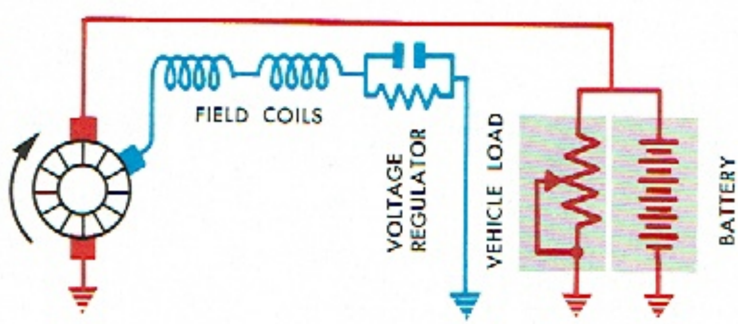
SPECIAL GENERATOR CIRCUITS

The discussion thus far has been concerned with the "Shunt" type generator. Its principles of operation and method of developing voltage have been explored. Other types of special generators have been designed for specific applications. However, the basic principles of operation are the same as for the shunt generator with only slight variations or additions made to this basic generator design. Examples of generators of other designs are the Third Brush, Interpole, Bucking Field and Split Field types.

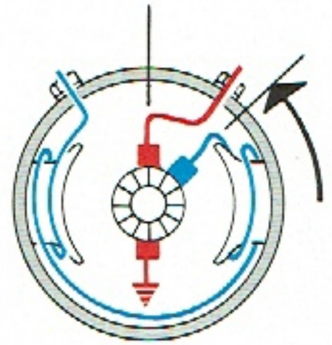
- THIRD BRUSH TYPE
- INTERPOLE TYPE
- BUCKING FIELD TYPE
- SPLIT FIELD TYPE

THIRD BRUSH GENERATORS

The Third Brush type generator uses three brushes instead of two. As an internal means of controlling maximum current output of the generator, the field circuit is connected so that the current fed to the field coil windings is taken off the commutator by the third brush. The two main brushes are located at the neutral points on the commutator where there is maximum voltage. The third brush is placed in an intermediate position between the two brushes. Consequently, it picks up less than maximum available voltage.

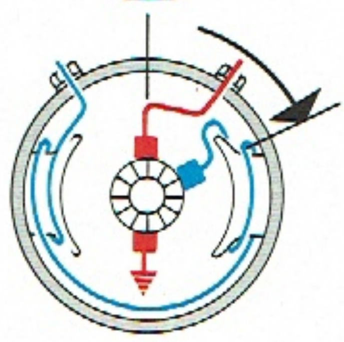


On most units the position of the third brush can be adjusted and set in various positions relative to the main brushes. Moving the third brush toward the adjacent main brush increases the voltage across the field circuit and current through the field windings is thereby increased. Increasing the field current increases the strength of the magnetic field and results in a higher generator output. Moving the third brush away from the adjacent main brush reduces the voltage across the field circuit, and current through the field windings is decreased. Reduced field current decreases the strength of the magnetic field resulting in a lower generator output.



HIGHER OUTPUT

FIELD: INCREASED VOLTAGE, INCREASED CURRENT, GREATER MAGNETIC STRENGTH



LOWER OUTPUT

FIELD: REDUCED VOLTAGE, DECREASED CURRENT, LESS MAGNETIC STRENGTH

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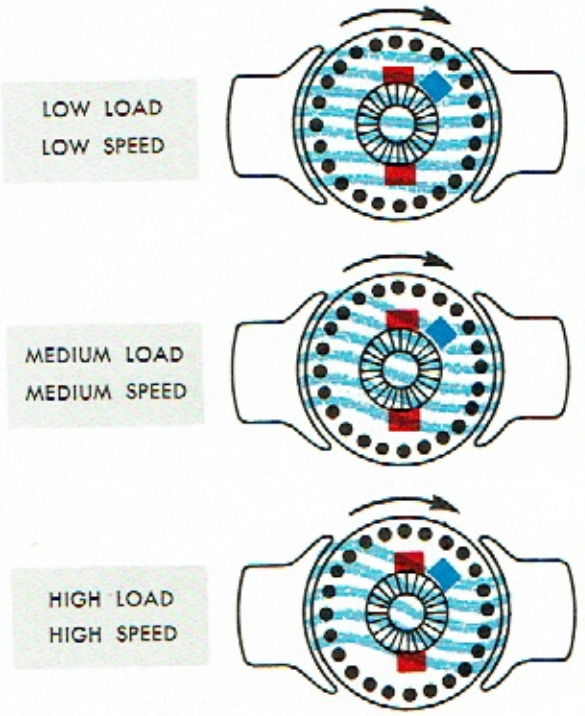
THIRD BRUSH GENERATORS

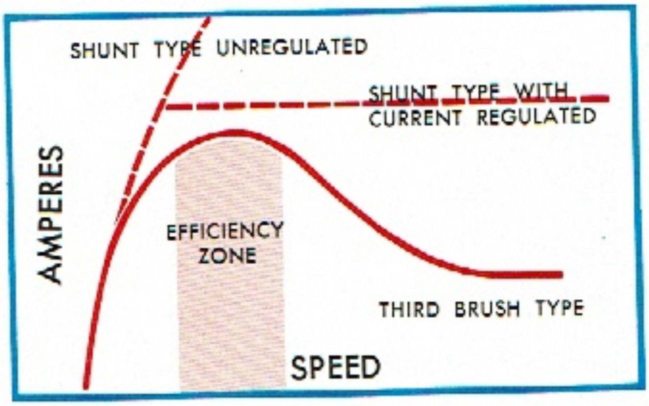


In the discussion on the effect of armature reaction, it was seen that the greater the current passing through the windings of the armature the greater the distortion of the magnetic field. Note this effect as shown in the illustration. It also shows how the voltage developed in the armature windings between the third brush and the ground brush decreases as fewer magnetic lines of force are cut by the armature conductors when the lines of force distort or shift their neutral position. This decrease in voltage forces less current through the field coil circuit. Therefore, less total voltage is developed between the main brushes resulting in less pressure to cause current to flow to the load circuit.

Therefore, this design allows the third brush generator to regulate its own current output without a current regulator. However, a voltage regulator is needed to prevent high voltage from developing. Its operation is similar to the voltage regulator previously described.

The third brush generator was originally adapted for automotive use because of its simplicity and because it was relatively easy to change generator output by shifting the position of the third brush. The fact that it limited its own current output was also advantageous.

The characteristic output curve of the third brush generator, however, soon rendered it obsolete for modern automotive use. The evolution of the present day automobile slowly kept adding electrical loads to the electrical system. New appliances were added to the automobile for passenger comfort and safety and consequently more and more electrical energy was needed to power these appliances and to recharge the battery. The fact that maximum current output could be obtained at medium speeds only, and that current output dropped or tapered off at high speeds, soon proved that the capacity of the third brush generator was insufficient to carry the increased electrical loads at higher road speeds.



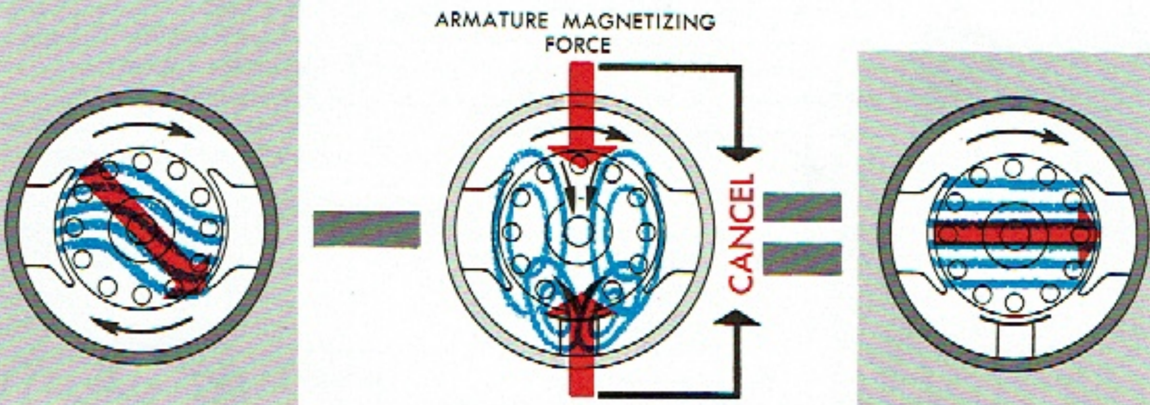
Although not in use on present day automobiles, the third brush generator still has widespread use on farm tractors.

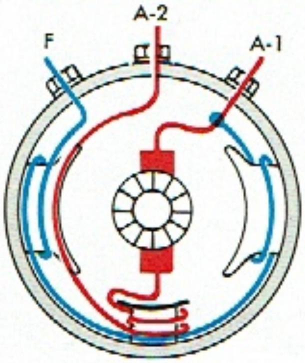
The shunt generator has replaced the third brush generator for automotive applications. It reaches its peak specified output at lower speeds than the third brush generator and can maintain this output throughout the generator speed range.

INTERPOLE GENERATORS

In the story covering neutral position, we learned that the magnetic field is distorted when current flows through the armature conductors. When there are a great number of conductors or there is high current flow, the distortion of the normal magnetic field becomes great.

It should be remembered that the mechanical neutral position is half-way between the pole shoes. This is a point where the armature conductor, connected to the brushes through the commutator, usually has zero current flow since the voltage that has been developed is changing from one direction to the other. However, with a distorted magnetic field, the conductor is still generating voltage at this point and there is a flow of current when the conductor is shorted by the brushes. This causes arcing at the brushes which results in short brush life.





INTERPOLE

To obtain both long brush life and good commutation without serious arcing, it is essential that the armature coil does not cut lines of force during commutation. It is possible to neutralize the magnetic force of the armature coils by installing an "interpole". This interpole is a narrow pole piece mounted on the generator frame between the two regular poles. It is wound with heavy bar copper since all the armature current goes through this winding. The number of turns in the interpole coil is calculated to produce enough ampere turns in the opposite direction to offset the magnetic field created by the current flow through the armature. Since the amount of current flowing through the armature and the interpole coil is always the same, the right amount of correction is always present to nullify the armature reaction and allow the normal magnetic field between the poles to remain in a straight line.

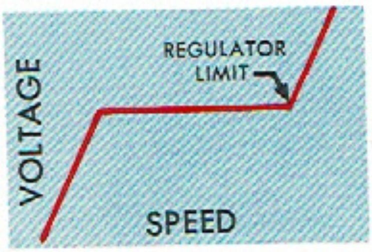
Because no field distortion occurs after the magnetic force, created by the current flow through the armature, is equalized in generators using interpoles, it is necessary that the brushes be located exactly on the mechanical neutral position rather than in an advanced position as is found practical on non-interpole generators. On certain installations where high speed and high current loads are important factors, the installation of an interpole type generator may increase brush life as much as two to eight times over similar generators without interpoles.

CONTINUED

BUCKING FIELD GENERATORS

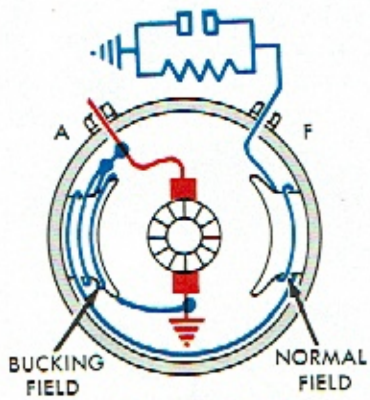
Some generators have additional turns of wire on the armature to develop the voltage necessary to obtain a current for the load circuit at very low operating speeds. Also where higher system voltage is used, such as on 32-volt marine applications, more armature turns are required to produce higher voltage at as low a speed as possible.

When there is a wide range of operating speeds for such generators, voltage regulation at the higher speeds becomes a very important problem. As stated earlier, the voltage produced in a generator depends upon the strength of the magnetic field, the number of armature conductors cutting through the field and the speed of armature rotation. When there is a large number of conductors and the speed is great, only a very weak field is needed to produce the required voltage, particularly when only a low current output is required by the load circuit.



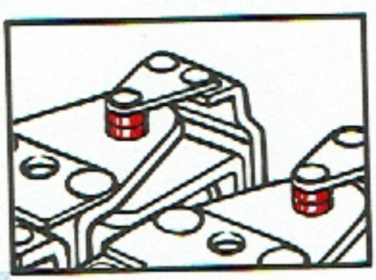
When such generators operate at very high speeds, it is possible to produce more than the required voltage even with a normally regulated field coil circuit. The residual magnetism of the pole shoes and the generator frame supply sufficient magnetic field strength to produce voltage, but this voltage cannot be controlled. Even though the voltage winding of the regulator opens the contact points and inserts a resistance in the field coil circuit, voltage will continue to climb.

Controlling voltage on this type of generator is made possible by the use of a "bucking" field coil. This is a shunt coil of high resistance, wound on one pole piece and connected directly across the brushes on the armature. The winding is connected in a reverse direction to the normal field winding and has an opposing magnetic effect to it. At low speeds, when the normal field current is large, the opposing effect of the bucking field is not great in proportion to the main field. At higher speeds, when current in the regular or main field circuit is reduced by the voltage regulator, the opposing effect of the bucking field is greater than the residual magnetic field and practically all of the magnetic lines of force are cancelled. With no magnetic field for the armature conductors to cut through, the generator voltage will immediately drop. Thus, the current flow through the main field coils can be controlled by the regulator and the effects of residual magnetism can be controlled by the bucking field and normal generator voltage can be maintained. The purpose of the bucking field is, therefore, an aid to regulation.



BUCKING FIELD

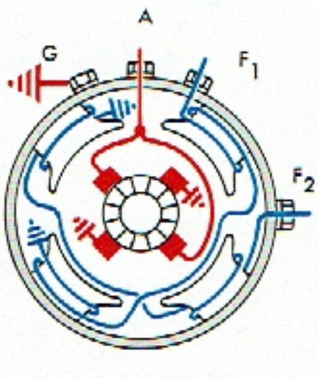
LIMITATION OF VIBRATING POINTS ON GENERATORS



The vibrating contact points used in generator regulation have a very definite limitation. As they open and close many, many times a second, they break and make the field circuit of the generator. Each time the points open, an arc occurs which burns the material used in making the points even though the best materials known are used in their construction. For long life and acceptable performance, system voltages and field currents must be held within certain limits. In general, on six-volt systems a maximum of two amperes is allowed in the field circuit. On twelve-volt systems a maximum of one and one-half amperes is allowed, whereas on twenty-four volt systems one ampere is allowable.

In reality, therefore, the design of a generator begins in the regulator. The engineer and designer must not exceed the limitations of the vibrating points in the design of their field circuit. This serves as a severe restriction in all design work.

SPLIT FIELD GENERATORS



SPLIT FIELD

The limited field coil current that can be handled by the vibrating contact points is a disadvantage on some applications. Either at engine idle or at low driving speeds, the armature does not turn at sufficient speed to cut enough magnetic lines of force to develop sufficient voltage to provide current for the load circuit. Under these conditions, current for all vehicle loads is supplied by the battery. If prolonged periods of idling and slow driving speeds prevail, the battery soon becomes discharged. Therefore, it is necessary on such applications to provide a means of generating sufficient voltage at low engine speeds to supply current for the load circuit.

The split field generator was designed for this purpose. As the name implies, it has two field circuits within the generator. By increasing the magnetic field strength with an added field coil circuit, the voltage necessary to provide current for the load circuit and for charging the battery can be reached at a much lower speed. Thus, current for the load circuit and charging the battery can be obtained at engine idle speeds preventing battery discharge.

The stronger field necessary for developing voltage at low speed is accomplished by splitting the field circuit into two separate circuits, each controlled by its own voltage and current regulator. Each set of field coils is designed for maximum allowable field coil current. The split field type generator has approximately double the field strength of a generator having only one field.

This type generator is successfully used on applications such as city busses, where long periods of engine idling and slow operating speeds due to congested city traffic require the use of such a generator to prevent battery "run-downs".

DOUBLE CONTACT REGULATED GENERATORS

The limitation of the field coil current that can be handled by vibrating points has, to a small degree, been offset by a new voltage regulator design which controls generator voltage by inserting resistance in series with the field circuit in two steps. In step one, a resistance of low value is inserted in series with the field coils in the usual manner. When generator speed and voltage climb to a predetermined value, step two shorts out the entire field circuit so that no current flows in the field coils.

This decrease in the resistance of field coil circuit permits slightly higher field coil current to be used. Higher field current means that the generator will develop regulated voltage at a lower speed and, if the design of the generator can withstand it, higher output can be developed.