training chart manual

SECTION e

GENERATORS

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

Delco - Remy

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SECTION E

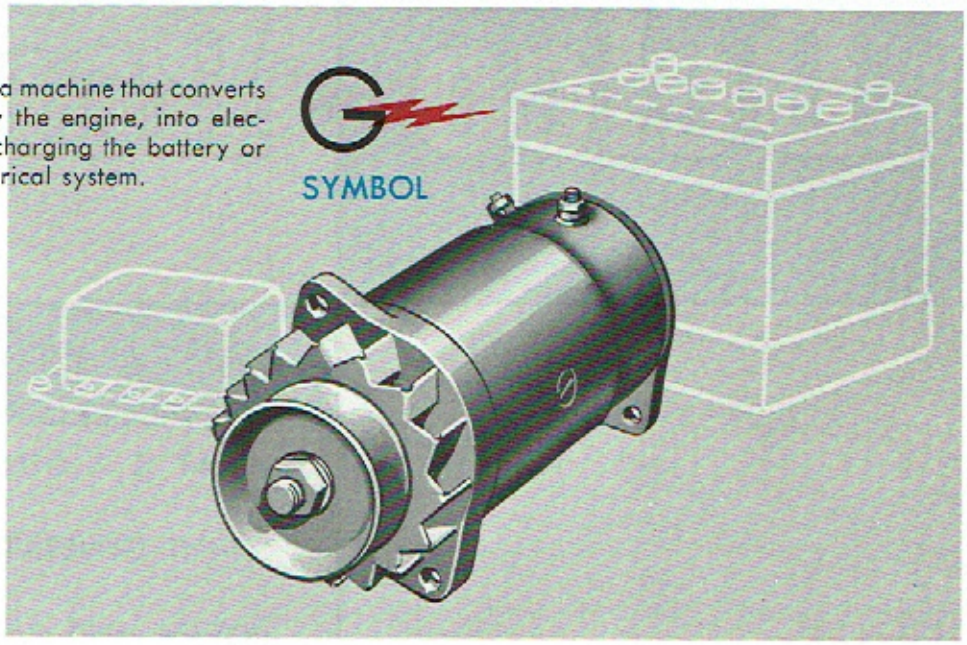
GENERATORS

a manual published as a guide for instructors using Delco-Remy training charts on automotive electrical equipment

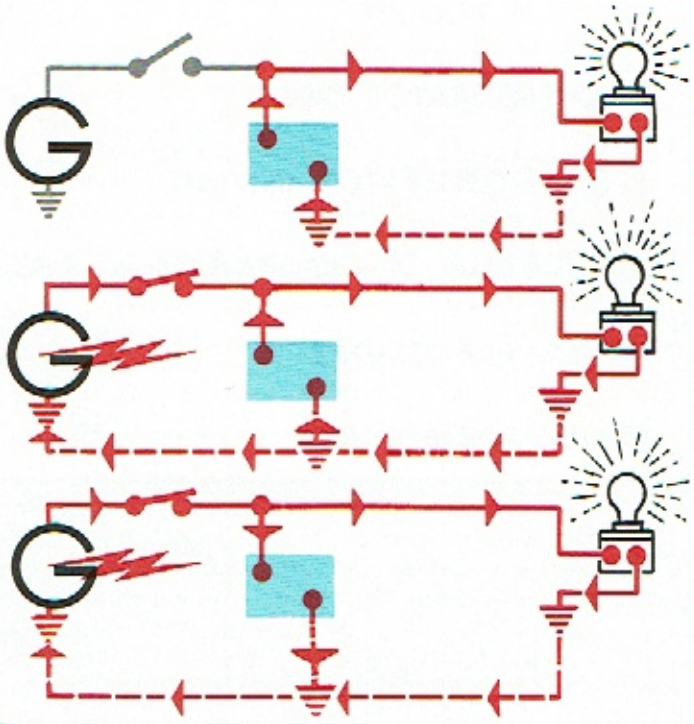
Published by
DELCO-REMY DIVISION OF
GENERAL MOTORS CORPORATION
ANDERSON, INDIANA, U.S.A.

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 for either 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.



When the standard automotive generator is either at rest or is operating at an extremely slow speed such as at engine idle or when in the heavy traffic of city driving, electrical energy for ignition, lights and accessories is supplied by the battery only not by the generator.

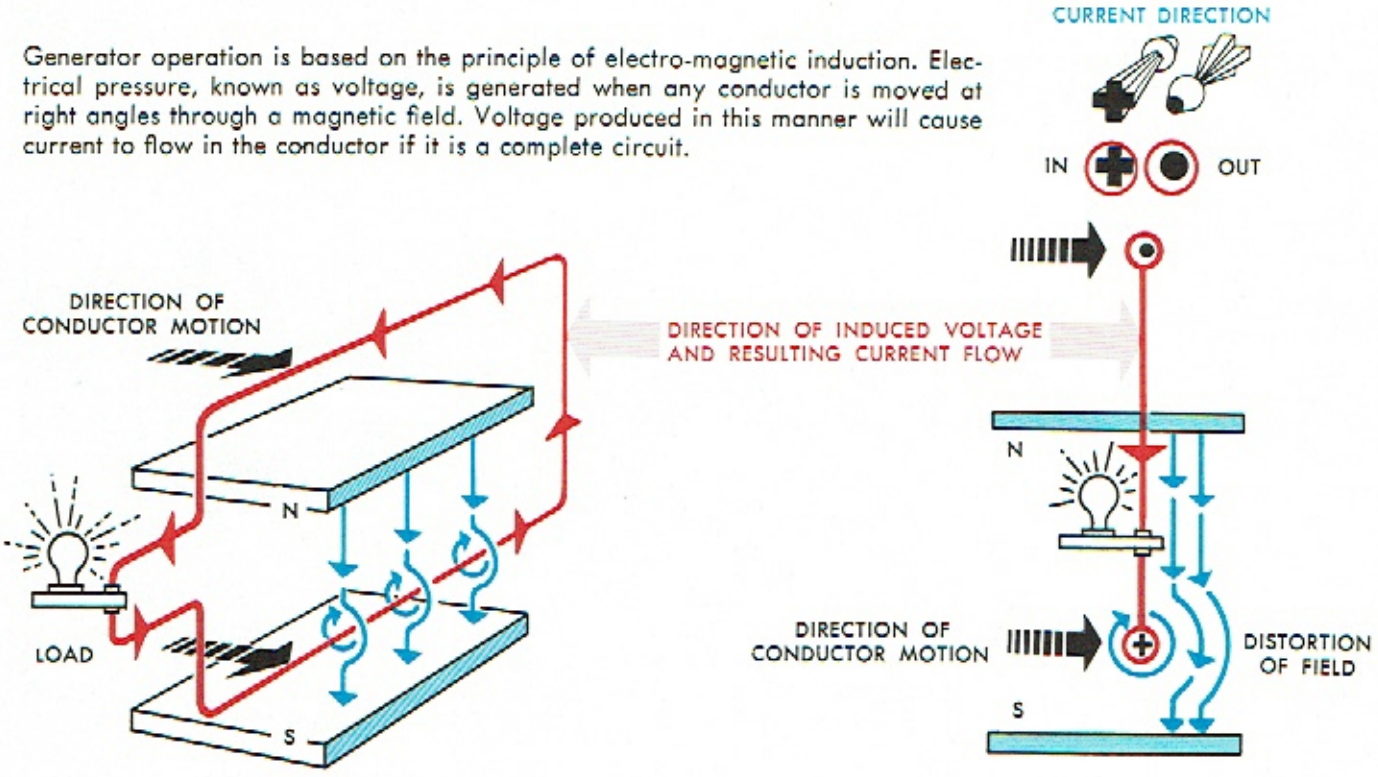
When it is operating at medium speeds, energy is supplied to the electrical system by both the generator and the battery

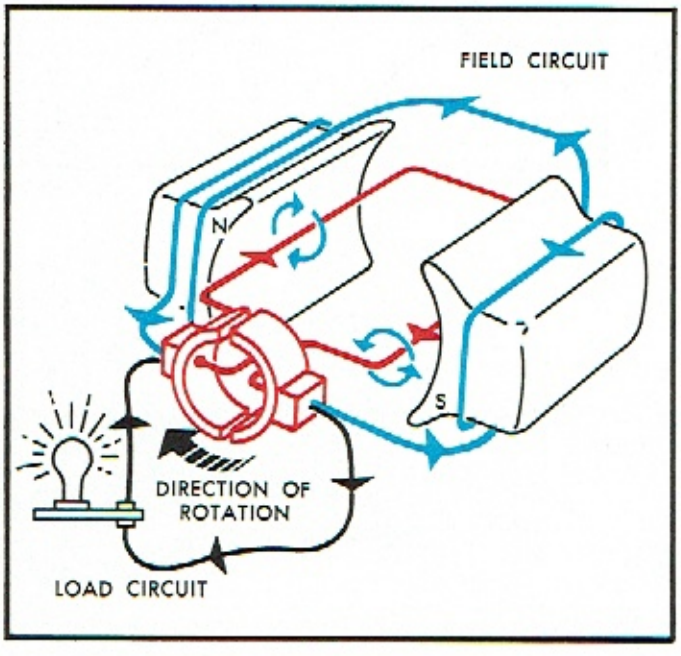
At high speed, as encountered on open highway driving, the generator alone supplies electrical energy to *RECHARGE THE BATTERY* and to *POWER* the electrical system.

SHUNT GENERATOR PRINCIPLES

HOW A GENERATOR DEVELOPS VOLTAGE

Generator operation is based on the principle of electro-magnetic 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 a complete circuit.





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

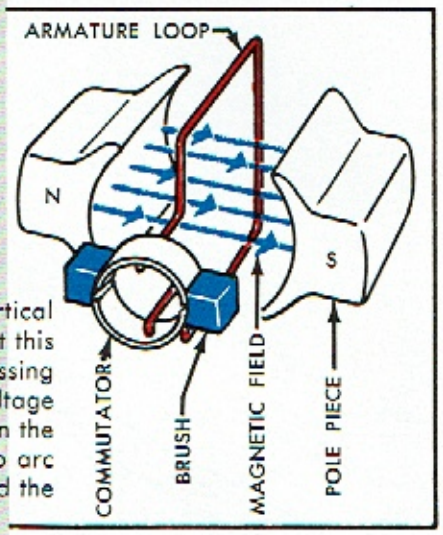
A simple generator with an armature having only one turn or loop of wire and two iron pole pieces is illustrated. These pole pieces retain some magnetism, known as "residual" magnetism, from their last use. They are very weak permanent magnets with a magnetic field between them. If the armature is rotated in a clockwise direction through this 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 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. 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.

CONTINUED

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, makes the poles electro-magnets. 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.

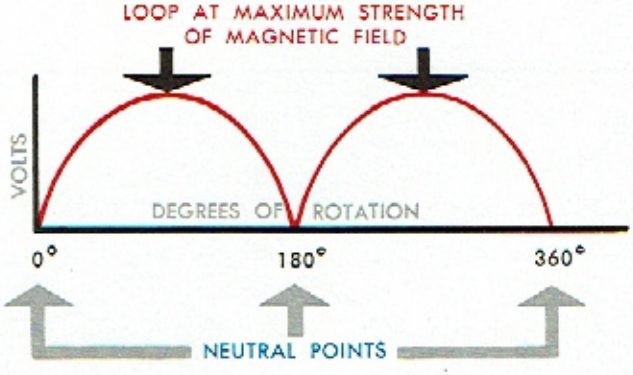
The voltage between the two ends of the armature loop also causes a flow of current through the load circuit as indicated when a light bulb is placed in the external circuit.

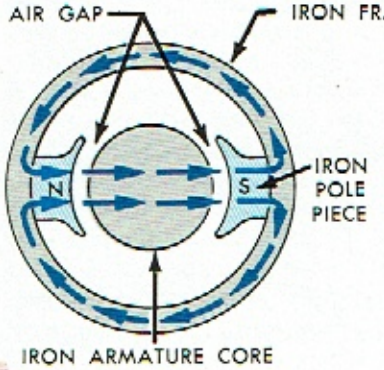
The ends of the armature loop are securely attached to a split ring called a "commutator". Riding on the commutator are the brushes. It is from these brushes that the voltage and the resulting current is transmitted to both the field and the load circuits. This is called "commutation".



As can be seen from the illustration, 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".

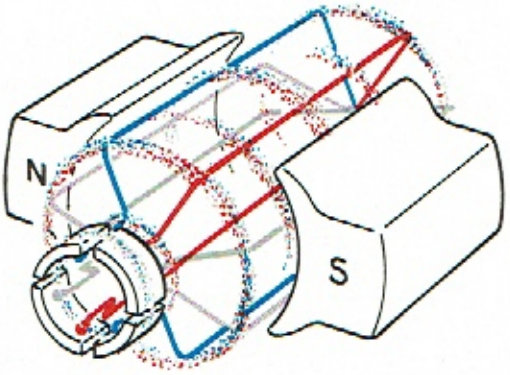
Notice the picture that shows the magnitude and direction of voltage during one complete revolution of the armature.

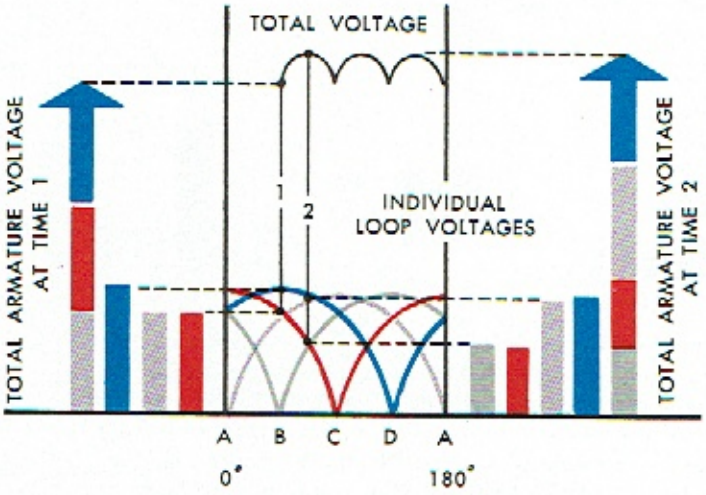


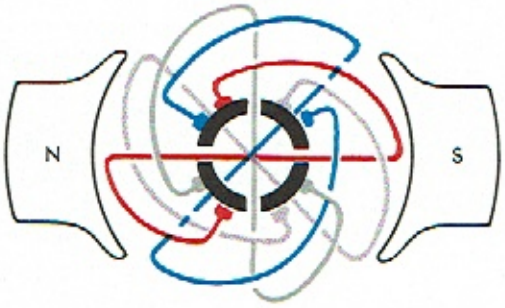


Just as electrical circuits must be complete, there must also be a complete magnetic circuit. The former illustration deals primarily with the electrical circuit, whereas the illustration at the left shows the magnetic circuit of a two pole generator. It is important to remember that all air gaps in the 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, note the figure at the right. Here is a more complete armature containing additional loops of wire imbedded in the slots of an iron core. Note also that all 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".

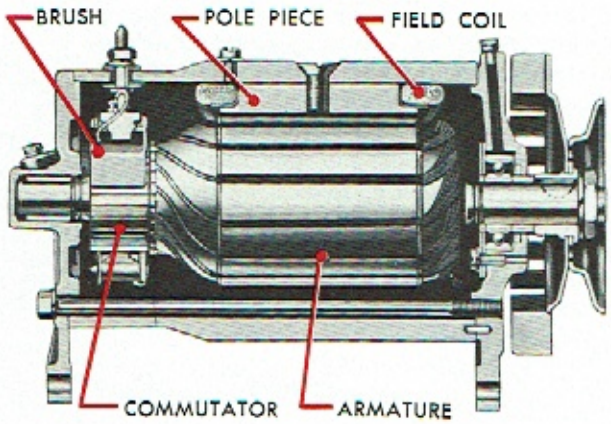


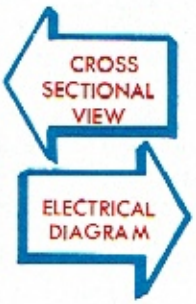


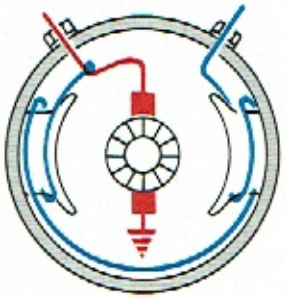


Voltage is increased by adding conductors to the armature. When more conductors and more commutator bars are used, note how the voltage waves overlap producing an almost constant value of D.C. voltage at a given speed and load.

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 armature rotation are the interrelated ingredients necessary to obtain electrical power from a generator. The engineer and designer work with these basic fundamentals to design a generator which will do its intended job.







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".

$$P = E \times I$$

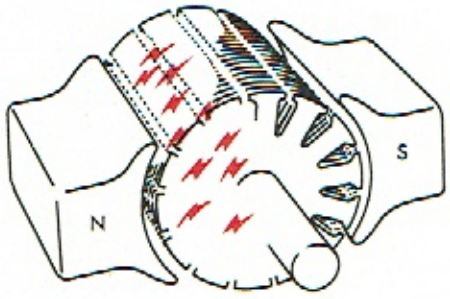
WATTS = VOLTAGE × CURRENT

Voltage or electrical pressure induced in the coils of the armature causes current to flow through the field coil 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.

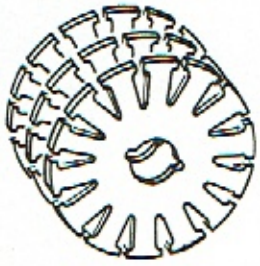
$$I = \frac{E}{R} \qquad E = I \times R \qquad R = \frac{E}{I}$$

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 over-heating can result from the 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.

EDDY CURRENTS CREATE HEAT



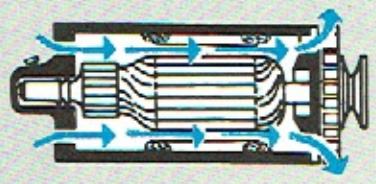
Another source of heat, called "iron loss", is present in the armatures of all generators. The iron core of the armature acts as one large conductor which cuts magnetic lines of force as it revolves, generating voltage within the core itself. This action results in current flow called "eddy currents". 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.



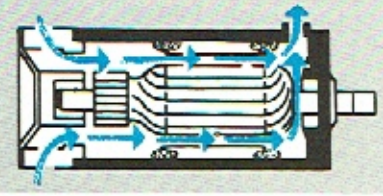
TYPICAL LAMINATION SECTIONS

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. Three methods of forcing air through a generator are by:

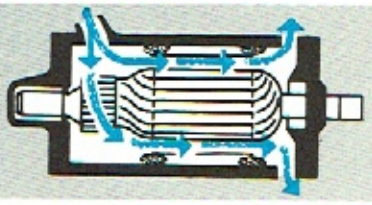
PLACING A FAN ON THE GENERATOR DRIVE PULLEY



PASSING THE ENGINE INTAKE AIR THROUGH THE GENERATOR



COOLING WITH PRESSURIZED AIR THROUGH A BLAST TUBE

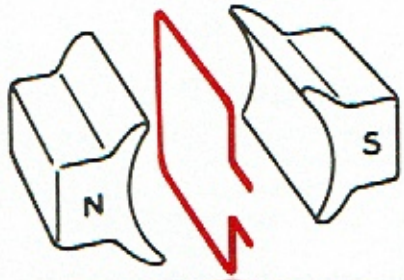


In summary, the power output or wattage of the generator is the product of its rated current times its regulated voltage. Heat is an enemy of all electrical equipment and must be taken into account when designing generators. The output of the generator must not be allowed to exceed its specified rating,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

$$P = E \times I$$

ARMATURE REACTION

ITS EFFECT ON BRUSH LOCATION AND NEUTRAL POINT



NEUTRAL POSITION

In explaining generation of electrical power, we 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 parrallel 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.

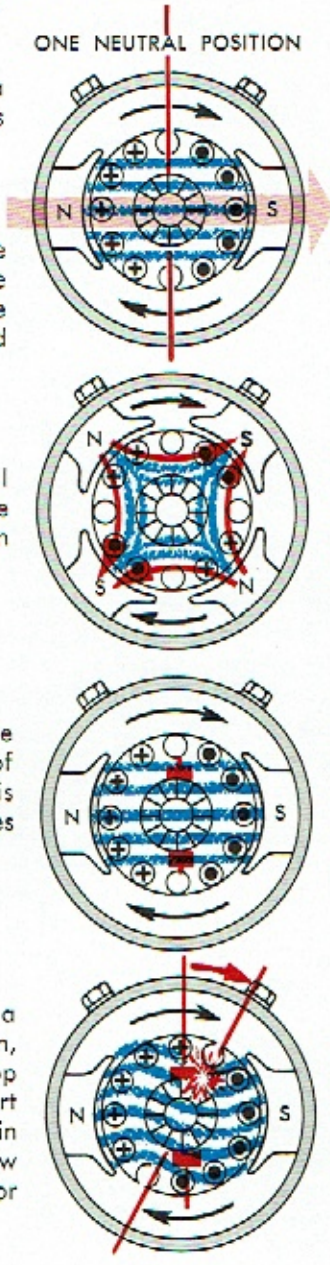
Direct current is obtained by switching the connections of the conductors with a commutator and brushes during the time the conductor is between the poles. This region is known as the "commutating zone", and lies at the neutral point.

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.

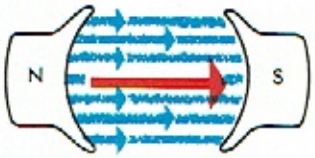
Generators with more than two poles have one neutral point for each pole. As an example, for a four pole generator, there are four neutral points, one between each two adjacent poles.

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

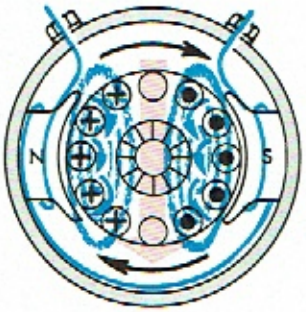


Such a distortion of the magnetic field as shown actually exists. This distortion is caused by the magnetic field set up around the armature conductors acting with the magnetic field of the poles. It is called "armature reaction".



Note the illustration that shows the normal magnetic field between the poles.

ARMATURE MAGNETIZING FORCE

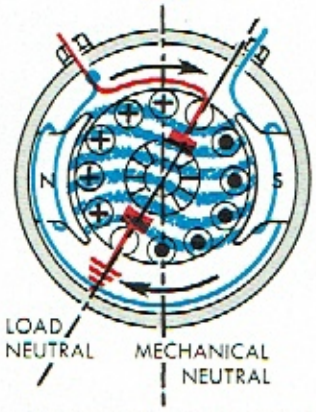


This illustration shows the magnetic field surrounding the coils of the armature that results when current flow is established in these coils. It must be remembered that all the load current flows through the conductors of the armature, and the greater the current flow the greater will be the strength of the surrounding magnetic field.

RESULTANT FLOW

The magnetic field formed after combining the magnetic field of the armature and the field of the pole pieces is illustrated. The change in the path of 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.

BRUSH PLACEMENT



All conductors in the armature are connected in series through the commutator so that load current flows through all of them. To obtain best commutations, it is necessary to locate the brushes at the "load" neutral rather than at the "mechanical" neutral. The "load" neutral is located ahead of the "mechanical" neutral in the direction of rotation.

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.