ALTERNATORS

PRINCIPLES of OPERATION

Ford

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ALTERNATOR

The alternator is made up of the same functional parts as that of a D.C. generator. It has a field coil for excitation which is called a rotor and as its name implies, it rotates within the alternator housing. The rotor looks like the generator armature but does not function like it. The rotor with its pole pieces, field coil, core and slip-rings produces the magnetic field. In the generator the field is stationary, in the alternator the field (rotor) rotates.

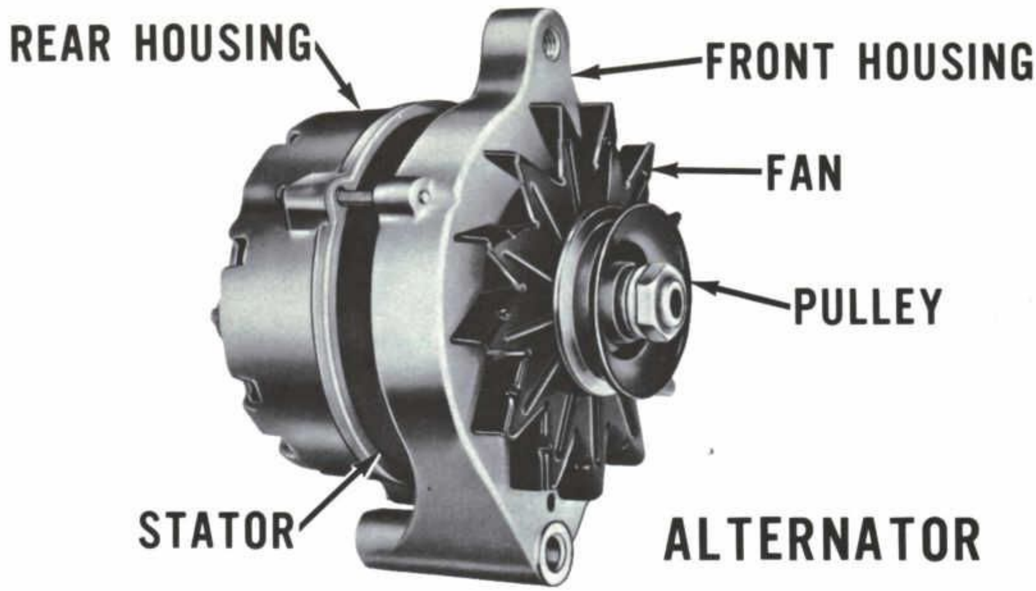
The alternator stator, as its name implies, is stationary. It contains the heavy current carrying wires in which the current is induced. It does the same job that the generator armature does except that it doesn't turn. In the generator, all the current generated by the armature must be transferred through the brushes to the charging system. In cases where the output is very high, the generator brushes would have to be quite large to handle the increased output. Also, the heavy windings would be rotating with the generator armature and subject to the effects of centrifugal force. The principal advantage of the alternator over the generator is the possibility of higher maximum operating speeds. Generator commutators are limited to speeds of approximately 10,000 rpm, whereas alternator speeds are limited only by bearing life and centrifugal force acting on the rotor. The alternator will operate at speeds up to 15,000 rpm. Thus, higher pulley ratios may be used with subsequent higher output at engine idle speed.

Heat dissipation would also be a problem in a high-output generator. With the alternator stator, this problem is eliminated because the windings are stationary. Heat can be easily conducted away by means of the alternator housing and the windings are not subject to the effects of centrifugal force as they would be in the generator armature. The heavy current is tapped off the alternator stator by three leads in the stator and doesn't require the use of brushes for this purpose.

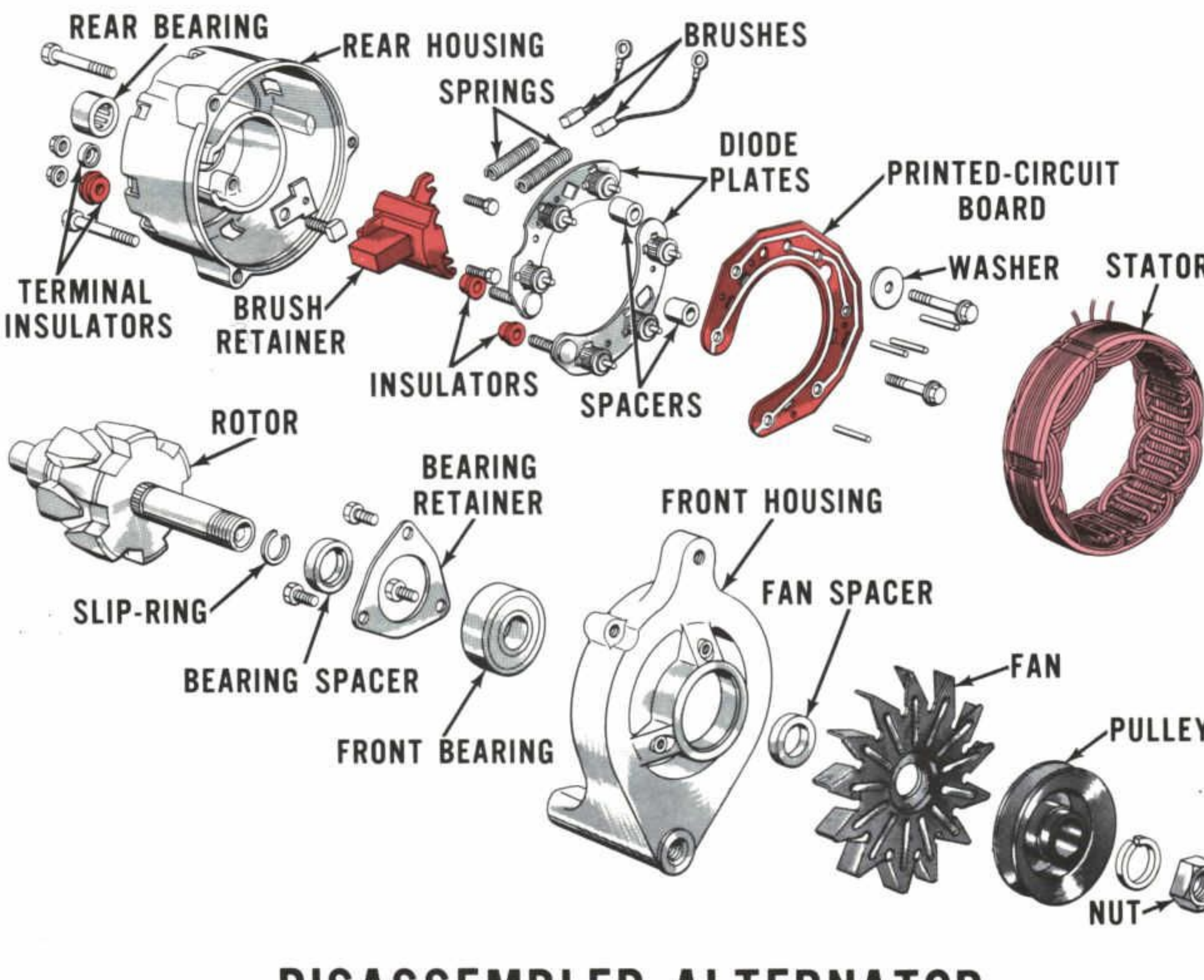
Both the generator and the alternator produce electric current by the process of electromagnetic induction, that is, in the generator we move the conductors through the magnetic field and in the alternator we move the magnetic field through the conductors located in the stator. In each case, current is induced within the conductors and transferred to the commutation or converting device. The induced current and voltage in both the alternator and the generator is alternating current. This alternating current must be converted or rectified into direct current before it can be used in the charging system of the automotive storage battery. The generator uses a mechanical switch (commutator and brushes) to convert the alternating current in the armature to direct current. The alternator system uses a diode rectifier to convert A.C. to D.C.

From the above facts, we can see that both the generator and the alternator operate on the same fundamental principle. The alternator is just a variation of the basic theory to produce more current in less space.

Now that we have discussed the "what" of an alternator, let's go back and review some of the fundamentals.



ALTERNATOR



DISASSEMBLED ALTERNATOR

MAGNETISM

Magnetism, like electricity, is invisible. Its effects, however, are well known. An example is the attraction of a bar magnet for iron filings. A magnet has a north pole, designated as "N", and a south pole, designated as "S". The space around the magnet in which iron filings are attracted is called the "field of force" or magnetic field, and is described as lines which come out of the north pole and enter the south pole.

When two permanent magnets are so placed that the north pole of one and the south pole of the other are close together, they are found to attract each other. Also, if the magnets are placed with their like poles adjacent, they are found to repel each other. From these facts we may state a fundamental law of magnetism. UNLIKE POLES ATTRACT EACH OTHER—LIKE POLES REPEL EACH OTHER.

When the wire, carrying electric current, is wound into a coil, a magnetic field with "N" and "S" poles is created just like in a bar magnet.

If an iron core is placed inside this coil, the magnetic field becomes much stronger, because iron conducts magnetic lines much easier than air. This arrangement, called an **electromagnet,** is used in generators to create strong magnetic fields by winding many turns of current carrying wire around iron cores called "pole" pieces.

We have seen that a magnetic field, made up of lines of force, is created around a wire when current is passed through it. Conversely, if a magnetic field is moved so that the lines of force cut across a wire conductor, a voltage will be induced in the conductor. The induced voltage will cause current to flow when an electrical load, such as a resistor, is connected across the conductor.

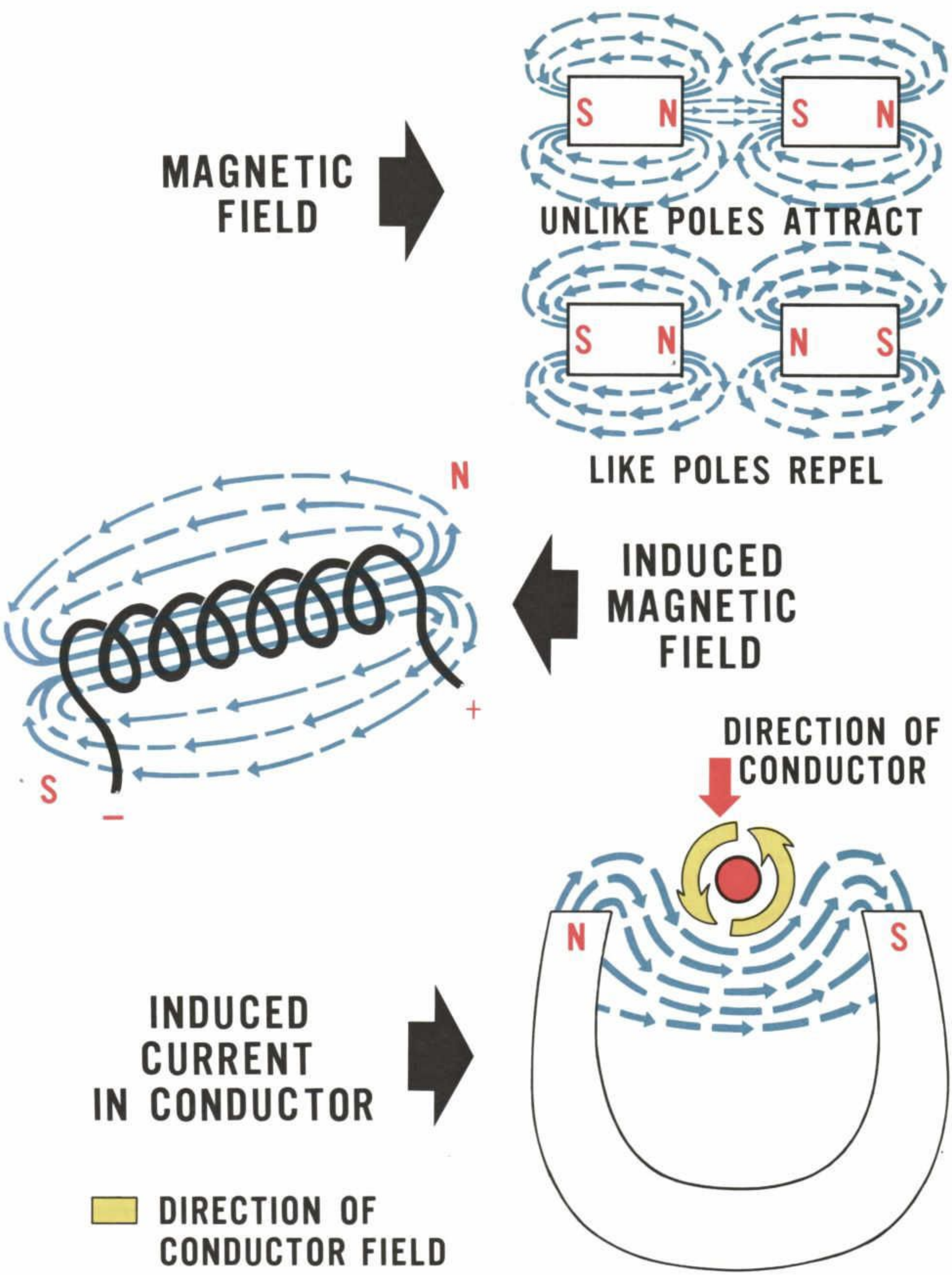
The direction of current flow is determined by the direction of the magnetic lines of force and the direction of motion of the magnetic field with respect to the conductor.

The direction of current flow can be determined by applying the "Left-Hand Rule" as follows; grasp the conductor with the left hand with the thumb pointed in the direction of current flow (current flows from negative to positive), the fingers wrapped around the conductor will point in the direction of the magnetic lines of force. Another application of this rule would be; with the left hand fingers wrapped around the leading edge of a conductor and pointing in the direction of the magnetic lines of force, the thumb will point the direction of current flow.

With current flowing in opposite directions in two adjacent parallel conductors, as in a simple electrical circuit, in which one wire carries current to the load while the other wire carries the return current, a definite magnetic field pattern is created. By applying the "Left-Hand Rule" for determining the direction of lines of force around a straight conductor, we see that each conductor alone creates a circular field of force.

The total number of lines between the conductors is the same as the total number of lines outside, since all the loops are continuous. The area between the conductors is very limited, however, as compared to the area outside. Therefore, a condition of unbalanced density is created. This unbalance causes forces to act on both conductors. These forces are in such a direction as to increase the enclosed area and thereby, minimize the unbalance. For instance, if the parallel conductors are held fast at the ends only, the intermediate portions will be pushed **away** from each other.

There is always a tendency for any current carrying conductor in a magnetic field to move in a direction to relieve the unbalance created in the magnetic field by the current in the conductor. **With a combined field between two conductors, the left-hand conductor will be moved to the left, and the right-hand conductor will be moved to the right.**


MAGNETIC FIELD
S N
S N
UNLIKE POLES ATTRACT
S N
N S
LIKE POLES REPEL
N
INDUCED MAGNETIC FIELD
+
S
–
DIRECTION OF CONDUCTOR
N
S
INDUCED CURRENT IN CONDUCTOR
DIRECTION OF CONDUCTOR FIELD

MAGNETISM

GENERATING ELECTRICITY

An alternating current generator made with a bar magnet rotating inside a single loop of wire is not practical since it is low in performance and very little current is produced.

The performance can be improved when both the loop of wire and the magnet are placed inside an iron frame. The iron frame not only provides a place onto which the loop of wire can be assembled, but also acts as a conducting path for the magnetic lines of force. Without the iron frame, magnetism after leaving the "N" pole of the rotating bar magnet, must travel through air to get to the "S" pole. Because air has high reluctance to magnetism, only a few lines of force will come out of the "N" pole and enter the "S" pole. This means that more lines of force will be cutting across the conductor which lies between the bar magnet and the frame.

In our review of electrical fundamentals, we observed that voltage will be induced in a conductor if a magnetic field is moved across it. For example, consider a bar magnet with its magnetic field rotating inside a loop of wire which is the conductor.

With the magnet rotating as indicated, and with the "S" pole of the magnet directly under the top portion of the loop and the "N" pole directly over the bottom portion, the induced voltage will cause current to flow in the circuit in the direction shown. Since current flows from negative to positive through the external or load circuit, the end of the loop of wire marked "A" will be positive (+) polarity and the end marked "B" will be negative (—).

After the bar magnet has moved through one-half revolution, the "N" pole will have moved directly under the top conductor and the "S" pole directly over the bottom conductor. The induced voltage will now cause current to flow in the opposite direction. The end of the loop of wire marked "A" will therefore become negative (—) polarity, and the end marked "B" will become positive (+). The polarity of the ends of the wire has therefore changed. After a second one-half revolution, the bar magnet will be back at the starting point, where "A" is positive (+) and "B" negative (—).

Consequently, current will flow through the load or external circuit first in one direction and then in the other. This is an alternating current which is developed by an A.C. generator.

It is important to note that a very large number of magnetic lines of force leave the magnet center, whereas there are only a few lines of force at the ends of the magnet. Thus, there is a strong magnetic field at the center and a weak magnetic field at the ends. This condition results when the distance, called the air gap, between the magnet and field frame is greater at the ends than at the center of the magnet.

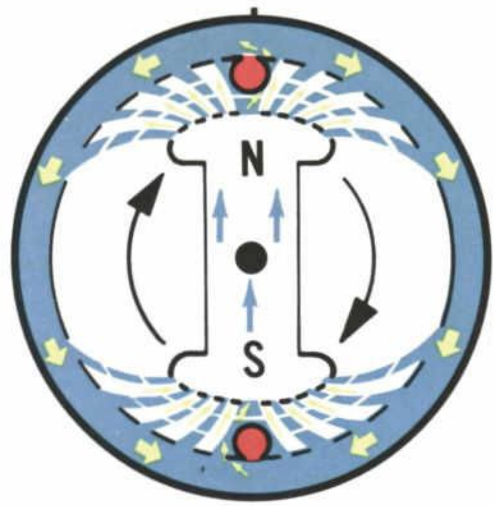
The amount of the voltage induced in a conductor is proportional to the number of lines of force which cut across the conductor per second. Therefore, if the number of lines of force is doubled, the induced voltage will be doubled.

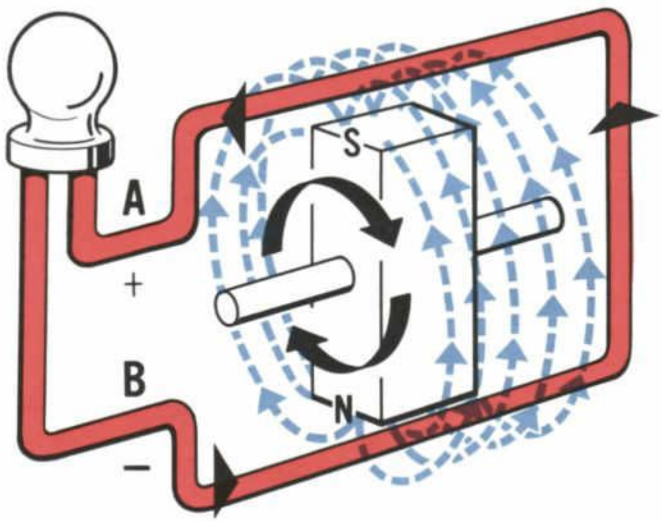
The voltage will also increase if the bar magnet is made to turn faster because the lines of force will be cutting across the wire in a shorter period of time.

It is important to remember that either increasing the speed of rotation of the bar magnet, or increasing the number of lines of force cutting across the conductor, will result in increasing the current. Similarly, decreasing the speed of rotation or decreasing the number of lines of force will cause the current to decrease.

The rotating magnet in an alternator is called the rotor, and the loop of wire and outside frame assembly is called the stator.

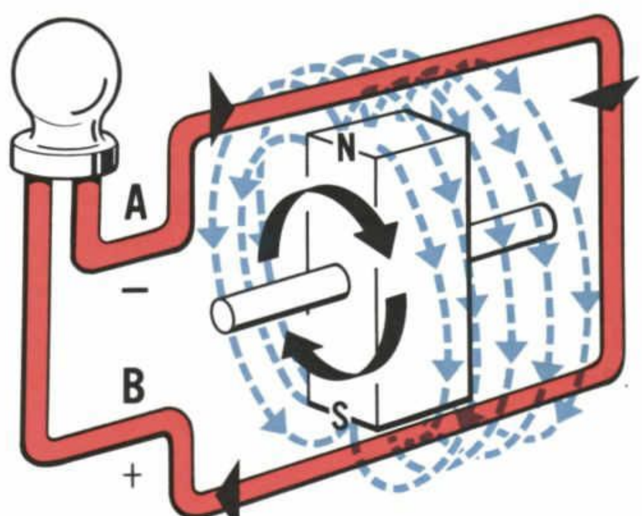
MAGNETIC FIELD THROUGH HOUSING





FIRST HALF REVOLUTION

SECOND HALF REVOLUTION



GENERATING ELECTRICITY

GENERATING A.C.

Pictured in the illustration are different positions of the rotor as it rotates at constant speed. In the top portion of the illustration is a curve showing the magnitude of the voltage which is generated in the loop of wire as the rotor revolves.

The voltage curve shows the generated voltage or electrical pressure which can be measured across the ends of the wire, the same voltage can be measured across the terminal posts of a battery.

With the rotor in the first position (1): there is no voltage being generated in the loop of wire because there are no magnetic lines of force cutting across the conductor. As the rotor turns and approaches position (2), the rather weak magnetic field at the top of rotor starts to cut across the conductor, and the voltage increases. When the rotor reaches position (2), the generated voltage has reached its maximum value, as shown above the horizontal line in the illustration. The maximum voltage occurs when the rotor is directly under the loop of wire because it is in this position that the loop of wire is being cut by the heaviest concentration of magnetic lines of force.

It should be noted in particular that the magnitude of the voltage varies because the concentration of magnetic lines of force cutting across the loop of wire varies. The voltage curve shown is not a result of a change in rotor speed, because in the illustration the rotor is considered to be turning at a constant speed.

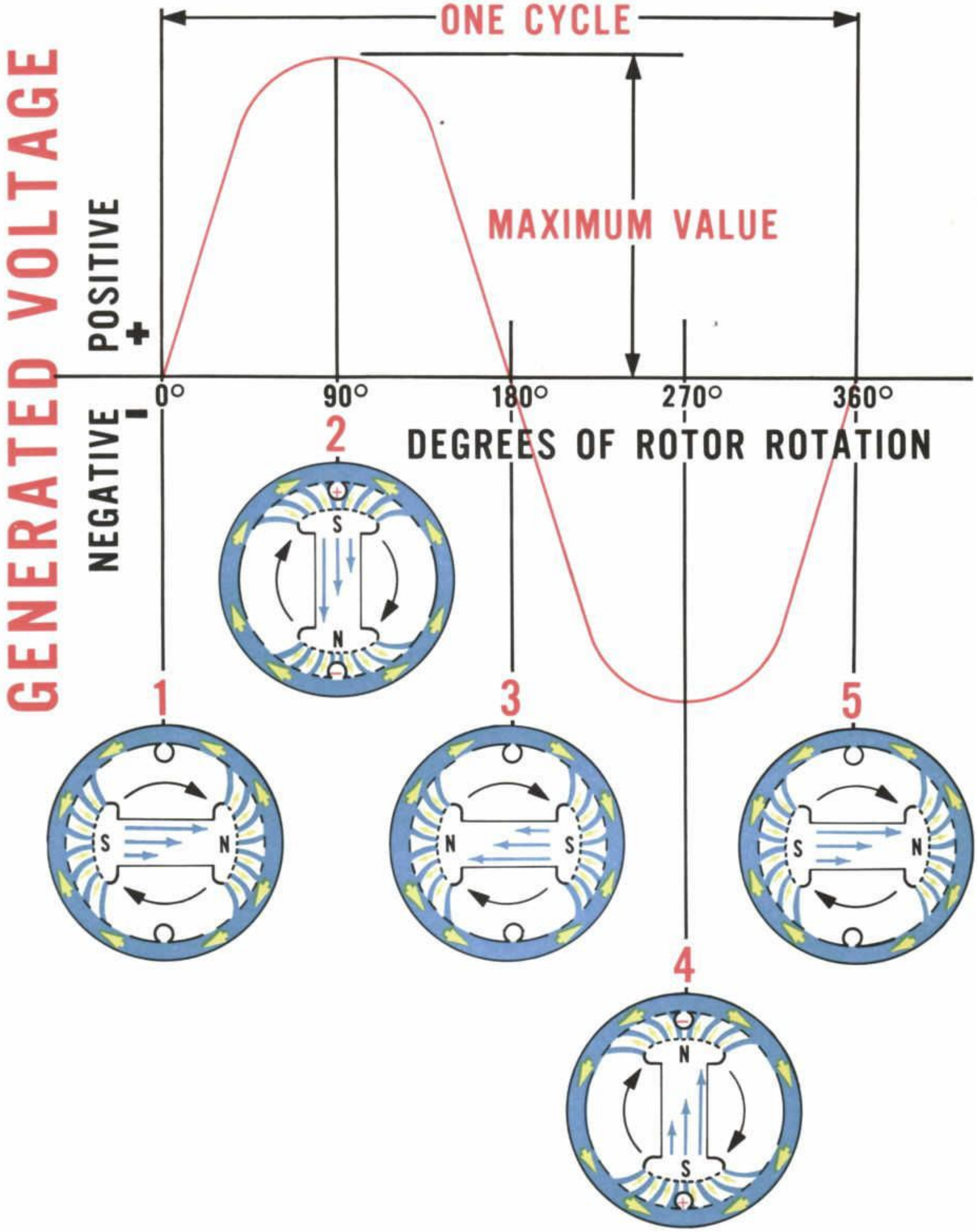
By applying the "Left-Hand Rule" to position (2), it is seen that the direction of current in the loop of wire will be out of the top end of the conductor, and into the bottom end. Note the stationary conductor leading edge is distorting the magnetic field and starting the conductor magnetic field direction. Thus, the top end of the conductor will be positive, and the bottom end negative. The voltage curve which is shown above the horizontal line represents the positive voltage at the top end of the wire loop which is generated as the rotor turns from position (1) to position (3).

As the rotor turns from position (2) to position (3), the voltage decreases until at position (3) it again becomes zero.

As the rotor turns from position (3) to position (4), note that the "N" pole of the rotor is now passing under the top part of the wire loop, and the "S" pole under the bottom part. The top end of the loop of wire is now negative, and the bottom end positive. The negative voltage at the top end of the loop is pictured in the illustration by the curve which is below the horizontal line.

The voltage again returns to zero when the rotor turns from (4) to (5).

The voltage curve in the illustration represents one complete turn or cycle of the rotor. With the rotor making 60 complete turns in one second, there will be 60 such curves, one coming right after the other, resulting in 60 cycles-per-second. The number of cycles-per-second is called the frequency. Since the alternator speed varies in automotive-type applications, the frequency also varies.



GENERATING A.C.

ROTOR

In the discussion so far, the rotor has been considered as a bar magnet for purposes of illustration. The rotor in an alternator is actually constructed with more than two poles. The Ford alternator has 12 poles.

In the 12-pole rotor, round wire is used to produce a strong magnetic field. D.C. current is supplied to the rotor coils through brushes and slip-rings. With many turns of wire in the stator windings, and a rotor which produces strong magnetic fields, the A.C. generator is an efficient source of electricity.

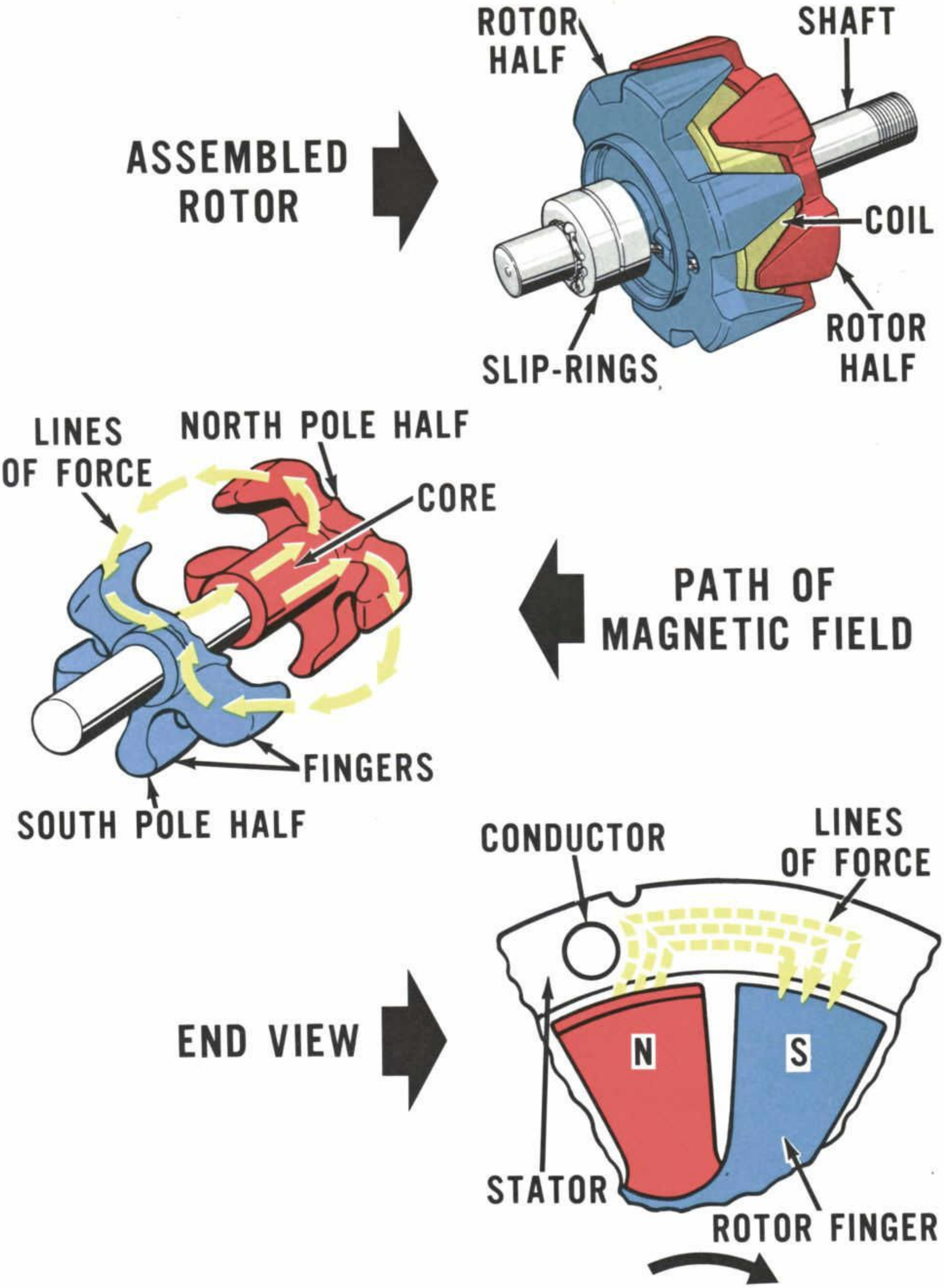
The field coil is encased in two six-fingered overlapping halves. The six rear fingers act as north poles; the six front fingers act as south poles. When the two halves are assembled together, each front finger (south pole) is adjacent to a rear finger (north pole), constituting six pairs of poles with lines of force running between.

When current is passed through the rotor coil, it will create magnetic lines of force. The core and the rotor halves form almost a complete path for these lines. As you will notice, the lines leave the north rotor half and return through the south rotor half. Because the coil is connected to a source of direct current through the slip-rings, this polarity will always remain the same.

When the rotor is placed within the stator, the lines of force will travel through the stator. This path is shown in the lower diagram. You can see that when the rotor is turning, the lines of force will cut the conductors.

Therefore, we can see that in the alternator, the lines cut the conductors. Whereas in the generator, it is just the opposite.

The rotor is driven by the engine drive belt and a fan is attached to the rotor shaft. The fan pulls a draft through the alternator rear housing across the rotor and out the front housing openings. This cooling draft is required because of the heat created by the generation of a current.


ASSEMBLED ROTOR
ROTOR HALF
SHAFT
COIL
ROTOR HALF
SLIP-RINGS
LINES OF FORCE
NORTH POLE HALF
CORE
PATH OF MAGNETIC FIELD
FINGERS
SOUTH POLE HALF
CONDUCTOR
LINES OF FORCE
END VIEW
N
S
STATOR
ROTOR FINGER

ROTOR

THREE-PHASE CURRENT

The single loop of wire acting as a stator winding serves to illustrate how an A.C. voltage is produced in an A.C. generator. A generator is actually constructed with three separate windings in the stator, and each winding contains many loops of wire. The stator windings, marked 1, 2 and 3, are each called a phase; hence, a stator connected as shown is known as a three-phase "Y" connected stator.

Three-phase current refers to the current delivered through three wires, with each wire serving as the return for the other two and with the three current components differing in phase successively by one-third cycle, or 120 degrees.

The alternator utilizes three series of conductors to produce a three-phase output. The three-phase circuit output is shown in simplified form. The curves are sine waves and are a graphical presentation of the rise and fall of current flow in the stator coils. The upper half is called the positive half-cycle because the polarity of the voltage produced is positive.

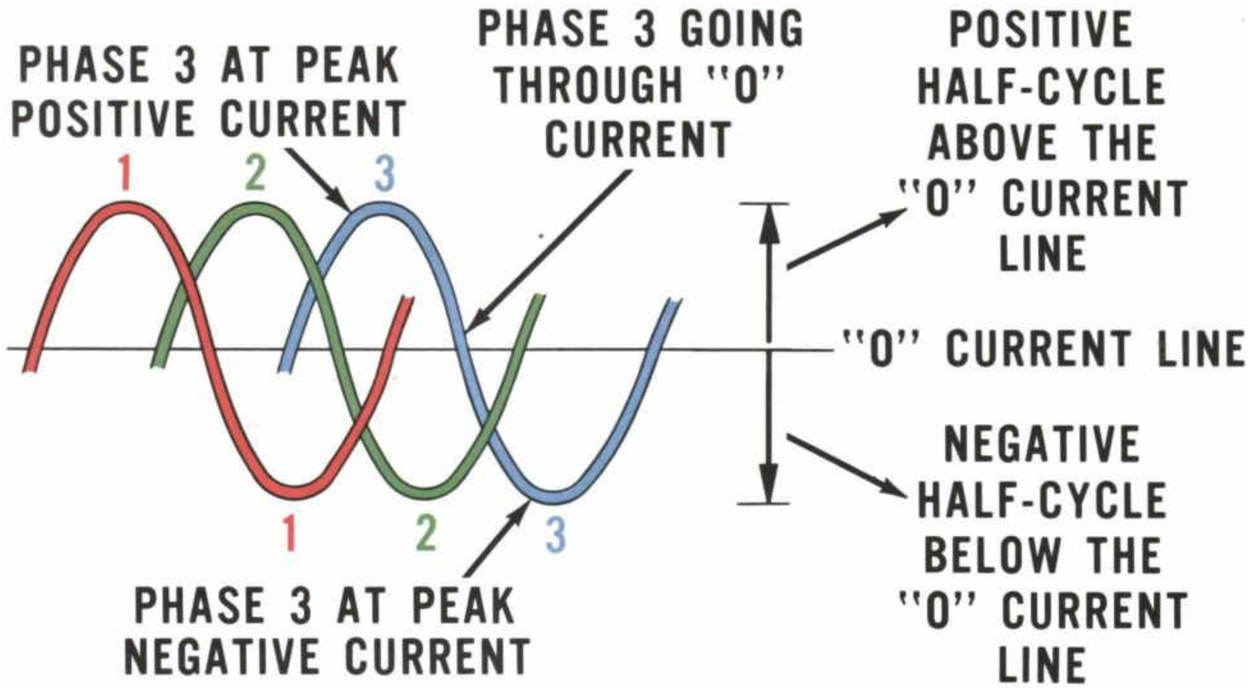
A simplified representation of the stator is shown in the bottom view. The stator coils overlap by the same amount as the sine waves. Only two coils are shown for each phase winding in the wiring diagram to illustrate the method of connection. Actually, each phase winding consists of 12 coils connected in series.

As the rotor poles revolve past the stator coils, the magnetic lines of force will cut the coil wires and induce a voltage in them. The north and south rotor poles will produce an alternating positive and negative voltage in each coil. The magnitude of the voltage produced is dependent on the strength of the magnetic field and the rotor speed. A strong magnetic field, faster rotation, or both, will result in an increased output.

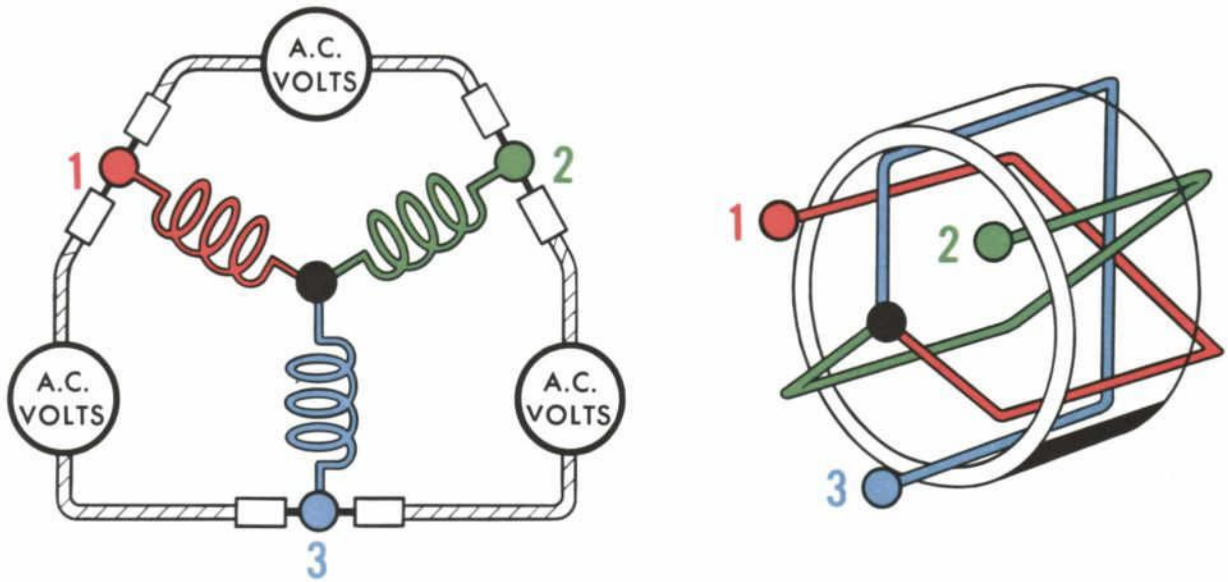
Current limiting in the alternator is accomplished by an electrical property called "inductive reactance." This may be considered as a resistance to current reversal in the stator coils. When full-field (rotor) excitation is applied to the rotor coil, the output voltage at the alternator terminal will increase with speed. However, as the speed increases, the frequency of current reversal also increases. This increase in frequency produces an increased reactance which causes the current output to stablilize rather than increase during high-speed operation.

The alternating current produced is transferred to the full-wave bridge diode for conversion to direct current.

To demonstrate the current flow in a three-phase, full-wave bridge diode circuit, several diagrams are required to trace the circuit action.



3-PHASE CIRCUIT OUTPUT



3-PHASE "Y" CONNECTION

THREE-PHASE

DIODES

The chemical composition of a diode is such that it will allow current to flow through itself in only one direction. Thus, when a diode is connected in a circuit with an A.C. voltage, current will flow as shown in circuit A, but will not flow in circuit B. Note that the diode is reversed in circuit B. There are, however, special types of diodes which will allow current to pass in the reverse direction.

When the alternator was originally introduced, the only practical means of converting alternating current (A.C.) to direct current (D.C.) was with a dry-plate selenium diode. For cooling purposes, this type of diode required positioning in an open area; therefore, cleaning at regular intervals was mandatory. This made it impractical for use by the average owner.

With the recent advent of commercially available, reasonably priced silicon diodes, alternators have become feasible. The silicon diode is a more efficient unit; it can withstand higher temperatures, and is much more compact. These characteristics permit the diode to be mounted inside the alternator as an integral part of the unit.

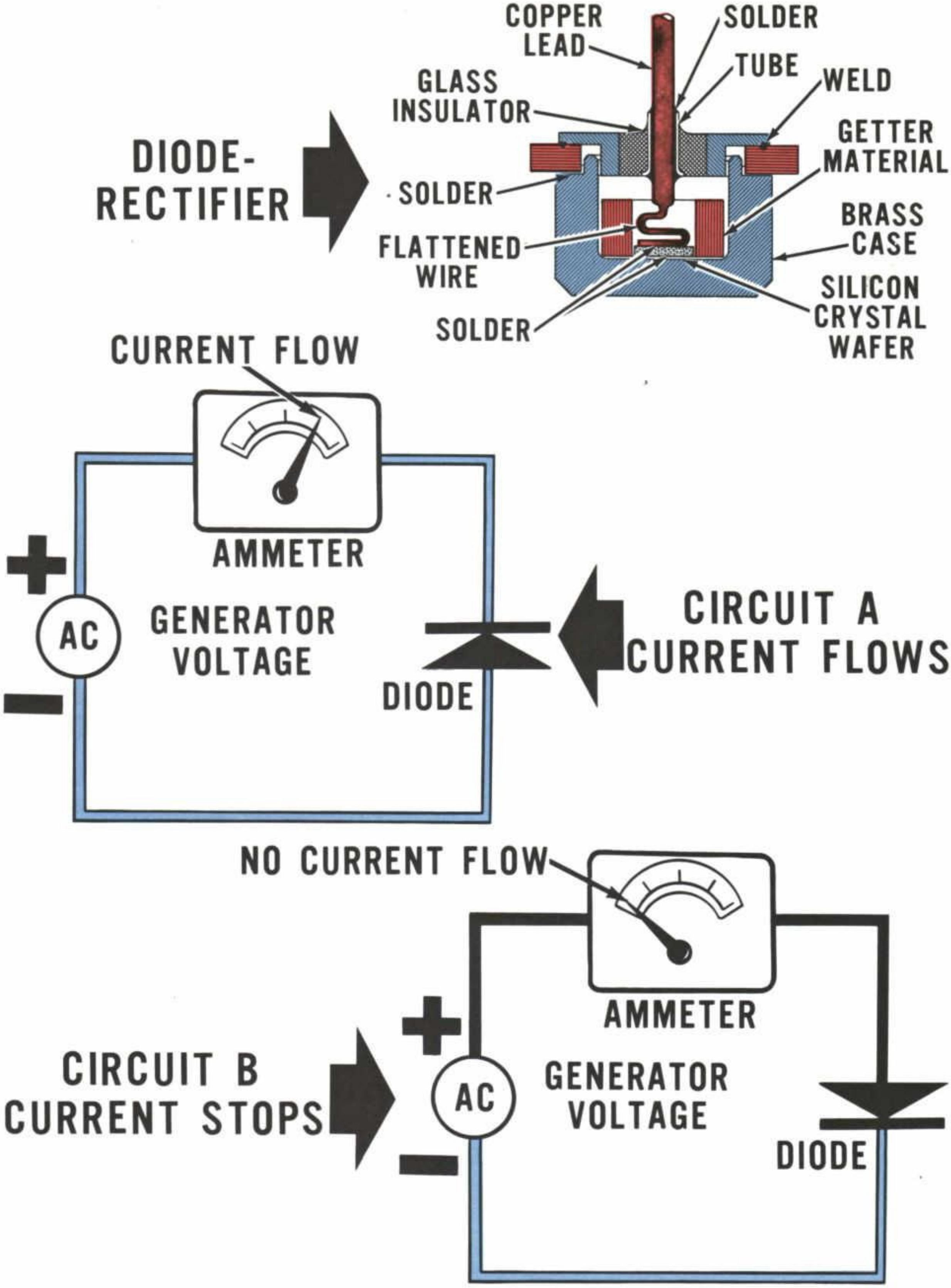
Two plate and diode assemblies are used to form the full-wave bridge-type diode. Three silicon diodes are soldered to depressions in a stamped steel plate to form the plate and diode assemblies. The steel plates serve as "heat sinks" and cool the diodes. The depressions in the plates present more cooling surface to the air which flows from vent slots in the rear housing to the fan at the front of the alternator.

An internal rectifier consists of six separate diodes connected together. The rectifiers change the three A.C. voltages into a single D.C. voltage which is measured across the positive and negative sides of the rectifier. The D.C. voltage is then used to charge the battery and operate the accessories in the automotive electrical system.

The three diodes connected to the "GRD" terminal are "negative diodes" and the three diodes connected to the "BAT" terminal are referred to as "positive diodes."

The actual working portion of the diode is a very small metallic disc or square wafer of pure silicon treated with a controlled impurity.

It is 0.008 to 0.010-inch thick and approximately 1/8-inch square (dependent on current rating). The rest of the diode package is merely hardware used to mount and attach an insulated electrical terminal to the silicon wafer.



DIODE-RECTIFIER

THREE-PHASE CIRCUIT CURRENT FLOW

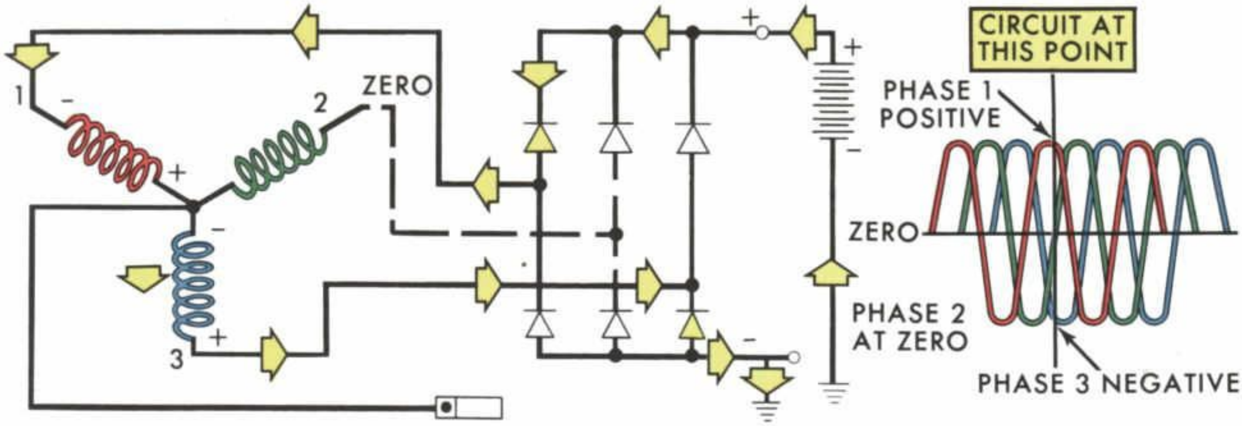
To demonstrate the current flow in a three-phase full-wave bridge diode circuit, several diagrams are required to trace the circuit action. The sine waves, at the right of the diagrams, show the positions of the three phases. The dashed vertical line shows the instantaneous point of operation for each circuit.

The upper drawing shows the current flow when Phase 1 coil is positive, Phase 2 coil is zero, and Phase 3 coil is negative. At this point, current flows from the Phase 1 coil through Phase 3 coil, through the Phase 3 negative diode, and to ground. Current will then flow to the electrical components or to the battery for recharging. From the battery positive terminal current flows through the Phase 1 positive diode to the Phase 1 coil completing the circuit.

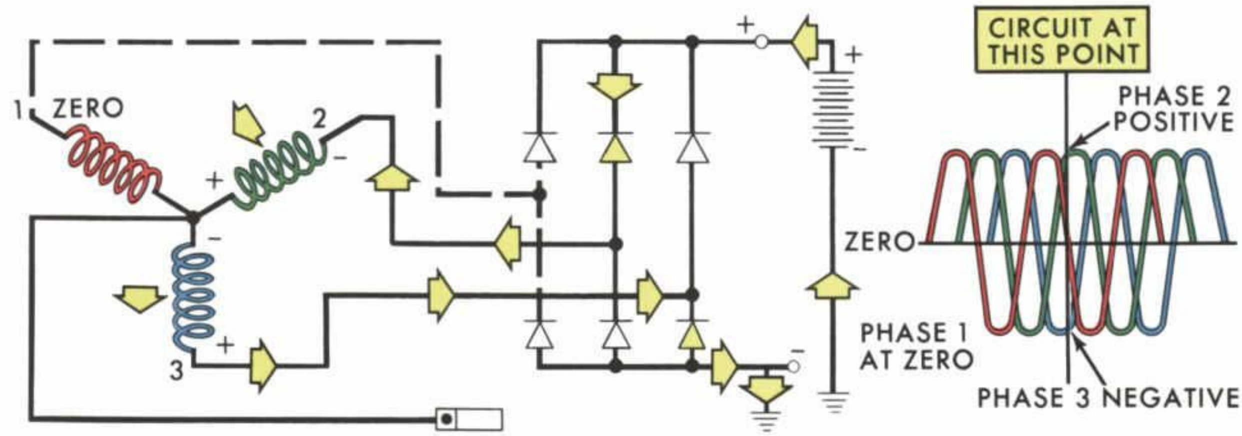
The voltage at the Phase 3 negative diode is negative with respect to the voltage at the Phase 1 positive diode. It should also be noted that a voltage difference also exists across the other diodes. However, they cannot conduct because the voltage across them is reversed in polarity and a diode will only allow current flow in one direction.

The polarity signs at the neutral junction provide a reference to the polarity of the junction with respect to ground. In this schematic, the Phase 1 coil provides an output to the field relay because its polarity is positive with respect to ground.

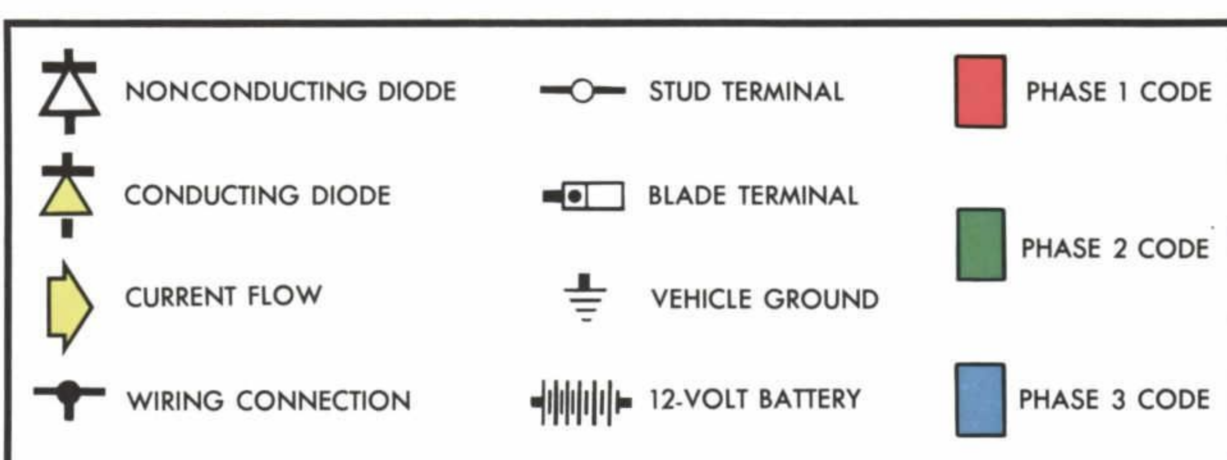
In the lower schematic, the dashed vertical line through the sine waves has been moved to the next point where Phase 1 crosses the zero line. With this instantaneous circuit condition, Phase 1 is zero, Phase 2 is positive and Phase 3 is still negative as in the preceding diagram. Current flow, as indicated by the arrows, continues through the Phase 3 negative diode. However, Phase 2 is now positive and the Phase 2 positive diode is now conducting.



THREE-PHASE CIRCUIT CURRENT FLOW—PHASE 1 COIL THROUGH PHASE 3 COIL



THREE-PHASE CIRCUIT CURRENT FLOW—PHASE 2 COIL THROUGH PHASE 3 COIL

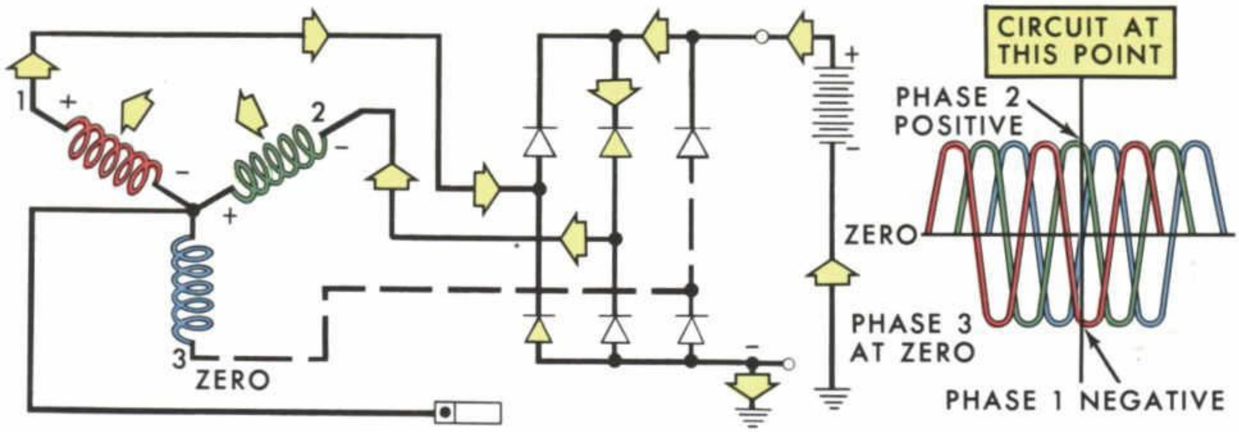


THREE-PHASE CIRCUIT CURRENT FLOW—Continued

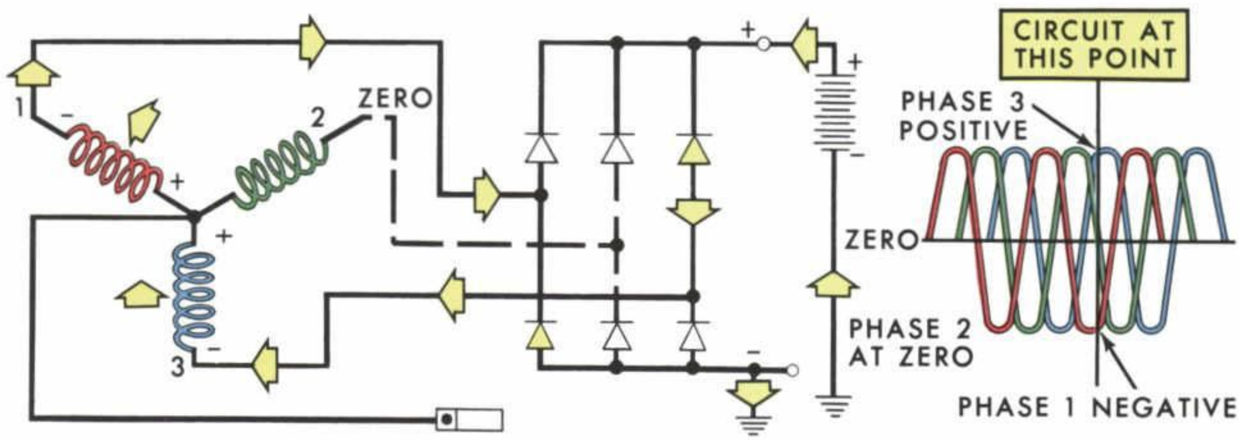
Again the sine waves, at the right of each schematic, shows the position of each of the three phases.

The upper schematic diagram shows Phase 3 coil at zero potential. Phase 2 coil is still positive, but Phase 1 coil is now negative. Again the vertical reference line through the sine waves defines the instantaneous circuit conditions that exist for only a split second. It is this instantaneous circuit condition that is illustrated in the circuit diagram to demonstrate diode action as well as three-phase operation. Phase 1 is now positive at the neutral junction, which causes it to take over control of the field relay coil from Phase 3.

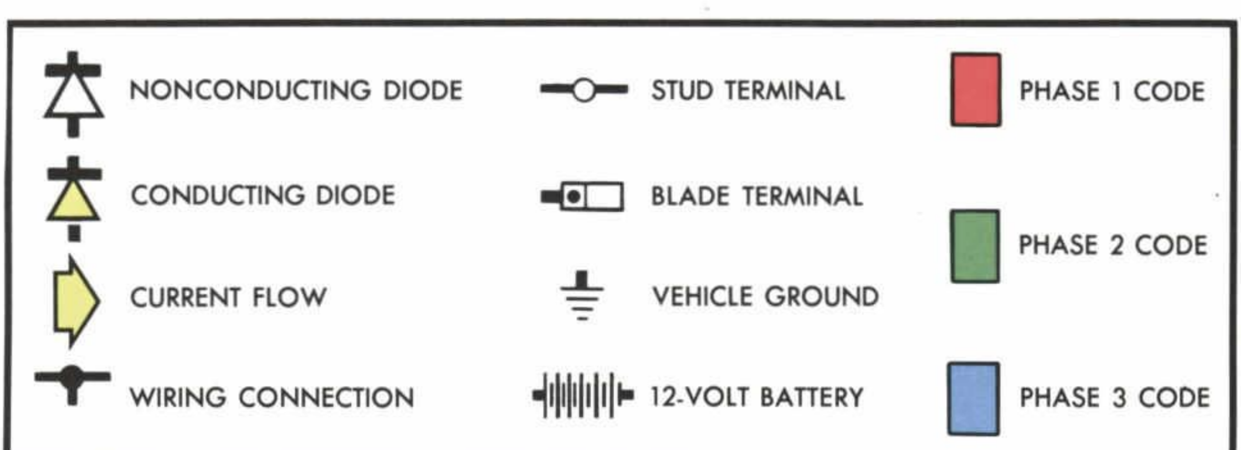
In the lower diagram, Phase 1 coil and Phase 3 coil have reversed polarity from the first diagram and Phase 2 coil is now at zero output.



THREE-PHASE CIRCUIT CURRENT FLOW— PHASE 2 COIL THROUGH PHASE 1 COIL



THREE-PHASE CIRCUIT CURRENT FLOW— PHASE 3 COIL THROUGH PHASE 1 COIL



VOLTAGE REGULATOR

The Ford alternator is of a design that is self-current limiting; therefore, current limiting is not a function of the alternator regulator.

A cutout relay is not required because the alternator diodes block the flow of battery current through the stator coils.

The voltage regulator assembly contains a two-stage electromechanical voltage limiter and a field relay.

Compensation for the effect of temperature on the magnetic strength of the voltage limiter coil is provided by a magnetic shunt and a ballast resistor. The limiter voltage is compensated for different ambient temperatures by the use of a bi-metal material in the armature hinge.

Due to the relatively high flux leakage of the rotor, an alternator may not develop sufficient voltage to be self-exciting. Therefore, provision must be made to supply battery current to the rotor coil when the engine is first started.

FIELD RELAY OPERATION—WITH CHARGE INDICATOR LIGHT

When the ignition switch is in the "IGN" (ON) or "ACC" positions, battery current will flow from the switch through the charge indicator light and the 15-ohm resistor to the voltage regulator "I" terminal. From the "I" terminal, current flows through the upper contacts of the voltage limiter to the "F" terminal of the regulator and to the rotor field coil. This relatively small current produces enough useful flux to permit the stator, when the engine is started, to develop sufficient voltage at the neutral junction to close the field relay.

When the field relay closes, full-system voltage is applied to the field circuit and the field current is no longer required to flow through the resistor and indicator light. System voltage is also applied to both sides of the indicator light. This provides maximum alternator field current and causes the indicator light to go out. The wiring diagram shows that the regulator field circuit wire connects directly to the power circuit and not through the ignition switch. Better voltage regulation is obtained from the direct field relay connection than would be possible with the ignition switch voltage drop causing the voltage limiter to sense an unrepresentative voltage source.

VOLTAGE REGULATOR—Continued

VOLTAGE LIMITER OPERATION—Continued

Resistor

A 50-ohm resistor is connected across the rotor field coil to act as a damping device for electrical surges in the field circuit. Surges in the field coils would otherwise be transmitted by transformer action to the stator coils where diode damage could occur. This resistor is called an "absorbing resistor."

Voltage limiter operation is partially stabilized by the resistor connected in series with the limiter coil. When the coil is cold, the copper wire has a lower resistance and therefore, would permit more current to flow. The increased coil current would in turn produce a stronger magnetic field, thus reducing the limiting voltage of the regulator. This effect is reduced by the increased voltage drop across the resistor. This resistor is called a "ballast resistor."

Magnetic Shunt

A magnetic shunt made of carpenter metal also helps to stabilize the operation of the limiter. The shunt is located at the top of the limiter coil and is in effect a magnetic short circuit between the coil core and the yoke. At low temperatures, the shunt has good magnetic conductivity and reduces the effectiveness of the limiter magnetic field. When the regulator temperature becomes stabilized, the shunt becomes less conductive and the magnetic field acts more effectively on the limiter armature.

Temperature Compensation

Optimum battery state-of-charge results when the limiter voltage is adjusted to the battery temperature. When the ambient temperature is low, the bi-metal used for the hinge of the voltage limiter increases the effort required to open the limiter contacts. The voltage impressed on the limiter coil will increase to provide the required stronger field. Thus, when ambient temperature is low and the battery is cold, the limited voltage is higher; when the battery is hot, the limited voltage is reduced.

Considerable expense has been incurred to provide a limiter voltage that is both temperature corrected and compensated. This becomes very important to the Service Technician because it is impossible to properly test or adjust the voltage limiter until the regulator is normalized and the exact temperature is known. The importance of these two considerations cannot be overemphasized.

VOLTAGE REGULATOR—Continued

FIELD RELAY OPERATION—WITH AMMETER

When the ammeter is used in the charging system, the "S" terminal (field relay) is connected to the ignition switch. With the ignition switch in the "IGN" (ON) position, full-battery current flows through the field relay and the field relay points are closed. As soon as the points close, full-battery current can flow through the field coil of the alternator. At this point, the alternator output is governed by the speed of the engine. As soon as the alternator output voltage reaches the battery, voltage current will start to flow through the regulator and the regulator will take over the control of the alternator output as previously described.

With the ignition key in the "START" position, there is no current flowing through the field relay coil, the points are open, no battery current flows through the alternator field and the system is inoperative until the switch is returned to the "IGN" (ON) position.

VOLTAGE LIMITER OPERATION

Two Stage Operation

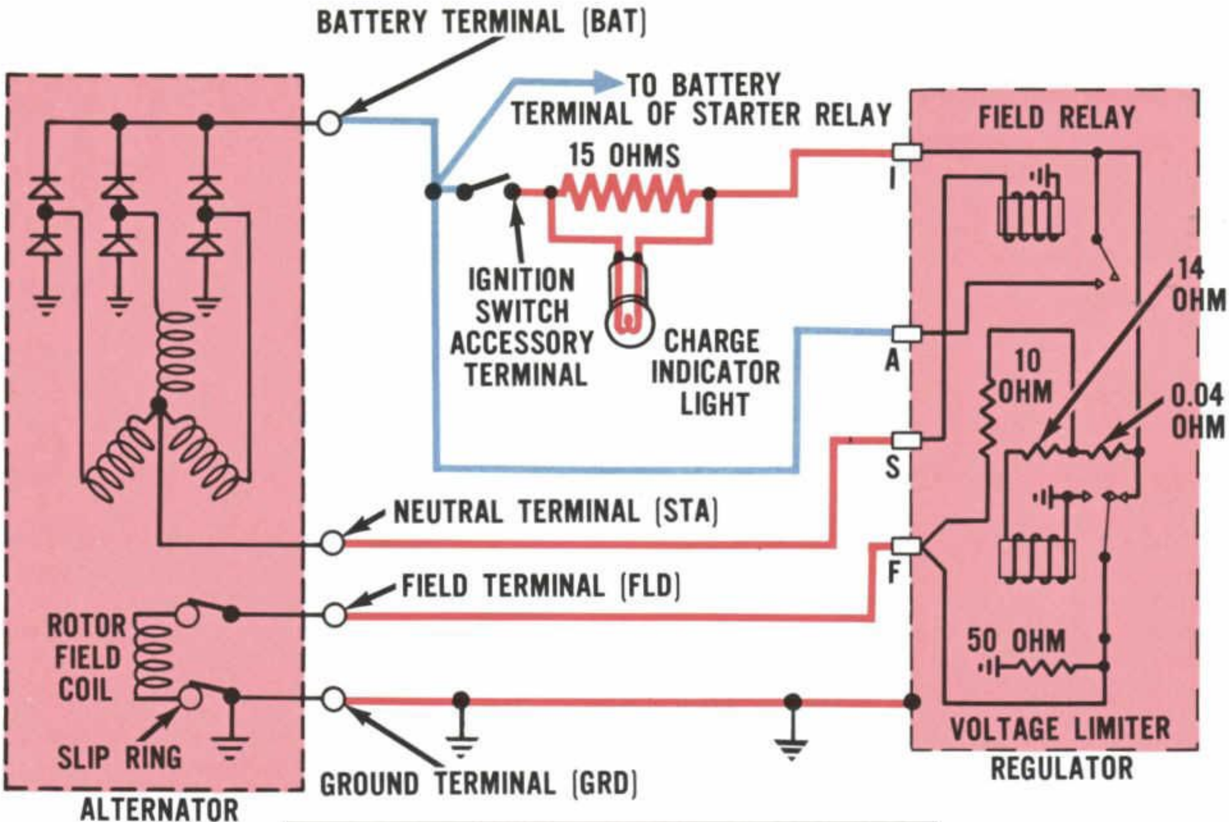
Voltage limiting is accomplished by an electro-mechanical limiter in the same manner as with a conventional generator charging system. A double-contact voltage limiter controls field current to the rotor coil. The limiter operates on the upper contacts when the load is heavy and the engine speed is relatively slow; lower contact operation occurs with light loads or at high engine speed or both.

When electrical system conditions require voltage limitation and a relatively strong field current, the limiter armature fluctuates between the upper contacts and the mid-position. When the upper contacts are closed, full-system voltage is impressed on the rotor coil and the maximum current flows. When the armature is in the mid-position, field current is reduced as it must flow through the "field" resistor.

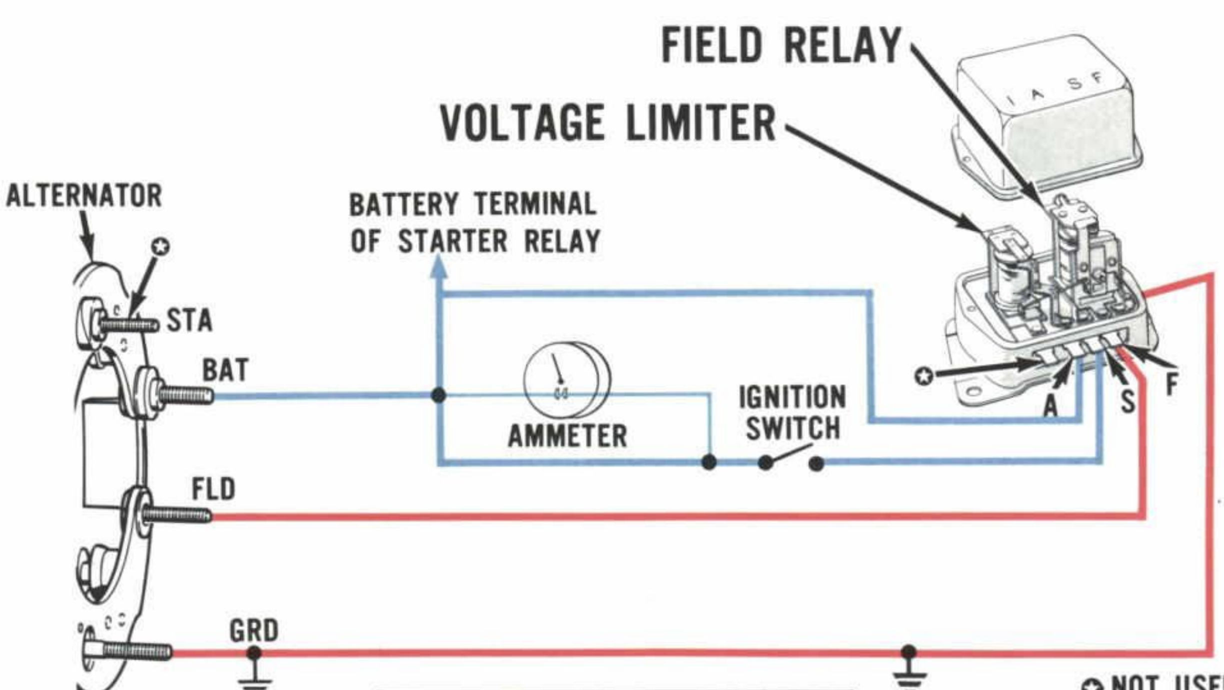
When operating conditions require a further reduction in field current, the limiter armature fluctuates between the mid-position and the lower contacts. When the lower contacts are closed, no field current will flow as both ends of the circuit are grounded. The field current now alternates between that supplied by the "field" resistor when the armature is in the mid-position and zero current when the lower contacts are closed.

The speed at which the armature fluctuates between the upper contacts and the mid-position or between the mid-position and the lower contacts is determined by the specific alternator speed and electrical load at the time.

An "accelerator coil," wound over the lower end of the limiter coil, helps to maintain these vibrations for improved limiting action.



INDICATOR LIGHT SYSTEM



AMMETER SYSTEM

Ford SERVICE TRAINING

TRANSISTORIZED VOLTAGE REGULATOR

DESCRIPTION

The transistorized voltage regulator controls the alternator voltage output in a similar manner to a mechanical voltage regulator, by regulating the alternator field current. The regulation is accomplished electronically with the use of transistors and diodes rather than by a vibrating armature relay. The voltage sensing element is a zener diode which has the characteristic of suddenly changing its resistance when a specified voltage is reached.

The field current supply diode is used to protect the power transistor.

The field current decay diode performs the same function as the resistors in a mechanical regulator, providing a path to ground for the energy from the field when the field current is interrupted.

The 140-ohm resistor is made of a special material that changes its resistance with temperature in such a manner that during cold weather the battery charging voltage is increased. This resistor performs the same function as the bimetal hinge on the voltage limiter armature of a mechanical regulator.

The regulator voltage limitation is adjusted by varying the 40-ohm adjustable resistor. Varying the adjustable resistor performs the same function as adjusting the voltage limiter armature spring tension on a mechanical regulator.

The 0.1-microfarad capacitor in series with the 56-ohm resistor causes the control transistor and the power transistor to switch on and off faster providing better control of the field current.

The remaining resistors in the unit provide proper operating voltages for the zener diode and the two transistors.

The field relay is still used in the transistorized system; but it is mounted separately from the voltage regulator. This field relay is not adjustable since the cover is crimped in place.

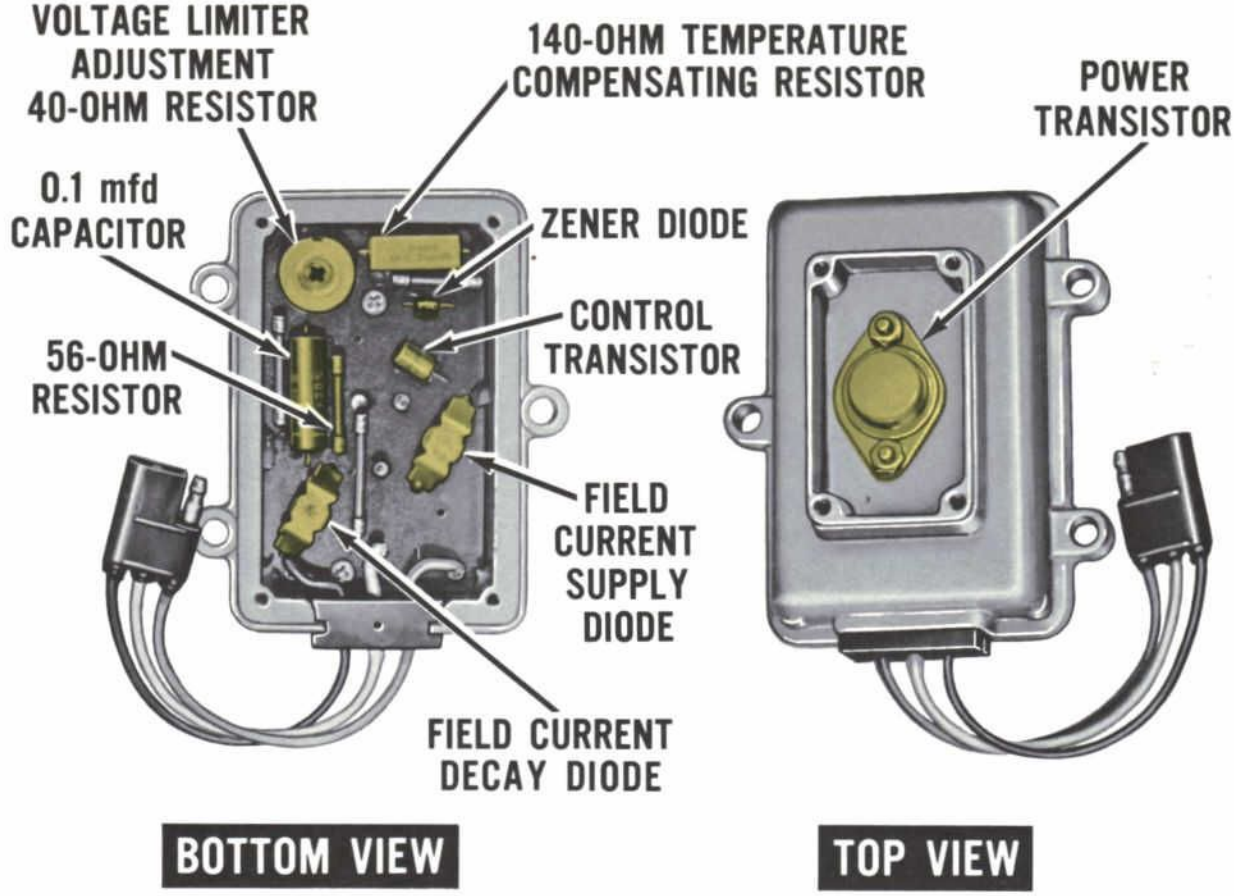
OPERATION

When the engine is started, battery current is supplied to the field through the field relay, field current supply diode, and the power transistor.

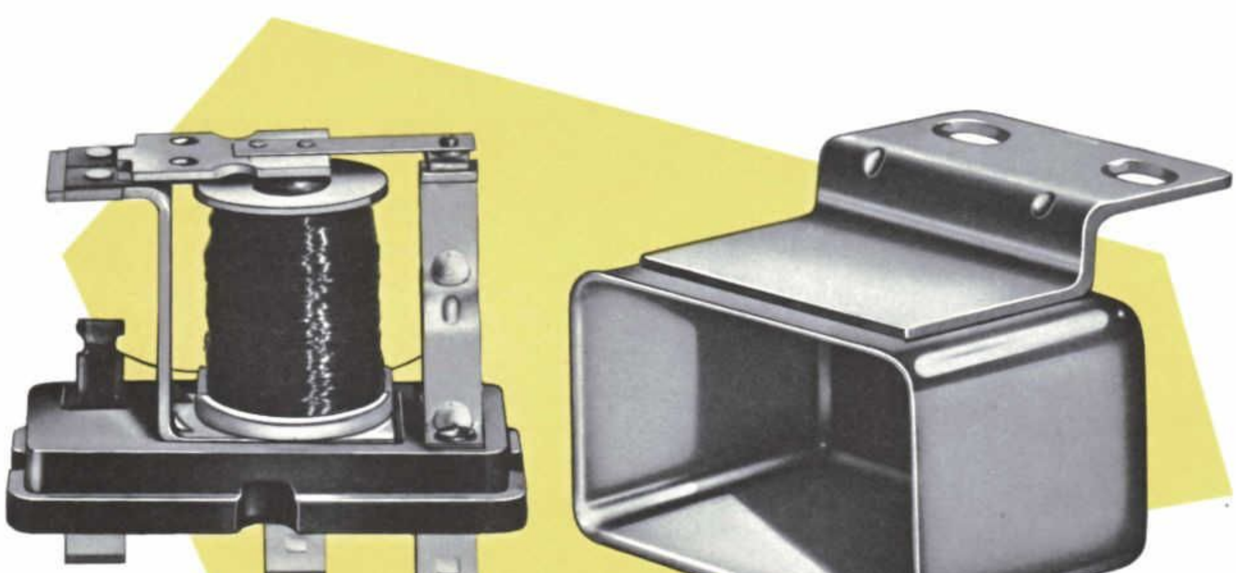
As the alternator begins to supply current, the battery voltage will increase. When the battery voltage reaches approximately 14.5 volts, the zener diode due to its characteristics, suddenly reduces its resistance and lowers the voltage to the control transistor.

The control transistor then acting as a switch applies battery voltage to the power transistor. The power transistor, also acting as a switch, opens cutting off battery current to the field. This causes the battery voltage to drop slightly, the zener diode increases its resistance, and opens the control transistor, which in turn closes the power transistor and battery current again flows to the alternator rotor (field).

This sequence of events repeats itself at an approximate rate of 2,000 times per second, which is faster than the rate that a mechanical regulator interrupts the field current.



TRANSISTORIZED VOLTAGE REGULATOR



FIELD RELAY TRANSISTORIZED SYSTEM

QUALITY
CAR CARE