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AUTOMOTIVE DIESEL MAINTENANCE 2. UNIT XVIII, ALTERNATOR AND REGULATOR SERVICING AND TESTING, AND AN INTRODUCTION TO TRANSISTOR REGULATORS.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

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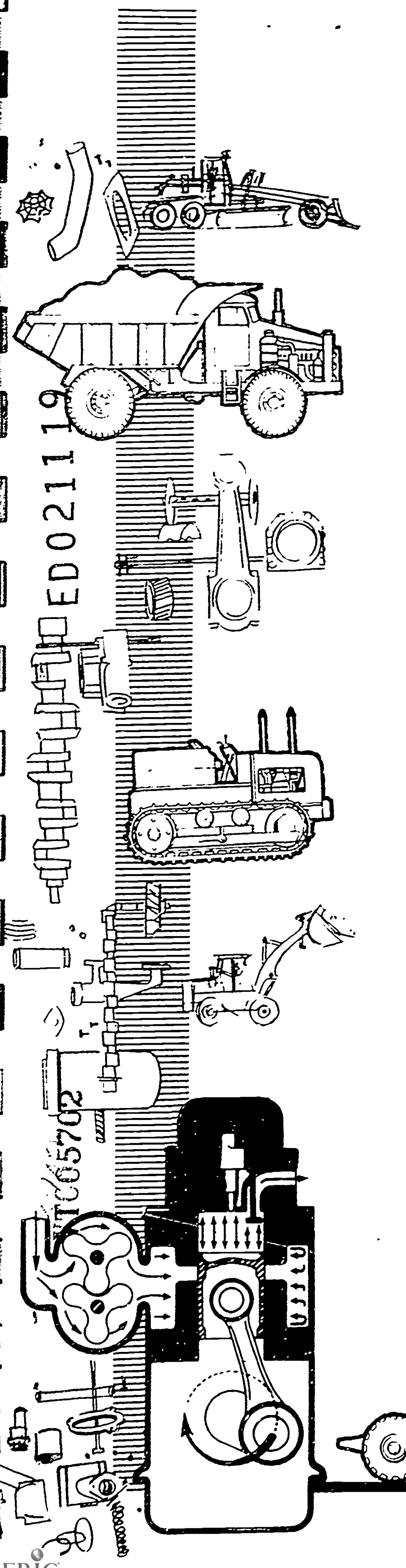
THIS MODULE OF A 25-MODULE COURSE IS DESIGNED AS A REVIEW OF THE OPERATING PRINCIPLES AND SERVICING PROCEDURES FOR GENERATORS AND AS AN INTRODUCTION TO TRANSISTOR CONTROLLED VOLTAGE REGULATION FOR GENERATORS USED ON DIESEL POWERED EQUIPMENT. TOPICS ARE (1) REVIEW OF GENERATOR PRINCIPLES, AC AND DC, (2) SERVICING AND TESTING ALTERNATORS, AND (3) INTRODUCTION TO TRANSISTOR REGULATORS. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL PROGRAMED TRAINING FILM "INTRODUCTION TO TRANSISTORS AND TRANSISTOR CONTROLLED AND TRANSISTORIZED REGULATORS" AND OTHER MATERIALS. SEE VT 006 685 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 HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)



STUDY AND READING MATERIALS

AUTOMOTIVE DIESEL MAINTENANCE 2

ALTERNATOR AND REGULATOR SERVICING AND TESTING, AND AN INTRODUCTION TO TRANSISTOR REGULATORS

UNIT XVIII

SECTION A	REVIEW OF GENERATOR PRINCIPLES, AC AND DC
SECTION B	SERVICING AND TESTING ALTERNATORS
SECTION C	INTRODUCTION TO TRANSISTOR REGULATORS

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SECTION A -- REVIEW OF GENERATOR PRINCIPLES, AC AND DC

THE PRINCIPLE OF ELECTRICAL GENERATION -- To fully understand the advantages of the alternator, it is necessary to go into the operation of the DC generator and of the alternator. The purpose of any generator, either AC or DC, is to keep the battery charged and to supply a sufficient amount of current to carry the electrical load requirements of the vehicle.

Generating this current depends upon magnetism -- or to be more specific, the invisible lines of magnetic force. These invisible lines can be illustrated (see Figure 1) by sprinkling iron filings on a piece of glass, and then holding a magnet under the glass. The iron filings will arrange themselves in lines which correspond to these invisible lines of magnetic force. The heaviest concentration of lines is at the poles (or ends) of the magnet where the magnetic forces are strongest. Every magnet has a north pole (or end), designated as "N", and a south pole, designated as "S". The actual magnetic field is represented by many invisible lines of magnetic force leaving the the magnet at the north pole and entering at the south pole.

Magnetism can be found in some metals in the natural state; these are known as permanent magnets. Passing an electrical current through a wire which is coiled around a piece of iron also creates a magnet, known as an electromagnet. See Figure 1.

But, how is electricity generated?

Any time a wire is moved through a magnetic field (or a magnetic field is moved past the wire), so that the lines of force are cut, a voltage is developed in the wire. When this wire is connected to an external circuit, current will flow. The direction of current flow in the wire will depend upon whether the relative motion of the wire is "up" or "down" in the field. The amount of voltage generated will depend upon the number of lines of magnetic force which are cut, the number of turns of the wire, and the speed at which the wire passes through the magnetic lines of force. See Figure 2.

We have just described the basic principles of generator operation, whether it be DC or AC. Now, let's look only at the DC generator - which consists basically of a stationary magnetic field and a rotating conductor. Figure 3 shows a simplified DC generator. The conductor consists of a loop of wire wrapped around an iron core, the assembly being called an ARMATURE. The wire loop is then attached to two copper segments--COMMUTATORS -- which are insulated from the iron core and from each other.

In order to carry the generated electrical current from the armature, a carbon brush is placed on each side of the commutator. Finally, the armature is mounted between the field coils, so that it is in the magnetic field set up by these coils.

As the armature is rotated by means of the generator pulley, the wire loop cuts through the magnetic lines of force being sent out by the field coils. This cutting action causes an electrical current to flow in the wire loop when the loop is connected to an external circuit. The amount of voltage generated at any instant will depend upon the number of lines being cut in each small increment of time.

At the instant when the loop of wire is horizontal (as shown in Figure 3), a maximum voltage will be generated in the direction shown. One-half of a revolution later, a maximum voltage again is generated, but in the opposite direction. Thus the voltage generated in the wire loop is a reversing pulse-like cycle. When the wire loop is connected to an external circuit, current will flow in this reversing cycle, which is known as alternating current or AC.

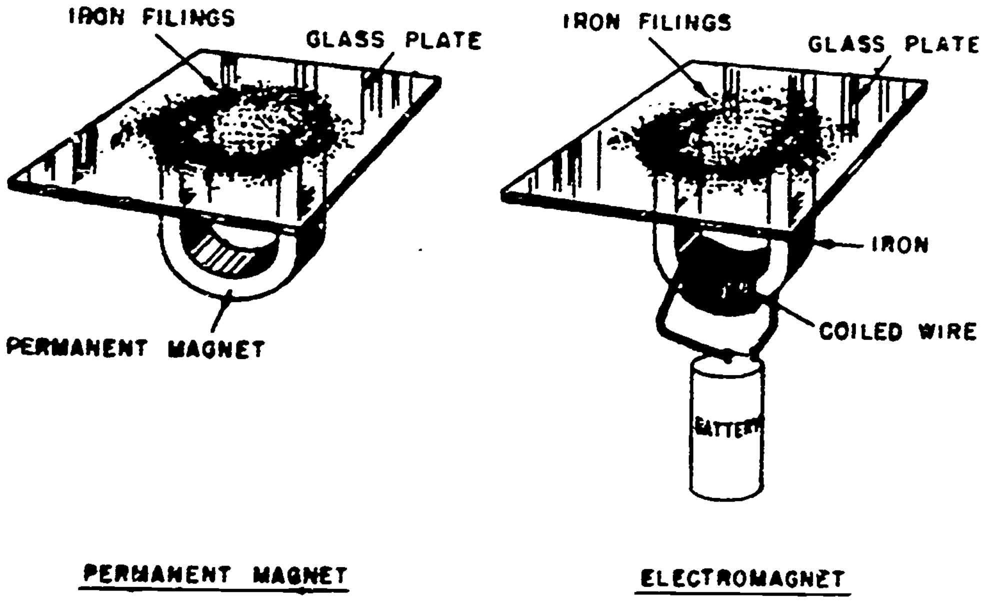


Fig. 1 Lines of magnetic force

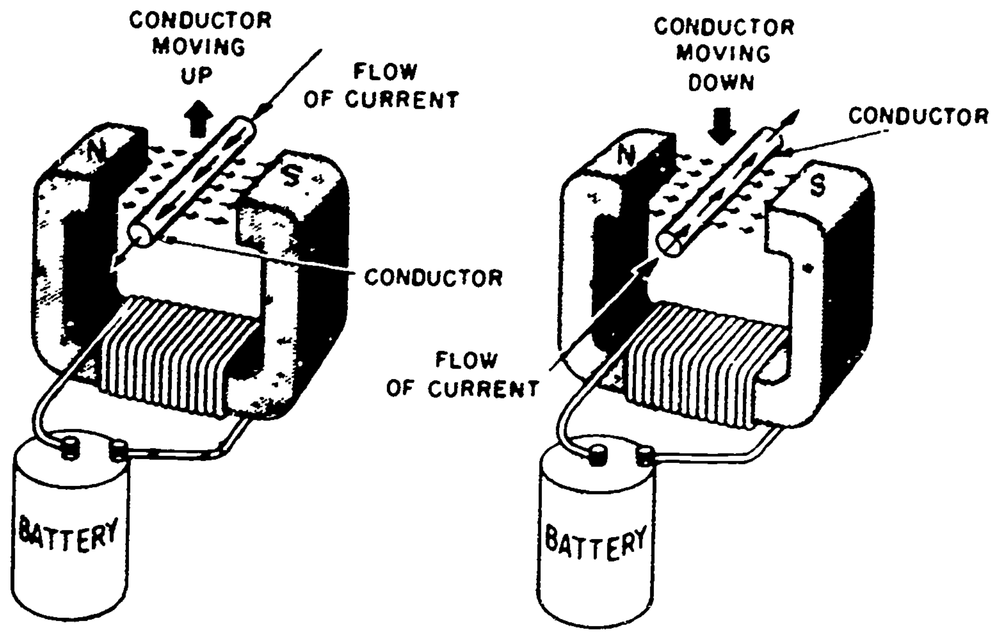


Fig. 2 Principles of generator

Because the automobile electrical system uses direct current, some method of changing this alternating current to direct (non-reversing) current is required. The commutator and brushes act as a mechanical reversing switch, which allows the electrical current to flow out of one brush and into the battery in the same direction continuously.

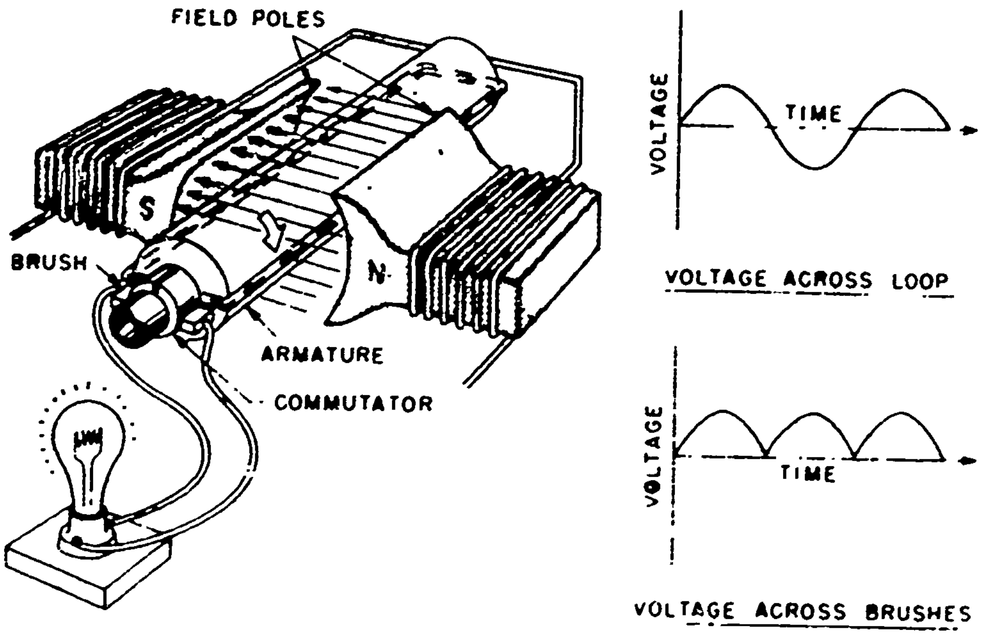


Fig. 3 Simplified DC generator

In reality, an automotive generator having only one conductor will not produce enough output to be useful. Therefore, many conductors (connected end to end) are used for each coil, and several coils and commutator segments are required for the armature. This results in a useful, direct current generator.

In the application of a DC generator to a vehicle, the drive ratio between crankshaft and generator pulley usually is a compromise. A high ratio is desirable so that the generator will rotate faster, cut lines of force more rapidly, and thus provide output at idle and slow speed driving. For continuous high-speed usage, (such as turnpike and expressway driving) a low generator drive ratio is required to reduce the rotational speed of the generator, and thus reduce wear. If all vehicle usage could be put into one or the other of these two classes, finding a generator drive ratio for each type would not be a difficult job. However, since most automotive usage requires both features, a compromise is necessary.

THE ALTERNATOR -- The basic principle of electrical generation for the ALTERNATOR is the same as for the DC generator -- relative motion between a magnetic field and a conductor causes voltage to be induced in the conductor. In a DC generator, the magnetic field is stationary, and the conductors are moved so that they cut across the lines of magnetic force. In an alternator, the magnetic field is moved so as to cut across the stationary conductors. The direction of electricity flow in the conductor will depend on whether the lines of force cut the conductor when they come out of one end of the magnet (north pole), or when they pass back into the other end of the magnet (south pole). See Figure 4.

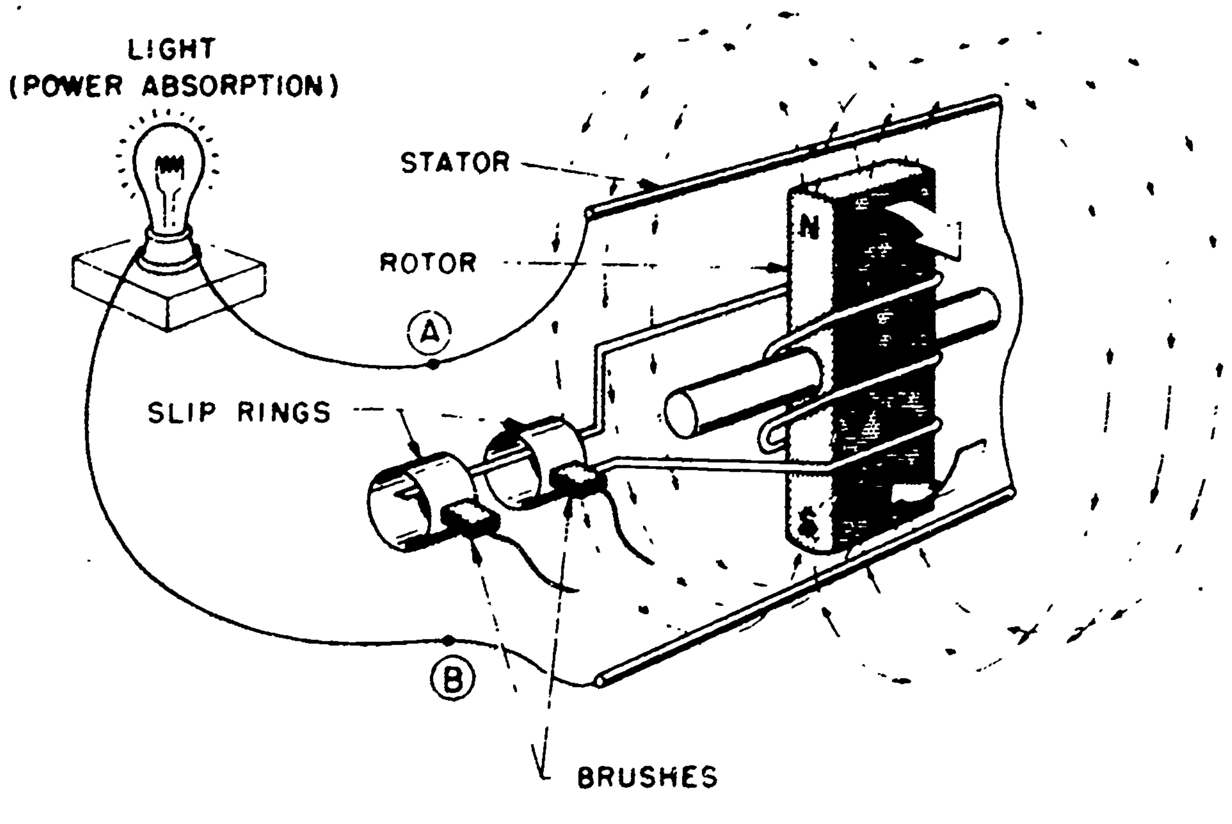


Fig. 4 Simplified alternator

In its simplest form, the STATIONARY CONDUCTOR of the alternator consists of a loop of wire wrapped around an iron core -- the assembly is called a STATOR. The moving magnetic field is created by a rotating electromagnet, called a ROTOR, inside the loop of wire. The ends of the wire running to the electromagnet are attached to slip rings which rotate with the rotor.

To supply current to the electromagnet, two brushes are placed in contact with the slip rings. If the electromagnet is rotated inside the loop of wire so that the lines of force are cutting across the conductor, a voltage will be induced, causing a current to flow through the completed circuit.

In Figure 4, the north pole is at the top and the south pole is at the bottom, so the flow of current is from point (A) to point (B). When the magnet is rotated 180 degrees, the south pole will be at the top and the north pole will be at the bottom. During this part of the cycle, the lines of force are cutting the conductor in the opposite direction and the induced voltage will cause current to flow from point (B) to point (A). Thus, current will flow through the loop first in one direction, and then in the other, in a reversing pulse or AC.

Up to this point, the simplified rotor has been described as a bar or two pole electromagnet. However, the rotor of most alternators consists of many turns of wire, the FIELD COIL, located inside two interlocking pole pieces. The pole piece segments may have four, six, or seven poles, providing eight, twelve or fourteen magnetic fields. See Figure 5.

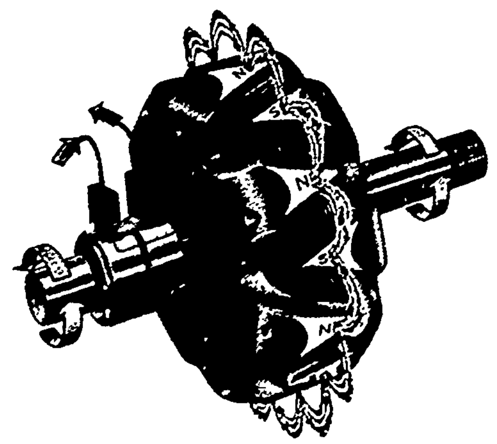


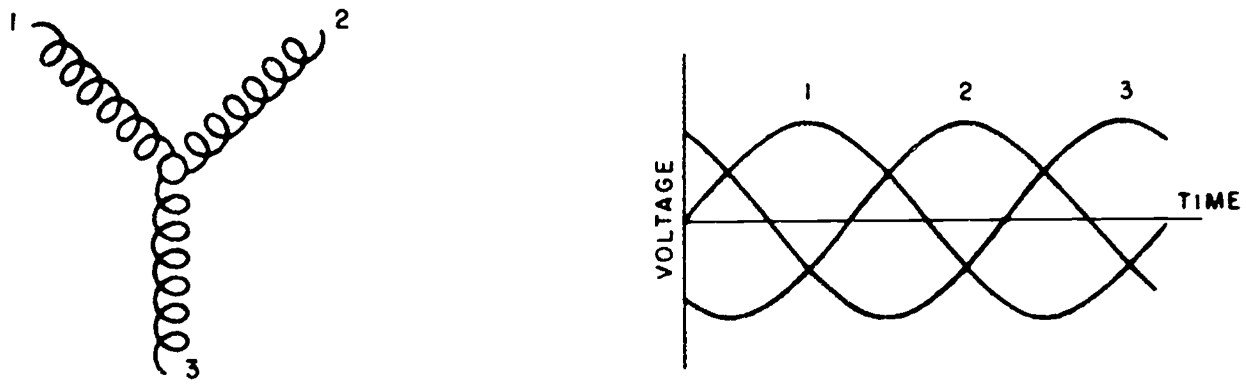
Fig. 5 Rotating magnetic fields

A simplified alternator having a single loop of wire is called a single phase alternator, regardless of the number of turns of wire in the loop winding. In other words, the term single phase applies when all the windings in the stator are connected end to end to form one continuous circuit.

Most automotive alternators have three sets of windings in the stator. One end of each winding is connected to a common junction. This is called a Y connection and the alternator is referred to as having a three phase Y-connected stator. The output is taken off the terminal end of each of the three windings.

Three of the reversing pulse waves can be used to illustrate the output of a three phase alternator. See Figure 6. The output of each phase overlaps, but does not coincide with the other two. The overlapping of the three phases smooths out the total flow of current from the stator windings. However, half the total output is still in one direction and the other half is in the opposite direction.

As has been mentioned before, alternating current cannot be used for cars and trucks mainly because of the battery. Therefore, it is necessary to change the alternating current, from the stator windings of the alternator, to direct current by a process called electrical rectification, using a DIODE or a RECTIFIER.



ELECTRICAL SCHEMATIC OF STATOR

VOLTAGE INDUCED IN STATOR WINDINGS

Fig. 6 Voltage induced

The DIODE is an electrical device that will allow current to flow in only one direction. In circuit or wiring diagrams (such as the full wave rectification diagram in Figure 7), the diode is commonly represented by the arrowhead symbol which shows that current can flow through the diode only in the direction indicated by the ARROW.

When three negative and three positive diodes are connected to the stator, as shown in Figure 7, the current output from the alternator to the battery will be in only one direction -- DC. Two of the several possible conditions for current output are shown in Figure 7. Regardless of which direction current is passing from one phase of the stator, current will always enter the positive terminal of the battery and return to the stator by way of the negative terminal of the battery. The output of the other stator phases is converted to direct current in an identical manner, resulting in full wave rectification -- the entire output is converted to DC.

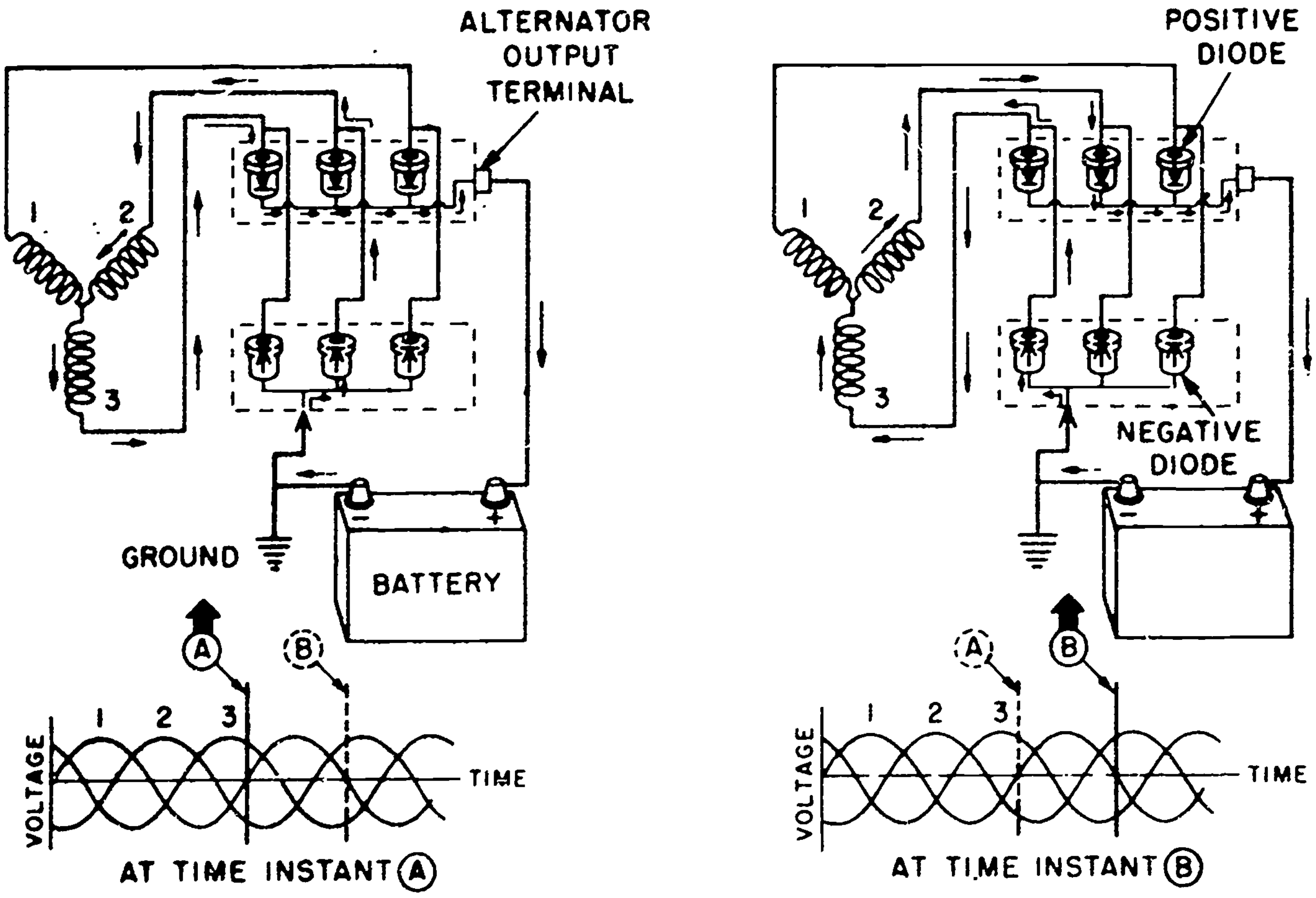


Fig. 7 Full wave rectification

Having reviewed the operation of both types of generators, AC and DC, let's look at a few of their more important differences.

Brushes are used in the alternator, and their expected life is two or three times those used in the DC generator. This is true because the alternator brushes are required to handle a field current of only about three amperes, while DC generator brushes carry the full output of 35 to 40 amperes (more on some heavy duty generators). Further, the alternator brushes ride on a smooth surfaced slip ring conductor instead of a serrated commutator bar.

The drive ratio for the alternator is not a compromise, as was the case with the DC generator. A comparison of the performance of the DC generator with that of the alternator shows that the alternator has a substantial output at low speed. See Figure 8. Furthermore, the drive ratio necessary for this output is such that neither rotational speed nor wear is excessive when high speeds occur.

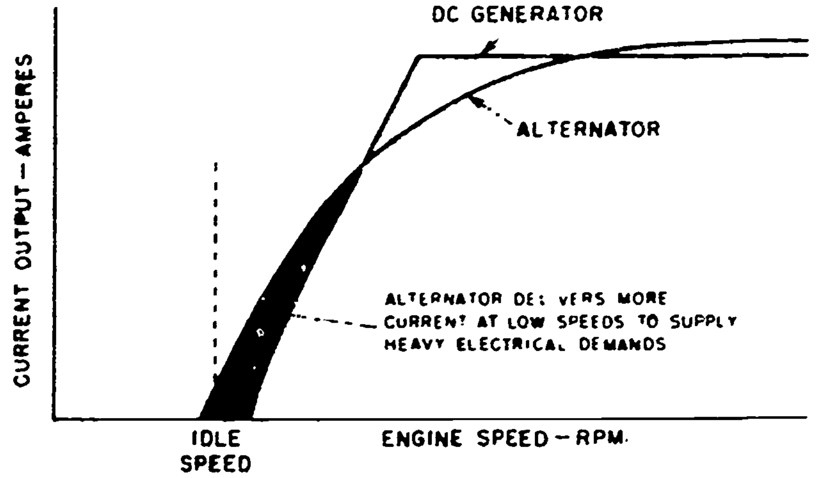


Fig. 8 Generator output, AC vs DC

Now let's look at a few of the design and construction features of the alternator.

The ROTOR -- The rotor contains the magnetic field producing components. It consists of a core pressed on the shaft around which the doughnut-shaped field coil is assembled.

On both sides of the coil and core assembly are the pole pieces (steel plates which are pressed on the rotor shaft). Each pole piece has seven fingers, which nest between the seven on the other pole, making a total of 14 poles. The 14 poles produce 28 magnetic fields, as shown in Figure 5. All of the fingers on one pole piece are north pole magnets, and those on the opposite piece are south pole magnets. Current is supplied to the field winding through two carbon brushes and two slip rings, which are mounted on the shaft and connected to the two ends of the field coil. A sealed ball bearing supports the pulley end of the shaft and a shielded roller bearing is used on the opposite end. Both bearings are lubricated for life and require no periodic attention.

THE STATOR -- The stator is made of laminated steel and has 36 or more slots (depending on make and model), and three distinct windings (each one called a phase) which are spaced one slot apart. The three phase design was selected because it enables the manufacturer to build a small and more efficient machine. The Y connection for the phases is an advantage in that there are two phases contributing to the output voltage. This arrangement gives current output at a lower rotational speed than if only one phase were contributing to the output.

The windings of the stator are designed to produce a current-limiting effect at higher speeds of the alternator -- making the current-limiting section of the regulator unnecessary. The diodes also make the cutout relay unnecessary. Since no current regulator and cutout relay are required, the output of the alternator is controlled by one unit, a voltage-limiting device called the VOLTAGE REGULATOR.

The end housings of most alternators are die-cast aluminum for several important reasons. Aluminum gives a weight reduction, and it acts as a nonmagnetic insulator to keep the alternator operating at a high rate of efficiency, by concentrating the magnetic field within its working path. Another feature of aluminum end housings is the heat transfer properties which are used to help cool the six silicon diodes found in the rear housing.

The diodes are pressed into the casting to provide a good electrical connection, to yield excellent heat transfer and to maintain a tight fit.

It should also be noted that an internal mounted capacitor (condenser) is connected across the charging circuit from the output terminal to ground. This capacitor is used to absorb voltage surges induced in the stator windings when the direction of current flow reverses, thus protecting the diodes.

The SILICON DIODES used to rectify the output of the alternator are a very important part of the generating system. In fact, the alternator was not economically practical for general automotive use until the recent development of this reliable, inexpensive rectifier. The actual diode consists of a crystal of silicon in a copper case or heat sink. The crystal itself is a semiconductor material (good conductor of current in one direction) and in this respect is similar to the transistors used in modern transistor radios. The crystal has a high electrical resistance in one direction and a low resistance in the opposite direction. The silicon diodes used in the standard automotive alternators will carry about 20 amperes in the forward direction at no more than 1.5 volts drop, and will block 15 volts with not more than one milliampere (one-thousandth of an ampere) leakage in the reverse direction.

The previously discussed silicon crystal is approximately .014 square inches in area and from .005 to .008 inches thick. It can be operated up to a temperature of about 390 F, and, in general can be used at any current which will not raise the temperature above this amount. Therefore, the amount of heat transfer (due to cooling air and outside air temperature) determines the current rating for a particular size of crystal. See Figure 9 for size of diode.

We should have a brief examination of the regulators which are required for both the alternator and the DC generator. The regulator for the

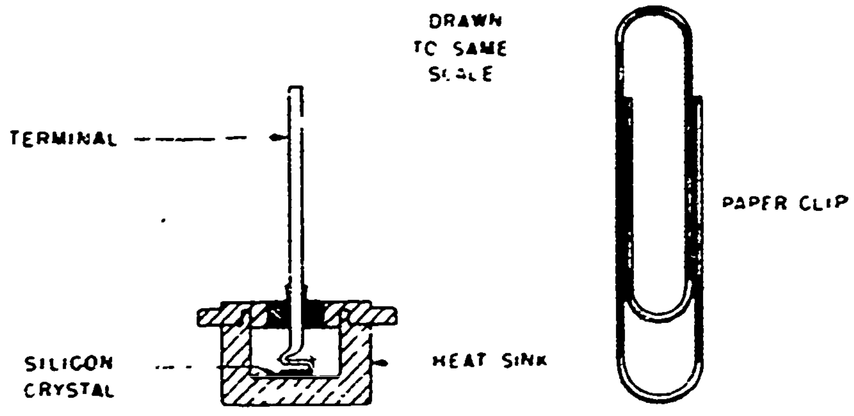


Fig. 9 Cross section of diode

alternator is very compact and requires only one unit, known as the voltage limiter or voltage regulator unit. Some manufacturers incorporate a field relay unit and a charging indicator light relay unit in the same housing; others have the field relay and the indicator relay units separate. The field relay unit can also be incorporated into the ignition (or diesel engine ON-OFF) switch, where an ammeter is used instead of an indicator light. In this case, the one unit (the voltage regulator) is all that is required.

The regulator for the DC generator, on the other hand, requires three units: a voltage regulator, a circuit breaker, and a current regulator. A quick look at each of their functions will reveal why this is true.

When the generator (either AC or DC) is producing current, the output is used to charge the battery and operate electrical loads. For low engine speed (such as idle), the DC generator is not producing, and some means of control is required to keep the battery from discharging through the generator. This is where the CIRCUIT BREAKER or reverse current relay unit performs two important functions. It completes the battery-generator circuit when the DC generator is producing current; and opens the circuit when there is no output, to prevent current from flowing out of the battery into the generator. For the alternator, this unit is not required, since the diodes prevent reverse current flow.

As the generator (again either AC or DC) rotates faster and faster, the current output becomes greater and greater. Therefore, in order to prevent the generator from overworking and overheating, some means of regulation is required to keep the output at a safe level.

For the DC generator, a CURRENT REGULATOR relay unit limits its field current, and thus output, so as to produce a sharp break in its performance curve (see previous performance curve in Figure 8).

The alternator, on the other hand, is designed so that it yields a smooth performance curve which levels off at a safe limit and requires no current regulation.

The battery can only hold so much energy. So, in order to prevent damage to the battery and the electrical components of the vehicle (caused by overcharging), a voltage regulator relay unit is required for both AC and DC generators. It performs its function by sensing the voltage output of the generator or alternator and then regulating the field current so as to limit the output voltage. Thus, the regulator for the DC generator incorporates three units while that of the alternator requires only one.

SECTION B -- SERVICING AND TESTING ALTERNATORS

Since the alternator and regulator are designed for use only on one polarity system, the following precautions must be observed when working on the charging system. Failure to observe these precautions will result in serious damage to the electrical equipment.

1. When installing a battery, always make absolutely sure the ground polarity of the battery and the ground polarity of the alternator are the same.

2. When connecting a booster battery, be sure to connect the negative battery terminals together and the positive battery terminals together (parallel).

3. When connecting a charger to the battery, connect the charger positive lead to the battery positive terminal, and the charger negative lead to the battery negative terminal.

4. Never operate the alternator on open circuit. Make absolutely sure that all connections in the circuit are secure.

5. Do not short across or ground any of the terminals on the alternator or its regulator.

6. Do not attempt to polarize the alternator.

Even though the alternator is constructed to give long periods of trouble-free service, a regular inspection procedure should be followed to insure its maximum life.

INSPECTION -- The frequency of inspection is determined largely by the operating conditions. High speed, high temperatures, dust and dirt all increase the wear of brushes, slip rings and bearings.

At regular intervals, inspect the terminals for corrosion and loose connections, and the wiring for frayed insulation. Check the mounting bolts for tightness; the belt for alignment, proper tension and wear. Belt tension should be adjusted in accordance with manufacturer's recommendations. When tightening belt tension, apply pressure against the stator laminations between the end frames, and not against either end frame.

Noise from an alternator may be caused by worn or dirty bearings, loose mounting bolts, a loose drive pulley, a defective diode, or a defective stator.

DISASSEMBLY -- After extended periods of operation, or at time of engine overhaul, the alternator may be removed from the vehicle for a thorough inspection and cleaning of all parts.

The alternator consists of four main components: the two end frames, the stator and the rotor. To disassemble the alternator, take out the thru-bolts, and separate the drive end frame and rotor assembly from the stator assembly by prying them apart at the stator slot. A scribe mark will help locate the parts in the same position during reassembly. The fit between stator and frame is not tight, and the two can be separated easily. Note that the separation is to be made between the stator frame and the drive end frame.

After disassembly, place a piece of tape over the slip ring end frame bearing to prevent entry of dirt and other foreign material. Also place a piece of tape over the shaft on the slip ring end. If brushes are to be re-used, clean them with a soft dry cloth. CAUTION: use pressure sensitive tape and not friction tape which would leave a gummy deposit on the shaft.

To remove the drive end frame from the rotor, place the rotor in a vise and tighten only enough to permit removal of the shaft nut. CAUTION: Avoid excessive tightening as this may cause distortion of the rotor. Remove the shaft nut, washer, pulley and the collar, and then separate the drive end frame from the rotor shaft.

ROTOR CHECKS -- The rotor may be checked electrically for grounded, open, or short circuited field coils. To check for grounds, connect a 110 volt test lamp or an ohmmeter to either slip ring and to the rotor shaft or rotor poles. If the lamp lights, or if the ohmmeter is low, the field winding is grounded. See Figure 10.

To check for opens, connect the test lamp or ohmmeter to each slip ring. If the lamp fails to light, or if the ohmmeter reading is high (infinite), the winding is open; see Figure 10.

The winding is checked for short circuits by connecting a battery and an ammeter in series with the two slip rings. Note the ammeter reading and refer to the appropriate Service Bulletin for specifications. An ammeter reading above the specified value indicates shorted windings. An alternate method for finding short circuits is to check the resistance of the field by connecting an ohmmeter to the two slip rings (Figure 10). If the resistance reading is below the specified value, the winding is shorted. The specified resistance value can be determined by dividing the voltage by the current given in the Service Bulletin.

If the rotor is not defective, and the alternator fails to supply rated output (described later in this section), the trouble is in the stator or the rectifying diodes.

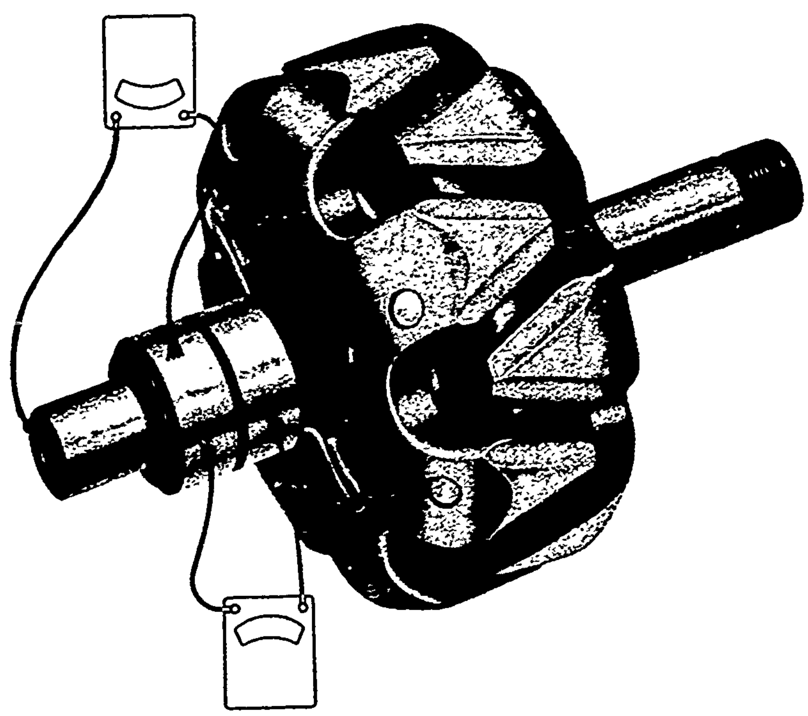


Fig. 10 Rotor checks

STATOR CHECKS -- To check the stator windings, remove all three stator lead attaching nuts, and then separate the stator assembly from the end frame. The fit between the stator frame and end frame is not tight, and the two can be separated easily. The stator windings may be checked with a 110 volt test lamp or an ohmmeter. If the lamp lights or if the ohmmeter is low when connected between any stator lead and the frame, the windings are grounded. If the lamp fails to light, or if the ohmmeter reading is high when connected between each pair of stator leads, the windings are open. A short circuit in the stator windings is difficule to locate without laboratory test equipment, due to the low resistance of the windings. However, if all other electrical checks are normal and the alternator fails to supply rated output, shorted windings are indicated.

DIODE CHECKS -- Each diode may be checked electrically for a shorted or open condition. Any one of the methods outlined below may be used.

Ohmmeter Method: One method of checking diodes is to use an ordinary ohmmeter, commonly found in service stations and garages. The lowest range scale on the ohmmeter should be used, and the ohmmeter should have a 1 1/2 volt cell. To determine the cell voltage, turn the selector to the lowest scale, and then connect the ohmmeter leads to a voltmeter. The voltmeter will indicate the cell voltage. With the stator disconnected, check a diode in the heat sink by connecting one of the ohmmeter leads to the heat sink, and the other ohmmeter lead to the diode lead, and note the reading. Then reverse the ohmmeter leads and note the reading. If both readings are very low, or if both readings are very high, the diode is defective. A good diode will give one low reading and one high reading. Check the other two diodes in the heat sink in the same manner.

To check a diode mounted in the end frame, connect one of the ohmmeter leads to the end frame, and the other ohmmeter lead to the diode lead, and note the reading. Then reverse the ohmmeter lead connections, and note the reading. As above, if both readings are very low, or if both readings are very high, the diode is defective. Check the other two diodes in the end frame in the same manner.

Test Lamp Method: An alternate method of checking the diodes is to use a test lamp (not more than 12 volts) in place of the ohmmeter. CAUTION: DO NOT USE 110 VOLT TEST LAMPS to check diodes.

With the stator disconnected, connect the test lamp leads across each diode, as previously described, first in one direction and then in the other. If the lamp lights in both checks, or if it fails to light in both checks, the diode is defective. When checking a good diode, the lamp will light in only one of the two checks.

Special Test Method: Special testers are available which operate without disconnecting the stator. To use these testers, follow the tester manufacturer's recommendations.

Diode Replacement: To replace a diode, use a suitable tool to support the end frame or heat sink, and use an arbor press or vise to push the diode out. Also use a special tool which fits over the diode outer edge to push the new diode in, and support the heat sink and end frame with a suitable tool. Note: Diode replacement tools are available from various manufacturers normally supplying tools and test equipment to the automotive industry. CAUTION: Do not strike the diode, as the shock may damage it, as well as the other diodes.

Slip Ring Servicing: If the slip rings are dirty, they may be cleaned and finished with 400 grain, or finer, polishing cloth. Spin the rotor and hold the polishing cloth against the slip rings until they are clean.

CAUTION: The rotor must be rotated in order that the slip rings will be cleaned evenly. Cleaning the slip rings by hand without spinning the rotor may result in flat spots on the slip rings, causing brush noise. Slip rings that are rough or out of round should be trued in a lathe to .002 inch maximum indicator reading. Remove only enough material to make the rings smooth and round. Finish with fine polishing cloth and blow away all dust.

BEARING REPLACEMENT AND LUBRICATION -- The bearing in the drive end frame can be removed by detaching the retainer plate screws, and then pressing the bearing from the end frame. If the bearing is in satisfactory condition, it may be re-used, and it should be filled one-quarter full with an approved lubricant before reassembly. CAUTION: Do not overfill, as this may cause the bearing to overheat.

To install a new bearing, press in with a tube or collar that just fits over the outer race. A new retainer plate should be installed if the felt seal in the retainer plate is hardened or excessively worn.

The bearing in the slip ring end frame should be replaced if its grease supply is exhausted. No attempt should be made to re-lubricate and re-use this bearing. To remove the bearing from the slip ring end frame, press out with a tube or collar that just fits inside the end frame housing. Press from the outside of the housing toward the inside.

To install a new bearing, place a flat plate over the bearing and press in from the outside toward the inside of the frame until the bearing is flush with the outside of the end frame. Support the inside of the frame with a hollow cylinder to prevent breakage of the end frame. Use extreme care not to misalign or otherwise place undue stress on the bearing. Saturate the felt seal with SAE 20 oil, and then reassemble the felt seal and the steel retainer.

BRUSH REPLACEMENT -- When the slip ring end frame assembly is separated from the rotor, and from the drive end frame assembly, the brushes will fall down onto the shaft and come in contact with the lubricant. If the brushes are to be re-used, they must be thoroughly cleaned with a soft dry cloth. Also, the shaft must be thoroughly cleaned before reassembly.

The brush springs should be inspected for any evidence of damage or corrosion. If there is any doubt as to the condition of the brush springs, they should be replaced.

To install new brushes, remove the brush holder assembly from the end frame by detaching the two brush holder assembly screws. Install the springs and brushes into the brush holder, and insert a straight wire or pin (a good toothpick may also be used) into the holes at the bottom of the holder to retain the brushes. Then attach the brush holder assembly onto the end frame, noting carefully the proper stack-up of parts, as shown in Figure 11. Allow the straight wire or pin to protrude through the hole in the end frame so that it can be removed when the slip ring end frame and rotor are assembled. When the straight wire or pin is withdrawn, notice a slight click as the brushes drop down on the slip rings.

HEAT SINK REPLACEMENT -- The heat sink is replaced by removing the BAT and GRD terminals from the end frame, and the screw attaching the condenser lead to the heat sink. During reassembly, note carefully the proper stack-up of parts, as shown in Figure 12.

Reassembly is the reverse of disassembly. Remember when assembling the pulley, secure the rotor in a vise just tight enough to permit the shaft nut to be tightened 50 to 60 ft-lbs. If excessive pressure is applied against the rotor, the assembly may become distorted. Install the slip ring end frame assembly to the rotor and drive end frame assembly by removing the tape over the bearing and shaft. Make sure the shaft is perfectly clean after removing the tape.

If the brushes have not been replaced or removed, insert a straight wire or pin, as previously mentioned, through the holes in the brush holder and end frame to retain the brushes in the holder. Then withdraw the wire after the alternator has been completely assembled. The brushes will then drop onto the slip rings.

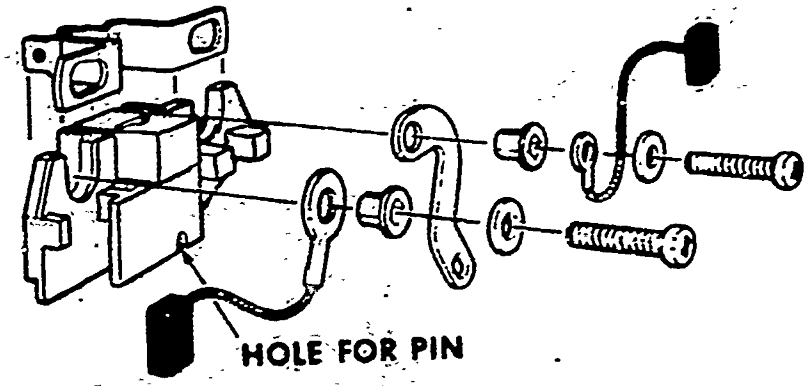


Fig. 11 Brush holder assembly

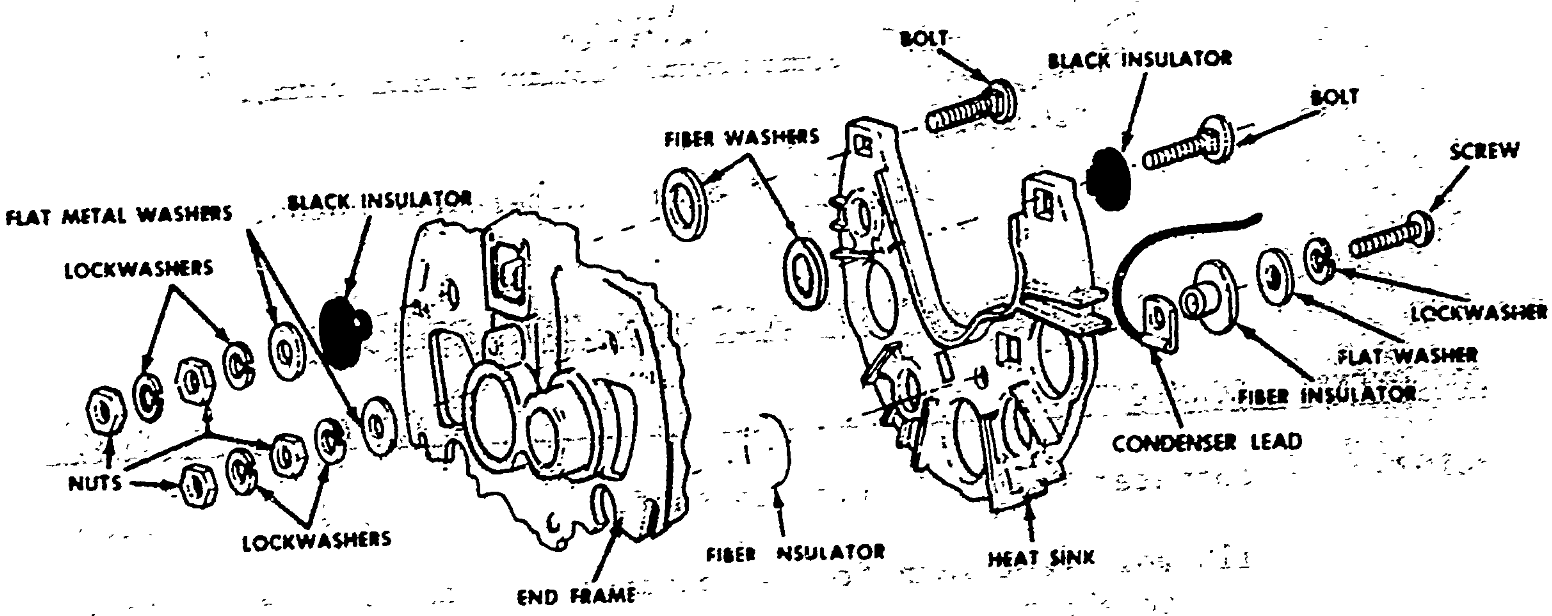


Fig. 12 Heat sink assembly

ALTERNATOR OUTPUT CHECK -- To check the alternator on a test bench, make electrical connections, as shown in Figure 13. Then operate it at the specified speed, and check for rated output as given in the Service Bulletin for the particular alternator being tested. Adjust the load rheostat, if necessary, to obtain the desired output. NOTE: A special adapter, used for making connections to the alternator, is available from tool companies and test equipment manufacturers normally supplying equipment to the automotive and truck trade.

CAUTION: On negative ground alternators, connect the negative battery post to the alternator frame. On positive ground alternators, connect the positive battery post to the alternator frame.

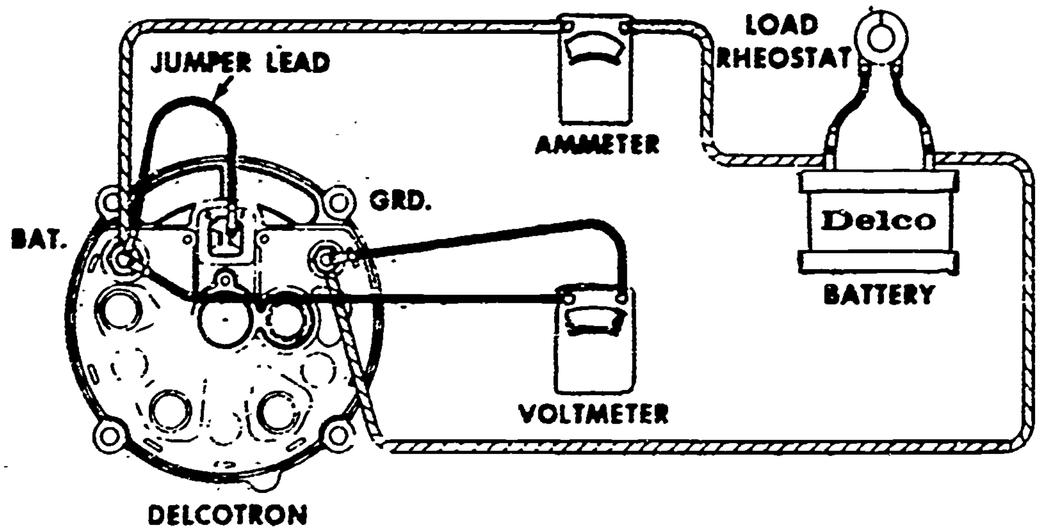


Fig. 13 Checking alternator output

SUMMARY OF ALTERNATOR CHECKS

COMPONENT	CONNECTION	READING	RESULT
ROTOR	ohmmeter from slip ring to shaft	very low	grounded
	110 volt test lamp from slip ring to shaft	lamp lights	grounded
	ohmmeter across slip rings	very high	open
	110 volt test lamp across slip rings	lamp fails to light	open
	battery and ammeter to slip rings voltmeter across slip rings	observe meter readings	compare with specs
STATOR	ohmmeter from lead to frame	very low	grounded
	110 volt test lamp from lead to frame	lamp lights	grounded
	ohmmeter across each pair of leads	reading high	open
	110 volt test light across each pair of leads	fails to light	open

SUMMARY OF ALTERNATOR CHECKS - continued

COMPONENT	CONNECTION	READING	RESULT
DIODE	ohmmeter across diode, then reverse connections	both readings very low	shorted
		both readings very high	open
	18 volt test lamp across diode, then reverse connections	lamp fails to light	open
		lamp lights in both checks	shorted

SECTION C -- INTRODUCTION TO TRANSISTOR REGULATORS

Transistors are electrical devices which act as electrical switches. They can be turned ON or OFF to control a circuit and fulfill the same function as a set of contact points which turn the circuit ON when they are closed and OFF when open.

A transistor has no moving parts and is a completely static device. Its operation is entirely electrical. There are no contact points or rubbing blocks to wear out. There appears to be no lifetime limit, provided it is used for the purpose for which it was designed. Transistors are readily available for most current and voltage ratings commonly used on vehicular electrical equipment. They are not susceptible to the mechanical vibrations found on various engines.

Transistors are sensitive to ambient (surrounding) temperatures. Therefore, a means for cooling has been incorporated into the design of its circuit so as to safely control the heat on the transistor.

The transistor offers itself as a good replacement for contact points. It is not subject to the limitations of the contact points and it is small in size. Better output, increased efficiency, more reliable and longer life systems, and less -- or no -- servicing requirements are features the transistor offers to the electrical systems.

For a simple understanding of the transistor, it is best to consider it as a chemical device that has very definite electrical characteristics. Figure 14(a) shows the materials that make up the transistor. Note that there are two pieces of P material and one piece of N material. The manner in which these materials react when placed in an electrical circuit can be predicted.

Figure 14(b) illustrates the construction of the transistor. A lead is connected to each of the three materials, the emitter, base, and collector. Note that the collector is the mounting pad of the transistor.

The transistor symbol used in wiring diagrams is shown in Figure 14(c). Note that there are only three connections. The arrow always points in the direction of current flow. Figure 14(d) portrays the actual appearance of a typical transistor. Many different types and sizes of transistors are manufactured. The one shown, is representative of those used in automotive electrical systems.

THE TRANSISTOR

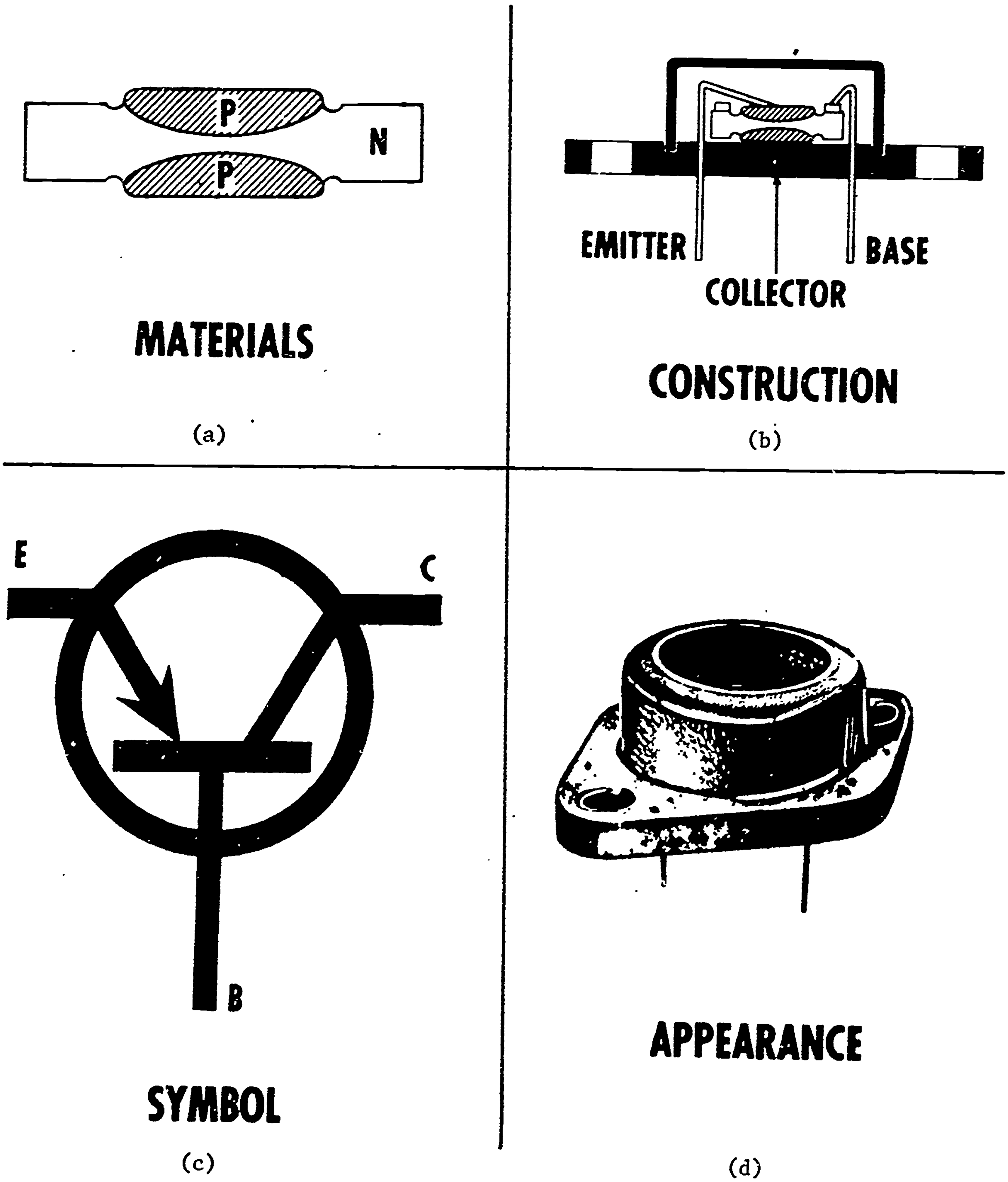


Fig. 14 The transistor

The illustrations in Figure 15 symbolically show a transistor and indicate the manner in which it operates. There is current flow in the emitter-collector circuit only when there is current flow in the emitter-base circuit. The emitter-base circuit, requiring only a small current, can act as a trigger to turn the electronic switch ON in the emitter-collector circuit. The small current in the emitter-base circuit controls a much larger current in the emitter-collector circuit.

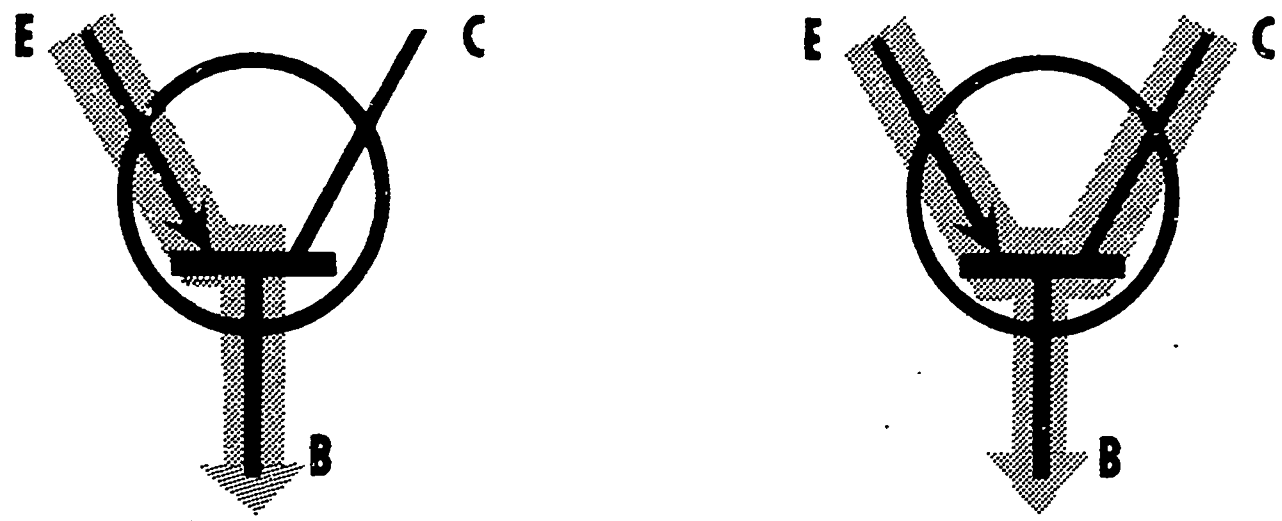
Conversely, if there is no current flow in the emitter-base circuit, then there is no current flow in the emitter-collector circuit. The emitter-base circuit, therefore, can act as a trigger to turn the electronic switch OFF in the emitter-collector circuit.

If the emitter-base circuit of the transistor can be manipulated either ON or OFF, then the greater current carrying emitter-collector circuit can also be made to operate simultaneously either ON or OFF. The emitter-collector circuit, therefore, is used in place of a set of contact points. The emitter-base circuit is the means by which the emitter-collector circuit is controlled.

The illustration in Figure 16 shows how the emitter-base circuit can be controlled by two different means. The upper view illustrates how a mechanical switch, operated by either manual or mechanical means, can be used to control the base circuit. A set of contact points can also be used to control the base circuit. These contact points would, however, be subjected to some of the same limitations that have been previously discussed.

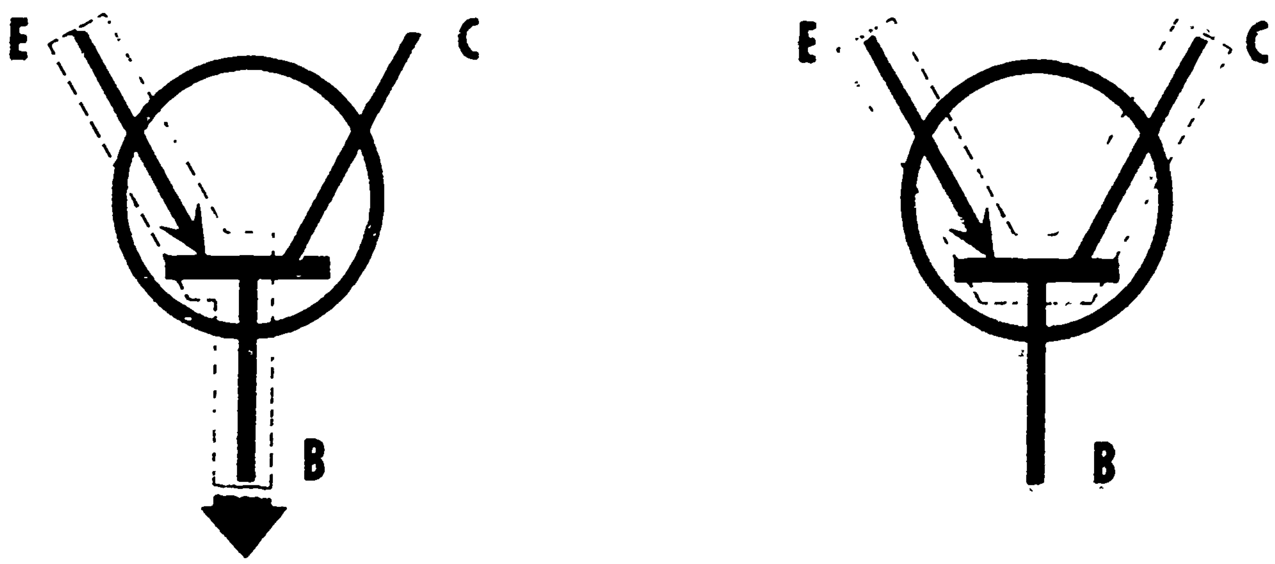
The lower illustration in Figure 16 shows how the base circuit can be controlled by electrical means. Only when the emitter-base circuit has the correct polarity and the correct voltage, will it carry current, thereby permitting current to flow in the emitter-collector circuit. When the polarity of the voltage is reversed, the emitter-base circuit is turned OFF and no current will flow in the emitter-collector circuit.

TRANSISTOR OPERATION



IF THIS • THEN • THIS

WITH VERY LITTLE CURRENT FLOW IN THE EMITTER-BASE CIRCUIT, A GREATER CURRENT CAN BE ESTABLISHED IN THE EMITTER-COLLECTOR CIRCUIT.

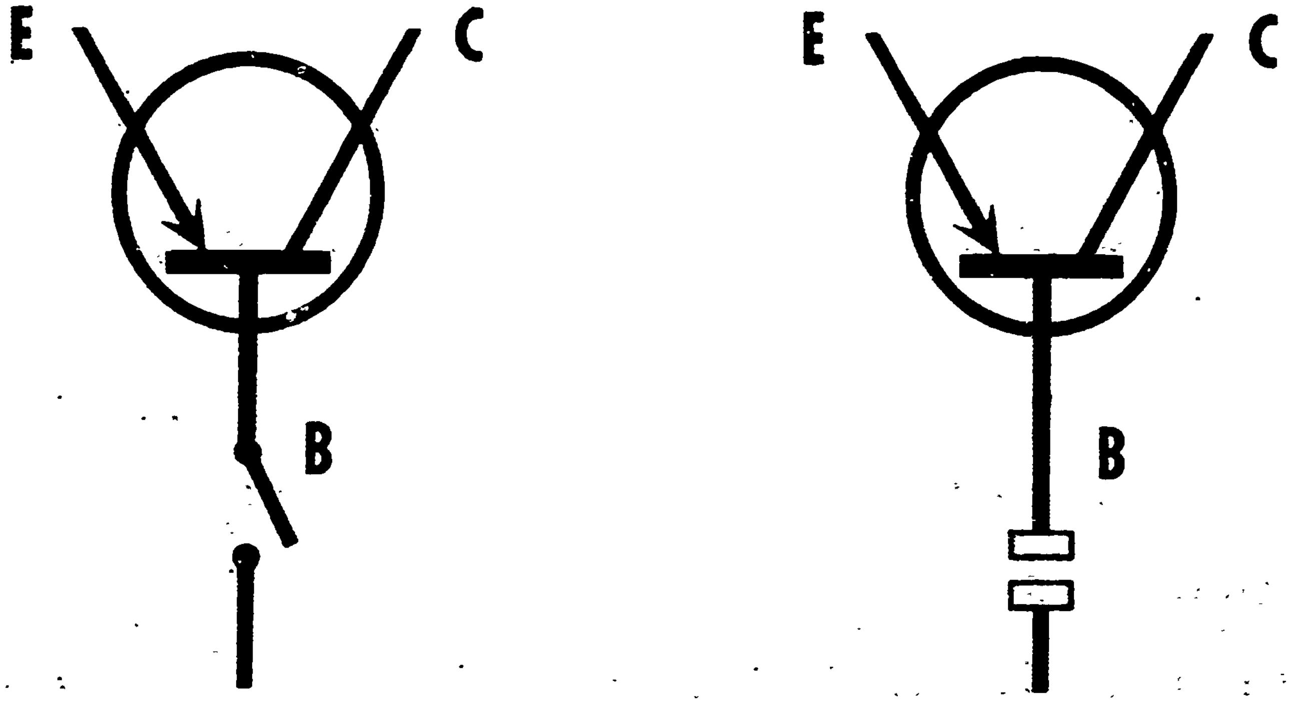


IF NO CURRENT FLOW HERE • THEN • NO CURRENT FLOW HERE

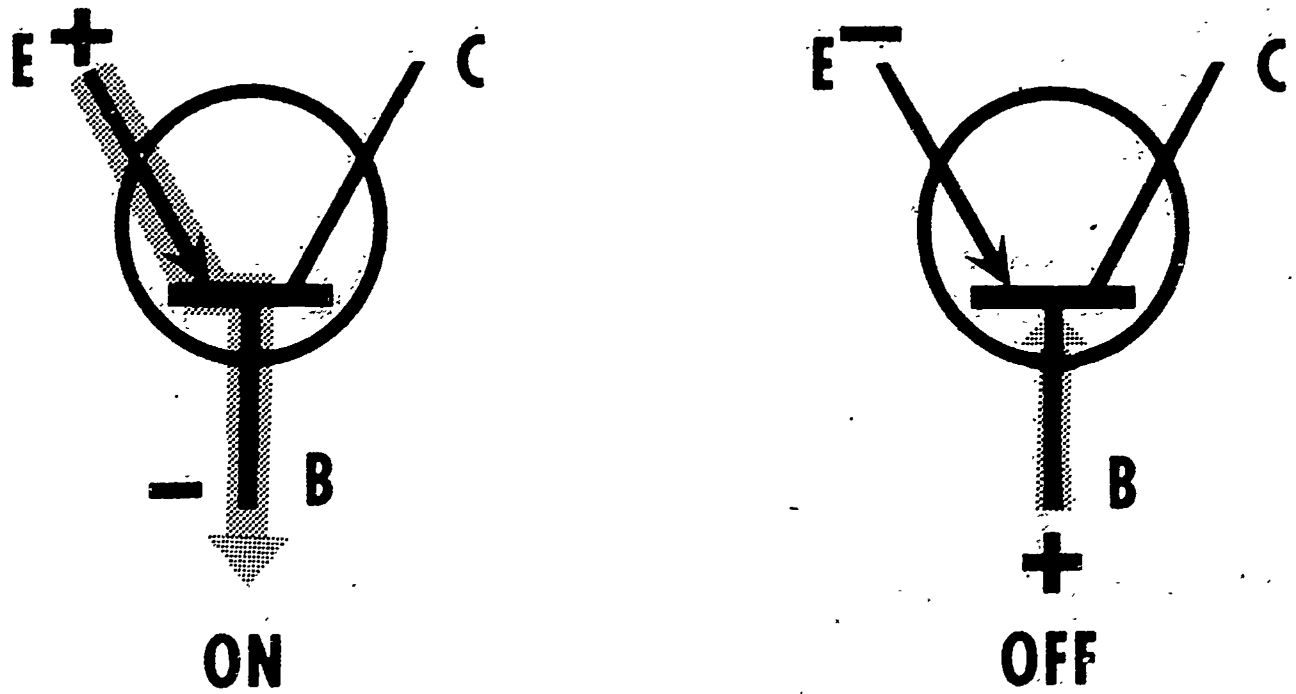
WITH NO CURRENT FLOW IN THE EMITTER-BASE CIRCUIT, THERE IS NO CURRENT FLOW IN THE EMITTER-COLLECTOR CIRCUIT.

Fig. 15 Transistor operation

TRANSISTOR CONTROL



A MECHANICAL SWITCH OR SET OF POINTS



AN ELECTRICAL MEANS OF REVERSING PRESSURE OR VOLTAGE AT THE BASE

Fig. 16 Transistor control

A transistor employing the latter means of operation can, therefore, completely eliminate the contact points of electrical circuits.

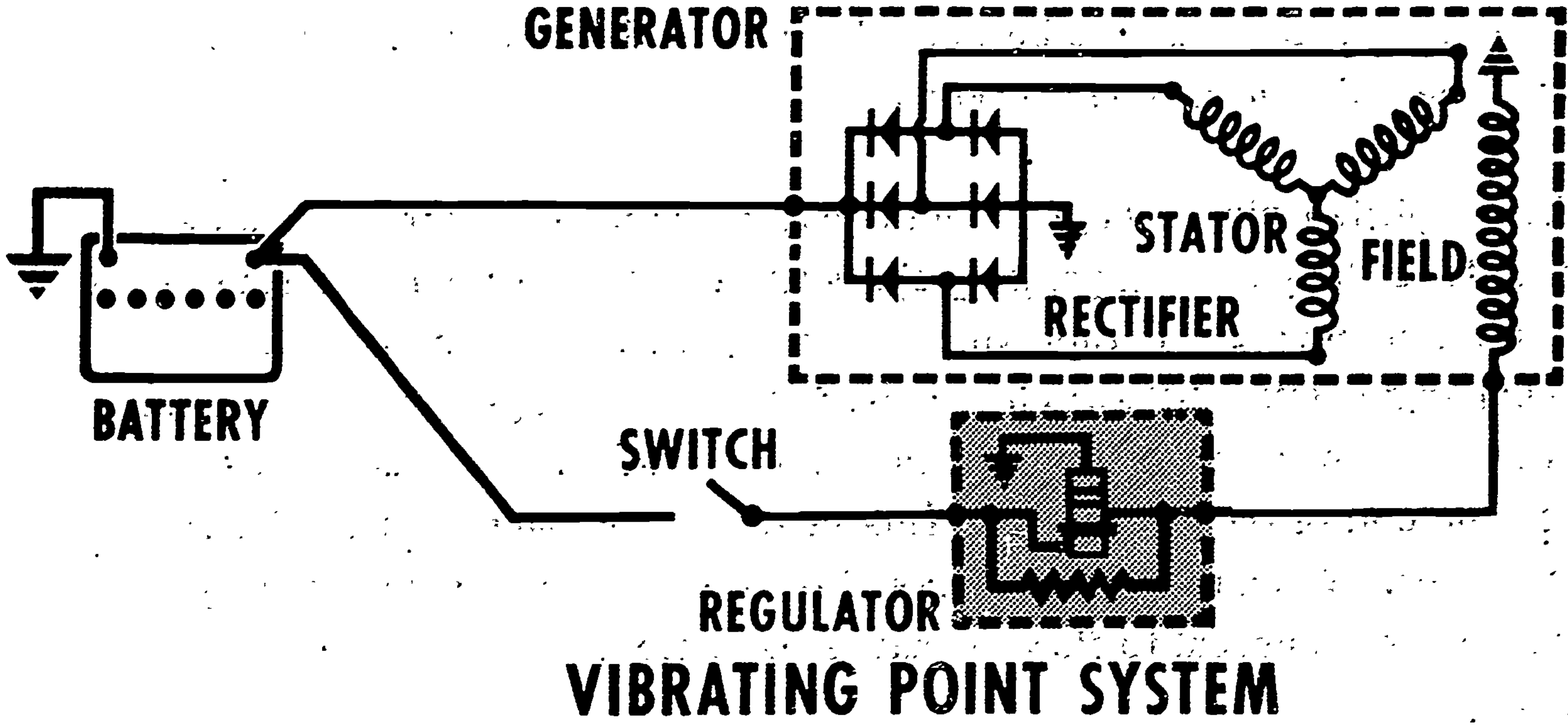
To understand the basic operation of the TRANSISTOR TYPE VOLTAGE REGULATOR that limits the alternator voltage, a comparison can be made between the vibrating point type regulator and the transistor regulator. This will show the similarities between the two regulators, and how the transistor takes the place of the contact points.

The simplified wiring diagram in the upper portion of Figure 17 shows the circuits of the vibrating point type of system. Its operation is discussed as a matter of review. In this type of system, when the ignition switch or diesel engine ON-OFF switch is closed, battery voltage supplies current through the lower contacts of the regulator, which are normally closed, to the field coil of the alternator. This provides the magnetic field for the alternator. When the engine starts, the alternator builds up in voltage, which causes current to flow to charge the battery and/or power the accessories.

As alternator speed increases, and as its voltage builds up to a predetermined value, the lower contact points of the regulator separate, and a resistance is inserted in series with the field coil of the alternator. This decreases the amount of current in the field coils, which in turn decreases the magnetic field in the alternator. As a result, alternator voltage drops to a predetermined level, and the lower contact points again close, permitting voltage to build up to the value when they can again open. This action takes place very rapidly and the contact points are said to vibrate.

As alternator speed continues to increase, its voltage continues to build up (even though the lower contact points are open) to a higher, predetermined value. At this value, the upper contacts close and both ends of the field coil are grounded. This prevents current flow in the field circuit; consequently, the voltage output of the alternator decreases. As a result,

COMPARISON OF CONVENTIONAL AND TRANSISTOR CONTROLLED CHARGING SYSTEMS



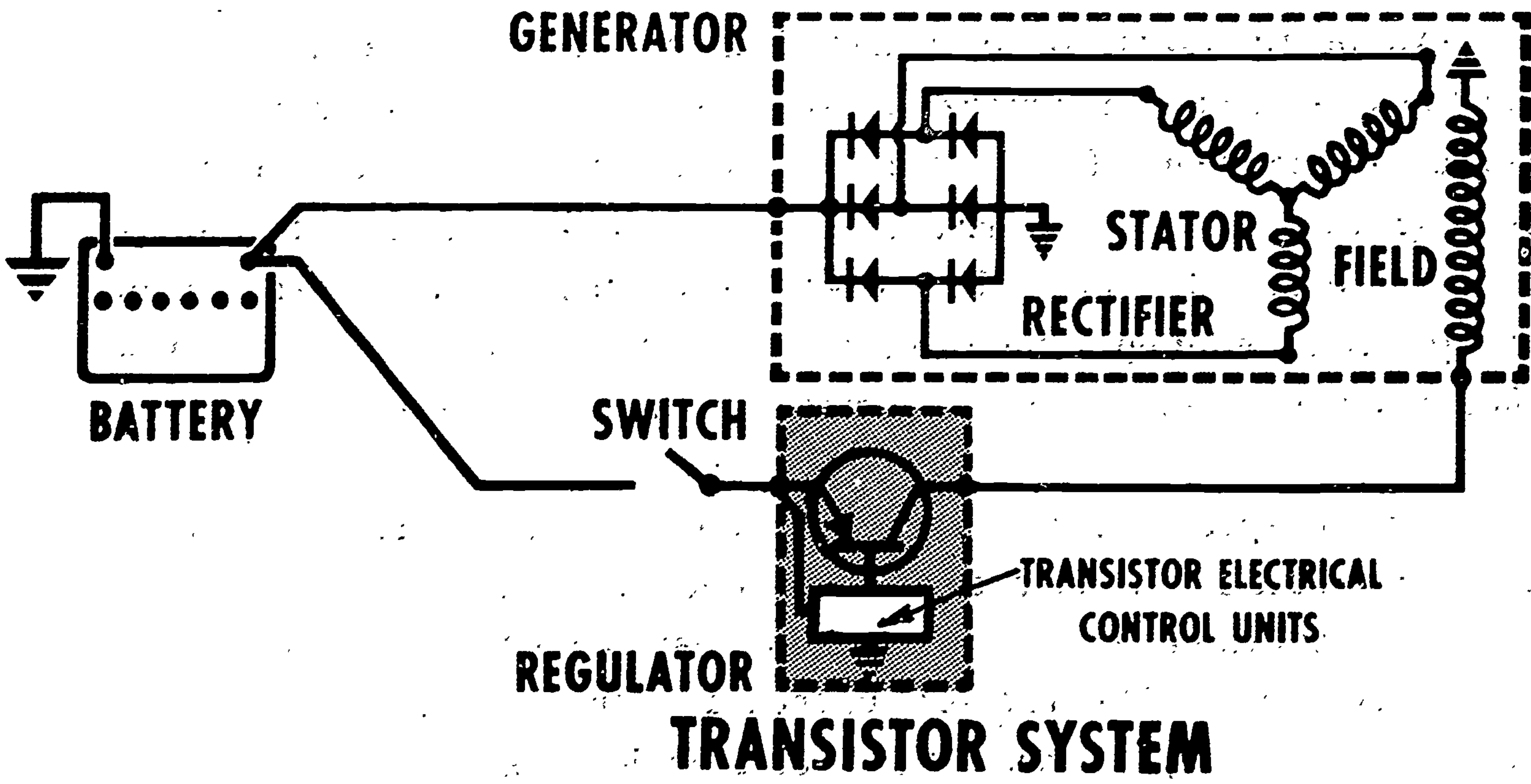


Fig. 17 Comparison of charging systems

alternator voltage drops to the predetermined value where the upper points open. Resistance is again placed in series with the field coil until such time as the voltage increases sufficiently to cause the upper points to close. The contact point action, therefore, acts as a switch to regulate the field circuit of the alternator, in order that the alternator voltage can be maintained at a safe value.

A simplified wiring diagram, depicting the circuit of the transistor regulator and its operation, is shown in the lower portion of <ins>Figure 17.</ins>

When the switch is closed, battery voltage supplies current through the emitter-collector of the transistor to the field coil of the alternator. This circuit is completed when the transistor is turned ON by a higher voltage on the emitter than on the base, permitting emitter-base current to flow. The flow of current to the field circuit of the alternator provides the magnetic field for the alternator. When the engine is started, the alternator builds up in voltage. This causes current to flow to charge the battery and/or power the accessories.

As alternator speed increases, its voltage builds up to a predetermined value. Then the electrical control portion of the regulator places a higher voltage on the base of the transistor than is impressed upon the emitter, and the transistor is turned OFF. With no current flow in the emitter-collector circuit, there is no current flow in the field circuit. As a result, alternator voltage drops to the predetermined value. Then, the electrical control portion of the regulator places a lower voltage on the base of the transistor than on the emitter, and the transistor is turned ON.

With current flow again in the emitter-collector and field coil circuits, the magnetic field is re-established in the alternator, and voltage can again build up. The ON and OFF switching action of the transistor acts to regulate the field circuit of the alternator in order that alternator voltage can be maintained at a safe value. The alternator voltage is limited by electrical means with the transistor regulator. It has no moving parts, as are used in the vibrating point type regulator.

Checking procedures are relatively simple and are discussed in detail in Service Bulletins for the particular model regulator being serviced.

DIDACTOR PLATES FOR AM 2-18D

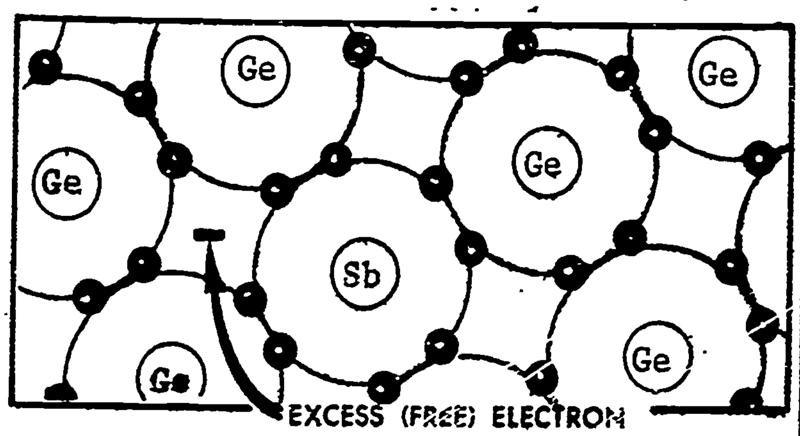


Plate I N type material;
Germanium(Ge) and Antimony(Sb)

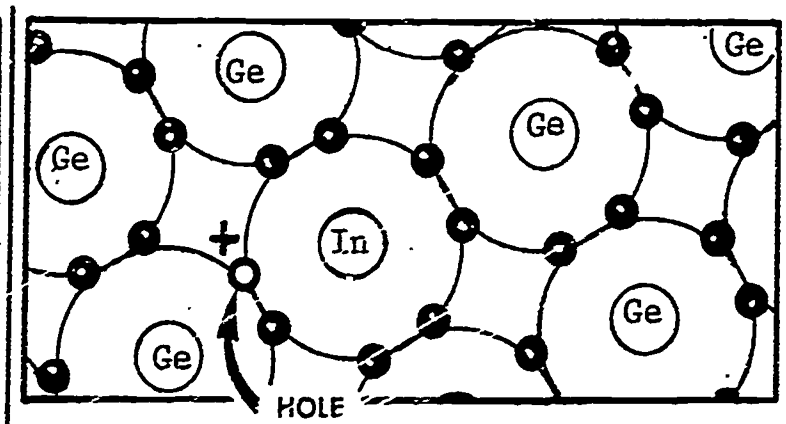


Plate II P type material;
Germanium(Ge) and Indium(In)

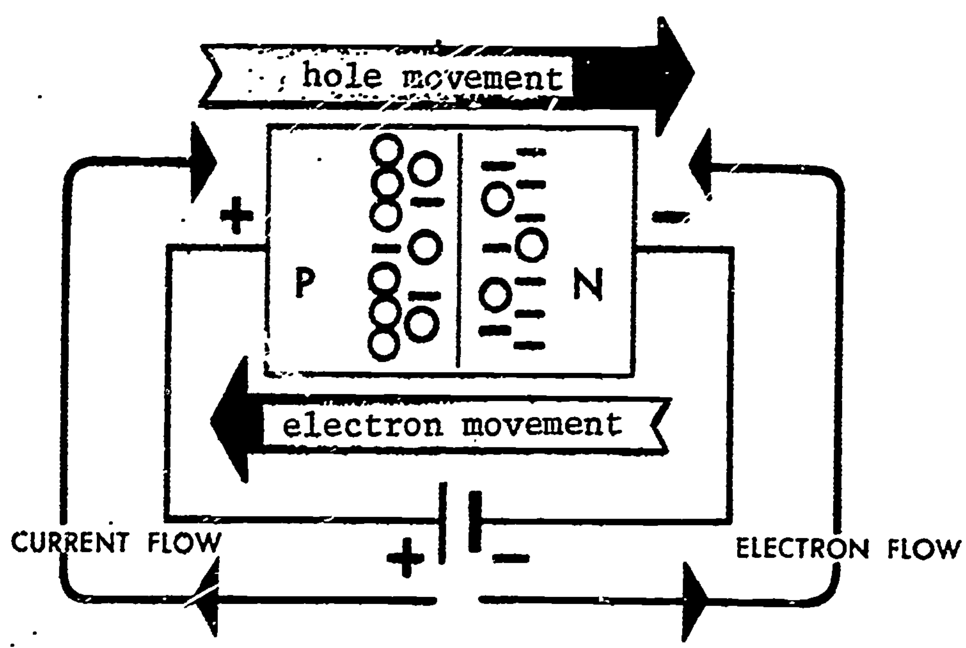


Plate III Forward bias connection

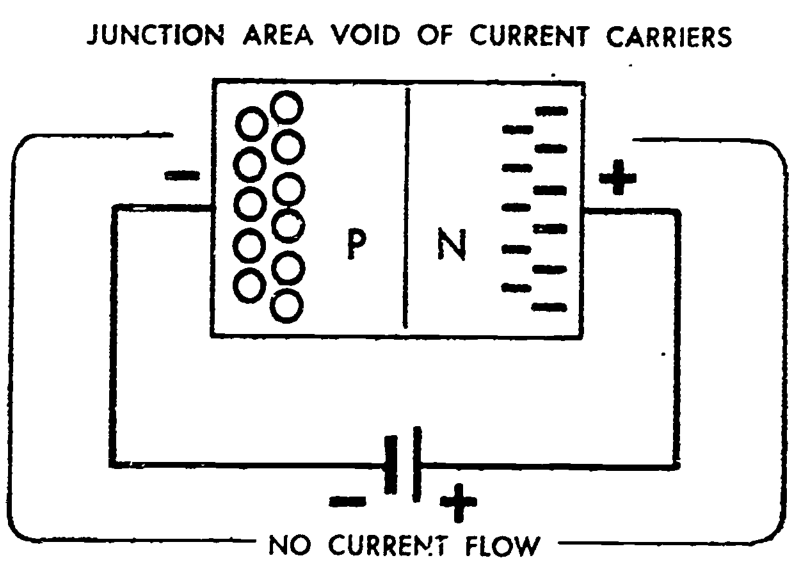
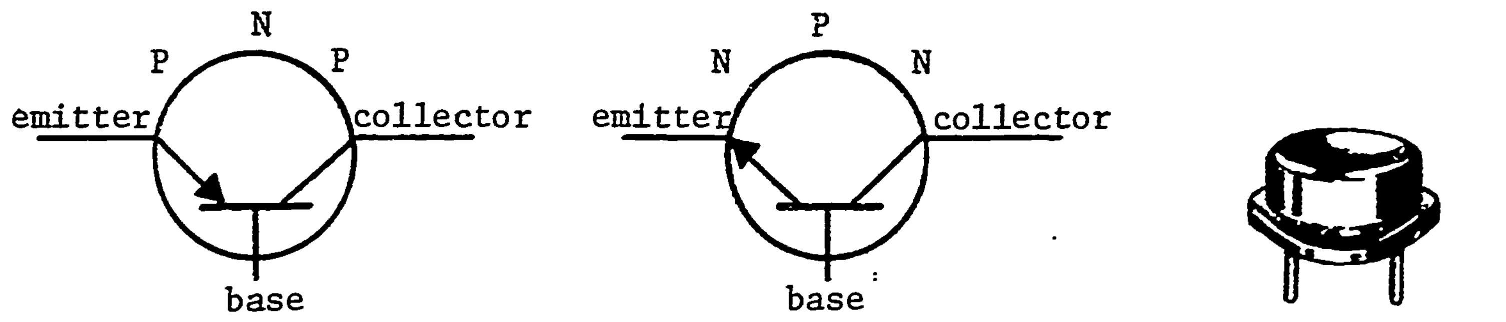
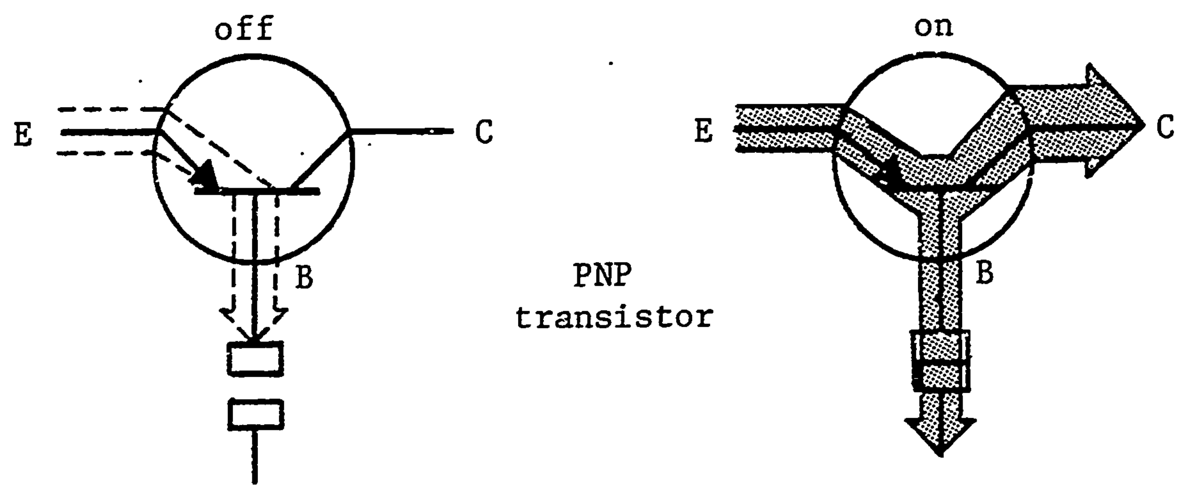


Plate IV Reverse bias connection



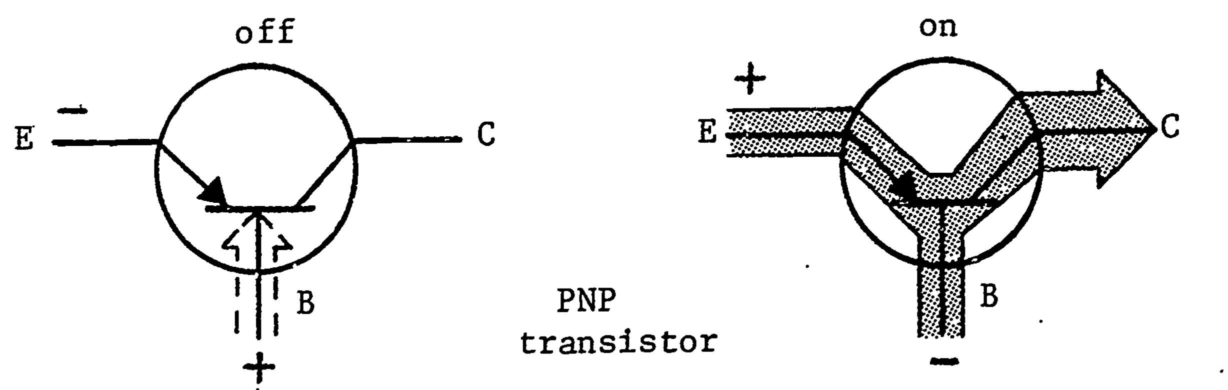
(a) PNP transistor symbol (b) NPN transistor symbol (c) typical transistor

Plate V



(a) points open (c) points closed

Plate VI Principle of transistorized regulator



(a) base positive
emitter negative

(b) base negative
emitter positive

Plate VII Principle of transistor controlled regulator

ALTERNATOR OUTPUT TEST

For vehicles equipped with transistorized or transistor controlled regulator

1. Disconnect the two wires from the alternator BAT (output) terminal. Connect these two wires together and insulate them.

2. Connect a test lamp of proper voltage between the alternator BAT terminal and ground.

3. Make sure the field relay is closed.

4. Interpreting the test results:

   Test lamp lights normally -- output satisfactory

   Test lamp lights dimly -- unsatisfactory output

   Test lamp fails to light -- no output

If the test results are unsatisfactory, the trouble could be in either the alternator or the regulator. DO NOT remove the alternator for further testing until the regulator has been tested.

Plate VIII

0

AM 2-18D
10/24/67

INTRODUCTION TO TRANSISTORS
and
TRANSISTORIZED AND TRANSISTOR CONTROLLED REGULATORS

Human Engineering Institute

Minn. State Dept. of Ed. Vocational Education

Press A — 1

Check to see that timer and index are OFF.

1

In this film we will discuss the use of the TRANSISTOR in automotive voltage regulation.

Voltage regulators equipped with transistors are coming into wide use today, especially in vehicles equipped with AC charging systems.

We will introduce you to transistor fundamentals and will discuss both transistor controlled and transistorized regulators.

A brief section on troubleshooting also will be included.
Press A — 2

1-1

2

In 1948, the Bell Laboratories perfected a new electrical device which became known as the TRANSISTOR.

The transistor is an electrical control device which acts as an electrical SWITCH. It can be turned OFF and ON to control an electrical circuit.

Press A — 3

1-2

3

In automotive applications the transistor has been used to take the place of contact points.

A transistor in the OFF condition corresponds to a(n) ___(1)___ set of contact points. A transistor in the ON condition corresponds to ___(2)___ contacts.

A. (1) closed (2) open — 4
B. (1) open (2) closed — 5

1-3

4

Incorrect.

A transistor in the ON condition allows current to flow and completes an electrical circuit. This corresponds to a CLOSED set of contact points.

A transistor in the OFF condition prohibits current from flowing. This corresponds to OPEN contact points.

Press A — 5

1-4

5

OK.

TRANSISTOR OFF -- OPEN CONTACT POINTS

TRANSISTOR ON -- CLOSED CONTACT POINTS

Transistors are made of SEMICONDUCTOR material. Semiconductors are elements that are combined with certain impurities, which enables them to conduct an electric current. Two commonly used semiconductors are silicon and germanium.

Press A — 6

1-5

6

Pure silicon and germanium are useless as semiconductors. However, if either of these is combined with a carefully controlled amount of a single impurity, it becomes an excellent semiconductor.

Elements which are used as impurities include antimony, indium, arsenic, gallium, boron and phosphorous.

According to the ELECTRON THEORY, a material is a good conductor if the outer electron shells of its atoms contain primarily __________ electrons.

A. free — 8
B. bound — 7

1-6

7

You are incorrect.

Bound electrons are those which are strongly attracted to the nucleus of the atom and are relatively hard to dislodge under the application of electrical force (voltage).

Free electrons are rather loosely attracted and are relatively easy to dislodge when voltage is applied.

Good conductors contain an excess of free electrons.
Press A — 8

1-7

8

OK.

Pure crystalline germanium, for example, is NOT a good conductor. Its atoms contain relatively few free electrons.

But, when a controlled amount of antimony, for example, is added to the germanium in a process called DOPING, an excess of free electrons results. The resulting SEMICONDUCTOR material is capable of conducting current under electrical stress (voltage).

Press A — 9

1-8

9

Crystals of pure germanium or silicon are ___(1)___. When doped with an impurity such as antimony, however, they are known as ___(2)___.

A. (1) non-conductors (2) semiconductors — 11
B. (1) semiconductors (2) insulators — 10
C. (1) conductors (2) insulators — 10

1-9

10

You are incorrect.

Pure crystalline silicon or germanium normally will not conduct an electric current. In the pure form they are NON-conductors or insulators.

But when one of them is doped with a single impurity such as antimony, it becomes able to conduct current under electrical stress (voltage).

Press A — 11

1-10

11

OK.

A material that normally is an insulator, but which acts as a conductor when doped with a controlled amount of an impurity, is called a SEMICONDUCTOR.

In the example given a few moments ago, crystalline germanium was doped with antimony.

The atoms of the two materials bond together in the doping process.

Press A — 12

1-11

12

For each antimony atom that bonds into the crystalline germanium, ONE free electron is left over. See Plate I. This electron can be made to move through the material easily.

Semiconductor material which contains an excess of free electrons (negative charges of electricity) is called N type or negative type material.

Press A — 13

1-12

13

Germanium doped with antimony, is N type semiconductor material.

When germanium is doped with certain other elements, such as indium, a different effect takes place. The atoms of the two materials bond together as before, but this time there is a DEFICIENCY of one electron for every atom of indium which is added.

Press A — 14

1-13

14

Think of this absence of an electron as a HOLE which occurs in the outer shell of each indium atom. See Plate II. Since there is an absence of one electron, the hole is, in effect, a POSITIVE charge of electricity that is free to move about.

Semiconductor material which contains an excess of these holes (positive charges of electricity) is called P type or positive type material.

Press A — 15

1-14

15

The material formed when germanium is doped with antimony contains an excess of free electrons. This is known as ___(1)___ semiconductor material.

When germanium is doped with indium, an excess of holes results. This is known as ___(2)___ semiconductor material.

A. (1) P type (2) N type — 16
B. (1) N type (2) P type — 17

1-15

16

Incorrect.

The germanium-antimony combination contains an excess of free electrons (negative charges). This is known as negative or N type material.

The germanium-indium combination contains an excess of holes (positive charges). This is known as positive or P type material.

Press A —17

1-16

17

OK.

It is not important to remember which particular combinations of elements form what kind of material.

The important thing to remember is that there are two basic types of semiconductor materials:

1. N type materials (which contain an excess of free electrons)
2. P type materials (which contain an excess of positively charged holes)

If you would like to review this brief introduction to semiconductors, press A. Otherwise, press B. 2 19

1-17

X(C)—18

18

OK.

There are two basic types of semiconductor materials:

1. N type materials (which contain an excess of free electrons)
2. P type materials (which contain an excess of positively charged holes)

Since you have made an error or two on the questions so far, let's quickly review this brief introduction to semiconductors.

Press A — 2

1-18

19

An important concept in the study of transistors is the PN JUNCTION. See Plates III and IV. Note that in each case a PN junction exists. A piece of P type material has been joined to a piece of N type material. The PN junction occurs at the point of contact between the two surfaces.

Press A — 20

2-19

20

See Plate III only.

A battery is connected as shown (negative battery terminal to the N type material: positive battery terminal to the P type material).

Under these conditions, the negative battery polarity REPELS the free electrons in the N type material. This causes the electrons to flow across the PN junction, toward the positive battery terminal.

Press A —21

2-20

21

At the same time, the positive battery polarity REPELS the positively charged holes in the P type material. The holes flow across the PN junction also, but in the direction of the negative battery terminal.

In the circuit illustrated in Plate III, electrons flow from ________

A. positive to negative — 22
B. negative to positive — 23

2-21

22

Incorrect. See Plate III.

In this circuit, electrons flow from the negative battery terminal toward the connection with the N type material. Since they are negatively charged, these electrons REPEL the free electrons in the N type material. This causes them to flow across the PN junction toward the positive battery terminal.

Press A — 23

2-22

23

OK.

The electrons flow from negative to positive. This may seem confusing, since conventionally we think of current as flowing from positive to negative.

There really is no conflict, however, because when electrons move from negative to positive, conventional current is said to flow from positive to negative. This is exemplified by the movement of the holes across the PN junction. The holes move in the circuit from positive to negative (see Plate III). Press A —24

2-23

24

When the polarities affecting the semiconductor materials are connected as shown in Plate III, we have a FORWARD BIAS connection. This means that with positive polarity affecting the P type material and negative polarity affecting the N type material, CURRENT will flow in the circuit. The PN junction acts like a CLOSED electrical switch.

Press A — 25

2-24

25

Now look at Plate IV. In this case, the polarities affecting the P type and N type materials are reversed. The P type material is connected to the negative battery terminal and the N type material to the positive battery terminal.

The negative battery polarity ________ the holes in the P type material.

A. repels — 26
B. attracts — 27

2-25

26

No.
Remember that the holes may be thought of as positive charges that are free to move about.

Since UNlike charges attract, the holes in the P type material are ATTRACTED by the negative battery polarity.

Press A — 27

2-26

27

OK.
Similarly, the positive battery polarity attracts the free electrons in the N type material.

Under these conditions the PN junction area is relatively free of current carriers (see Plate IV). The PN junction acts like an OPEN electrical switch and no current flows in the circuit.

Press A — 28

2-27

28

When the polarities affecting the semiconductor materials are connected as shown in Plate IV, we have a REVERSE BIAS connection.

A reverse bias connection acts like a(n) ___(1)___ electrical switch; a forward bias connection is similar to a(n) ___(2)___ electrical switch.

A. (1) open (2) closed — 30
B. (1) closed (2) open — 29

2-28

29

No. (See Plates III and IV).

With a forward bias connection, the current carriers flow across the PN junction (in opposite directions) and complete the electrical circuit. The FORWARD bias connection is similar to a CLOSED electrical switch.

With a reverse bias connection, the current carriers avoid the PN junction and no current flows. The REVERSE bias connection acts like an OPEN electrical switch.

Press A — 30

2-29

30

OK. So far we have discussed only a two layer sandwich of semiconductor materials. This is not a complete transistor.

To form a complete transistor, it is necessary to add a third layer of semiconductor material. Transistors may be constructed in one of two ways -- PNP or NPN.

A PNP transistor is made of a single layer of ___(1)___ material sandwiched between two layers of ___(2)___ material.

A. (1) P type (2) N type — 31
B. (1) N type (2) P type — 32

2-30

31

You are incorrect.

A PNP transistor consists of a single layer of N type material sandwiched between two layers of P type material. The name PNP tells you this by the positions of the letters.

Press A — 32

2-31

32

OK. An NPN transistor on the other hand, consists of a single layer of P type material sandwiched between two layers of N type material.

Plate V shows the symbols for the PNP and the NPN transistors. A picture of a typical transistor also is included. Note that there are three parts to the transistors -- the emitter, the collector and the base.

In the PNP transistor the BASE is ___(1)___ material; in the NPN transistor the base is ___(2)___ material.

A. (1) N type (2) P type — 34
B. (1) P type (2) N type — 33

2-32

33

No. (See Plate V.)

The middle letter of the name of the transistor type tells you the material of which the BASE is made.

In the PNP transistor (Plate V (a)), the base is N type material. In the NPN transistor (b), the base is P type material.

Press A — 35

2-33

34

OK. If the base is N type material, we have a PNP transistor; if the base is P type material, we have an NPN transistor. (See Plate V.)

The direction of the arrow in the transistor symbol tells the direction of conventional current flow in the EMITTER-BASE CIRCUIT when the transistor is in the ON condition.

If you would like to review the PN junction and transistor construction, press A. — 19

Otherwise, press B. — 36

X(C) — 35

2-34

35

OK.

You have had trouble with a question or two in this section, so let's have a brief review of the PN junction and basic transistor construction.

When you answer all the questions correctly we'll see how the transistors are used to control electrical circuits.

Press A — 19

2-35

36

Let's see how a transistor may be used to control an electrical circuit. In the discussion that follows we will use the PNP transistor as an example.

TRANSISTOR OPERATION

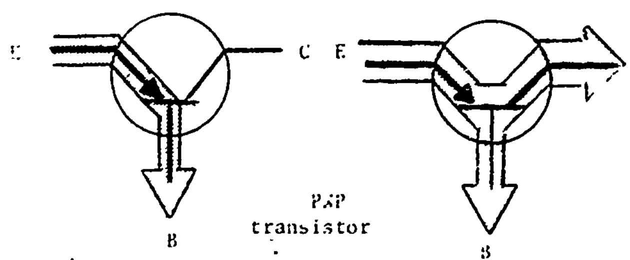
Only when current flows in the EMITTER-BASE circuit of the PNP transistor will current flow in the EMITTER-COLLECTOR circuit.

Press A — 37

3-36

37

Only a small amount of current is needed to activate the emitter-base circuit. This small current acts as a trigger which permits a larger current to flow in the emitter-collector circuit.



Press A — 38

3-37

38

In a PNP transistor, a small current in the ___(1)___ circuit acts as a trigger which permits a relatively large current to flow in the ___(2)___ circuit.

A. (1) emitter-collector (2) emitter-base — 39
B. (1) emitter-base (2) emitter-collector — 40
C. I'm not sure — 36

3-38

39

You are incorrect.

Remember that current WILL NOT flow in the emitter-collector circuit unless current first flows in the emitter-base circuit.

What happens in the emitter-base circuit determines what will happen in the emitter-collector circuit.

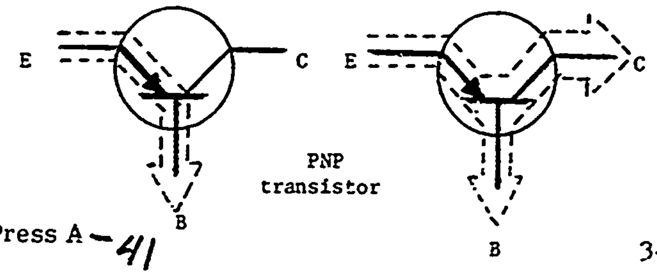
Let's review briefly. Press A — 37

3-39

40

Good. A small current in the emitter-base circuit permits a larger current to flow in the emitter-collector circuit.

As you might suspect, the absence of current flow in the emitter-base circuit means that NO current will flow in the emitter-collector circuit.



Press A — 41

3-40

41

By manipulating the small current in the emitter-base circuit, we can control the larger current in the emitter-collector circuit.

If the emitter-base circuit of a PNP transistor is ON (if current is flowing through it), then the emitter-collector circuit will be ____________.

A. ON — 44
B. OFF — 42
C. I'm not sure — 43

3-41

42

No.
Remember that when a small current flows in the emitter-base circuit, a larger current can then flow in the emitter-collector circuit.

In order for the emitter-collector circuit to be ON (in order for current to flow through it), the emitter-base circuit must be ON also.

Press A — 44

3-42

43

The two circuits operate simultaneously. As long as the emitter-base circuit is OFF, the emitter-collector also is OFF.

If the emitter-base circuit is ON (if current flows through it), then the emitter-collector circuit also is ON.

Press A — 41

3-43

44

OK.
Both circuits are either ON or OFF simultaneously.

Control of the emitter-base circuit enables us to use the transistor as an electronic switch, to open and close an electrical circuit.

Let's see how the transistor has found application in the automotive field as a useful means of controlling generator voltage.

Press A — 45
X(C) — 44.1

3-44

44.1

OK.
Both circuits are either ON or OFF simultaneously.

By controlling current flow in the emitter-base circuit, we can use the transistor as an electronic switch, to open and close an electrical circuit.

Let's have a quick review, since you have missed at least one question in this section.

Press A — 36

3-44.1

45

In automotive applications, generator voltage control (voltage regulation) is accomplished by controlling ____________.

A. the speed of rotation — 46
B. the number of conductors — 46
C. the strength of the field — 47

3-45

46

Not quite.

The factor you chose does help to determine generator voltage, but it is not the primary means of automotive voltage control.

In automotive applications, generator voltage control is most easily accomplished by varying the STRENGTH OF THE FIELD.

Press A — 47

3-46

47

OK.
With a means of varying the strength of the magnetic field (by controlling the current in the field circuit), the voltage of an automotive generator can be controlled.

Transistors are employed in two distinct types of regulators in order to control generator voltage.

Press A — 48

3-47

48

See Plate VI. The generator regulator may include a transistor which works together with a diode and set of contact points to regulate the generator field current.

A voltage regulator unit that includes a transistor and a set of contact points is called a TRANSISTORIZED regulator.

Press A — 49

3-48

49

In a transistorized regulator, the contact points work to turn the emitter-base circuit of the transistor ON and OFF.

If the contact points are open, current _________ flow in the transistor emitter-collector circuit.

A. will — 50
B. will not — 51

3-49

50

You are incorrect.

See Plate VI(a). In a transistorized regulator, no current flows in the emitter-base circuit when the contact points are open. This means that no current will flow in the emitter-collector circuit of the transistor.

The transistor is then in the OFF condition and the generator field current is temporarily turned off.

Press A — 51

3-50

51

OK. See Plate VI. With the contacts open, the emitter-collector circuit is turned off. This temporarily opens the field circuit. Plate VI(a).

With no field current flowing, the generator voltage drops immediately. Once it falls below the voltage regulator setting, spring tension pulls the contacts closed, Plate VI(b), and the voltage builds up again.

Eventually, magnetism created in the regulator windings becomes strong enough, and the points open again.

Press A — 52

3-51

52

The cycle of opening and closing the points repeats many times per second to limit the generator voltage to a pre-set value.

A generator regulator that contains a transistor, a diode and a conventional set of contact points is called a _______________ regulator.

A. transistorized — 54
B. transistor controlled — 53

3-52

53

Incorrect.

We will talk about transistor CONTROLLED regulators next.

A regulator that contains a diode, a conventional set of contact points and a transistor that work together to control generator field current is called a transistorized regulator.

Press A — 54

3-53

54

OK.
One of the two types of regulators containing transistors is the TRANSISTORIZED regulator.

The second type is the TRANSISTOR CONTROLLED regulator (often called, simply, a transistor regulator). A transistor controlled regulator consists of TWO transistors working together with a pair of diodes and with a group of resistors to control field current of the generator.
Press A — 55

3-54

55

A (1) regulator contains a set of vibrating contact points; a (2) regulator contains no moving parts.

A. (1) transistor controlled (2) transistorized —56

B. (1) transistorized (2) transistor controlled —57

3-55

56

No.
Remember, it is the transistorIZED regulator that contains a conventional set of vibrating contact points.

A transistor CONTROLLED regulator operates through the action of transistors, diodes and resistors -- it is a completely solid state device that contains no moving parts.

Press A —57

3-56

57

OK.
To summarize briefly the operation of a transistor controlled regulator:

The generator field current is turned OFF and ON through the action of the transistors, diodes and resistors in the regulator. Instead of using a set of contact points, the transistors are turned ON and OFF by electronic means.

Press A —58

3-57

58

The transistors are controlled by changing the relative polarities of the emitter and the base, in order to control current flow in the emitter-base circuit.

Current in the emitter-collector circuit of the transistor can be turned off electronically by making the base relatively POSITIVE, compared to the emitter (Plate VII(a)).

Press A—59

3-58

59

If the emitter-collector circuit of a transistor is part of the generator field circuit, the field current will be turned ____________ temporarily whenever the emitter is negative and the base is positive.

A. ON —60
B. OFF —62
C. I'm not sure —61

3-59

60

Your answer is incorrect. See Plate VII(a).

When the base of a PNP transistor is electrically POSITIVE and the emitter is NEGATIVE, no current flows in the emitter-base circuit. As we learned earlier, this also prevents current from flowing in the emitter-collector circuit.

When the base is positive and the emitter is negative, generator field current is temporarily turned OFF.

Press A —62

3-60

61

See Plate VII(a).

By making the transistor base electrically POSITIVE in relation to the emitter, current is prevented from flowing in the emitter-base circuit. This of course means that NO current will flow in the emitter-collector circuit.

If the emitter-collector circuit is part of the generator field circuit, the field current will be temporarily turned OFF with the transistor base POSITIVE and the emitter NEGATIVE.

Press A —59

3-61

62

OK.
Plate VII(a), shows the condition of the transistor during the time that the field current is turned off.

Turning off the field current causes the generator voltage to drop. This decrease in voltage, together with the action of the other regulator components, causes the electrical potentials of the transistor emitter and base to change.

Press A —63

3-62

63

As the generator voltage decereases, the transistor emitter becomes relatively more POSITIVE, compared to the bas^.

With the emitter positive and the base negative, current can flow in the emitter-base circuit. This in turn allows current to flow in the emitter-collector circuit. The generator field current is now turned on. See Plate VII(b).

Press A – 64

3-63

64

As the generator voltage builds up and approaches the maximum limit for which the regulator is set, the transistor base becomes increasingly POSITIVE. When the voltage reaches the pre-set value, the field current is turned off again.

The cycle of turning the field current on and off is repeated many times per second to limit generator voltage to the pre-set value.

Press A – 65

3-64

65

In a transistor controlled regulator, generator field current is turn^d ON when the transistor ___(1)___; the field current is turned OFF when the transistor ___(2)___.

A. (1) emitter is positive and the base is negative – 67
   (2) emitter is negative and the base is positive

B. (1) emitter is negative and the base is positive – 66
   (2) emitter is positive and the base is negative

3-65

66

You are incorrect.

The generator field current is turned ON when the transistor emitter is positive and the base is negative (Plate VII(b)).

When the emitter is negative and the base is positive, the generator field current is turned OFF. (Plate VII(a)).

Press A – 68

3-66

67

OK.
The transistor controlled regulator limits generator voltage by electronically altering the polarities of the transistor emitter and base.

If you would like to review both transistorized and transistor controlled regulator operating principles, press A. Press B if you want to review only transistor controlled regulators.

36 54

Press E if you prefer to go on.

69 XC–68

4-67

68

OK.
Emitter positive; base negative -- field current ON.
Emitter negative; base positive -- field current OFF.

Since you have had trouble with a question or two, let's have a brief review of the basic operating principles for TRANSISTORIZED and TRANSISTOR CONTROLLED regulators.

Press A – 45

3-68

69

Generator voltage regulation is achieved by controlling the field current in systems equipped with ________________.

A. a transistorized regulator – 70
B. a transistor controlled regulator – 70
C. either of the above – 71

4-69

70

Your answer is correct, but is incomplete.

BOTH the transistorized and the transistor controlled regulator control generator voltage by varying the strength of the generator field current.

Press A – 71

4-70

71

OK.
Both types of regulators accomplish their purpose by varying the generator field current. To that extent they are similar.

We already know that the two types are different because of the manner in which the field current is turned ON and OFF in each.

Another way they differ is in the systems in which they generally are used.

Press A — 72

4-71

72

Transistorized regulators are normally used in lower voltage systems.

Transistor controlled regulators are normally used in higher voltage systems.

(Any system of more than 12 volts is considered a high voltage system.)

Press A — 73

4-72

73

An AC charging system incorporating a TRANSISTORIZED regulator consists of:

1. AC generator (alternator)
2. Transistorized regulator
3. Circuit breaker switch (cutout switch)
4. Ammeter or indicator lamp

The field relay unit may be contained within the regulator case (four terminal regulators) or may be mounted separately (three terminal regulators).

Press A — 74

4-73

74

An AC charging system incorporating a TRANSISTOR CONTROLLED regulator consists of:

1. AC generator (alternator)
2. Transistor controlled regulator
3. Circuit breaker switch (cutout switch)
4. Ammeter (with shunt in some cases) or indicator lamp

Transistor controlled regulators normally employ an external (separate) field relay unit.

Press A — 75

4-74

75

Externally mounted field relay units are found on systems incorporating either a transistor controlled regulator or a __________ terminal transistorized regulator.

A. four — 76
B. three — 77
C. I'm not sure — 73

4-75

76

Incorrect.
A four terminal transistorized voltage regulator normally employs a self-contained field relay unit. The field relay is mounted inside the regulator case.

Externally mounted field relay units are used with transistor controlled and THREE TERMINAL transistorized regulators.

Press A — 77

4-76

77

OK.
Let's look at some precautions to observe when working with transistorized and transistor controlled regulators.

Transistors and diodes are designed for specific current values. Passing a higher current through them will result in their being BURNED OUT.

When a transistor or diode is burned out, an open circuit exists across it.

Press A — 78

4-77

78

Transistors and/or diodes can be BURNED OUT by:

1. Shorting across the terminals of either the generator or the regulator (for example, using a screwdriver to check generator output).
2. Reversing the normal polarity of the system.
3. Using a fast charger without first disconnecting the battery from the system.

Press A — 79

4-78

79

If a trickle charger or a booster battery is used, the connections to the vehicle battery should be ______________.

A. series (POS to NEG) — 80
B. parallel (POS to POS; NEG to NEG) — 81

X(C) — 83

4-79

80

Incorrect.
The trickle charger or booster battery should be connected in parallel with the vehicle battery (positive to positive; negative to negative).

Connecting them in series will cause reversed polarity and excessive current flow, which may burn out the transistors and/or diodes.

Press A — 69

4-80

81

OK.
The TEST FOR ALTERNATOR OUTPUT is the same for systems equipped with a transistorized or a transistor controlled regulator. The test procedure is outlined in Plate VIII.

If the wires are not disconnected from the alternator BAT terminal, the test lamp will light ____________.

A. only if alternator output is UNsatisfactory — 82
B. whether alternator output is satisfactory or not — 84

X(C) — 83

5-81

82

You are incorrect.

Failure to remove the two wires from the alternator BAT terminal (prior to connecting the test lamp) may lead to false interpretation of the test.

If the wires are NOT disconnected, the test lamp will light, but it will be reading BATTERY CURRENT.

Press A — 84

5-82

83

OK.
Let's have a quick review of our comparison of the two systems and the service precautions, since you made an error on at least one question.

When you answer the questions correctly, we'll discuss generator output testing and troubleshooting.

Press A — 69

4-83

84

OK.
Failure to disconnect the wires may lead to false interpretation of the output test.

Step 3 in Plate VIII says, "Make sure that the field relay is closed." To do this, it may be necessary either to increase the engine rpm (on vehicles equipped with a fuel pressure switch), or to connect a jumper lead between the No. 1 and No. 2 terminals of the FIELD RELAY UNIT.

Press A — 85

5-84

85

In the alternator output test, a dimly lighted or unlighted test lamp means that the alternator output is unsatisfactory.

If alternator output is low, ______________.

A. the alternator is at fault — 86
B. the regulator is at fault — 86
C. either the alternator or the regulator may be at fault — 87

5-85

86

Not necessarily.

If the test indicates unsatisfactory alternator output (or NO output) either the alternator or the regulator may be at fault.

Not until the regulator is tested can you be sure which component is defective.

Press A — 87

5-86

87

OK.

It is not necessary to remove the alternator for further testing until you have tested the regulator. If the fault lies strictly with the regulator, alternator testing will, of course, be unnecessary.

The test procedures for the regulator vary slightly, depending upon whether it is transistorized or transistor controlled. Let's look at the test for transistorized regulators first.

Press A —88

5-87

88

TRANSISTORIZED REGULATOR TEST

To determine if the regulator is the cause for decreased alternator output:

1. Leave wires connected together and insulated as in Step 1, Plate VIII.
2. Connect a test lamp as in Step 2, Plate VIII.
3. Disconnect the F-1 wire from its regulator terminal. Ground this wire.
4. Start the engine and run at idle (only long enough to perform the test).
5. Disconnect the F-2 and BAT wires from regulator and touch them together.

Press A —89

5-88

89

If the procedure outlined in the previous frame is followed:

1. The test lamp will light if the alternator is producing current normally. The transistorized regulator is the source of the trouble in this case.
2. If the test lamp does not light or lights only dimly, then the alternator is at fault.

Press A if you want another look at the test procedure. —88

Press B if you prefer to go on. —90

5-89

90

In the troubleshooting test for transistorized regulators, a brightly lighted test lamp means that the alternator ___(1)___ producing current. The ___(2)___ probably is defective.

A. (1) is (2) alternator —91
B. (1) is (2) regulator —93
C. (1) is not (2) regulator —91
D. (1) is not (2) alternator —92

5-90

91

Only part of your answer is correct.

When a transistorized regulator is tested, following an unsatisfactory alternator output test:

A brightly lighted test lamp means that the alternator is producing current normally. This means that the source of low output is the regulator.

Press A —90

5-91

92

Both parts of your answer are incorrect.

A brightly lighted test lamp indicates that the alternator itself is producing current normally. But since the original output test showed unsatisfactory output, the trouble is assumed to be in the transistorized regulator.

Press A —90

5-92

93

OK.

If the lamp glowed dimly or not at all, then the trouble would be in the alternator.

If the alternator output test is unsatisfactory and the vehicle is equipped with a transistor controlled regulator, use the test that follows to pinpoint the source of reduced output.

Press A —94

5-93

94

TRANSISTOR CONTROLLED REGULATOR TEST

1. Leave the wires connected together as in Step 1, Plate VIII.
2. Connect a test lamp as in Step 2, Plate VIII.
3. Disconnect the wire from the regulator F-1 terminal. DO NOT ground.
4. Start the engine and run at idle (only long enough to perform test).
5. Touch the regulator F-1 wire to the BAT wire, disconnected from the No. 2 terminal of the field relay unit.

Press A —95

5-94

95

Although the test procedures differ slightly for transistorized and transistor controlled regulators, the test results mean the same thing.

A brightly lighted test lamp means that the alternator is producing current and is OK. The regulator is at fault.

If the test lamp fails to light or lights only dimly, then the alternator is at fault.

Press A for another look at the test procedure for transistor controlled regulators. 94

Press B if you prefer to go on. 96

5-95

96

In the troubleshooting tests for transistorized and transistor controlled regulators, the test lamp will glow (1) if the regulator is the cause of reduced alternator output; the lamp will glow (2) if the alternator itself is at fault.

A. (1) brightly (2) dimly or not at all – 98

B. (1) dimly or not at all (2) brightly – 97

5-96

97

Incorrect.

Whether you are testing a transistorized or a transistor controlled regulator:

1. The test lamp will glow brightly if the regulator is the cause of reduced alternator output.
2. The test lamp will glow dimly or not at all if the alternator itself is faulty.

Press A – 99

5-97

98

OK. If test results show that the alternator itself is at fault, it may have to be removed and tested according to the procedures outlined in AM 2-17D, "AC Generators II".

If the regulator is found to be at fault, it will be necessary to consult the appropriate manufacturer's Service Bulletin for specific information regarding regulator service.

Press A if you would like to review, starting with our comparison of systems incorporating transistorized and transistor controlled regulators. 69

Press B if you prefer to review only alternator output testing and regulator testing. Press D if you do not want to review. 81 100

X(C) – 99

5-98

99

OK.

You have missed a question or two in this section on alternator output testing and the troubleshooting tests for transistorized and transistor controlled regulators.

Let's have a quick review of this section.
Press A – 81

5-99

100

Congratulations. You have successfully completed this film.

We have attempted here to introduce you to general and basic fundamentals of transistor operation. This information should become increasingly useful to you as transistors come into wider use in automotive applications.

Press REWIND.

5-100

INSTRUCTOR'S GUIDE

Title of Unit: ALTERNATOR AND REGULATOR SERVICING AND TESTING, AND AN INTRODUCTION TO TRANSISTOR REGULATORS

AM 2-18
9/26/67

OBJECTIVES:

1. To review the principles of generation, to help the student fully understand the advantages of the alternator over the DC generator.
2. To explain how AC is rectified (changed) to DC and why it is necessary. To introduce the student to some new electrical symbols; sine wave of three phase AC, diode and transistor symbols.
3. To review the precautions that must be followed when working on charging systems equipped with alternators.
4. To inform the student of the correct methods of alternator tests and maintenance procedures.
5. To introduce the student to the transistor controlled voltage regulator that is used with alternators. To show how the transistor operates and the advantages gained from using it in electrical circuits.
6. To show a comparison between the vibrating point type regulator and the transistor regulator; to show the similarities between the two regulators, and to show how the transistor takes the place of the contact points.

LEARNING AIDS suggested:

VISUAL AIDS: Delco-Remy training charts and manuals 5133-W and DR-9011-A
Delco-Remy service bulletin 1R-265; Relays and Regulators

MODELS: Any components or assemblies that can be brought into the classroom for disassembly and inspection. Alternators, regulators, both the vibrating-point type and the transistor controlled type. Ammeter, voltmeter, ohmmeter and a diode tester may be demonstrated.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. What is the primary purpose of the generator or alternator?

2. What does the process of sprinkling iron filings on a piece of glass and then holding a magnet under the glass prove?

3. What are the three conditions necessary to generate electricity? (Not produced by chemical action, as in a battery.)

4. Explain how the alternating current developed in a DC generator is changed to DC by the commutator bars and brushes.

5. What is the basic difference between the DC generator and the alternator?

6. What function does the stator assembly serve in an alternator, and what is its counterpart in a DC generator?

7. How is the field current supplied to the rotating field winding in an alternator?

8. What is the meaning of the terms: self-excited and externally-excited field circuits?

9. What is meant by the terms: single-phase and three-phase generators?

10. How many diodes are used in the typical automotive type alternator? Explain.

11. Why is it possible to drive the alternator at a much higher speed than the DC generator?

12. Is the difference in drive ratio between the alternator and the DC generator an advantage or a disadvantage? Explain.

13. How many of the three phases in an alternator are conducting current at one time? Explain.

14. Why is it not necessary to have a cutout relay and current regulator with an alternator?

QUESTIONS (continued)

15. Why is polarity so important when servicing alternators and associated equipment?

16. Why is it not necessary to polarize an alternator?

17. Why do instructions concerning testing diodes contain a CAUTION against using a 110 volt test lamp?

18. What is meant by the term "the transistor is a static device"?

19. How does the transistor replace the vibrating type contact points in alternator voltage regulators?