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ALTERNATORS and CHARGING SYSTEMS

REV. 4-95 PPD **194-218**

Ideally, the battery should be inspected and tested whenever a vehicle undergoes routine maintenance. There is, however, no recommended schedule for battery service. This section provides an overview of diagnostic and testing procedures. Detailed procedures can be found in the appropriate vehicle Service Manual.

PRELIMINARY INSPECTION

To save time, energy and needless cost, preliminary checks should be made before battery testing. Often a malfunction can be determined by observing the physical condition of the battery.

The following visual inspections should be made before testing:

- Check the battery date code to ensure that the battery has not exceeded its service life.
- Inspect the battery case and cover (Figure 3-1) for cracks or buckling. These conditions could result from hold-down attachments that are either too tight or too loose, exposure to extreme heat in the engine compartment or freezing of the electrolyte. Acid deposits on the battery cover may indicate leakage, spill-over or gassing due to a high charging rate.
- Inspect the cable clamps for excessive corrosion deposits, acid erosion or loose battery post connections. Any of these conditions could result in voltage loss through the cables.
- Check for secure ground connections at the engine and body. Also check for proper connections at the generator and voltage regulator.

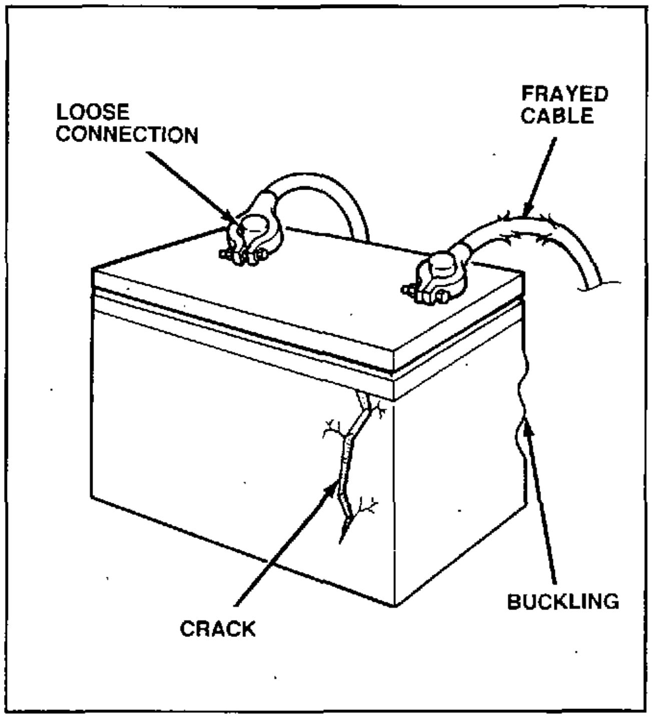

Figure 3-1 Battery Case

- Make sure that the battery terminals are not broken or loose. These connections should also be clean and free of deposits.

In addition, check the external surface and the battery posts for signs of abuse such as hammering or improper cable removal. These can often provide clues to battery malfunctions.

If the discharged battery is relatively new, test for current drain. The following are some of the most common current drain problems.

- Glove compartment lamp stays on indefinitely after door closed.
- Hood lamp stays on constantly.
- License plate lamp or interior lamp stays on constantly.

TESTING PROCEDURES

Battery tests determine the battery's state of charge and its capacity to crank an engine. The purpose of these tests is to show whether the battery is good, needs recharging or must be replaced. The cause of a battery malfunction is not always obvious. The testing procedures that follow will help you to pinpoint the source of the concern. Refer to the appropriate vehicle Service Manual for more detailed procedures.

Testing Instruments

Several devices are used to test and diagnose automotive batteries. They include the volt-ohmmeter Rotunda Tool Number 105-00051, test lamp and Rotunda Starting and Charging Tester (VAT-40), Rotunda Tool Number 078-00005.

The volt-ohmmeter (Figure 3-2) has several applications, including:

- Determining battery condition and state of charge

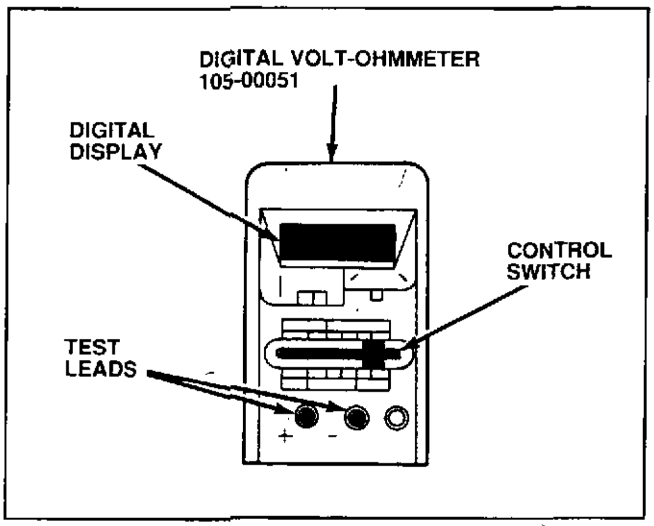

Figure 3-2 Digital Volt-Ohmmeter

- Testing battery cables
- Testing electrical systems for shorts and drains

The volt-ohmmeter can be used to check the state of charge for conventional, low maintenance and maintenance-free batteries. The test values cited in this text are referenced to Ford Rotunda volt-ohmmeters. Use of a different tester may result in different values.

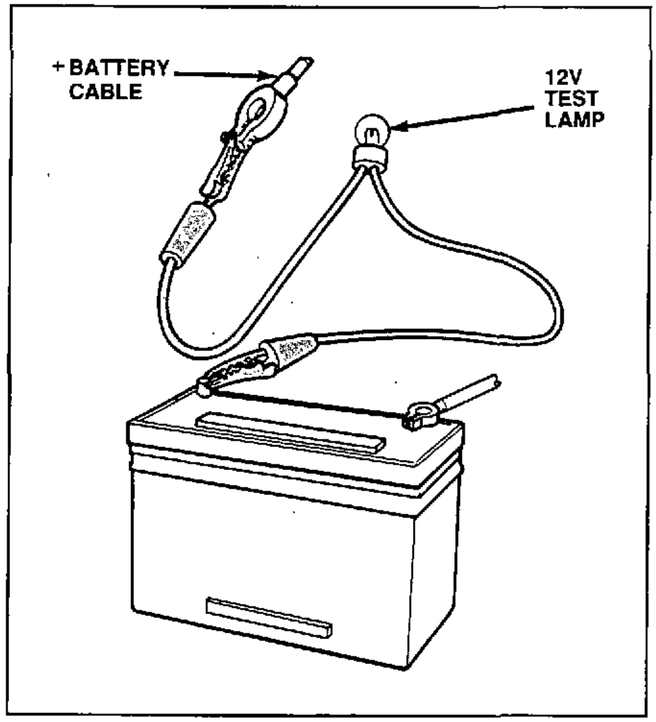

Figure 3-3 Test Lamp

A test lamp (Figure 3-3) is used to detect current drain from the battery. It consists of a small lamp connected between two leads. Current flowing between the connections will cause the lamp to light.

The Starting and Charging Tester (VAT-40) (Figure 3-4) is a multi-purpose tester used to test the battery's capacity to start the engine. For the tests described in this text, we will use the Rotunda Starting and Charging tester (VAT-40), Rotunda Tool Number 078-00005.

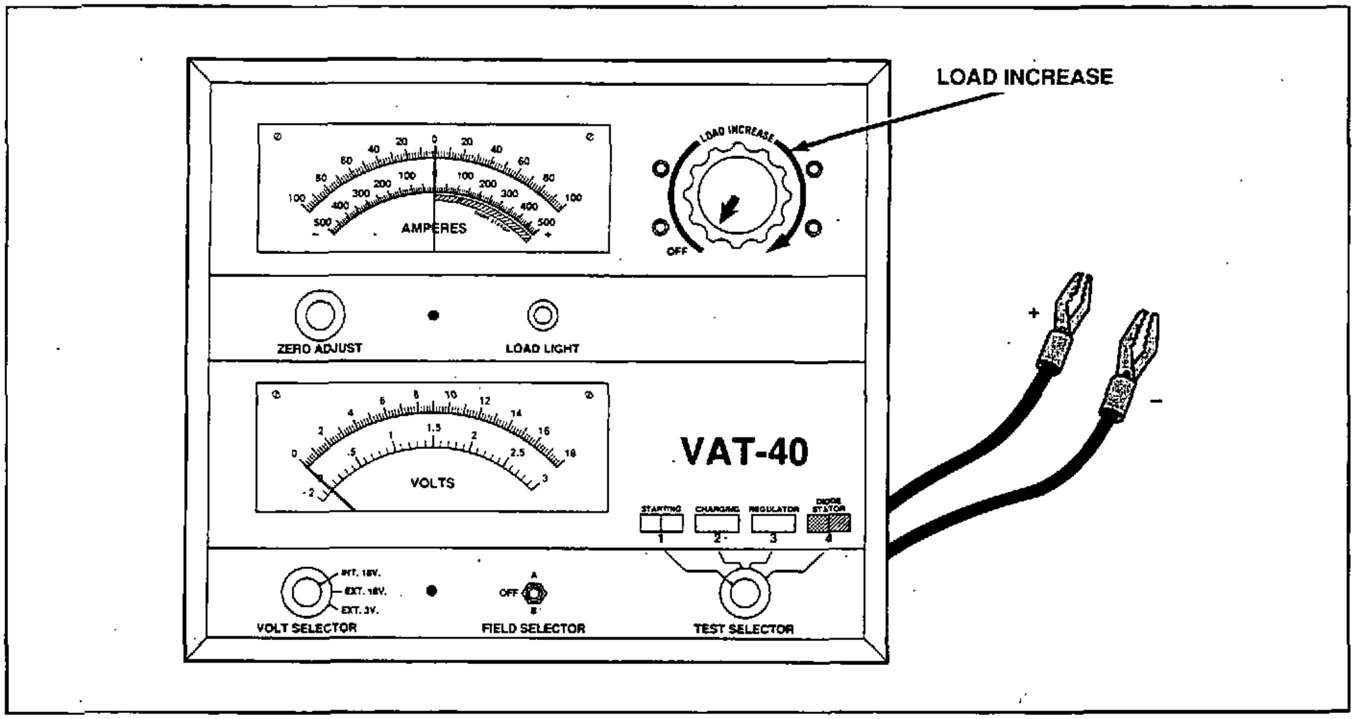

Figure 3-4 Rotunda Starting and Charging Tester (VAT-40)

Open Circuit Voltage (OCV) Test

The open circuit voltage test is used to indicate the battery's state of charge.

1. If the battery has just been recharged or has been in service, the present surface charge must be removed before accurate voltage measurements can be made. If in service, turn on the high beams for ten seconds, turn the headlights off. Then let the vehicle stand for two minutes.
2. With the engine and all accessories off, disconnect the negative battery cable. Touch the volt-ohmmeter's fixed probe to the negative (-) terminal and the volt-ohmmeter's red lead to the positive battery (+) terminal. Then read the voltage (Figure 3-5).

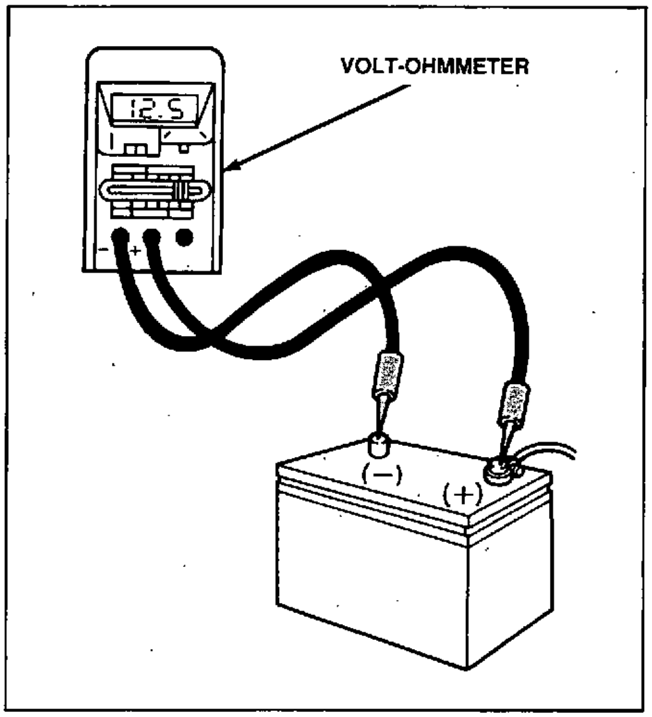

Figure 3-5 Open Circuit Voltage (OCV) Test

NOTE: If the reading on your volt-ohmmeter is a negative (-) sign, the battery has reversed polarity and must be replaced, or you have connected the meter incorrectly.

3. A battery at or near full charge for this test should read 12.50 volts or above.
4. To determine the battery's specific gravity or state of charge, use the battery state of charge chart (Figure 3-6).

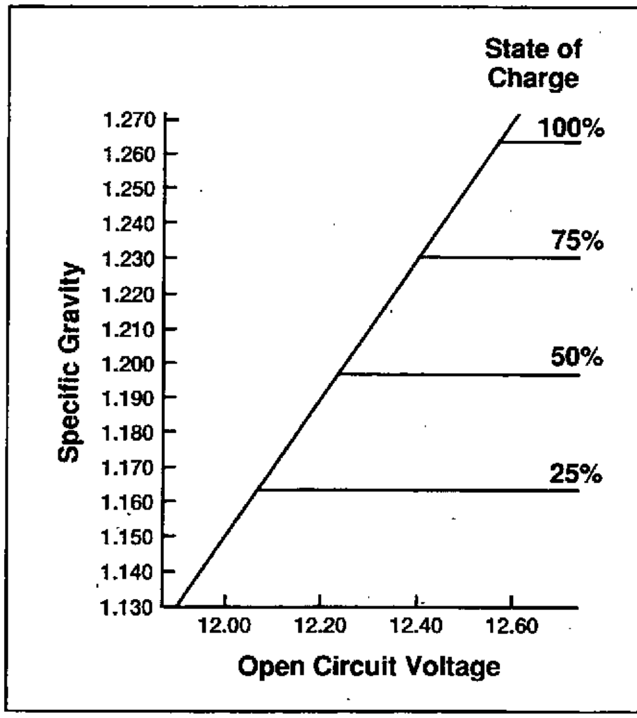

Figure 3-6 Battery State of Charge Chart

Follow the voltage up the linear curve to determine the state of charge or specific gravity.

5. If the volt-ohmmeter gives no reading at all, make sure you have connected it properly. Check the meter and leads on a good battery. If the connections are proper and you still have no reading, charge the battery to an OCV greater than 12.5 volts before continuing to test the battery.

Battery Drain Test With Clamp-On DC Ammeter

Battery drain testing can determine if there is a drain on the battery that may cause it to discharge. This type of test can be done using a clamp-on DC ammeter or a volt-ohmmeter.

NOTE: OCV must be greater than 11.5 volts to perform the following tests.

1. Turn the ignition to the OFF position and make sure there are no electrical loads. After determining that the underhood lamp is turning off properly when the hood is closed, disconnect the bulb.
2. Clamp the meter clip securely around the positive or ground battery cable (all cables if two or more lead to post).

NOTE: Do not start the vehicle with the clip on the cable.

The current reading (current drain) should be less than 0.05 amp. If it exceeds 0.05, it indicates a constant current drain which could cause a discharged battery. Possible sources of current drain problems are vehicle lamps (underhood, glove compartment, luggage compartment, etc.) that do not shut off properly.

If the drain is not caused by a vehicle lamp, remove the fuses, one at a time, until the cause of the drain is located.

Battery Drain Test With Volt-Ohmmeter

Using a volt-ohmmeter for the battery drain test will render specific values. By establishing a number of different drain values, it may be easier to determine the cause of the drain.

This test requires a volt-ohmmeter with an appropriate low-voltage scale. The meter must read within .01 millivolts. You will also need a shunt assembly.

NOTE: The volt-ohmmeter will react to the very small normal drain caused by "always-on" electronic systems such as anti-theft, illuminated entry, etc. These drains are so small they cause no problem when functioning normally.

The steps for this test are outlined below:

1. Turn the ignition to OFF and make sure there are no electrical loads. After determining that the underhood lamp is shutting off properly when the hood is closed, disconnect the bulb.
2. Check the battery voltage. If voltage is under 11.5 volts, charge the battery to above 11.5 volts.
3. Disconnect the negative battery cable.
4. Connect the shunt assembly as shown in Figure 3-7.

CAUTION: Do not crank the engine. It could destroy the shunt. Also do not use the shunt to measure starting currents.

5. Set the volt-ohmmeter to 200 or 300 millivolt (mv) scale for an accurate reading. It must be within 0.01 millivolts.
6. Connect the meter leads to the shunt. With this size shunt (50 mv = 50 amps) and meter, a direct current drain measurement can be made.

The current reading should be less than 0.05 amp. If the reading is between 0.2 and 0.6, a possible source is a vehicle lamp (glove compartment, underhood, luggage compartment, etc.) that does not turn off. If the problem is not a lamp, remove the fuses from the fuse panel, one at a time, until the cause of the drain is located.

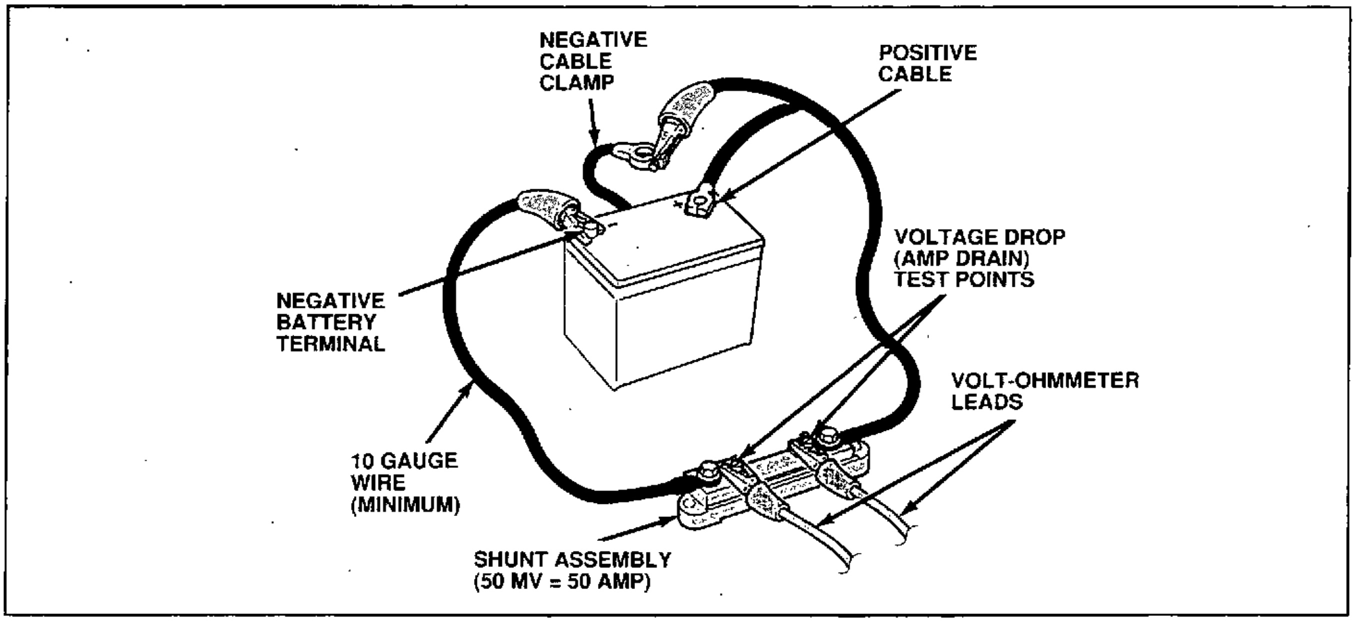

Figure 3-7 Battery Drain Test With Voltmeter and Shunt

To Test Vehicles With Major Key-Off Loads Such as Air Suspension or Load Leveling

Vehicles equipped with these features will have temporary current drains that may last up to 70 minutes after the ignition is switched OFF. These drains can range from 0.1 to 20 amps if the compressor is cycling. This action can often mask a problem and must be considered when evaluating test results. To test for this kind of drain:

1. Follow Steps 1 through 5 of the Battery Drain Test With Volt-Ohmmeter.
2. Turn the ignition to RUN for a moment and then OFF again.
3. Disconnect the major key-off circuits.
4. Make sure illuminated entry is off, if applicable.

The drain should be less than 0.05 amp. If it is higher, disconnect the fuses as in the previous test to locate the problem circuit.

If the drain is less than 0.05 amp, reconnect the major key-off load circuits, turn ignition ON and then OFF, and wait 70 minutes to make sure they shut off properly. If current drain is still greater than 0.05 amp after 70 minutes, disconnect each of the components, one at a time, until the source of the drain is located.

To Check for Electronic Drains Which Shut Off When the Battery Cable is Disconnected

1. Follow Steps 1 through 5 of the Battery Drain Test With Volt-Ohmmeter.
2. Without starting the engine, turn the ignition switch to RUN for a moment and then OFF. If applicable, wait one minute for the illuminated entry lights to shut off.
3. Connect the volt-ohmmeter and read the voltage.

The current reading (current drain) should be less than 0.05 amp. If it exceeds 0.05 after a few minutes, and if this drain did not show in previous tests, the drain is most likely caused by a malfunctioning electronic component. As in previous tests, remove fuses one at a time, to locate the problem circuit.

Hydrometer Test

The hydrometer measures the specific gravity of the battery.

The hydrometer, Rotunda Tool Number 021-00046, is a bulb-type syringe which, when squeezed and released, draws electrolyte from a battery cell. A float with a graduated specific gravity scale is housed inside the barrel of the hydrometer.

The float covers an approximate specific gravity range from 1.100 to 1.300. (This rating is based on the relative weight of equal volumes of water and electrolyte. Pure water has a rating of 1.000.) Specific gravity varies both with chemical composition and with temperature. As temperature rises, specific gravity decreases and vice versa. Therefore, most hydrometers combine the basic hydrometer and a thermometer to provide a temperature corrected reading.

NOTE: Only batteries with removable vent caps can be tested with a hydrometer. This includes conventional and low maintenance batteries.

WARNING: WHEN PERFORMING THE HYDROMETER TEST, ALWAYS WEAR SPLASH-PROOF GOGGLES AND PROTECTIVE GLOVES. BE CAREFUL NOT TO COME INTO CONTACT WITH ANY BATTERY ACID. SEE THE SAFETY PRECAUTIONS SECTION OF LESSON 2 IN THIS PUBLICATION.

To perform the hydrometer test:

1. Raise the hood and put a fender cover in place.
2. Remove all vent caps.
3. Make sure the electrolyte level is high enough to withdraw the proper amount of acid into the hydrometer barrel. Take no readings immediately after adding water. Water must be thoroughly mixed with the underlying electrolyte, by charging, before hydrometer readings are reliable.
4. Insert the hydrometer pick-up tube into a cell with the bulb squeezed tightly by thumb pressure (Figure 3-8).

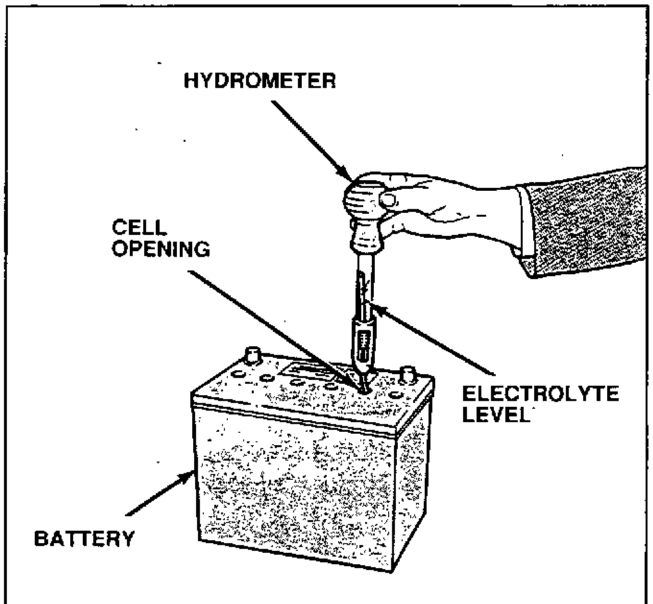

Figure 3-8 Testing Specific Gravity With a Hydrometer

5. Slowly release thumb pressure until the bulb is fully expanded and the float is suspended freely in the barrel. Always hold the barrel vertically to prevent the float from binding or sticking to the sides.
6. With the hydrometer at eye level, read the float scale at the electrolyte level. (Hydrometer floats are calibrated at 80°F.)
7. Read the specific gravity directly on the float scale where it intersects the lower surface of the electrolyte in the hydrometer barrel.
8. Record the specific gravity reading. Read the correction at the side of the thermometer column and add this value to, or subtract it from, the indicated float reading to obtain a temperature-corrected reading. Refer to the table in Figure 3-9 for the state of charge indicated by the hydrometer reading.

Specific Gravity	% Charged
1.135	Discharged
1.165	25%
1.200	50%
1.235	75%
1.265	Full Charge

Figure 3-9 Specific Gravity and State of Charge

9. Repeat Steps 3 through 8 for each cell in the battery.

NOTE: To assure that the hydrometer remains usable, wash the barrel and float assembly periodically with soap and water. Also, while the hydrometer is disassembled, inspect the float assembly for leaks.

If the gravity readings for the individual cells are 1.235 or higher, the state of charge is OK. Perform a Load Test.

If one or more cells have a gravity reading below 1.235, but with less than 50 points difference between the cells, charge the battery for 20 minutes at 35 amperes; then conduct a Load Test.

If there is a 50-point variation between any cells, replace the battery. (An example of a 50-point variation would be if the highest reading is 1.200 and the lowest is 1.150. 1.200-1.150 = 50 points.)

Capacity Test (Load Test)

The capacity test determines if the battery is capable of meeting the demands required to start the engine. The steps for this test are outlined below:

To complete this test, use the Starting and Charging Tester (VAT-40).

1. Be sure the load control knob on the VAT-40 is in the OFF position.
2. Attach the tester's positive lead to the positive (+) battery terminal and negative lead to the negative (-) battery terminal (Figure 3-10).

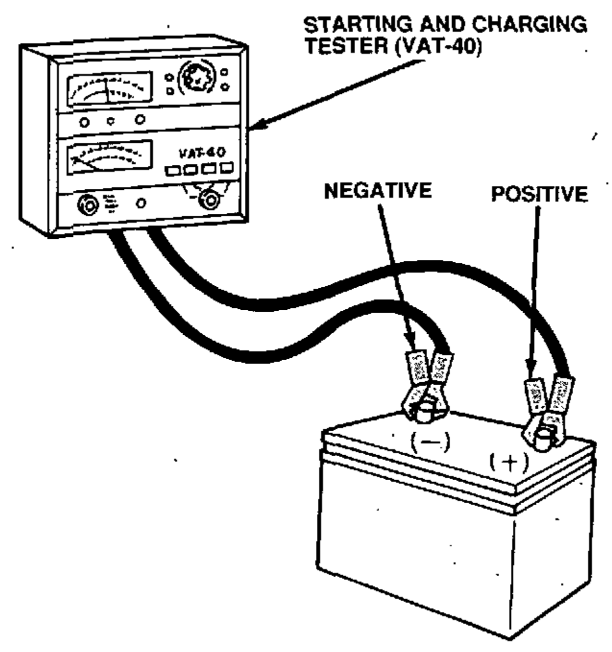

Figure 3-10 Load Test

NOTE: If the tester being used has separate volt-ohmmeter and ammeter leads, it is important that the volt-ohmmeter clips contact the battery terminals and not the high rate discharge tester clips.

3. Turn the load control knob clockwise until the amperage reading is one-half of the "cold-cranking amps." This value is specified on the battery label.

If cold-cranking amperage data is not available, the general rule is: tester load may be added until an amperage reading equal to three times that of the ampere-hour rating of the battery is reached. See chart in Figure 3-11.

Battery Ampere-Hour Rating	Tester Amperage Reading
48	230
58	270
72	325
84	425

Figure 3-11 Ampere-Hours/Ampere Readings

4. Maintain the specified load for 15 seconds. The voltage reading should be above 9.6 volts. The reading may be somewhat lower if the ambient temperature is less than 21°C (70°F). Thus, a battery with an adequate capacity to crank and start an engine may have voltage readings as listed in the chart in Figure 3-12.

Approximate Temperature	Minimum Voltage
21.0°C (70°F)	9.6
15.5°C (60°F)	9.5
10.0°C (50°F)	9.4
3.0°C (40°F)	9.3
-1.0°C (30°F)	9.1
-6.6°C (20°F)	8.9
-12.0°C (10°F)	8.7
-17.8°C (0°F)	8.5

Figure 3-12 Temperature/Voltage/Cranking Capacity

If the battery does not reach the minimum prescribed voltage, charge it for 25 minutes at 35 amperes. Then, repeat the test. If it still does not come up to minimum voltage specifications, replace the battery.

For batteries with removable vents: If the voltage reading is less than the voltage listed in the chart, replace the battery. If the voltage reading equals or exceeds the voltage listed in the chart in Figure 3-12, charge the battery, if necessary, and return it to service.

BATTERY CHARGING

When the battery state of charge has been largely exhausted by discharging the battery, the battery may be recharged. This is done by passing an electric current through the battery from positive to negative instead of from negative to positive as in discharging. The charging process reverses the chemical action and restores the electrolyte to its state before discharge.

Charging methods and types of chargers vary widely. Whichever method and equipment is used, charging must be done carefully to achieve proper results and avoid damage to batteries and possible personal injury.

CAUTION: Specific instructions accompany each make of battery charger and should be followed exactly. Safeguards provided by the equipment manufacturer should not be disregarded by the operator.

Before recharging a discharged battery, inspect and service the following conditions, if they exist:

- Loose generator belt
- Pinched or grounded generator/voltage regulator wiring harness
- Loose harness connections at the generator and/or voltage regulator
- Loose or corroded connections at battery, starter relay and/or engine ground
- Excessive battery drain

The three basic battery charging concepts are:

- Slow charging
- Fast charging
- Constant potential charging

In simplest terms, slow charging involves a low current applied over a long period of time. Fast charging is the opposite — high current over a relatively short period of time. If a fast charge is prolonged — longer than 2 hours or so — serious damage to the battery may result.

The amount of charge a battery requires depends on the battery size and its initial state of charge. For example, a battery with a reserve capacity of 120 minutes will require twice the amount of charge as one with 60 minutes reserve capacity; and a completely discharged battery will require twice the amount of charge as one which is half charged.

A cold battery (below 40°F) will not readily accept a charge. When a fast charger is connected to a cold battery, the charging rate will be low at first, and then increase as the battery temperature increases. Do not attempt to charge a frozen battery. Allow it to warm to approximately 60°F before starting the charge.

A battery which is in a highly discharged state (OCV below 12.5) may be slow to accept a charge at first and in some cases may not accept a charge at the normal charger setting. Batteries in this condition can be charged with the use of the dead battery switch on chargers so equipped. Batteries may be charged by any of the following methods:

Slow Charging

The slow charge method offers two important advantages:

- It is the preferred method to restore a battery to full charge.
- Since the charging current is relatively low, the chances of overcharge damage are minimized.

Slow charging should be done at a rate equal to one percent of the cold-crank rating of the battery being charged (about 3 to 5 amperes, depending on battery size). Charging should not stop until the battery is fully charged. The average charging time is 12 to 16 hours, but could be as much as 24 hours or more.

Fast Charging

Fast charging is designed to bring a battery's state of charge, within a short period of time, up to a level that will enable the battery to perform its critical function: cranking the engine. Fast charging, however, cannot bring a battery up to full charge, so it must be followed by a period of slow charge.

This latter requirement is normally met by the vehicle's charging system.

Since excessive fast-rate charging can damage a battery, charging time must be carefully controlled. Fast charging equipment can vary widely in design and operation. Thus, it is important to strictly follow the charger manufacturer's operating instructions. Generally speaking, a "boost" charge at 30 amps for a 12 volt battery (or 60 amps for a 6 volt battery) for up to 30 minutes is most common. If the battery was deeply discharged to begin with and further fast charging is required, the rate should be reduced to 20 amps for a 12 volt battery (40 amps for a 6 volt battery) and continued for up to one and one half hours more. Fast charging beyond two hours sharply increases the risk of battery damage, so transferring to a slow-rate charger is recommended.

The recommended method of fast charging is to use the "Automatic" setting on chargers so equipped. This setting maintains the charging rate within safe limits by automatically adjusting the voltage and current which prevents excessive gassing and spewing of electrolyte. Another advantage of this method is that it is not necessary to know the electrical size of the battery nor its state of charge since the battery will accept only the amount of charge required. The charging time will depend on the battery size and state of charge. Completely discharged automotive size batteries will require approximately 2 to 4 hours to recharge to a serviceable state.

Constant Potential Charging

Constant potential chargers start the charge off at a high rate. As the battery voltage builds up, the charge rate tapers off to a lower value, depending on the design of the charger and on the condition, age and temperature of the battery. A battery in good condition is not harmed by this type of charging. A badly sulfated battery, however, may not come up to full charge in a normal way on this type of charger.

Reserve Capacity Rating		80 or Less			81 – 125			126 – 180			181 – 250			Above 250		
Charging Rate (Amperes)		5	10	20	5	10	20	5	10	20	5	10	20	5	10	20
Open Circuit Voltage*	**Specific Gravity**	**Charging Time in Hours**														
12.25 – 12.40	1.200 – 1.225	4	2	1	6	3	1½	8	4	2	10	5	2½	14	7	3
12.05 – 12.24	1.170 – 1.200	6	3	1½	8	4	2	12	6	3	16	8	4	22	11	5
11.90 – 12.04	1.145 – 1.170	8	4	2	12	6	3	16	8	4	22	11	5½	30	15	7
Less than 11.90	Less than 1.145	10	5	2½	14	7	3½	20	10	5	28	14	7	38	19	9

Figure 3-13 Charging Rate and Time Table

The table in Figure 3-13 shows the approximate charging times and rates required to recharge batteries in various states of charge to a serviceable state. Higher charging rates than those shown can be used as long as electrolyte spewing does not occur or the battery does not feel excessively hot (over 125°F). If spewing occurs or the battery feels excessively hot, the charge rate must be reduced to a level at which the spewing will stop. This is particularly true for maintenance-free batteries where excessive gassing will result in non-replaceable loss of electrolyte and thus shorten battery life. In general, the higher the charge rate, the more closely the battery must be watched while being charged. The rates and times shown in the table will not fully charge the battery but will recharge it to a state of charge at which point a properly operating vehicle charging system will charge the battery up to the normal operating level.

NOTE: In certain situations, a completely discharged battery may stand for a prolonged period of time (over one month). Under these conditions the battery may show no indication of accepting a charge even with the use of a dead battery switch. The initial charging rate accepted by batteries in this condition may be so low that the ammeter on certain chargers will not show any indication of charge for five to ten minutes.

A method of determining whether a battery is accepting a charge is as follows:

Follow the charger manufacturer's instructions for use of the dead battery switch if necessary. If the dead battery switch is the spring loaded type, it should be held in the ON position for up to three minutes. After releasing the dead battery switch and with the charger still on, measure the battery voltage. If it shows 12 volts or higher, the battery is accepting a charge and is capable of being recharged. However, it may require up to 30 minutes, particularly with cold batteries (below 40°F), before the charge rate is high enough to show on the charger ammeter.

Charging a Single Battery

NOTE: A conventional or low maintenance battery must first be filled with electrolyte before charging.

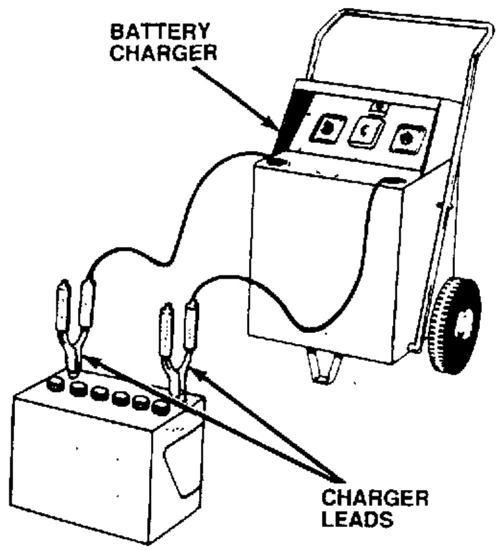

Figure 3-14 Battery Charging

To charge the battery, follow these procedures:

1. Measure the battery's state of charge.
2. Connect the battery to the charger — positive to positive and negative to negative. Be careful not to reverse the polarity.
3. Plug the charger into the power source.
4. Adjust the charger for the desired rate. If the charger is not the constant potential type, see the Charging Rate and Time Table for the proper charging duration.
5. Check periodically for spewing, excessive gassing and high temperature (over 125°F). If any of these conditions are present, reduce the rate or stop the charging temporarily.
6. Unplug the charger and disconnect the leads when the charging operation is complete.

Multiple Battery Charging

In addition to charging batteries individually, it is common practice to charge more than one battery on the same charger. Depending on the type of charger used, either a series or parallel connection will work for multiple charging.

A series connection (Figure 3-15) is made when the positive terminal of one battery is connected to the negative terminal of the next battery in the total charging hook-up. With this type of connection, each battery receives the full current output of the charger. The quantity of batteries which can be charged in series depends upon the voltage rating of the charger. Batteries with various capacity ratings may be charged simultaneously in a series connection, but the charging and the rate of charge must not exceed that specified for the unit with the lowest capacity.

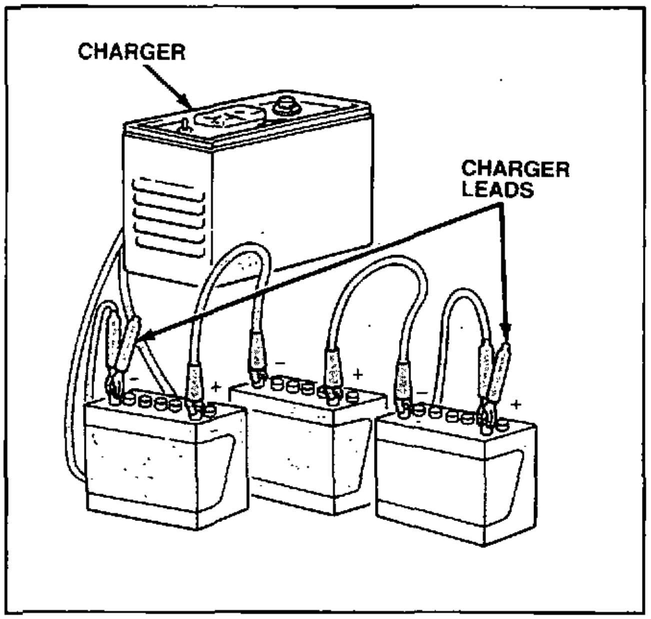

Figure 3-15 Series Connections for Multiple Charging

Batteries charged in parallel connection will have all the positive terminals connected to each other in sequence (Figure 3-16). Similarly, the negative terminals will be connected to each other in sequence.

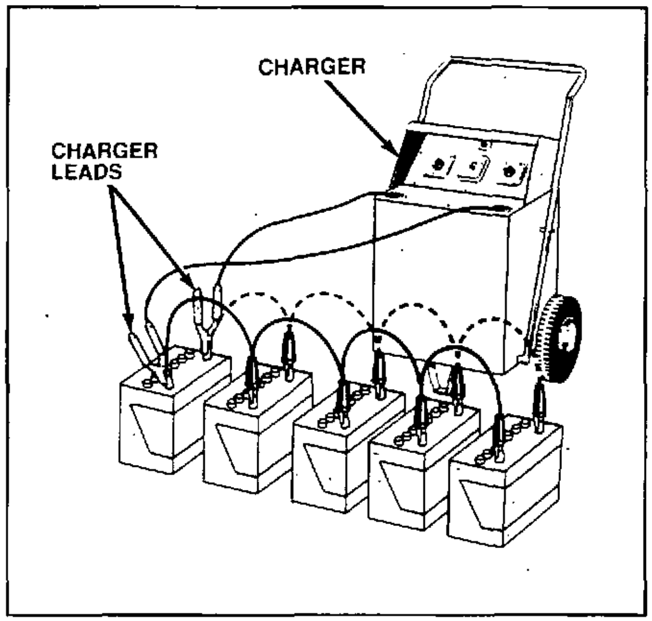

Figure 3-16 Parallel Connections for Multiple Charging

With a parallel connection, there are two things in particular to remember:

- All batteries in the charging circuit must be of the same capacity (i.e., all 12 volt or all 6 volt).
- The output of the charger will be divided among all batteries in the circuit.

In theory, this division would mean that charge is distributed equally to each battery. Actually, factors such as each battery's rating and its state of charge when it is introduced into the circuit will govern the distribution of the charge. As with series connections, the charger voltage rating determines the number of batteries that can be handled in a parallel connection.

WARNING: WHEN CHARGING BATTERIES, CHECK PERIODICALLY FOR ELECTROLYTE SPEWING, EXCESSIVE GASSING OR HIGH TEMPERATURES. OBSERVE ALL SAFETY PRECAUTIONS AND FOLLOW MANUFACTURER'S INSTRUCTIONS.

SAE J1930 TERMINOLOGY

For the 1993 model year, Ford has extensively revised the list of names for the various terms and components used in automobiles. These changes have been mandated by the Society of Automotive Engineers' (SAE) list of terms entitled J1930. The terminology used in this list must soon be standardized among all vehicle manufacturers. As a result, the language used to convey automotive service information will be standardized and less confusing.

One change to note in reading this book includes the term **GENERATOR** in place of **ALTERNATOR**. This change has been mandated by SAE J1930 and is used consistently throughout this book.

GENERATOR OPERATION

The generator converts mechanical energy from the engine into electrical energy. It is the vehicle's source of electricity when the engine is running and it maintains the battery's proper state of charge.

All generators operate on the principle that a magnetic field moving past a conductor will cause the conductor to generate electricity.

The generator is belt-driven from the engine. It supplies field current to the rotating field through the brushes and slip rings. The rotating magnetic field cuts across the conductor windings (the stator) and generates current.

When the engine is started, the generator produces power in the form of alternating current. This current is then rectified to direct current by built-in diodes in the recifier. Field current is automatically adjusted by the voltage regulator to maintain generator output voltage within specified limits.

There are three different types of generators:

- Integral Alternator Regulator (IAR) — External Fan Type
- Integral Alternator Regulator (IAR) — Internal Fan Type
- Integral Alternator Regulator (IAR) — Internal Fan and Regulator Type

A fuse link is included in the charging system wiring on most vehicles. The fuse link is used to prevent damage to the wiring harness and generator if the wiring harness should become grounded, or if a booster battery with the wrong polarity is connected to the charging system.

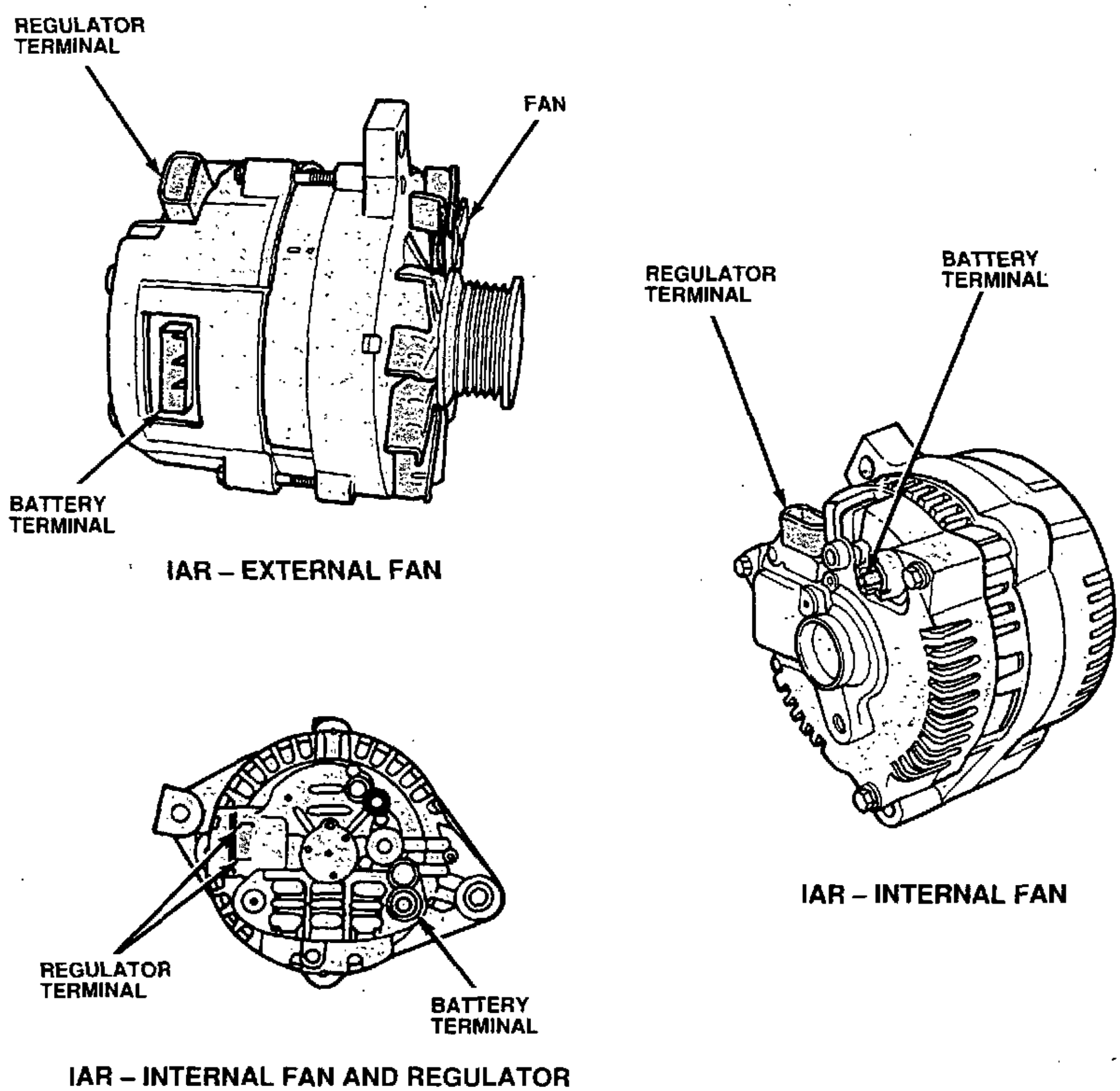

Figure 4-1 Generator Types

GENERATOR COMPONENTS

The main components of the generator are the rotor, stator, rectifier, brushes, voltage regulator and housing.

Rotor

The magnetic field that rotates within the stator winding is called the rotor. To maximize the magnetic force, a very small clearance (approximately 0.005 inch) is required between the rotor and the stator. Voltage is produced as the rotor spins and the magnetic lines of force around it cut the stator windings.

The construction of the rotor creates the magnetic lines of force which surround it. Two six-fingered pole pieces (Figure 4-2) fit around a field winding and provide alternating north and south poles. Current alternates as the pole fields pass across the conductors in the stator windings. Two slip rings, pressed onto the end of the rotor shaft, *rotate and rub against the carbon brushes to* conduct current to the rotor.

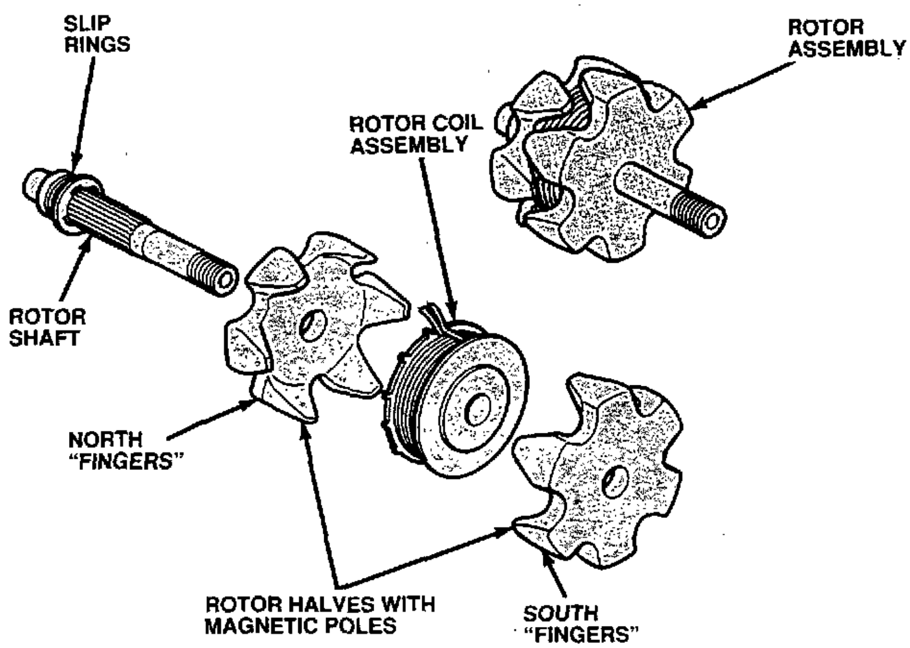

Figure 4-2 Rotor Assembly

Stator

Current is produced in the stator windings as the magnetic field (rotor) turns inside the stator (Figure 4-3). The stator is made of three phases of conductor windings wound in slots around a core. The voltage generated in each winding is determined by:

- Field current in the rotor windings
- Rotational speed of the rotor inside the stator
- Wire in the stator windings — both the wire gauge and the number of turns per slot

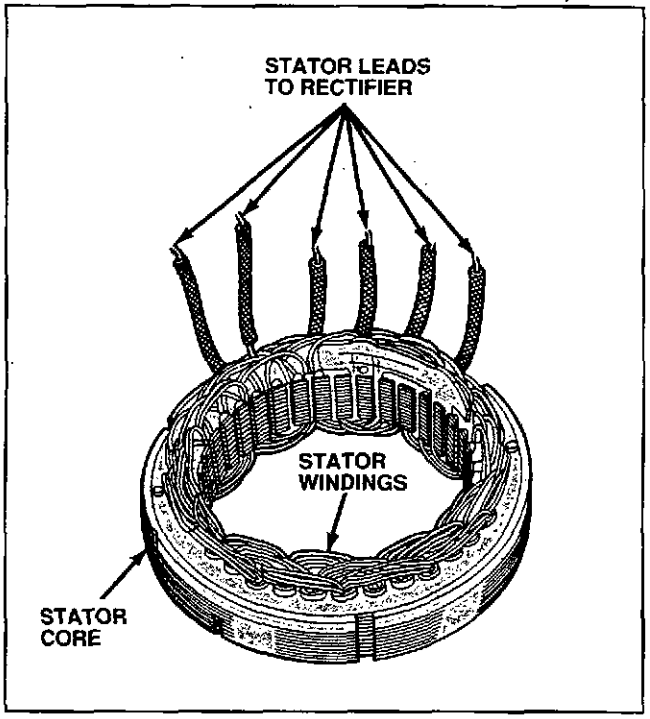

Figure 4-3 Stator

Rectifier

The generator has a built-in rectifier. Diodes in the rectifier convert alternating current into direct current. Half of the diodes are negative, the other half positive.

NOTE: IAR — Internal fan type generators contain eight diodes, while other generators contain six.

The diode acts as an electronic "check valve," allowing the alternating current of the stator to flow only in one direction. Thus, the current is "rectified" to direct current to power the vehicle's electrical systems.

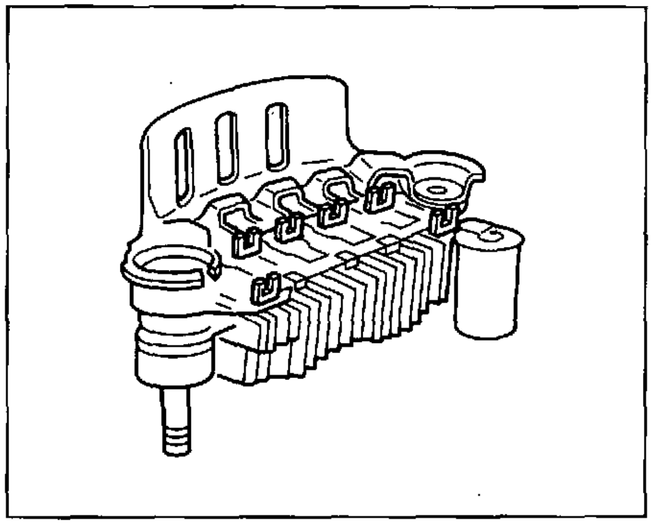

Figure 4-4 Rectifier Assembly

Brush Assembly

Two carbon brushes in the generator rub against the copper slip rings at the end of rotor to conduct electric current to the rotor. It is imperative to maintain constant contact between the brush and slip ring. This is accomplished by spring pressure against the brushes. See Figure 4-5.

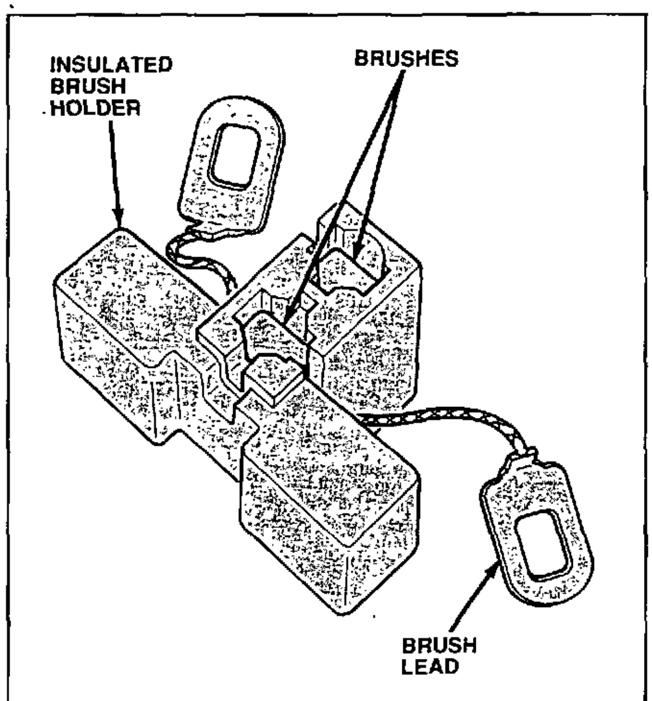

Figure 4-5 Brush Assembly

Generator Housing

The two end housing portions of the generator support the rotor shaft with mounted front and rear bearings.

Voltage Regulator

A voltage regulator (Figure 4-6) controls the generator's output voltage by modifying the generator field voltage to meet system demands. The regulator increases generator current output to recharge the battery when battery voltage is low and electrical accessory load is high. This means that the regulator will permit accessory operation under a heavy electrical load with little drain on the battery. In this case, most of the current will come directly from the generator. Generator current output is reduced when the battery is fully charged and the accessory load is low.

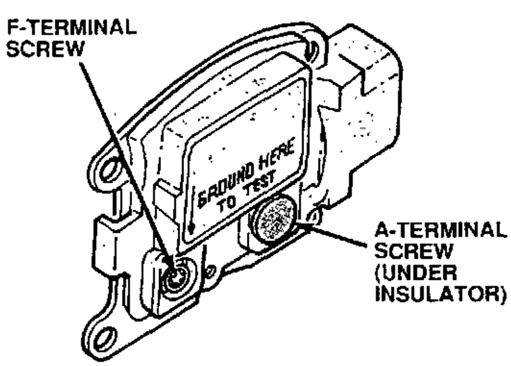

Figure 4-6 Integral Voltage Regulator

The Integral Alternator/Regulators (IARs) are mounted at the rear of the generator housing. Its position makes it easier to test and replace on most vehicles.

NOTE: IAR — Internal fan and regulator type generators have an internal regulator. They are not mounted to the rear housing of the generator, but are designed into the generator housing.

GENERATOR CIRCUIT DESCRIPTION

The following is a description of the circuits and connections designed for IAR-type generators.

B+ Output

The B+ output connection supplies the generator output to the battery and the electrical system.

I-Circuit

The I-circuit (ignition circuit) is used to turn on the voltage regulator. This circuit is powered when the ignition is turned to the RUN position. This circuit is also used to turn the charging indicator lamp on if there is a fault in the system or wiring circuit.

A-circuit

The A-circuit (battery sense circuit) is used to sense battery voltage. The regulator uses this voltage to determine the generator output. This circuit also supplies power to the generator field coil. The circuit is connected back to the load distribution point and is a protected circuit.

S-Circuit

NOTE: The S-circuit is internal and not serviceable on IAR-type generators with internal fan and regulators.

The S-circuit (stator circuit) is used to feed a voltage signal from the generator to the regulator. This voltage, typically 1/2 battery voltage, is used by the regulator to turn off the charging indicator lamp. (Figure 4-7)

NOTE: *On some applications with 2-pin* regulator connectors, terminal designations will differ.

L-circuit corresponds to the I-circuit on the previous generator application.

S-circuit corresponds to the A-circuit on the previous generator application.

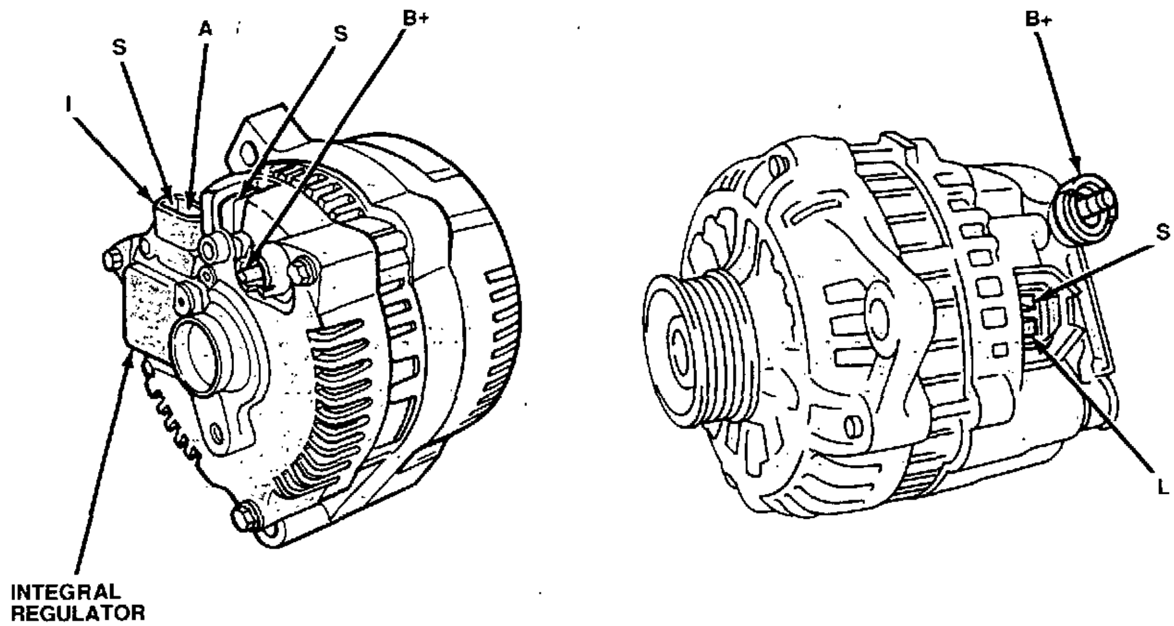

Figure 4-7 Terminal Designations – Typical

GENERATOR CIRCUIT OPERATION

With the ignition key in the RUN position, voltage is applied through the charge indicator lamp I-circuit to the voltage regulator. This turns the voltage regulator on, allowing current to flow from the battery sense A-circuit to the generator field coil. When the engine starts the generator produces alternating (AC) current. This current is then converted to direct (DC) current by the rectifier assembly inside the generator. This current then powers the vehicle's electrical system through the output connector B+ located on the rear of the generator.

Once the generator begins producing current, a voltage signal from the stator feeds back to the voltage regulator S-circuit, turning off the charge indicator lamp.

With the system functioning normally, the generator output current is determined by the voltage of the A-circuit (battery sense voltage). The regulator then compares the A-circuit voltage to its internal set voltage. It then controls the generator field current to maintain proper generator output. The set voltage will vary with temperature and is typically higher in the winter than in the summer. This allows for better battery recharge in the winter and reduces the chance of overcharging in the summer.

CHARGING SYSTEM DIAGNOSIS AND TESTING

The first component to check when the vehicle's electrical system is not working properly is the battery. If a relatively new battery is dead or low in charge, check first for an excessive drain caused by a light that was not turned off or some other electronic component or wiring problem. These common conditions can cause the battery to discharge continuously.

If the battery has been tested and found to have a full charge, check the wiring (Figure 5-1) and connections in the charging system. If these conditions are satisfactory, check the voltage regulator and then the generator.

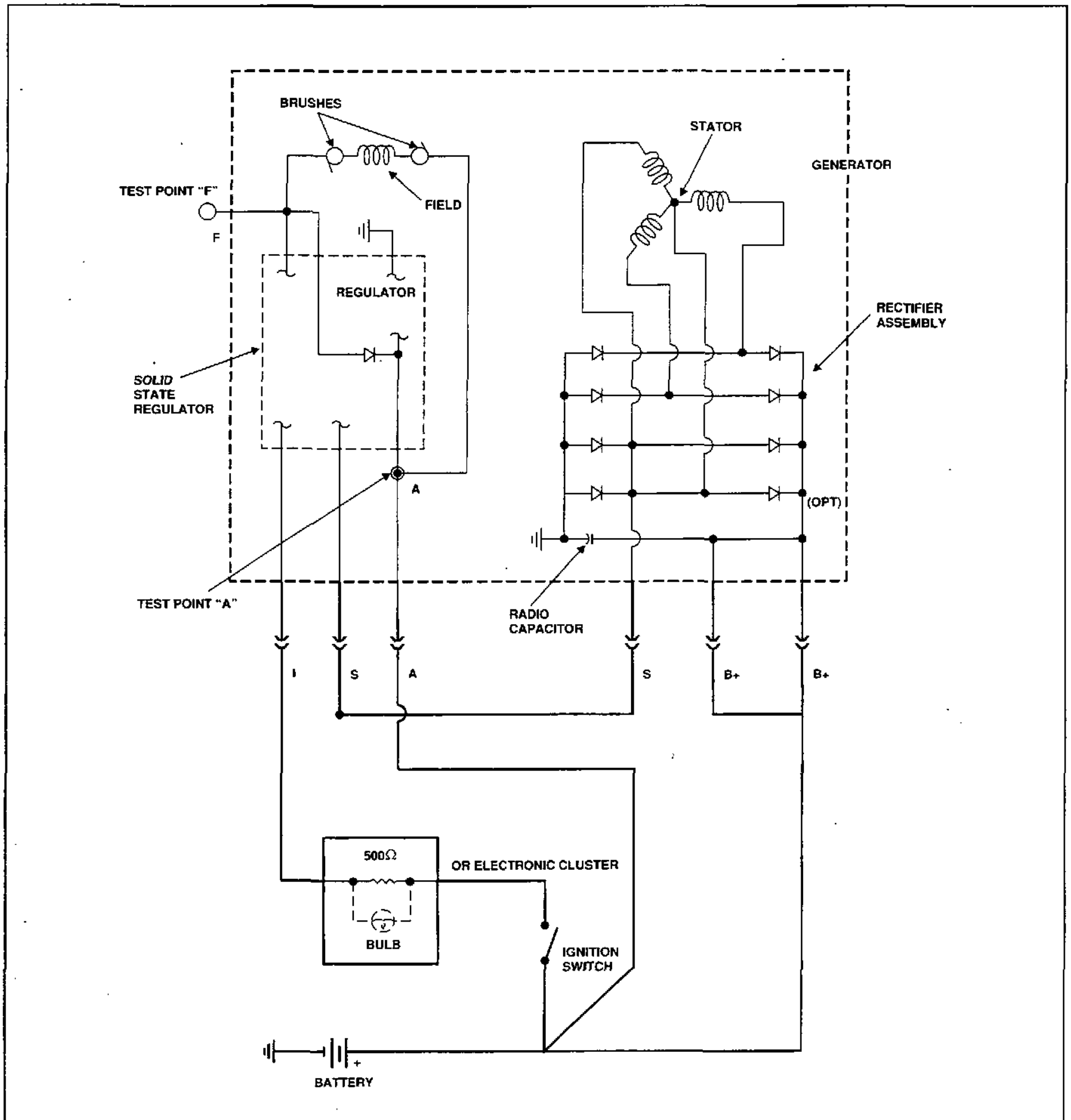

Figure 5-1 Wiring Diagram IAR — Internal Fan-Type Generator

SAFETY PRECAUTIONS

Whenever testing the generator and charging system, it is extremely important to observe the following safety precautions:

- Always disconnect the battery ground cable before disconnecting any charging system connections.
- Avoid contact with the generator output terminal (BAT) since it is "hot" at all times when the battery cables are connected.
- Never connect the battery ground cable until all wiring harness connections have been made.

PRELIMINARY INSPECTION

Malfunctions in the charging system usually start out small and gradually become worse. Charging system problems may be identified visually in several ways. Some simple checks should be performed before beginning a series of time-consuming or costly tests.

- Check for symptoms of undercharging, such as slow cranking, dead battery, low voltage or the generator warning lamp.
- Look for symptoms of overcharging, such as battery boiling, high voltage or generator warning lamp.
- Check ground connections at the engine and body.
- Check the battery condition and state of charge. A fully charged battery is necessary for making accurate tests on the system.
- If applicable, check the fuse link located between the starter relay and generator. If the link is burned out, replace it.
- Check the battery terminal and battery cable clamps for clean and tight connections.
- Check for proper connections at the generator and regulator and the engine.
- Check and adjust drive belt tension. Refer to the appropriate Service Manual for detailed procedures.
- Check connections at the power distribution box or starter relay.

CHARGING SYSTEM CHECK

NOTE: Only check the charging system with a fully charged and properly operating battery. Refer to the "Battery Diagnosis and Testing" section of this publication for complete procedures.

The following section provides general procedures for the charging system check which will help you to quickly diagnose malfunctions and determine which component requires servicing. The charging system check should be performed before testing any individual charging system components.

These tests require a volt-ohmmeter, a test lamp and a jumper wire.

CAUTION: Special care should be taken when using the ohmmeter near "hot" circuits. Disconnect the component to be checked from the battery cables to prevent damage to the ohmmeter.

CAUTION: Do not make jumper wire connections except as directed. Doing so may damage the regulator.

NOTE: Battery posts and cable clamps must be clean and secure to assure accurate meter readings.

For detailed, vehicle-specific procedures and diagnostic flow charts, refer to the appropriate Service Manual.

Fuse Link Continuity

The fuse link continuity test confirms continuity in the vehicle's electrical circuits. Use the following steps to perform this test:

1. After making sure that the battery is functioning properly, turn on the headlamps. If the headlamps do not operate, the fuse link is probably burned out.
2. On some vehicles there are several fuse links. Use the same procedure as in Step 1 to test the fuse link that protects vehicle equipment.

To test the fuse link that protects the generator, make certain the battery is functioning properly. Then check with a volt-ohmmeter for voltage at the BAT terminal of the generator. No voltage indicates that the fuse link is probably burned out.

Field Circuit Drain — Integral Alternator/Regulator (IAR) System

Connect the volt-ohmmeter negative lead to the generator rear housing for all of the following readings:

1. With the ignition in the OFF position, contact the volt-ohmmeter positive lead to the regulator F-terminal screw. If the system is operating normally, the meter will indicate battery voltage. Go to Step 2 if less than battery voltage is indicated to find the cause of the current drain.
2. Disconnect the wiring plug from the regulator and contact the volt-ohmmeter positive lead to the wiring plug I-terminal. No voltage should be indicated. If voltage is indicated, service the I-lead from the ignition switch to identify and eliminate the voltage source.
3. If no voltage was indicated in Step 2, contact the volt-ohmmeter positive lead to the wiring plug S-terminal. No voltage should be indicated. If no voltage is indicated, replace the regulator.
4. If voltage was indicated in Step 3, again contact the volt-ohmmeter positive lead to the regulator wiring plug S-terminal. If voltage is still indicated, service the S-lead to the generator plug to eliminate the voltage source. If no voltage is indicated, replace the generator rectifier assembly.

NOTE: The rectifier assembly is not serviceable on the IAR — internal fan type generator.

Refer to the Service Manual for detailed procedures.

Indicator Lamp System (Some Applications Use Voltmeter)

NOTE: Several vehicles do not use an indicator lamp. Some applications utilize a voltmeter to indicate system charge.

If the system is working properly, the following conditions will be present:

- With the ignition switch OFF, the charge indicator battery symbol lamp is off.
- With the ignition switch ON and the engine not running, the charge indicator (generator) lamp is on.
- With the ignition switch ON and the engine running, the charge indicator (generator) lamp is off.

I-Circuit (Integral Alternator/Regulator [IAR] System)

NOTE: The I-circuit on 3-pin connectors corresponds to the L-circuit on some 2-pin applications.

If the charge indicator lamp does not come on with the ignition switch in the RUN position and the engine not running, check the I-circuit (ignition switch to regulator I-terminal) for an open circuit or burned out charge indicator lamp. If necessary, replace the lamp.

1. Disconnect the wiring connector from the regulator.
2. Connect a jumper wire from the wiring connector I-terminal to the battery negative post cable clamp (Figure 5-2).

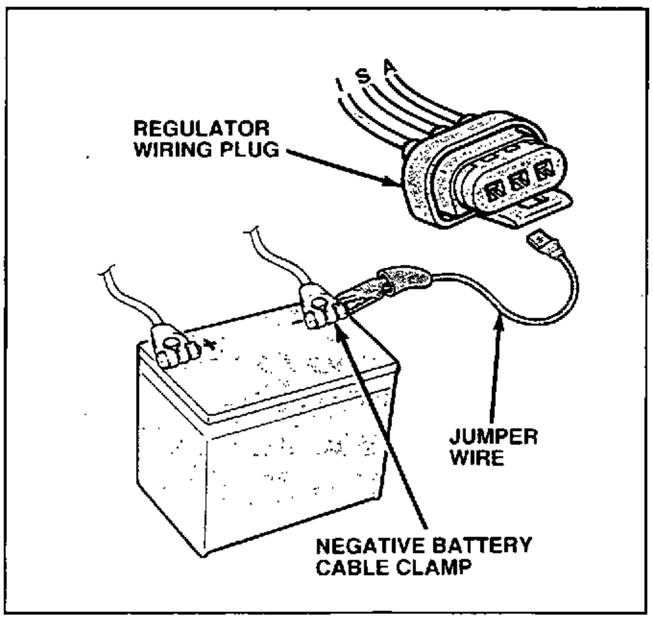

Figure 5-2 Indicator Lamp System Check — IAR System

3. Turn the ignition ON with the engine off. If the indicator lamp does not light, check the indicator bulb for continuity. If the bulb is burned out, replace it. If the bulb is still good, perform the regulator I-circuit tests.
4. If the indicator lamp lights, remove the jumper wire and check voltage at the regulator S-terminal.
5. If battery voltage is indicated, service the S-circuit wiring.
6. If battery voltage is not indicated, clean and tighten the ground connections to the engine, generator and regulator. Tighten loose regulator mounting screws from 15 – 26 lb-in. (1.7 – 2.8 N·m).
7. Turn the ignition ON with the engine off. If the indicator lamp still does not light, replace the regulator.

GENERATOR/REGULATOR TESTS

Several short, simple tests are used to check the generator and regulator. To perform these tests, you will need a Rotunda Starting and Charging Tester (VAT-40) 078-00005, or equivalent, a test lamp and a jumper wire. Perform these tests only after you have made preliminary inspections and fully charged the battery.

To check the charging system using the VAT-40:

1. Connect the positive and negative leads of the tester to the battery.
2. Connect the current probe to the generator output lead (to measure generator output).
3. With the engine running at approximately 2000 rpm, set the load adjustment to determine generator output (with an ambient temperature of less than 27°C (80°F).

NOTE: Refer to the tester procedure manual for complete directions on checking out the charging system.

When performing charging system tests, turn off all lamps and electrical accessories. Place the transmission/transaxle in NEUTRAL and apply the parking brake.

CAUTION: Do not make jumper wire connections except as directed. To do so may damage the regulator or fuse links.

NOTE: Battery posts and cable clamps must be clean and tight to ensure accurate meter indications. Reference measurements to ground should be made to the battery negative post.

Base Voltage Test

This test will give you a base voltage from which to base the following tests.

1. With the ignition OFF and no electrical load, connect the negative lead of the volt-ohmmeter to the negative battery cable clamp.
2. Connect the positive lead of the volt-ohmmeter to the positive battery cable clamp (Figure 5-3).

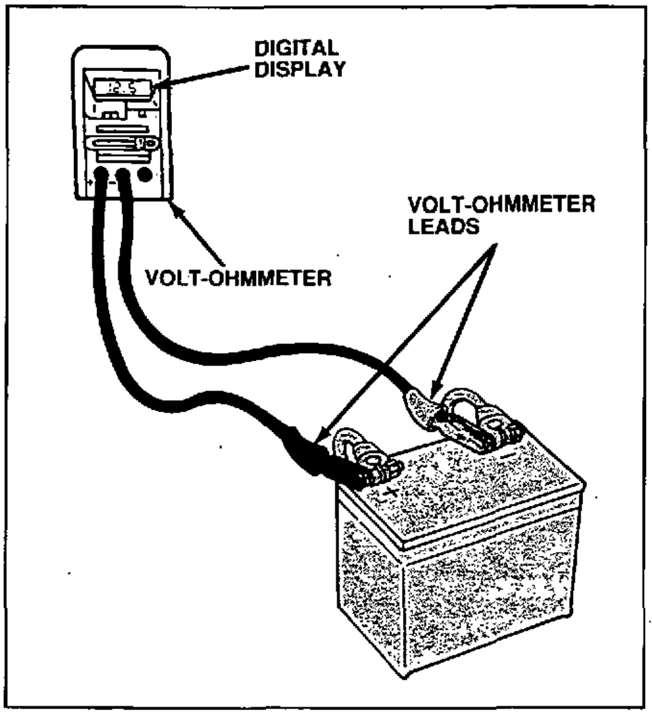

Figure 5-3 Base Voltage Connections

3. Record the battery voltage reading shown on the volt-ohmmeter scale. This is the base voltage.

NOTE: Prior to running this test, turn the headlamps on for 10 to 15 seconds to remove any surface charge from the battery. Then, wait until the voltage stabilizes prior to performing the base voltage test.

NOTE: If the base voltage is less than 12.4 volts, the battery must be recharged before proceeding.

No-Load Test

This test enables you to check the output of the charging system under a no-load condition.

1. Connect a tachometer to the engine.
2. Start the engine and increase engine speed to approximately 1500 rpm. With no other electrical load (foot off brake pedal and vehicle doors closed), the volt-ohmmeter reading should increase, but not more than 2.5 volts above the base voltage.

NOTE: The reading should be taken when it stops rising. It may take a few minutes to reach this point. If the voltage increases to proper level, perform the Load Test. If the voltage continues to rise, perform the Over-Voltage Tests. If the voltage does not rise to proper level, perform Under-Voltage Tests.

Load Test

This test enables you to check the output of the charging system under a load condition.

1. With the engine running, turn the heater or air conditioner blower motor on high speed and the headlamps on high beam.
2. Increase engine speed to 2000 rpm. The volt-ohmmeter should indicate a minimum of 0.5 volt above base voltage. If not, perform the Under-Voltage Tests.

If the above tests indicate proper voltage readings, the charging system is operating normally. Use the test lamp and check for battery drain.

Over-Voltage Tests

Over-voltage tests will help determine the cause of the charging system malfunction and provide the technician with possible solutions to the problem.

If the volt-ohmmeter indicated more than (see applicable Service Manual for specific data) above base voltage in the No-Load Test, follow these procedures:

1. With the ignition ON and the engine not running, connect the volt-ohmmeter negative lead to the generator rear housing. Contact the volt-ohmmeter positive lead first to the generator output connection and then to the regulator A-screw head.
2. If the voltage difference between the two locations is greater than 0.5 volt, service the A-wiring circuit to eliminate the high resistance condition indicated by the excessive voltage drop.
3. If the over-voltage condition still exists, check for loose regulator and generator grounding screws. Tighten loose regulator grounding screws to 1.7 – 2.8 N·m (15 – 26 lb-in.).
4. If the over-voltage condition still exists, connect the volt-ohmmeter negative lead to the generator rear housing. With the ignition OFF, contact the volt-ohmmeter positive lead first to the regulator A-screw head and then to the regulator F-screw head. Different voltage readings at the two screw heads indicate a malfunctioning regulator, grounded brush lead or a grounded rotor coil. Service the entire integral generator/regulator assembly.
5. If the same voltage reading (battery voltage) is obtained at both screw heads, replace the regulator.

Under-Voltage Tests

If the volt-ohmmeter did not indicate more than (see applicable Service Manual for specific data) above the base voltage, follow these procedures:

1. Connect the volt-ohmmeter negative lead to the generator rear housing. Contact the volt-ohmmeter positive lead to the regulator A-terminal screw. The meter should indicate battery voltage. If there is no voltage, service the A-wiring circuit. Perform the Load Test after servicing.

2. If the volt-ohmmeter indicates battery voltage, connect the volt-ohmmeter negative lead to the generator rear housing. With the ignition switch OFF, contact the voltmeter positive lead to the regulator F-terminal screw. The meter should indicate battery voltage. If there is no voltage, service the integral generator/regulator unit for an open field circuit. Perform the Load Test after servicing.
3. If the volt-ohmmeter indicates battery voltage, disconnect the wiring plug from the regulator and connect an ohmmeter between the regulator A-terminal and F-terminal screws. The meter should indicate more than 2.4 Ω. If less than 2.4 Ω is indicated, service the integral generator/regulator unit for a failed regulator and check the generator for a shorted rotor or field circuit. Perform the Load Test.

CAUTION: Do not replace the regulator before a shorted rotor coil or field circuit has been serviced. The result could be another damaged regulator.

4. If the above ohmmeter reading is greater than 2.4 Ω, reconnect the regulator wiring plug and connect the volt-ohmmeter negative lead to the generator rear housing. Turn the ignition switch ON (engine off) and contact the volt-ohmmeter positive lead to the regulator F-terminal screw. The volt-ohmmeter should indicate 1.5 volts or less. If more than 1.5 volts is indicated, perform the I-circuit tests and service the I-circuit if needed. If the I-circuit checks normal, replace the regulator and perform the Load Test.
5. If 1.5 volts or less is indicated, connect a jumper wire from the generator rear housing to the regulator F-terminal screw. Repeat the Load Test with the volt-ohmmeter positive lead connected to the generator output connection. If the voltage rises more than 0.5 volt, replace the regulator. If the voltage does not rise more than 0.5 volt, service the generator.

Regulator I-Circuit Test

NOTE: The I-circuit on 3-pin connectors corresponds to the L-circuit on some 2-pin applications.

1. Disconnect the wiring plug from the regulator. Connect the volt-ohmmeter negative lead to the battery ground terminal and the positive lead to the wiring plug I-terminal. No voltage should be indicated with the ignition switch OFF. If voltage is indicated, service the I-lead from the ignition switch to identify and eliminate the voltage source.
2. Turn the ignition switch ON. The volt-ohmmeter should indicate battery voltage at the wiring plug I-terminal. If there is no voltage reading, service the I-lead from the ignition switch to the regulator for an open or grounded circuit.
3. If the volt-ohmmeter readings in Steps 1 and 2 are normal, check the resistance value of the I-circuit resistor. Make the resistance check with the regulator wiring plug disconnected. For vehicles with an indicator lamp, remove the bulb. The resistor nominal value is 500 Ω for warning lamp systems. Replace the resistor if its value is off by more than 50 Ω.
4. Connect the wiring plug to the regulator and replace the bulb for vehicles with an indicator lamp.

Regulator S-Circuit Test

NOTE: Not applicable on vehicles with IAR-type generators with internal fans and regulators.

1. Disconnect the 1-pin S-terminal connector with the engine idling.
2. Connect the volt-ohmmeter negative lead to battery ground. Connect the positive lead to the S-terminal on the generator and then to the output terminal.
3. The voltage should read approximately one-half that of the output terminal.
4. If no voltage is present, service the generator assembly.

CHARGING SYSTEM SUMMARY

We'll now review some important preliminary checks often overlooked in charging system diagnosis. These preliminary checks can save time and expense for you and the customer. Be sure to follow these steps before proceeding with diagnosis.

- Only test the charging system with a fully charged, operating battery. Be sure that all cable connections are clean and secure.
- Check for secure ground connections at the engine and the body. Also ensure secure connections at the generator and the regulator.
- When a battery is dead or low in charge, first suspect and test for current drain. See "Battery Diagnosis and Testing" for proper procedures. Be sure to check some of the most common drain problems.
  - Glove compartment lamp on when door is closed
  - Hood, trunk, license plate or interior lamps on continuously
  - Other electronic component malfunctions
- Check the testing equipment and its documentation. If you suspect the equipment or instructions to be faulty, check them on a properly operating vehicle.

Be sure to check the appropriate manufacturer literature or service manual for specific operating values.

- Be aware that the IAR charging system warning lamp may come on to indicate a high voltage condition. This feature was not always included on older systems. Overcharging the battery or a faulty regulator can cause the warning lamp to come on.