

11. CHARGING SYSTEM

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11-1. Description

The charging system consists of the alternator complete with a means of rectification for producing DC output power, and the two-element regulator unit for controlling the voltage.

In the alternator, the armature is stationary; it consists of three coils mounted on the stator in such a way as to produce three-phase alternating voltage. This voltage applies to the rectifier for full-wave rectification. The rectifier delivers power in the form of direct current.

Against the stationary armature, revolving magnetic fields are produced by the field winding carried in the rotor. This feature of construction of the alternator strikes a distinct contrast to the dynamo (DC generator), in which the field is in the stator while the armature is in the rotor.

The magnitude of three-phase AC power available from the alternator to its rectifier is directly proportional to rotor speed and field (excitation) current. It is the function of the regulator unit to control the field current automatically in such a way that the output voltage remains constant; another function is to control the circuit of the charge warning light. Thus, the regulator unit has two elements; one is voltage regulator for performing the first function and the other is voltage relay for the second function.

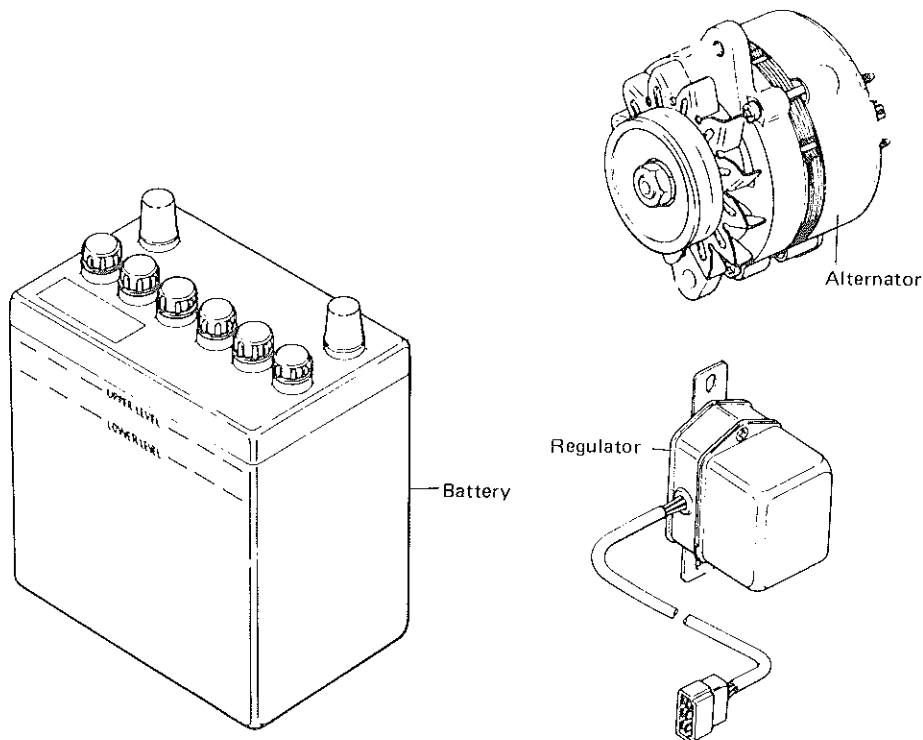


Fig. 11-1

11-2. Charging Operation

The following description of the system operation is referenced to the circuit diagram indicated in Fig. 11-2. Closing the ignition switch connects the charge warning light to the battery; a small current flows through the light, lighting this light to signify that the alternator is not charging the battery, and through the contact point of voltage relay to ground. Another current flows from the battery through the contact point of voltage regulator into the field winding in the alternator rotor, thereby producing magnetic fields around the rotor. These fields, which are stationary at this time because the rotor is not running, link the armature coils and the rotor poles through the air gap between stator and rotor.

Under these conditions, suppose the engine is started up. The rotor begins to run, and its magnetic fields revolve to "cut" the three armature coils in succession. In each armature coil, an electromotive force is generated by electromagnetic induction. This force changes its direction alternately. Consequently, the three armature coils apply three alternating voltages to the rectifier. Viewed collectively, these voltages constitute the three-phase output voltage of the alternator.

The rectifier consists of three pairs of rectifying diodes, forming three one-way paths of current for full-wave rectification to convert the alternator output power into a direct current power, which is available from the "B" terminal of the alternator-rectifier unit, relative to "E" (ground) terminal.

As the engine picks up speed, the electromotive force induced in each armature coil increases, so that the output voltage appearing at terminal "B" (relative to terminal "E") becomes high enough to "push" electricity into the battery through its positive terminal. In other words, the battery begins to draw a charging current.

Let's take a look at the pressure coil of the voltage relay. One end of this coil is connected to terminal "E" and the other end to the neutral point "N" of the three armature coils. Potential level of "E" (ground) is now so much lower than that of "N" that a current flows in the pressure coil to develop a magnetic pull on its armature carrying point "P5". Consequently, point "P5" separates from point "P4" and touches point "P6"; the charge warning light thus becomes shunted and stops burning to signify that the battery is getting charged.

During the early stage of engine starting, the alternator output voltage may be lower than the battery voltage; even in such a case, no current flows from the battery into the alternator because of the rectifier diodes. The reason why a cutout relay is not used here is explained by the presence of the diode rectifier.

The function of the voltage regulator with its voltage coil is to alter the path of field (excitation) current for the field coil, in order to maintain the alternator output voltage at a relatively constant level. When this voltage rises owing to a rise in engine speed, the voltage coil pulls point "P2" away from point "P1", thereby introducing the control resistor "R1" into the field circuit. Field current falls slightly because of this resistance and, consequently, the output voltage falls to the normal level. If the engine picks up speed further, the magnetic pull developed by the voltage coil increases to bring point "P2" into contact with "P3", thereby shunting the field coil to reduce the field current to zero. Under this condition, voltage generation in the alternator is dependent on the residual magnetization of the rotor, which is small enough to keep down the output voltage to the normal level.

The foregoing description of the voltage regulator operation may be summarized as follows: the regulator controls the alternator output voltage by controlling the field current in three steps; first allowing a full field current to flow; secondly, by inserting a resistor into the circuit to reduce the field current; and thirdly, by shunting the field coil to reduce the current to zero, all for maintaining the output voltage at a relatively constant level.

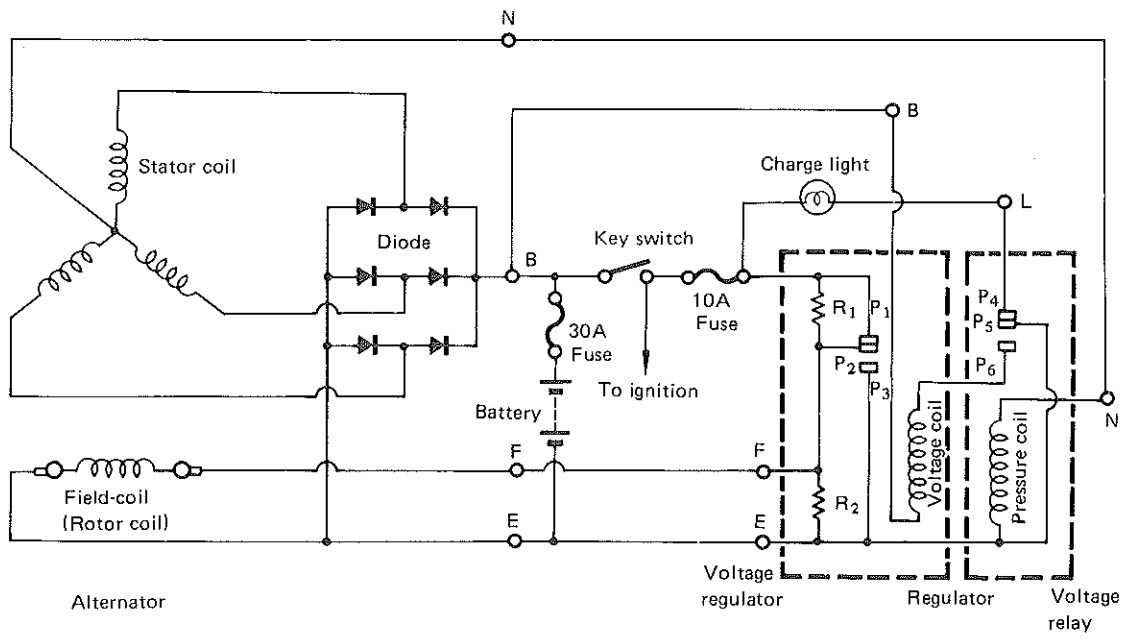


Fig. 11-2

11-3. Alternator

Description

In order to distinguish it from conventional automotive dynamos, the AC generating device is called an alternator for it produces a DC output from three alternating currents generated in its winding.

The alternator consists of: the rotor (which produces revolving magnetic fields), stator (which is a series of coils disposed and arranged to form three coil groups), two slip rings and two brushes (through which DC excitation current is fed into the field winding of the rotor), and the rectifier (which consists of 6 semiconductor diodes, and is built in the alternator).

In operation, the revolving magnetic fields "cut" the stator coils. In other words, the three groups of coils experience changes in magnetic flux. By the flux changes, an alternating electromotive force (emf) is induced in each coil group. Thus, three alternating voltages are available from the stator.

The six diodes are arranged so that they "rectify" or convert the three alternating outputs into a DC output. Three-phase full-wave rectification is effected by the built-in rectifier.

In terms of electric current, a diode is a circuit element that passes the current only in one direction. Of the six diodes, three are arranged to pass currents in the same direction, and the remaining three in the opposite direction. Since three alternating currents undergo full-wave rectification and are combined into one by superposition, the DC output of this alternator is much steadier and carries much less pulsating or ripple components than a DC output made available by full-wave rectification of a single-phase alternating current.

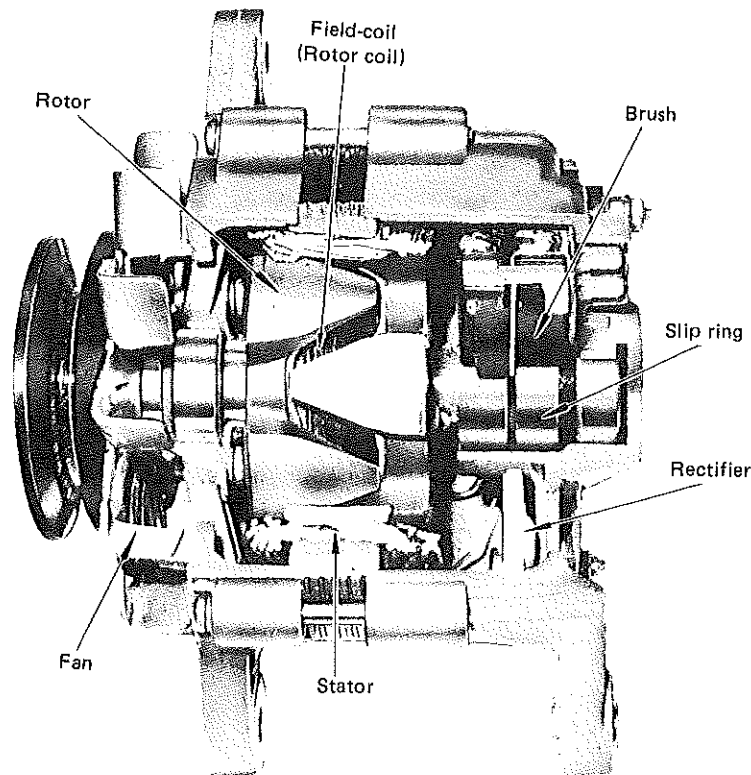


Fig. 11-3

Data and Specification

Nominal operating voltage	12 Volts
Maximum alternator output (14 V)	40A
Polarity	Negative ground
Effective pulley diameter	65 mm (2.56 in.)
No-load alternator speed	1,000 – 1,100 r/min 14 Volts at normal temperature
Full-load alternator speed	5,500 r/min maximum, 40A, 14 Volts at normal temperature
Direction of rotation	Clockwise as viewed from pulley side
Maximum permissible alternator speed	13,500 r/min
Working temperature range	-40°C ~ 80°C (-104°F ~ 176°F)
Rectification	Full-wave rectification

Removal

- (1) Disconnect the negative (–) battery cable from the battery.
- (2) Disconnect from the alternator the white cord and circuit coupler.
- (3) Remove the bolts securing "V" belt adjusting arm and alternator and take down the alternator.

Alternator Disassembly

Remove the 3 bolts fastening the end frame to the rotor housing; tap on the rotor housing with a wooden mallet to separate stator and rotor housing from the end frame and rotor.

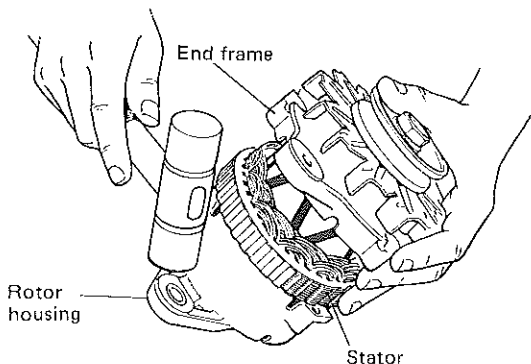


Fig. 11-4

Fix the rotor with vise, and loosen the nut to remove the pulley, fan and end frame.

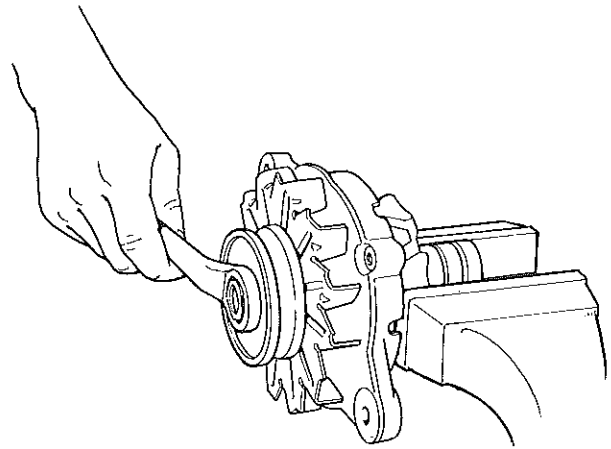


Fig. 11-5

Remove the 3 screws securing the rectifier holder in place, and one other nut holding down the terminal insulator. Remove the rotor housing.

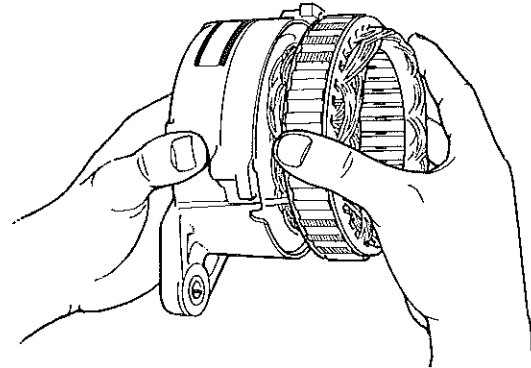


Fig. 11-6

Remove the brush holder from the stator.

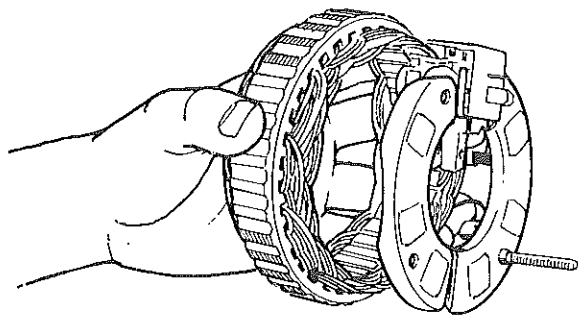


Fig. 11-7

NOTE:

The alternator is to be reassembled by reversing the foregoing sequence of steps. Before inserting the rotor into the housing, be sure to have the brushes installed in the holder. (Use a proper size rod (A), manipulating it from the rectifier side, to set the brush in the holder.)

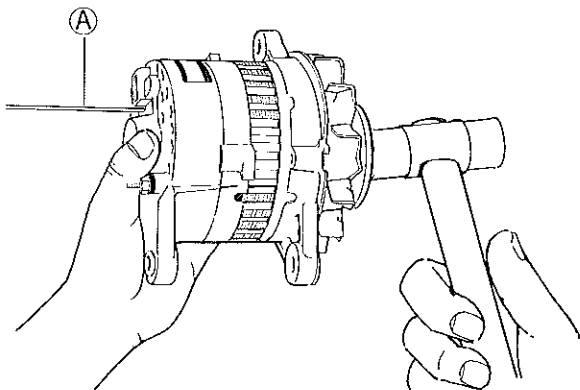


Fig. 11-8

Maintenance Services

(1) Rotor

- Testing the rotor for open-circuit

Check to be sure there is continuity between the two slip rings when tested as shown. Absence of continuity means that the field coil is open-circuited and must be replaced.

Ring-to ring circuit resistance	Several ohms
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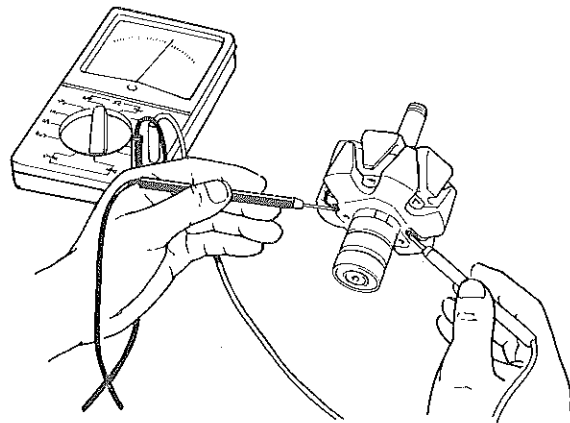


Fig. 11-9

- Testing the rotor for grounding

Check to be sure there is no continuity between the slip ring and the rotor shaft when tested as shown. Presence of any continuity means that the insulation on the field coil has failed, making it necessary for the rotor to be replaced.

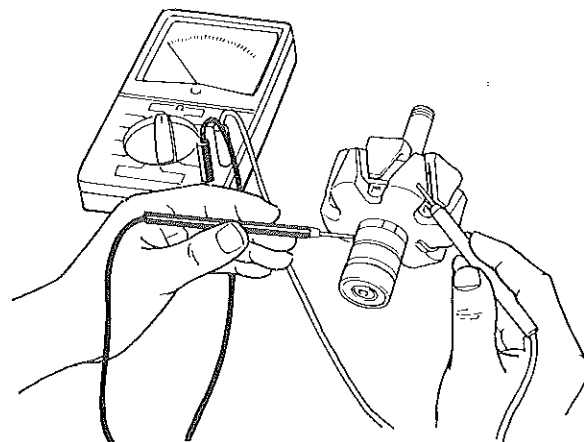


Fig. 11-10

(2) Stator

Check to be sure there is no continuity between the stator core and each armature coil; any continuity noted means that the coil is grounded. A grounded armature coil can be corrected by locating the faulted point and repairing the fault.

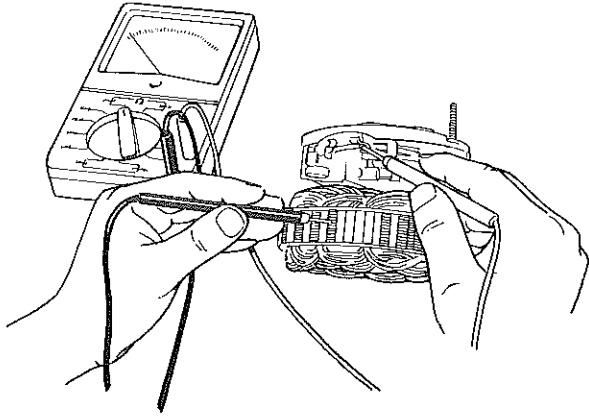


Fig. 11-11

(3) Brushes

Check each brush for wear by measuring its length, as shown. If the brush is found worn down to the service limit, replace the brush and holder altogether.

Brush length	Standard	Service limit
	13.5 mm (0.53 in.)	5.0 mm (0.20 in.)

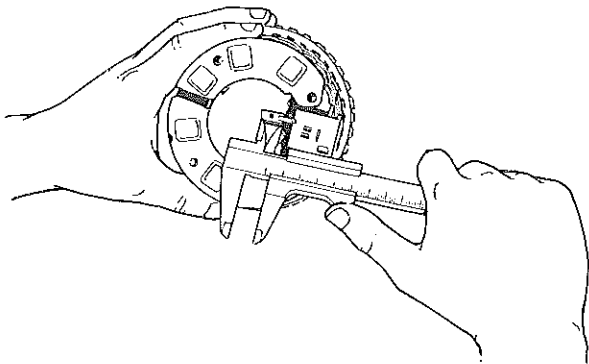


Fig. 11-12

(4) Rectifier

The rectifier is to be checked with the circuit tester for continuity in one direction and non-continuity in the other direction.

Put one tester lead to terminal "B" and the other lead to terminal "N"; then swap the two leads. Of the two tester indications, one should be about 20 ohms, meaning continuity, and the other should be infinity (non continuity).

Put one tester lead to terminal "N" and the other lead to terminal "E"; then swap the two leads. In this case, too, the two tester indications should be similar to those mentioned above.

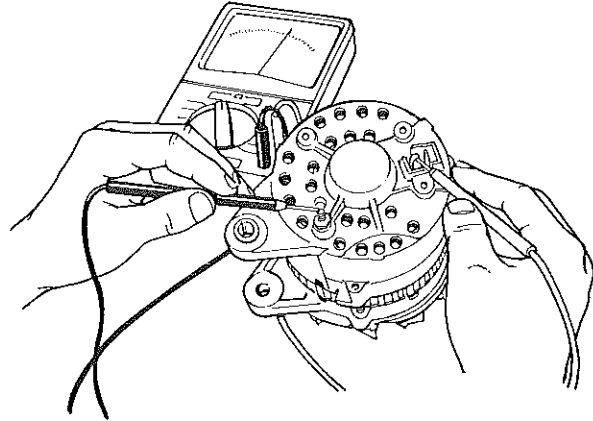


Fig. 11-13

(5) Alternator load performance

With the alternator-rectifier unit in place, run the engine in a speed range of 3,000 to 4,000 rpm, with head lights, 4-way flashers and wiper motor turned on, and check the alternator output voltage and current. Compare the readings against the prescribed values, indicated below. An output current which is small means the possibility of the rectifier being defective, any of the stator (armature, coil open-circuited, or an insulation failure resulting in a grounding fault).

Standard output voltage and current	13.8 ~ 14.8 volts, 20A minimum
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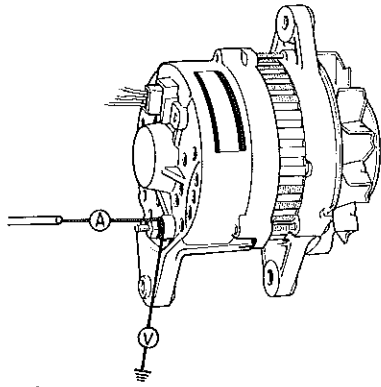


Fig. 11-14

11-4. Alternator Regulator

In the two-element regulator, one coil acts as voltage limiter or regulator and the other coil as relay for controlling the charge warning light. It should be noted in the circuit diagram that the magnetic pull developed by the voltage coil to move its moving point "P2" is roughly proportional to the alternator output voltage, whereas the magnetic pull developed by the pressure coil of the relay is dependent on the potential level of neutral point "N" of the armature with respect to the ground. A clear understanding of these relations is essential in checking, testing and servicing the regulator unit.

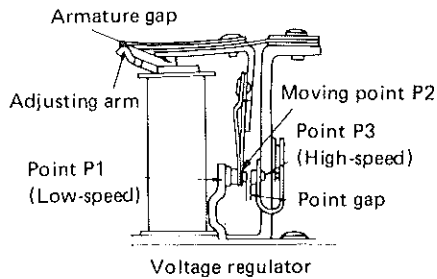


Fig. 11-15

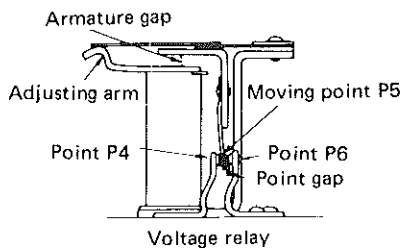


Fig. 11-16

Specifications

Regulated voltage	13.8 ~ 14.8 volts
Voltage-relay cut in voltage	4.2 ~ 5.2 volts

Maintenance services

- (1) Voltage-regulator limiting action test
Hook up a voltmeter, inserting it between the alternator "B" terminal and ground, and run the engine within a range of 2,000 to 3,000 rpm, while reading the voltmeter indication. The voltage read is the charging voltage as limited by the action of the voltage regulator; the reading should be within the prescribed range, which is indicated below. If the charging voltage is found too high or too low, adjust it by bending the adjusting arm of the voltage regulator.

Prescribed range of charging voltage	13.8 ~ 14.8 volts for 2,000 ~ 3,000 engine rpm
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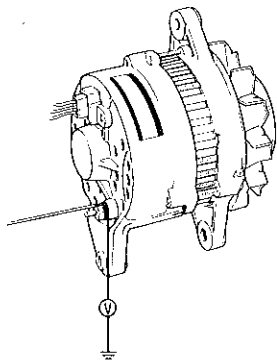


Fig. 11-17

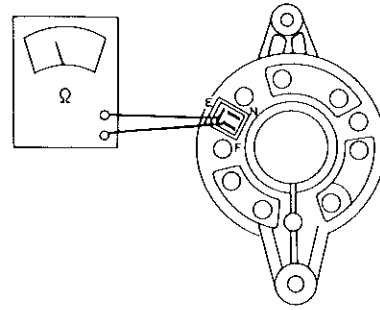


Fig. 11-18

- Ⓐ If the charging voltage is noted to oscillate or otherwise be unstable, it is most likely that the contact point faces in the voltage regulator are dirty or roughened. Cleaning and smoothening the faces will remedy this malcondition.
- Ⓑ If the charging voltage is too high, the possible causes are as follows:
 - Armature gap is too wide on low-speed side or high-speed side in the voltage regulator.
 - Contact resistance at high-speed side point is too large.
 - The coil of voltage regulator or relay is open-circuited.
 - Open circuit in the line to "N" or "B" terminal of the regulator unit. (Refer to Fig. 11-19).
 - Contact pressure is too high on low-speed side point.
 - Imperfect grounding of the regulator unit.

(2) Continuity test on field coil

Using the circuit tester, check for continuity between the "E" and "F" terminals of the alternator, as shown. The tester should indicate continuity with a resistance value meeting the following specification:

Standard field circuit resistance	Several ohms
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- Ⓐ If the resistance value noted is too small, it is likely that there is a short-circuit through insulation layers in the coil.
 - Ⓑ If the resistance value noted is too large, the following possibilities must be considered:
 - An open-circuit is developing in the field coil.
 - The brushes are not seated properly on the slip rings.
 - Brushes or slip rings are burnt.
- (3) Checking terminal-to-terminal resistances
Pull off the connector from the regulator unit, remove the cover, and check the resistance between terminals. Refer the resistance readings to the following chart to diagnose the internal condition of the regulator unit:

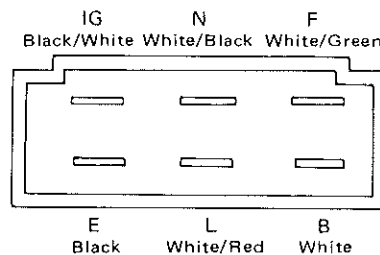


Fig. 11-19

Guide on regulator diagnosis				
Terminal checked	State of vol. relay	State of vol. regulator	Normal resistance value (ohms)	Diagnosis
IG-F		Standstill	Zero	If not zero, point contact is defective on low-speed side.
		Operated	Approx. 11	If infinity is noted, control resistor is open-circuited.
L-E	Standstill		Zero	If not zero, relay contact point is not closing fully.
	Operated		Approx. 100	If zero, relay point faces are fused together. If infinity is noted, voltage coil is open-circuited.
N-E			Approx. 24	If zero, pressure coil is shorted. If infinity, pressure coil is open-circuited.
B-E	Standstill		Infinity	If not infinity, relay point faces are fused together.
	Operated		Approx. 100	If zero, voltage coil is shorted. If infinity, voltage coil is open-circuited or contact action of the point is defective.
B-L	Standstill		Infinity	If not infinity, relay point faces are fused together.
	Operated		Zero	If not zero, contact action of the point is defective.

NOTE:

In the above chart, "standstill" means that the regulator unit is in de-energized state; "operated" means that the armature is manually (with a fingertip) actuated as if it were pulled in by the coil.

(4) Gap adjustment

Ⓐ Voltage relay

Using a thickness gauge, check the two gaps, point gap and armature gap. Refer the gauge readings to the specification value, below, and adjust the gaps as necessary.

Gap specifications	
Armature gap	Approx. 1.2 mm (0.047 in)
Point gap	Approx. 0.9 mm (0.035 in)

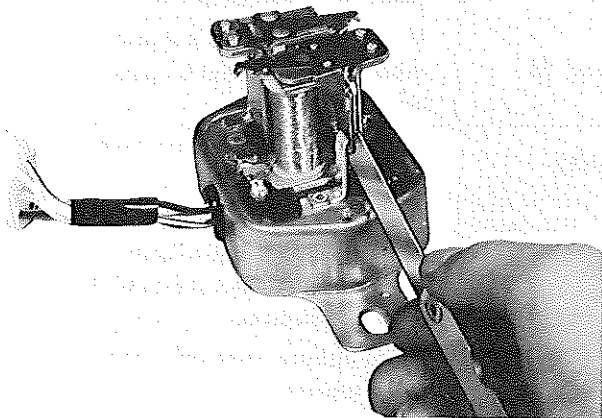


Fig. 11-20

Ⓑ Voltage regulator

Two gaps are to be checked: point gap, and armature gap. Use a thickness gauge, and compare the readings taken against the following specifications. Adjust the gaps as necessary.

Gap specifications	
Armature gap	Approx. 1.0 mm (0.039 in)
Point gap	Approx. 0.38 mm (0.015 in)

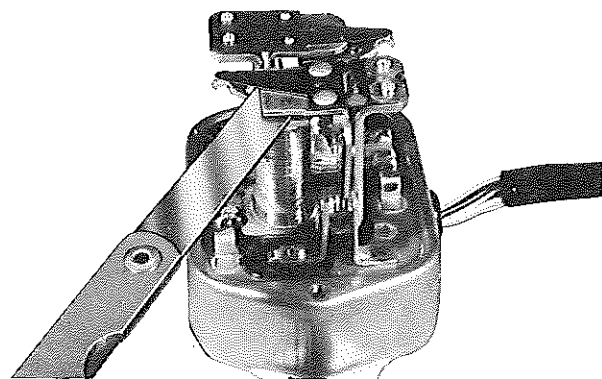


Fig. 11-21

11-5. Battery

1) Battery specifications

NS40S type

Rated capacity	30AH/20HR, 12 Volts
Electrolyte	2.2 litres (4.6/3.9 US/Imp. Pt.)
Electrolyte S.G.	1.26 when fully charged at 20° C (68° F)

NT60 - S4 type

Rated capacity	35AH/20HR 12 Volts
Electrolyte	2.5 litres (5.3/4.4 US/Imp. Pt.)
Electrolyte S.G.	1.28 when fully charged at 20° C (68° F)

2) Care of the battery

The following information is basic in nature and is nothing new; it is merely a reiteration of what every Service shop personnel knows about the automotive storage battery. The information is intended to serve as a reminder to the reader, with a hope that he will, in turn, remind each final user of the important basic facts about the battery whenever opportunity permits him to engage in a conversation with the final user in the shop or out of the shop.

- (1) The battery is a very reliable component, but needs periodical attentions.
Keep the battery container clean; prevent rust formation on the terminal posts; keep the electrolyte up to the upper level uniformly in all cells; and try to keep the battery fully charged at all times.
- (2) Preserve the capacity of the battery.
There is a limit to the ability of the battery to hold electricity in store. This limit is called "capacity."

There are several ways for the battery to lower its capacity:

- Ⓐ Loss of electrolyte, or fall in electrolyte level.
When this happens, the battery cannot hold so much electricity as it originally could. Handle the battery with care when you take it down. Barring the loss of electrolyte by careless spilling or otherwise, the electrolyte level goes down gradually in the battery at work because the water content of it evaporates. Periodically refill distilled water to each cell, as necessary, so that the electrolyte is always up to the specified level. Never allow its surface to fall so much as to expose the cell plates.
- Ⓑ Overcharging the battery in place or off the machine.
In recharging the battery off the machine, caution must be exercised so as not to overcharge it. Overcharging gives rise to several complexities. For one thing, it heats up the battery to deform the battery container to result in a destroyed battery. Overcharging could occur in a battery in place if the voltage regulator is maladjusted to allow the alternator (or the dynamo in other machines) to develop too high an output voltage. For another thing, "gassing" occurs in a battery being overcharged to result in a loss of water content. One of the most serious consequences of overcharging is the swelling of positive-plate grids, causing the grids to crumble and the plates to buckle.
- Ⓒ Undercharging the battery in place.
Regulator malfunctioning is usually the cause of the battery remaining in a state of charge far below its capacity. This condition is very undesirable in freezing weather, for the electrolyte in such a battery can easily freeze up to result in a destroyed battery. Moreover, an undercharged battery is an easy prey to a greater evil-sulfation.
- Ⓓ Sulfation.
Let us recall the electrochemical reactions that take place in the battery during charging and discharging. As the battery gives out its energy (discharging), the active materials in its cell plates are converted into lead sulfate. During recharging, this lead sulfate is reconverted into active material. If the battery is allowed to stand for a long period in discharged condition, the lead sulfate becomes converted into a hard, crystalline substance, which will not easily turn back to the active material again during the subsequent recharging. "Sulfation" means the result as well as the process of that reaction. Such a battery can be revived by very slow charging and may be restored to usable condition but it is a damaged battery and its capacity is lower than before.

(3) Keep the battery cable connections clean.

The cable connections, particularly at the positive (+) terminal post, tend to become corroded. The product of corrosion, or rust, on the mating faces of conductors resists the flow of current. The inability of the starter motor to crank the engine is often due to the rust formation in the battery cable connection. Clean the terminals and fittings periodically to ensure good metal-to-metal contact, and grease the connections after each cleaning to protect them against rusting.

(4) Be always in the know as to the state of charge of the battery.

The simplest way to tell the state of charge is to carry out a hydrometer test. The hydrometer is an inexpensive instrument for measuring the specific gravity (S.G.) of the battery electrolyte. Why measure the S.G.? Because the S.G. of the electrolyte is indicative of the state of charge.

The direct method of checking the battery for state of charge is to carry out a high-discharge test, which involves a special low-reading voltmeter, an expensive instrument used generally in the service shops but no recommendable to the user of the machine.

At 20°C of battery temperature (electrolyte temperature):

The battery is in FULLY CHARGED STATE if the electrolyte S.G. is 1.26 (1.28).

The battery is in HALF CHARGED STATE if the S.G. is 1.20 (1.22).

The battery is in NEARLY DISCHARGED STATE if the S.G. is 1.150 and is in danger of freezing.

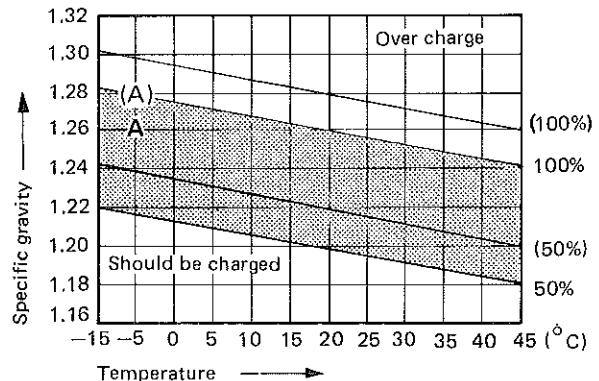
What if the battery temperatures not 20°C (68°F)? Since the S.G. varies with temperature, you have to correct your S.G. reading (taken with your hydrometer) to the value at 20°C, and apply the corrected S.G. value to the three-point guide stated above. This manner of correction needs a chart showing the relation between S.G. and temperature. There is a simpler way: refer to the graph given below, which tells you the state of charge for a range of S.G. value and a range of temperature.

How to use the temperature-corrected state-of-charge graph.

Suppose your S.G. reading is 1.26 (1.28) and the battery temperature is -5°C (23°F). Locate the intersection of the -5°C line and the 1.26 (1.28) S.G. line. The intersection is "A". It is in the zone for CHARGED STATE. How much is the battery charged? To find out the answer, draw a line parallel to the zone demarcation line, extending it to the right, and see where this line crosses the percentage scale. In the present example, the line crosses at, say, 85% point. The battery is 85% fully charged.

NOTE:

The electrolyte specific gravity of NT60-S4 type battery is 1.28 at 20°C (68°F).



() For NT60-S4 type battery

Fig. 11-22