Starter

General

The starter, which is used to crank the engine, must overcome the combined resistance of the compression, piston friction, and bearing friction. In order to be able to provide the considerably large torque required for this purpose, the starter draws a very high current.

Construction and Function

The design of the starter is similar to that of the generator. The main difference lies in the fact that the starter is a current consumer and the generator a current producer.

The overrunning clutch coupling, mounted on the starter drive, breaks the connection between engine and starter as soon as the peripheral speed of the flywheel exceeds that of the starter pinion.

The driver, coupled with the pinion by the overrunning clutch, is mounted on the long helical spline of the armature shaft. The rotation of the armature and spline pushes the pinion forward to engage the flywheel ring gear. The forked end of the solenoid lever is held between two spring loaded washers in the middle of the driver sleeve on which the starter gear is mounted. The forked end of the actuating lever engages between the two actuating rings to advance the pinion. The pinion is also advanced by the inertia action of the helical spline. The commutator end of the starter is closed by an end cap. The starter is actuated electromagnetically by a solenoid switch mounted on the starter and in turn actuated by the ignition/starter switch mounted on the instrument panel.

Engaging

After the starter has been switched on, the actuating lever is first moved against spring pressure without the field and armature windings switched on. The actuating lever pushes the driver and pinion toward the ring gear by the actuating ring on the pinion side and against the coil spring; the driver and pinion thereby turn on the helical spline. Should the pinion be in line with a tooth space in the process, it meshes instantly.

Shortly before the pinion meshes fully, the switch mounted on the starter is closed so that the starter armature begins to rotate. As the starter shaft accelerates the starter pinion is fully engaged with the ring gear by the worm action of the helical spline shaft. When the pinion gear reaches the end stop on the starter shaft it is firmly seated and the starter begins to drive the flywheel through the overrunning clutch. When the solenoid switch closes the actuating lever stops but the driver continues forward tensioning the coil spring nearest the armature.

Should the advancing pinion come against a tooth, the actuating lever compresses the coil spring at the pinion end, until the switch closes. The pinion being turned passes the tooth face and engages the succeeding tooth space under pressure exerted by the coil spring. Because of the long helix no axial pressure that would jam the mechanism occurs. The solenoid switch mounted on the starter contains one actuating and one holding coil. Both coils are in action while actuating the plunger. When the starter current is switched on, the actuating coil is short-circuited, and the holding coil alone remains energized.

Disengaging

The overrunning clutch used to protect the armature from damage is connected to the pinion gear. When the pinion gear speed exceeds the armature speed it is free to rotate on the roller and ramp type overrunning clutch. As shown in Fig. 19 the rollers become jammed against the shaft and couple the pinion gear to the armature when driving. The rollers are pushed back into the larger gap when driven by the engine. When the gear is stationary, springs push the rollers into the engaged position so that the pinion gear will be driven as soon as the starter is actuated. The pinion gear remains engaged with the flywheel ring gear as long as the starter is running and the solenoid is activated. The pinion gear is withdrawn from the starter ring gear only when the solenoid is released. The pinion gear is returned to the neutral position by the coil spring on the shaft and the solenoid return spring.

This spring holds the pinion gear in the neutral position even during engine vibration and vehicle acceleration until the starter is again used.

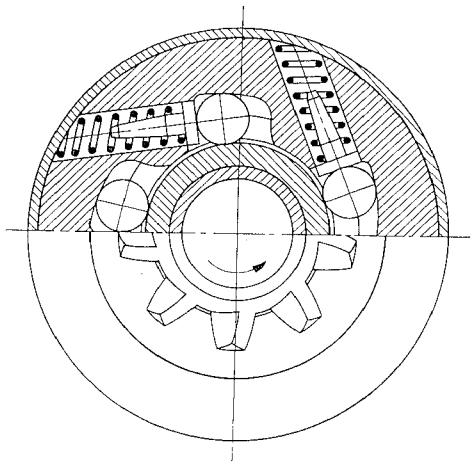


Fig. 19

5-Roller Overrunning Clutch

Maintenance

The armature bearing requires no lubrication during normal operation but should be serviced when the engine is overhauled. The starter bushing in the transmission housing should be inspected for wear when the starter is removed and lubricated with high temperature grease before installing the starter. The starter end cap should be removed every 6000 miles (10,000 km) to inspect the condition of the brushes. Replace worn brushes or weak springs (page L 85).

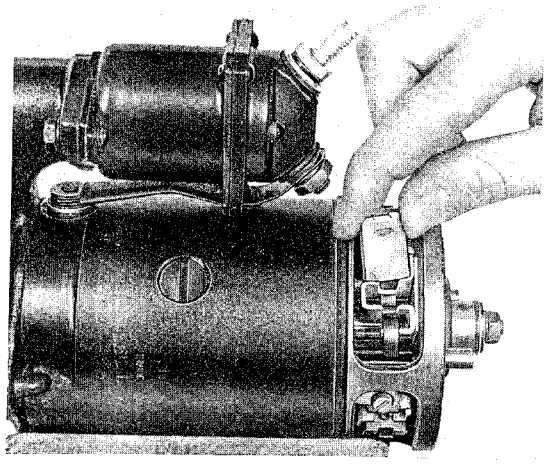
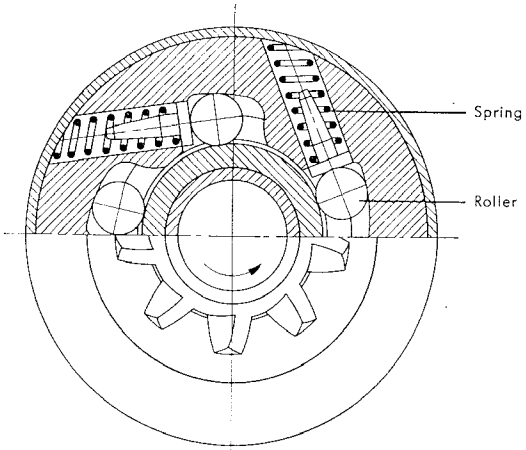


Fig. 20

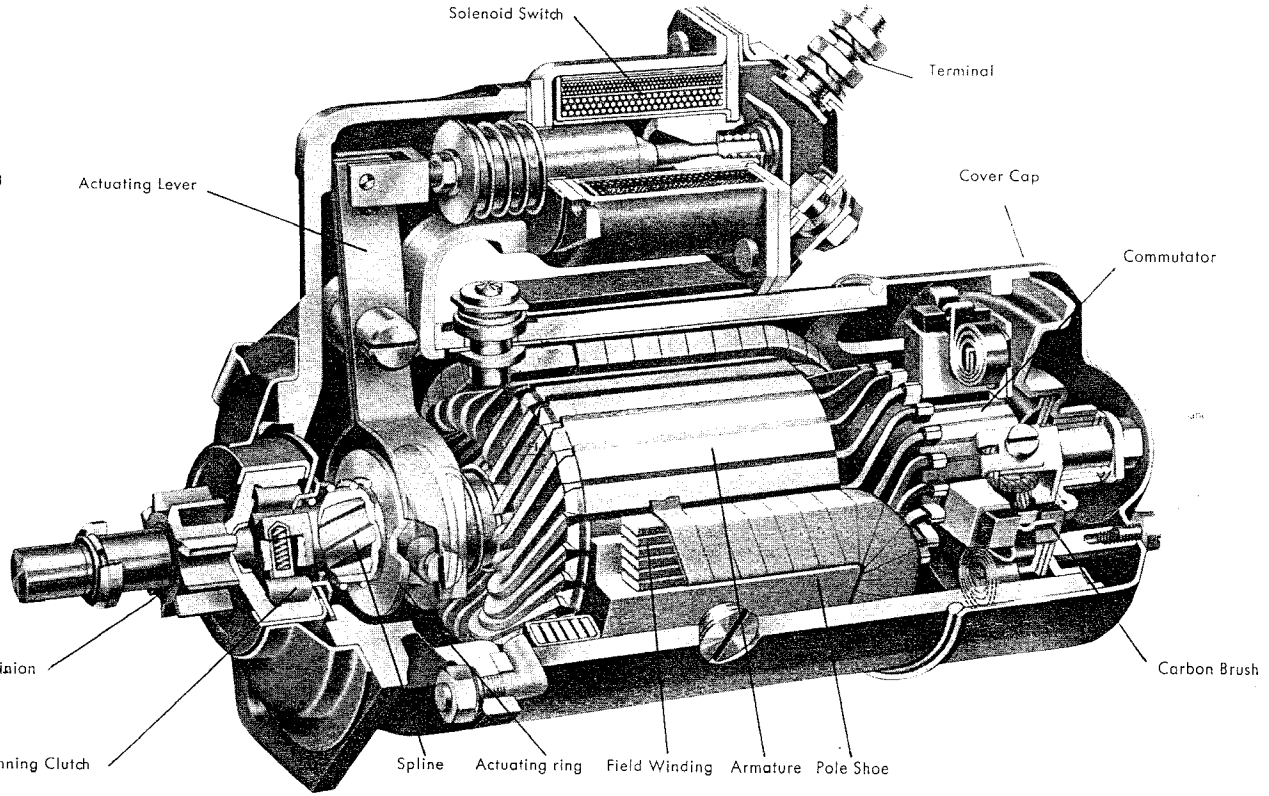
Armature Brake

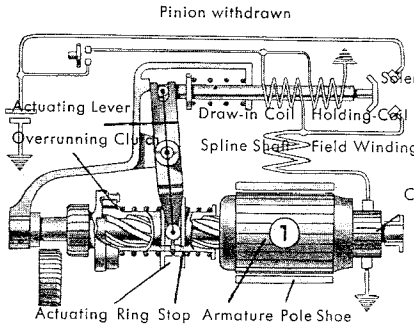
A brake is mounted at the commutator end of the starter in order to stop the armature as soon as possible after cutting off the current so that a fresh start may be made quickly if necessary. The brake consists of a spring washer, a holding washer, and a friction washer (Fig. 27). The braking torque is designed so that it does not impede the generator during operation yet is sufficient to arrest the armature quickly when it is switched off. The friction torque should be from 2.5 to 5 cm.kg. (2.2 to 4.4 in.lb.). The commutator must be clean and free of oil. A dirty commutator may be cleaned using a clean rag soaked in solvent or carbon tetrachloride. If the commutator is badly worn or shows signs of arcing, the starter should be overhauled. When replacing the end cap insure that the rubber seal ring is in good condition or is replaced if necessary.

Bosch Solenoid Starter

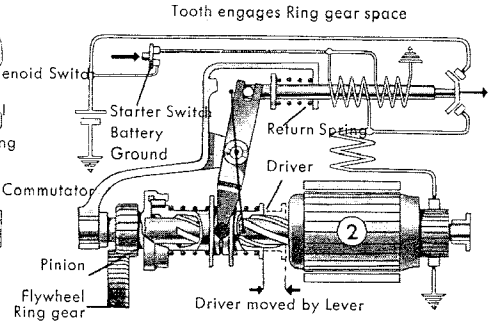


Overrunning Clutch

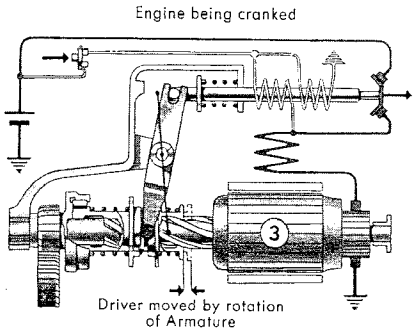




Rest position / no current flowing



Draw-in and holding coils energised
Pinion meshes instantly
Just before main circuit is switched-in



Engaging lever in end position / Draw-in coil dead / Main circuit closed / Pinion fully meshed / Engine being cranked

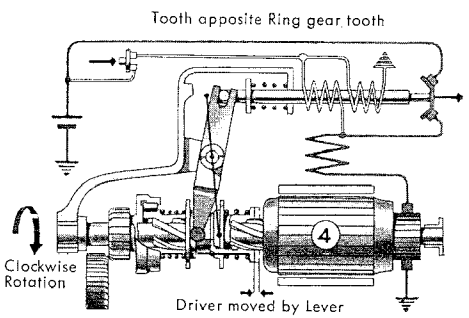


Fig. 21

Engaging lever in end position / Draw-in coil dead / Main circuit closed / Armature rotates / Pinion seeks tooth space and meshes fully / Engine being cranked

Removing and Installing Starter

12 LI

Removal

1. Disconnect ground strap at battery.
2. Disconnect battery cable and cable to generator and ignition switch from terminal 30 of the starter.
3. Disconnect control cable (to starter/ignition switch) from terminal 50 of the starter.
4. Remove starter by removing the flange screws.

Installation

The installation is accomplished in the reverse order of removal observing the following points:

1. Lubricate starter shaft bushing with high temperature grease.
2. Apply sealing compound to face of intermediate bracket flange and transmission case.
3. Make sure that terminals and cables are clean and properly connected.

Note

If the flywheel gear is excessively worn, the gear teeth may be refaced a maximum of 2 mm ($1/16$ in.). They must be accurately and evenly rechamfered to assure proper operation of the starter and balance of the flywheel. Do not alter the solenoid switch setting.

Connections

1. Generator and battery cables to upper solenoid terminal.
2. Solenoid actuating cable to small terminal.
3. Ground strap to battery.

Removing and Installing Solenoid Switch

13 LI

Removal

1. Remove connector strap from solenoid switch.

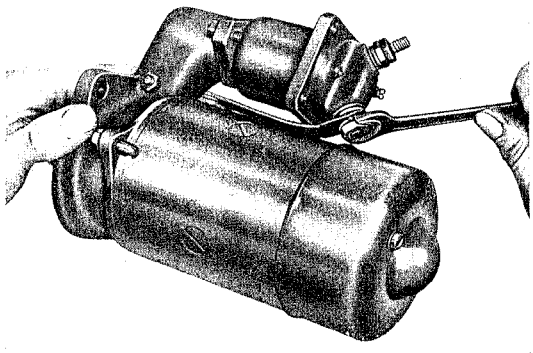


Fig. 22

2. Remove bolts that attach solenoid switch to intermediate bracket.
3. Pull out starter pinion and remove solenoid switch. A defective solenoid switch must be replaced.

At a general engine overhaul it is advisable to replace the switch. Never alter the setting of the switch.

Installation

The installation is accomplished in the reverse order of removal observing the following points:

1. Hold cable ends from twisting while tightening terminal nuts; do not use excessive force.

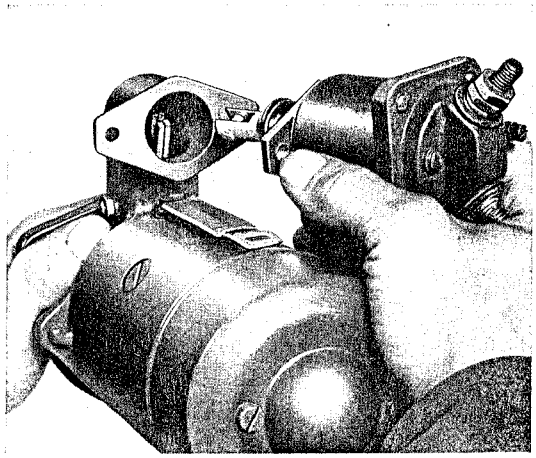


Fig. 23

2. To facilitate connecting the solenoid switch with the actuating lever, slightly pull out the starter pinion.

3. When installing a new switch, adjust the plunger so that the centerline of the pivot pin in the yoke is 32.4 ± 0.1 mm (1.275 ± .004 in.) from the solenoid flange.

Note: Testing solenoid switch

1. Total armature travel should be 10 ± 0.2 mm (.394 ± .008 in.). Of this, 3 mm (.118 in.) is contact reserve.

2. To check, connect a 6 V lamp between the main terminals and push in the armature. Measure the travel remaining after the test lamp lights.

3. When installed in the starter the solenoid switch must pull the armature in when 4 volts are applied between terminal 30 and ground. If it does not, check for proper starter brush seating.

14 LI

Testing Brushes and Commutator

1. Remove starter end cap.

2. Inspect brushes for wear and free movement in the guides of the brush holders. If the brushes are worn so that they will not bear on the commutator they must be replaced by new ones of the same type. Replace brushes which are oil saturated or have loose flexible connectors.
When installing brushes the flexible connectors should be positioned so that they will not hinder brush movement during operation and subsequent wear. Always install a complete set even if only one brush requires replacement.

3. Test tension of brush springs. Replace weak springs.

4. If the commutator is oily or gummed, it may be cleaned with a cloth dampened with solvent or carbon tetrachloride wrapped around a piece of wood.
Dirt or solvent should not enter the bearing.

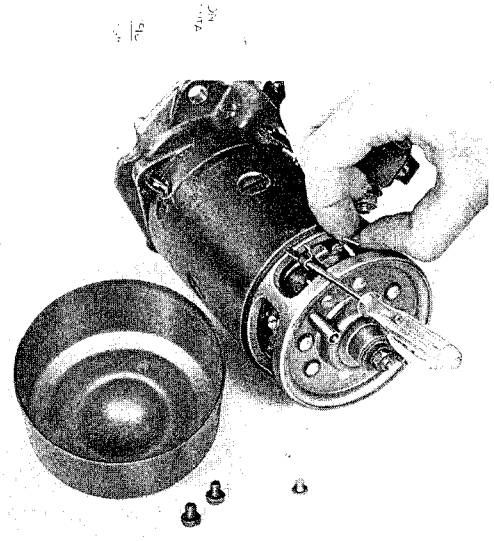


Fig. 24

5. If the commutator surface is scored or shows burned spots, the starter must be overhauled.

Dissasembling and Assembling Starter

15 LI

Exploded view of complete starter

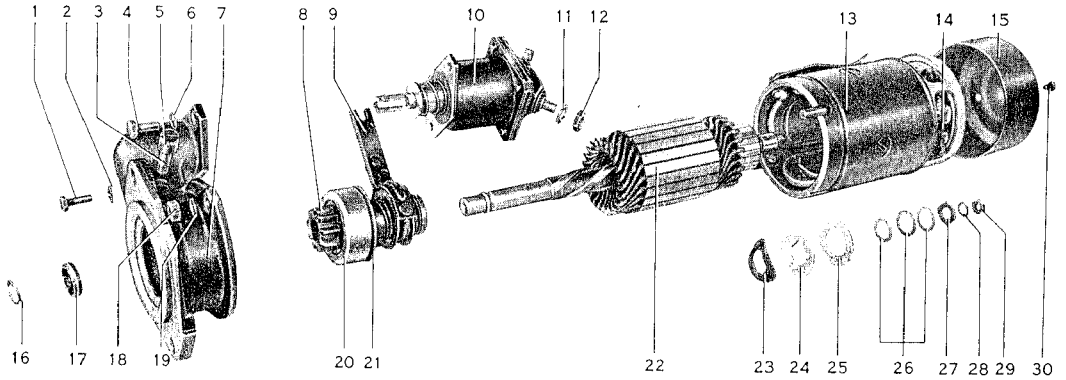


Fig. 25

① Bolt
② Lock ring
③ Pivot pin
④ Bolt
⑤ Pivot pin screw head
⑥ Lock washer
⑦ Intermediate flange
⑧ Pinion gear
⑨ Actuating lever
⑩ Solenoid
⑪ Lock washer
⑫ Nut
⑬ Housing
⑭ Brush
⑮ Cover
⑯ Lock ring
⑰ Pinion stop
⑱ Nut
⑲ Lock washer
⑳ Overrunning clutch
㉑ Thrust washer
㉒ Armature
㉓ Spring washer
㉔ Holding washer
㉕ Thrust washer
㉖ Shims
㉗ Drive washer
㉘ Lock washer
㉙ Nut
㉚ Cover screw

Exploded view of starter housing with armature and armature brake

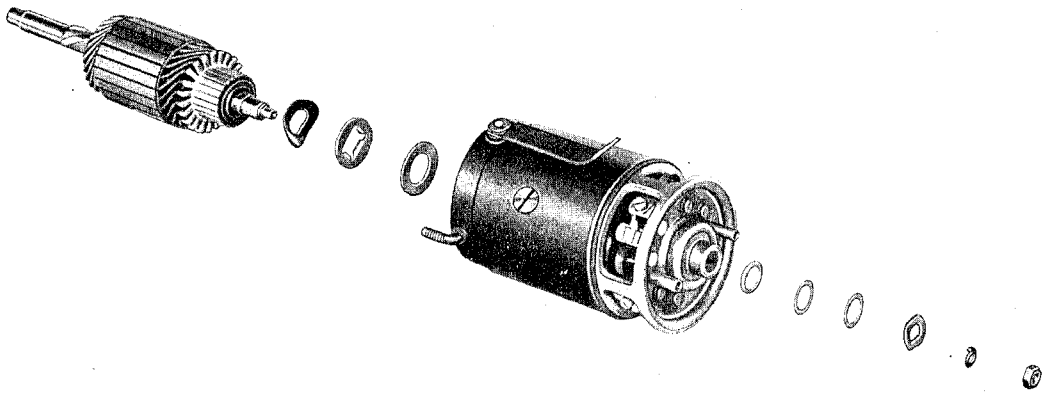


Fig. 26

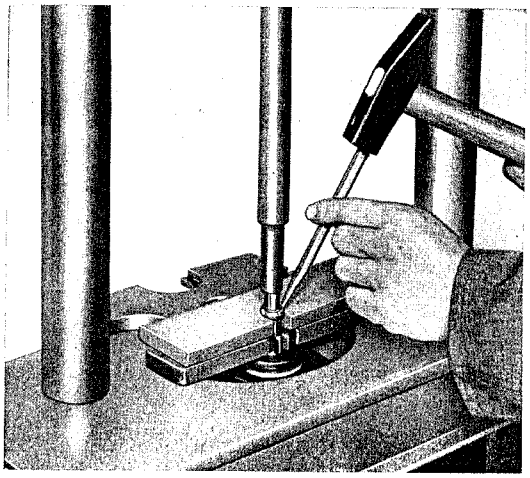


Fig. 30

5. Do not forget end cap gasket.

6. To avoid starting trouble caused by water entering the starter, the following points should be sealed with sealing compound:

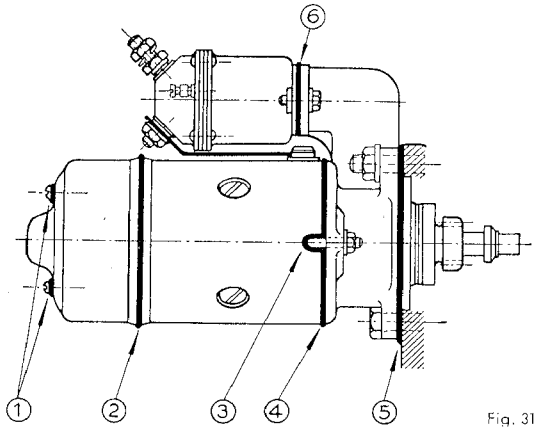


Fig. 31

① **Holes for slotted screws in end cap**
② **Rubber seal between housing and end cap**
③ **Holes in housing for hook studs of intermediate bracket**
④ **Joint faces between housing and intermediate bracket**
⑤ **Joint faces between transmission housing and intermediate bracket**
⑥ **Joint faces between solenoid switch and intermediate bracket**

Testing Armature

16 LI

In many cases the armature does not show visible evidence of damage. The armature is tested for open circuits, short circuits and internal ground.

Test

1. Open circuits in the armature are usually readily apparent, since this condition causes burned spots between adjacent commutator segments due to the brush deposits which bridge the insulation between segments. Check soldered commutator connections.

2. The armature is tested for short circuits on the growler. Place the armature on the growler and slowly revolve it while holding a thin steel strip or hack saw blade on the armature core. Short circuits in the armature cause the steel strip or hack saw blade to vibrate against the core when the blade is held above the slot containing the shorted winding.

3. The armature is grounded when the armature core comes into contact with the winding or when carbon dust has entered the windings (direct and indirect ground). The armature ist tested electrically for ground placing one lead of a 40 volt test lamp from a 40 volt source on the armature core and the other on the commutator. The test lamp should not light.

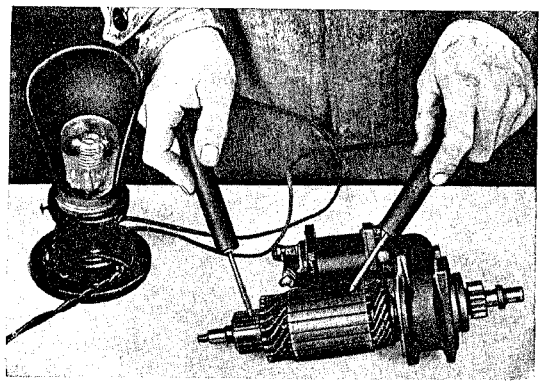


Fig. 32

4. The commutator consists of copper segments separated by mica plates. If the commutator is out of round and scored or burned it should be turned on a lathe to obtain a true surface. Maximum permissible run-out 0.05 mm (.002 in.). Do not remove more metal than is necessary. The mica should then be undercut 0.3 to 0.5 mm (.012 to 0.20 in.). This operation should be performed with a motor driven undercutter which will provide a small chamfer on each segment, or in an emergency very carefully with a thin hacksaw blade.

   No metal chips should remain between the segments since these will lead to short circuits. Remove all burrs from the undercut slots to provide a smooth running surface for the brushes.

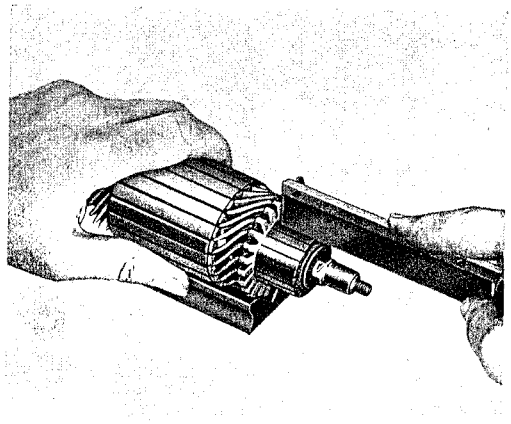


Fig. 33

17 LI

Testing Field Coils

The two field coils are tested for open circuits, short circuits and ground.

Test

1. Test each field coil individually for open circuits with a 6 volt test lamp in series with the battery.

2. If the outer insulation of the field coils is found to be in order there is rarely a short circuit in the windings. Finding short circuits is generally beyond the scope of workshops as this requires a very sensitive ohmmeter or resistance bridge. However, if they have been disassembled, the field coils may also be tested on the growler by hanging them on an iron bar over the growler. If the coil becomes warm, a short must be present.

3. Test for a grounded field coil (coils installed) by connecting a 40 volt test light and 40 volt source between one coil connection and the starter housing. The lamp should not light.

4. Also check the electrical connection between the two field coils for continuity with a 6 volt test lamp.

Service Diagnosis

Trouble	Cause	Repair
Starter does not operate when the starter switch is turned	Switch on lights for this test: a. If lights do not burn: Loose cables or poor ground connections. Battery is run down b. If lights go out when turning starter switch: Insufficient current due to loose connections or corroded terminals c. If lights suddenly go dim when turning the starter switch: Battery run down or old d. If lights stay bright when turning starter switch: Connect jumper lead between terminals 30 and 50 at starter. If the starter operates, there is an open circuit in the cable to the starter switch, or to the battery or the switch is defective e. If lights stay bright and the plunger in the solenoid switch is pulled when pressing starter button: Disconnect the battery cable from terminal 30 at the starter and connect it to the terminal stud of the connector strap. If the starter operates, the contacts of the solenoid switch are worn or dirty	a. Check battery cables and connections. Test voltage of battery and charge if necessary b. Clean battery terminals and cable clamps, clean and tighten connections between battery, starter and ground c. Charge battery, or replace d. Eliminate open circuits, replace defective parts e. Replace solenoid switch
Starter does not operate when battery cable is directly connected with terminal stud of connector strap Sluggish or slow action of the starter	a. Brushes sticking b. Brushes worn c. Weak spring tension Brushes do not make contact d. Commutator dirty e. Commutator rough, pitted or burned f. Armature or field coils defective	a. Clean brushes and guides of brush holders b. Replace brushes c. Replace springs d. Clean commutator e. Overhaul starter f. Overhaul starter
Starter can be heard operating, but cranks engine erratically or not at all Drive pinion does not disengage	a. Battery run down b. Insufficient current flow due to loose or corroded connections c. brushes sticking d. Brushes worn e. Commutator dirty f. Commutator rough, pitted or burned g. Armature or field coils defective	a. Charge battery b. Clean battery terminals and cable clamps, tighten connections c. Clean brushes and guides of brush holders d. Replace brushes e. Clean commutator f. Overhaul starter g. Overhaul starter
Starter can be heard operating, but cranks engine erratically or not at all	a. Drive pinion defective b. Flywheel ring gear defective	a. Replace drive pinion b. Rework ring gear or replace flywheel
Drive pinion does not disengage	a. Drive pinion or spline shaft dirty b. Solenoid switch defective	a. Immediately shut off engine to prevent further damage to starter Overhaul starter b. Replace solenoid switch