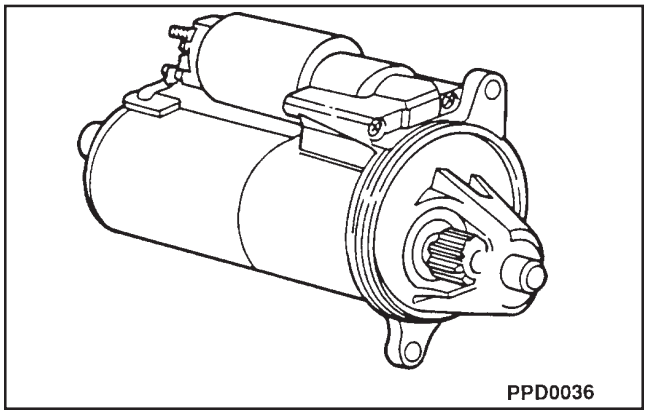
INDEX

GENERAL INFORMATION

The function of the starting system is to crank the engine at a speed fast enough to permit the engine to start. Heavy cables, connectors, and switches are used in the starting system because of the large current required by the starter while it is cranking the engine. The amount of resistance in the starting circuit must be kept to an absolute minimum to provide maximum current for starter operation. A discharged or damaged battery, loose or corroded connections, or partially broken cables will result in slower than normal cranking speeds, and may even prevent the starter from cranking the engine.

The starting system includes the permanent magnet gear-reduction starter motor with a solenoid-actuated drive, the battery, a remote control starter switch (part of the ignition switch), the starter relay, the heavy circuit wiring, and may include starter lock-out, controlled by the ICM through a starter lockout relay.

Field Service



Starter Motor Assy 11001

Sequence Of Operation

1. The ignition switch is turned to the START position.

2. A remote starter relay is energized, which provides voltage to the starter solenoid. The starter solenoid is energized, creating a magnetic field in the solenoid coil.

3. The iron plunger core is drawn into the solenoid coil.

4. A lever connected to the drive assembly engages the drive pinion gear to the flywheel ring rear.

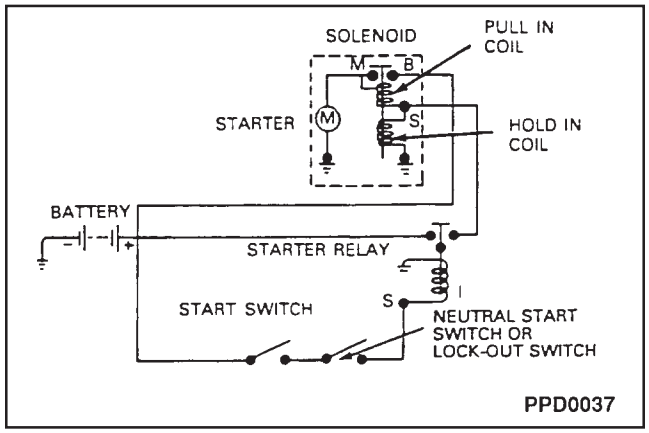
5. When the iron plunger core is all the way into the coil, its contact disc closes the circuit between the battery and the motor terminals.

6. The current flows to the motor, and the drive pinion gear drives the flywheel and the engine crankshaft.

7. As current flows to the motor, the solenoid pull in coil is bypassed.

8. The hold-in coil keeps the drive pinion gear engaged with the flywheel.

9. The gear remains engaged until the ignition switch is released from the START position.



NOTE: The ICM is programmed to lock the starter out when the engine is operating over 600 rpm and the following sequence takes place:

Starter Lockout Relay

See page 07-6 for further details.

1. During start up with key in the on position 12V (B+) is applied to relay through circuit 32A (RD/LB) 16G.

2. With ignition switch turned to the crank position, current flows from ignition switch to relay circuit 32A (RD/LB) 16G through relay and out circuit 32 (RD/LB) 16G to starter solenoid.

3. The starter than should respond as in steps 2 through 9 in sequence of operation circuit 113 (YL/LB) 18G is connected to ICM C3 Pin “D”. The ICM keeps circuit 113 open until it reads 400+ engine rpm. Over 600 rpm the ICM grounds circuit 113 causing the relay to open circuits 32A and 32. This will prevent starter engagement while engine is running.

NOTE: An overrunning clutch in the drive assembly protects the starter from the excessive speeds during the brief period before the driver releases the ignition switch from the START position (as the engine starts).

For cases of a starter that cranks the engine very slowly, connect a 12-volt booster battery to the system.

NOTE: Engine may not start if crank sensor reads less than 140 RPM.

Jump Starting

To avoid damage to the vehicle or equipment and battery or the possibility of personal injury, follow these instructions and precautions:

WARNING: HYDROGEN AND OXYGEN GASES ARE PRODUCED DURING NORMAL BATTERY OPERATION. THIS GAS MIXTURE CAN EXPLODE IF FLAMES, SPARKS OR LIGHTED TOBACCO ARE BROUGHT NEAR THE BATTERY. WHEN CHARGING OR USING A BATTERY IN AN ENCLOSED SPACE, ALWAYS PROVIDE VENTILATION AND SHIELD YOUR EYES.

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH SKIN, EYES OR CLOTHING, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

CAUTION: Do not disconnect the battery of the vehicle to be started. Disconnecting the battery could damage the vehicle's electronic system.

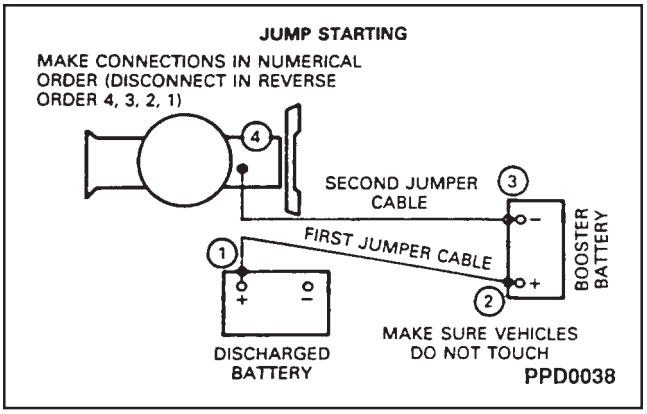
Negative Grounded Battery

WARNING:TO AVOID INJURY, USE PARTICULAR CARE WHEN CONNECTING A BOOSTER BATTERY TO A DISCHARGED BATTERY.

1. Position vehicles or equipment so jumper cables will reach, being careful that vehicles do not touch.

WARNING: MAKING THE FINAL CABLE CONNECTION COULD CAUSE AN ELECTRICAL SPARK NEAR THE BATTERY AND COULD CAUSE AN EXPLOSION. REFER TO WARNING AT THE BEGINNING OF THE JUMP STARTING PROCEDURE.

WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER UNDERHOOD WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES.



NOTE: Be sure to disconnect battery negative cable before servicing starter.

2. Make jumper cable connections.

   a. Connect one end of first jumper cable to positive (+) **1** terminal of discharged battery and other end of positive (+) **2** terminal of booster battery.
   b. Connect one end of second jumper cable to negative (-) **3** terminal of booster battery. Connect other end to an engine bolthead or good metallic contact spot on engine **4** of equipment to be started. NOT TO NEGATIVE (-) BATTERY TERMINAL.
   c. Make sure jumper cables are not in way of moving engine parts.
   d. Start engine of vehicle with good battery. Run engine at a moderate speed.
   e. Start engine of vehicle with discharged battery. Follow starting instructions in the Owner Guide.

3. Completely discharged batteries may require an electrical load to initialize charging.

4. Remove cables in exact REVERSE sequence. Begin by removing negative (-) cable from engine of vehicle **4** that had discharged battery.

If the starter does not turn the engine over, even with the booster battery attached, refer to On Vehicle Testing.

DIAGNOSIS AND TESTING

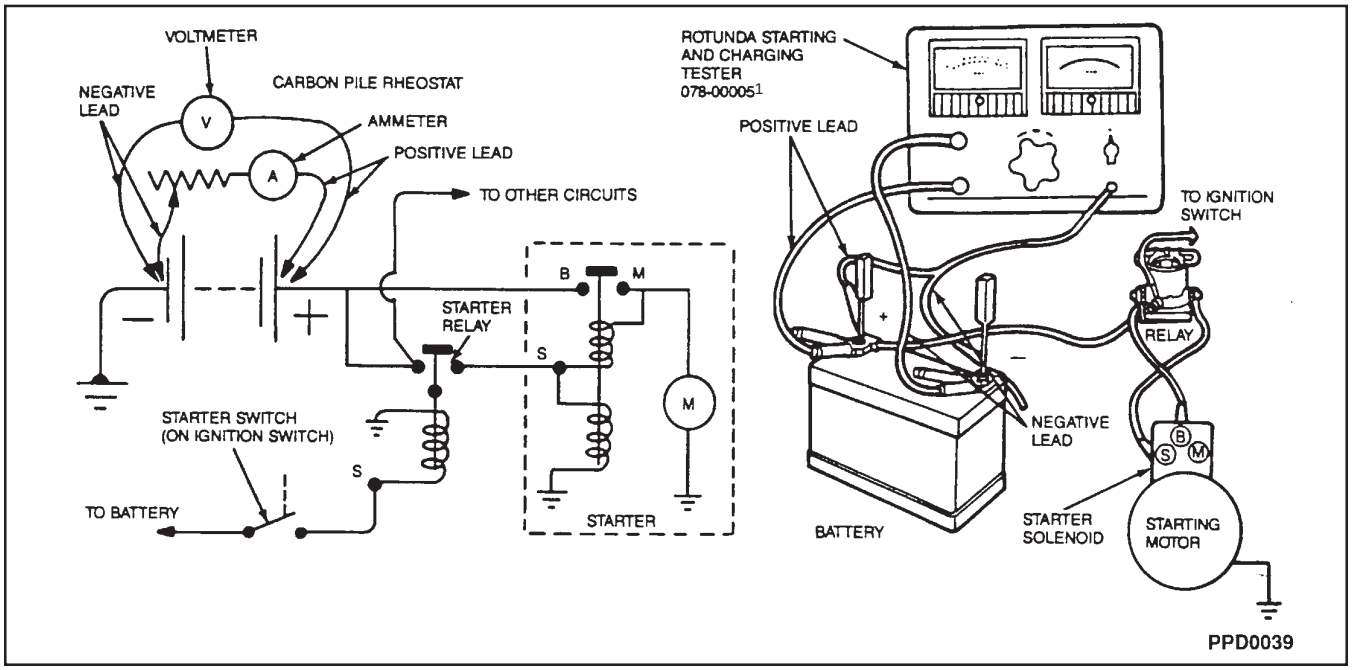
Starter Load Test

Conduct this test if the starter cranks slowly and it is desired to compare current to specifications.

1. Connect Rotunda Starting and Charging Tester 078-00005 or equivalent. Make sure that current is not flowing through ammeter and heavy-duty carbon pile rheostat portion of circuit (rheostat at maximum counterclockwise position).

2. Disconnect load from engine. Place transmission in NEUTRAL. Crank engine with ignition off, and determine exact reading on voltmeter. This test is accomplished by disconnecting push-on connector "S" at starter relay and by connecting a remote control starter switch from positive battery terminal to "S" terminal starter relay.

3. Stop cranking engine and reduce resistance of carbon pile until voltmeter indicates same reading as that obtained while starter cranked the engine. The ammeter will indicate starter current draw under load. Check this with value listed in Specifications on page 07-19.



Bench Tests

CAUTION: Make sure that the starter is securely mounted in bench vise while energizing, as starter will move or jump.

1. Connect a fully charged battery, Rotunda Starting and Charging Tester 078-00005, or equivalent. Make sure that the battery and starter motor are grounded.

2. Engage the remote starter switch.

3. The starter motor should eject the starter drive and run smoothly. If the starter motor does not run smoothly, replace it.

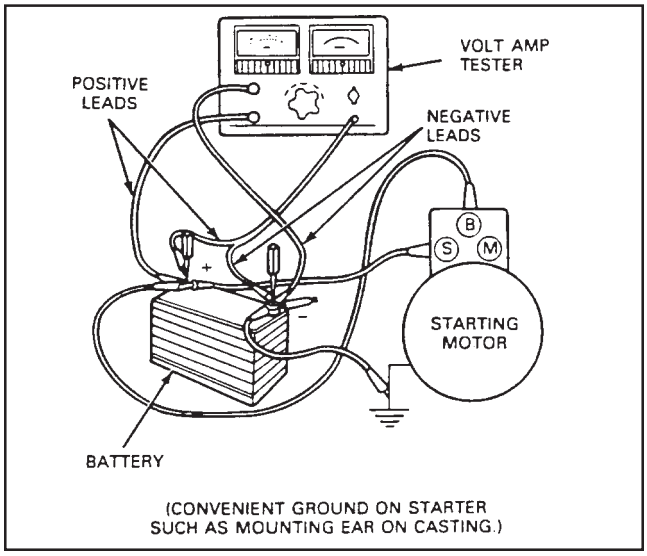
4. While the starter motor is running, check the voltmeter and ammeter.

5. If the voltage is lower than the 11.0 volts, or the amperage is higher than 70 amps, replace the starter motor.

NOTE: Service parts for rebuilding permanent magnet starter are not available from Ford Power Products.

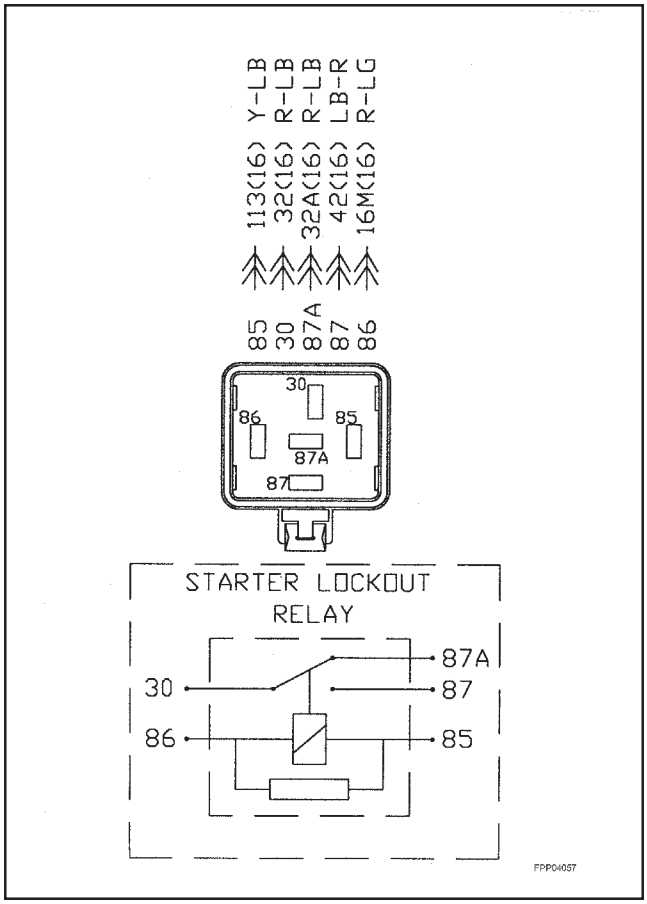
[1]Rotunda 1-800-578-7375

Starter No-Load Test



CAUTION: Make sure that the starter is securely mounted in bench vise while energizing, as starter will move or jump.

Starter Lock-Out Relay

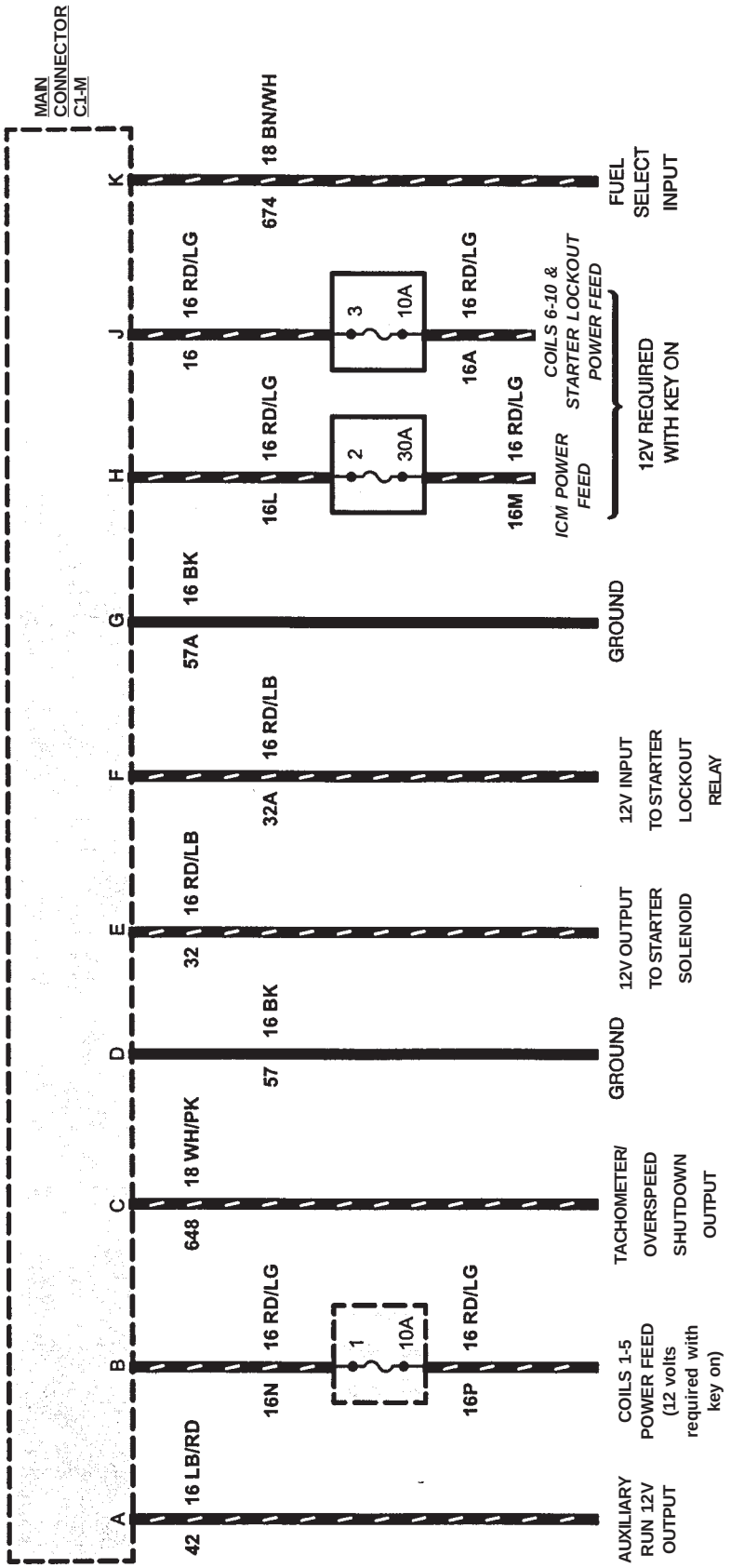


Circuit	Relay Terminal	Circuit Description
32	30	Voltage to Starter
16M	86	Relay Coil Power
113	85	To ICM
32A	87A	Ignition Feed
42	87	Auxiliary Run Output

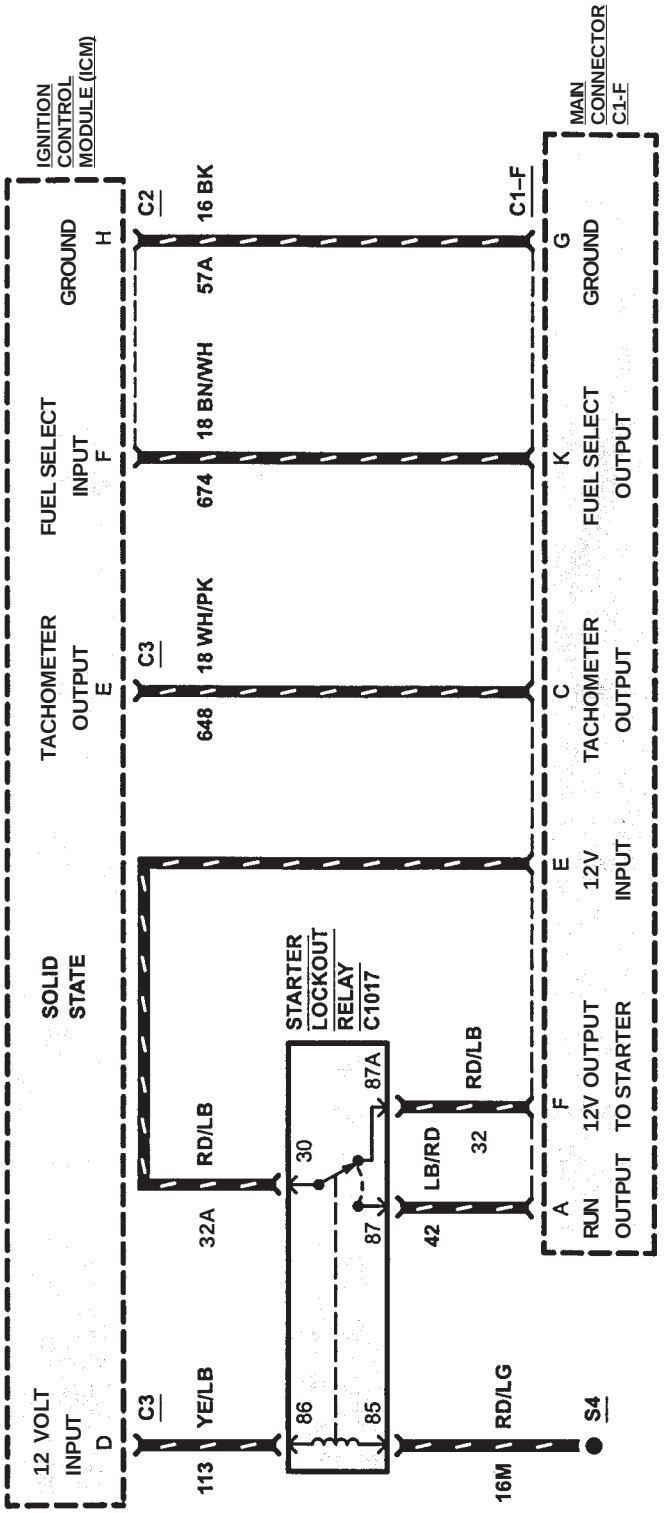
NOTE: All readings are made with connector attached to relay and back probing connector using a paper clip and fully charged battery.

Function	Normal Specs.	Area to Check (Out of Specs.)
Circuit 16M		
K- Off =	0V	Ignition or wiring
KOEO =	12V	Check fuse and wiring
KOER =	12V	Check fuse and wiring
Crank =	12V	Ignition switch or wiring
Circuit 32		
K- Off =	0V	Wiring
KOEO =	12V	Ignition switch & wiring
KOER =	0V	ICM & wiring
Crank =	12V	Ignition switch & wiring
Circuit 32A		
K- Off =	0V	Wiring
KOEO =	12V	Ignition or wiring
KOER =	12V	Ignition or wiring
Crank =	12V	Ignition or wiring
Circuit 42		
K- Off =	0V	Wiring
KOEO =	0V	Ignition or wiring
KOER =	12V	Ignition or wiring
Crank =	0V	Ignition or wiring
Circuit 133		
K- Off =	0V	Ignition or wiring
KOEO =	12V	Relay or wiring
KOER =	12V	Relay or Wiring
Crank =	12V	Relay or wiring

Main Jumper Harness (XU1L-14324-BB)



Starter Lockout Relay Schematic (part of SK2U1L-12A200-BA)



System Inspection and Verification

CAUTION: When disconnecting the plastic hardshell connector at the solenoid "S" terminal, grasp the plastic connector and pull lead off. DO NOT pull separately on lead wire.

WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES.

NOTE: Be sure to disconnect battery negative cable before servicing starter.

1. Inspect starting system for loose connections.

2. If system does not operate properly, note condition and continue diagnosis using the symptom chart.

WARNING: WHEN WORKING IN AREA OF THE STARTER, BE CAREFUL TO AVOID TOUCHING HOT EXHAUST COMPONENTS.

SYMPTOM CHART

CONDITION	POSSIBLE SOURCE	ACTION
Starter solenoid does not pull in and starter does not crank (audible click may or may not be heard).	• Low battery. • Defective remote relay. • Open circuit or high resistance in external feed circuit to starter solenoid.	• Charge battery and retest. • Go to Test A. • Go to Test A.
Unusual starter noise during starter overrun.	• Starter not mounted flush (cocked). • Noise from other components. • Ring gear tooth damage or excessive ring gear runout. • Defective Starter.	• Realign starter on transmission bell housing or SAE housing. • Investigate other powertrain accessory noise contributors. • Replace flywheel ring gear. • Replace starter. See removal and installation procedure this section.
Starter cranks but engine does not start.	• Problem in fuel delivery system. • Problem in ignition system. • Engine-related problem. • Engine does not exceed 100 RPM.	• Refer to manufacture installed fuel system information. • Refer to ignition system section. • Refer to Section 01, Diagnosis and Testing.
Starter cranks slowly.	• Low battery. • High resistance or loose connections in starter solenoid battery feed or ground circuit. • Ring gear runout excessive. • Defective Starter. • Auxiliary Drive binding.	• Charge or replace battery. • Check that all connections are secure. • Replace ring gear. • Check starter load. • Inspect auxiliary drives and components.
Starter remains engaged and runs with engine.	• Shorted ignition switch. • Battery cable touching solenoid "S" terminal (defective or mispositioned cable). • Defective Starter.	• Go to Section 03. • Replace or relocate cable. • Replace starter. See removal and installation procedure this section.
Starter clicks and engages but engine will not crank.	• Hydrolocked cylinder. • Seized main or rod bearing.	• Remove all plugs one at a time while checking for fluid in cylinders. • Repair as needed. Refer to Section 01.

Pinpoint Test A - Starter Lockout Relay Check

Inspection and Verification

1. Visually inspect for obvious signs of mechanical and electrical damage.
2. Visually inspect for and note auxiliary system connections not shown on the **recommended wiring schematic**.

Normal Operation

Terminals 30 and 87A of the starter lockout relay are normally closed while the ignition switch is in the start/crank position and the engine rpm is less than 600. When the engine has reached 600 rpm or greater the ICM will ground the relay terminal 85 and open terminals 30 & 87A which will not allow the starter to be engaged while the engine is operating above 600 rpm.

Step	Action	Values	Yes	No
1	1. Check Fuse 1 for an open 10A fuse Is the fuse open?			GO to Step 2
2	1. Disconnect the starter lockout relay. 2. KOEO. 3. Using an ohmmeter, measure for battery voltage on Circuit 16 RD/LG at the starter lockout relay connector. Is the voltage within the specified value?	Battery Voltage	GO to Step 3	Repair Circuit 113 Y/LB for short to VPWR and RETEST GO to Step 3
2	1. Disconnect the ICM connector C1. 2. Check Circuit 113 Y/LB for a short to Was a repair necessary?		Re-test	REPLACE the ICM and retest.
3	1. Refer to the pin numbers molded on the Starter Lockout Relay. 2. Measure resistances between pin 85 and all others. 3. One measurement should be between 40 and 120 ohms, with the other measurements being greater than 10,000 ohms. Are all resistance checks OK?		GO to Step 4	REPLACE the Starter Lockout Relay and retest.
4				

Pinpoint Test B - Starter Does Not Crank

Inspection and Verification

1. Visually inspect for obvious signs of mechanical and electrical damage.
2. Visually inspect for and note auxiliary system connections not shown on the **Recommended Customer Connections Wiring Schematic**.

Normal Operation

Terminals 30 and 87A of the starter lockout relay are normally closed while the ignition switch is in the start/crank position and the engine rpm is less than 600. Battery voltage flows to the starter solenoid engaging the starter. When the engine has reached 600 rpm or greater the ICM will ground the relay terminal 85 and open terminals 30 & 87A which will not allow the starter to be engaged while the engine is operating above 600 rpm. Once the relay is energized it will not reset until the ICM is turned off and then back on.

Step	Action	Values	Yes	No
1	Have you preformed Pin Point Test E Ignition Check?		GO to Step 2	Go to Section 03 Pin Point Test A
2	1. Note: This test may require an assistant depending on the application. 2. Turn and hold the Ignition switch in the START position. 3. Using an ohmmeter, measure for battery voltage at the starter solenoid START terminal. Is the voltage within the specified value?	Battery Voltage	GO to Section 0 7	GO to Step 3
3	1. Disconnect the starter lockout relay. 2. Turn and hold the Ignition switch in the START position. 3. Using an ohmmeter, measure for battery voltage on Circuit 32A RD/LB at the starter lockout relay connector. Is the voltage within the specified value?	Battery Voltage	GO to Step 4	Repair Circuit 32A RD/LB between the starter lockout relay and the ignition switch S terminal for OPEN circuit and RETEST
4	1. Key OFF 2. Using an ohmmeter, measure resistance between Circuit 32 RD/LB at the starter lockout relay connector and the starter solenoid ignition start terminal. Is the resistance less than 5 Ohms?		GO to Step 5	Repair Circuit 32 RD/LB between the starter lockout relay and the starter solenoid ignition start terminal for OPEN circuit and RETEST
5	1. Disconnect the starter lockout relay. 2. KOEO 3. Turn and hold the Ignition switch in the START position. 4. Using an ohmmeter, measure resistance between Circuit 113 YL/LB at the starter lockout relay connector and known good ground. Is the resistance greater than 5 Ohms?		GO to Step 7	GO to Step 6
6	1. Key Off. 2. Disconnect the starter lockout relay. 5. Using an ohmmeter, measure resistance between the Starter Lockout Relay terminals 30 and 87A. Is the resistance less than 5 Ohms?		GO to Step 7	REPLACE The Starter Relay and RETEST

Step	Action	Values	Yes	No
7	1. Key OFF. 2. Disconnect the ICM connector C4. 3. Disconnect the starter lockout relay. 4. Using an ohmmeter, measure resistance between Circuit 113 YL/LB at the starter lockout relay connector and known good ground. Is the resistance less than 5 Ohms?		REPLACE the ICM and retest.	REPAIR the circuit(s) in question. TEST the system for normal operation.

Component Tests

Starter Motor - Voltage Drop Test

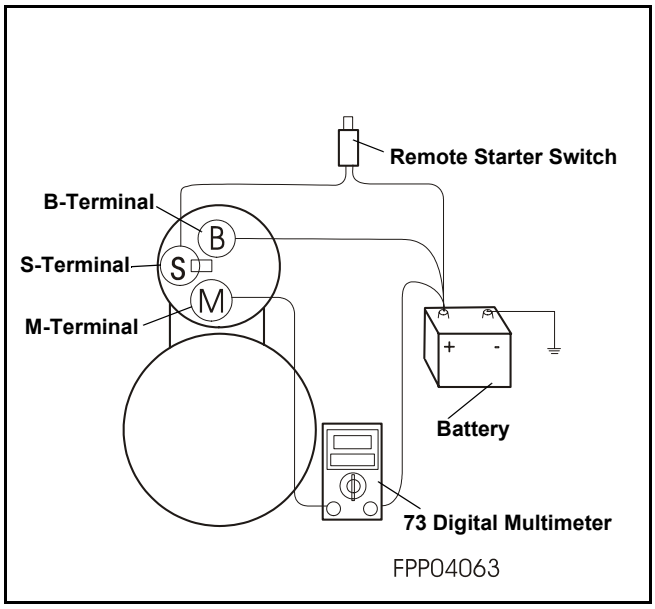
WARNING: WHEN REPAIRING THE STARTER MOTOR OR PERFORMING OTHER UNDERHOOD WORK IN THE VICINITY OF THE STARTER MOTOR, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES. WHEN SHORTED TO GROUND, MAY CAUSE PERSONAL INJURY.

CAUTION: A protective cap or boot is provided over the battery input terminal on all vehicle lines and must be replaced after repairing. Failure to replace protective cap could cause electrical short that may damage electrical system. Be sure to disconnect the battery ground cable before repiaring the starter motor.

NOTE: Always connect the 73 Digital Multimeter at the component terminal rather than at the wiring end connector. Making a connection at the wiring end connector could result in false readings because the meter will not pick up a high resistance between the wiring connector and the component.

Starter Motor - Motor Feed Circuit

1. Make sure the battery is fully charged.
2. Connect a remote starter switch between the starter motor solenoid S-terminal and the battery positive (+) terminal.
3. Connect the 73 Digital Multimeter positive lead to the battery positive (+) post. Connect negative lead to the starter motor solenoid M-terminal.

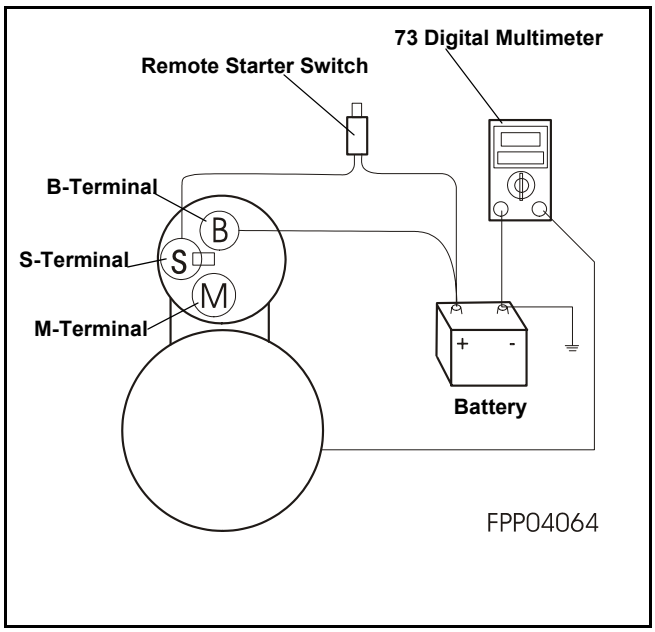


4. Engage the remote starter switch. Read and record the voltage. The voltage reading should be 0.5 volts or less.
5. If the voltage reading is 0.5 volts or less -- Refer to"Starter Motor - Motor Ground Circuit" on page 14.
6. If the voltage reading is greater than 0.5 volts, indicating excessive resistance, move the 73 Digital Multimeter negative lead to the starter motor B-terminal and repeat the test. If the voltage reading at the B-terminal is lower than 0.5 volts, the concern is either in the connections at the starter motor solenoid or in the starter motor solenoid contacts.
7. Remove the cables from the starter motor solenoid B-, S- and M-terminals. Clean the cables and connections and reinstall the cables to the proper terminals. Repeat Steps 3 through 6. If the voltage drop reading is still greater than 0.5 volts when checked at the M-terminal or less than 0.5 volts when checked at the B-terminal, the concern is in the solenoid contacts. Replace the starter motor.
8. If the voltage reading taken at the starter motor solenoid B-terminal is still greater than 0.5 volts after cleaning the cables and connections at the solenoid, the concern is either in the positive (+) battery cable connection or in the positive battery cable itself.
9. By moving the 73 Digital Multimeter negative lead toward the battery and checking each mechanical connection point, the excessive voltage drop can be located. When the high reading disappears, the last mechanical point that was checked is the concern. Repair or replace this connection as required.

Starter Motor - Motor Ground Circuit

A slow cranking condition can be caused by resistance in the ground or return portion of the cranking circuit. Check the voltage drop in the ground circuit as follows:

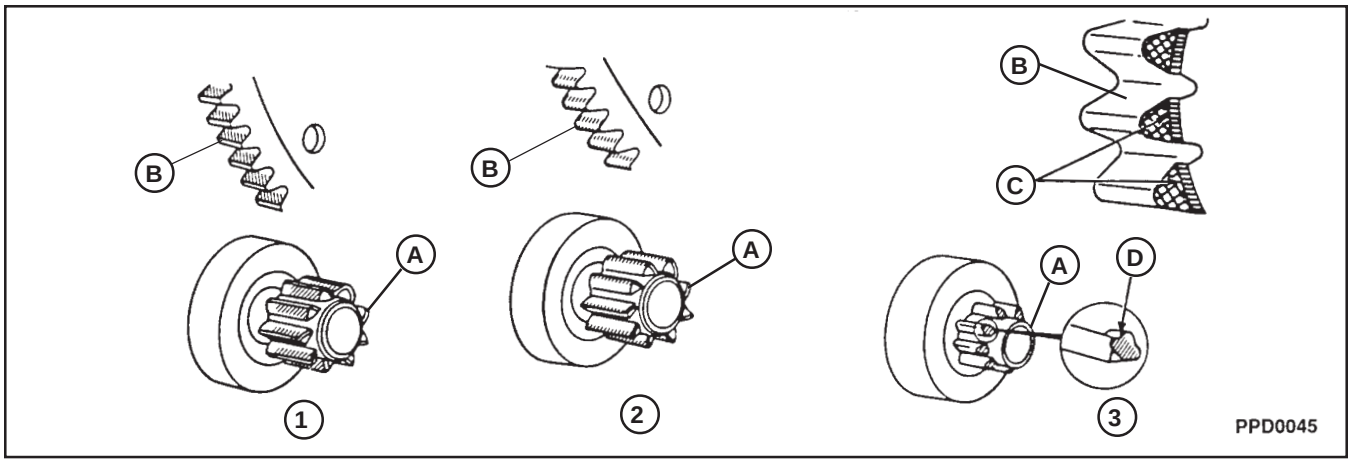
1. Disconnect the inertia fuel shutoff switch (on road vehicle only).
2. Connect a remote starter switch between the starter motor solenoid S-terminal and the battery positive (+) terminal.
3. Connect the 73 Digital Multimeter positive lead to the starter motor housing (the connection must be clean and free of rust or grease). Connect the negative lead to the negative (-) battery terminal.



4. Engage the remote starter switch and crank the engine. Read and record the voltage reading. The reading should be 0.5 volts or less.
5. If the voltage drop is more than 0.5 volts, clean the negative cable connections at the battery and body connections, and retest.
6. If the voltage drop is greater than 0.5 volts, determine which way the current is flowing in the cable. Connect the 73 Digital Multimeter positive lead to the end of the cable nearest battery positive.
7. Connect the multimeter negative lead to the terminal at the other end of the cable.
8. Crank the engine and observe the voltage reading. The voltage reading should be 0.5 volts or lower. If the voltage drop is too high, clean the terminal ends. Retest, and if still high, replace the cable. If the voltage reading is less than 0.5 volts and the engine still cranks slowly, replace the starter motor.

Starter Drive and Flywheel Ring Gear Inspection

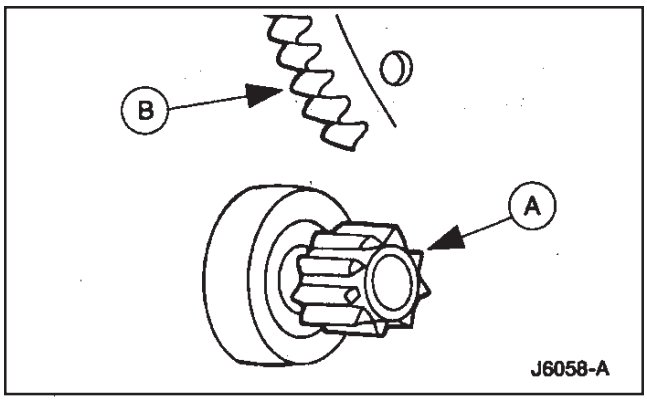
Pinion and Ring Gear Wear Patterns



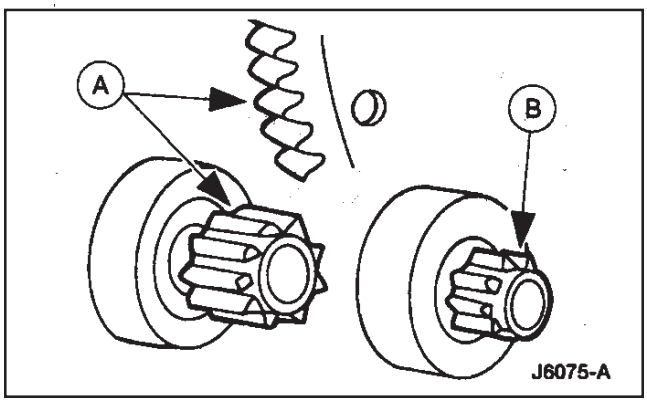
(1) **NORMAL WEAR PATTERN**
(A) Armature Gear
(B) Flywheel Gear

(2) **SMALL WEAR PATTERN**
(A) Armature Gear
(B) Flywheel Gear

(3) **MILLED GEARS**
(A) Armature Gear
(B) Flywheel Gear
(C) Milled Condition Excessive Wear on 3 or 3 Teeth
(D) Milled Tooth Metal Build-up Will Not Permit Engagement

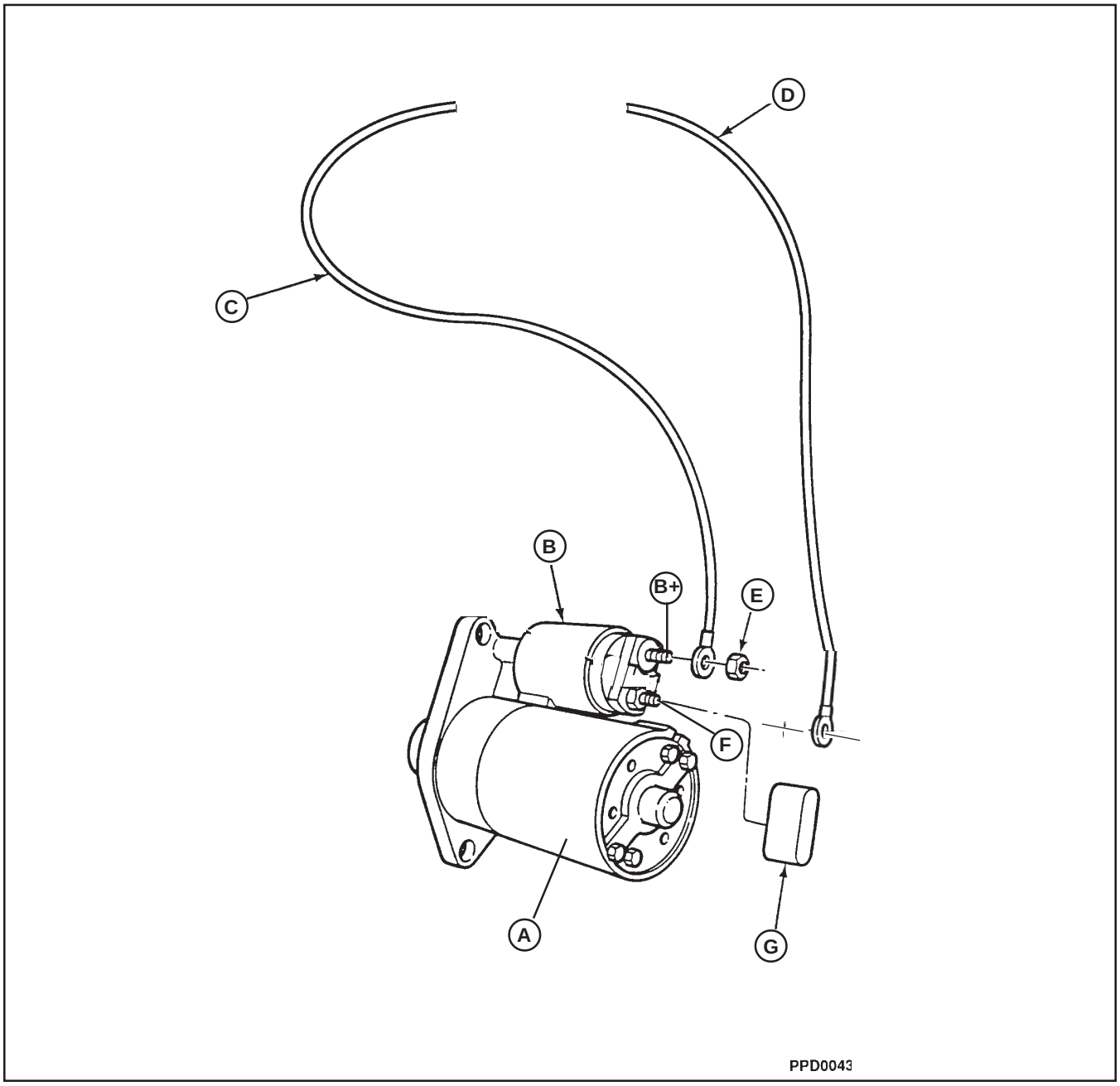


1. Check the wear patterns on the (A) starter drive (11350) and the (B) flywheel ring gear. If the wear pattern is normal, install the starter motor; refer to Starter Motor - Installation on page 07-18.



2. If the (A) starter drive gear and the flywheel ring gear are not fully meshing or the gears are (B) milled or damaged, replace the starter motor; refer to Starter Motor - Installation on page 07-18. Replace the flywheel ring gear.

REMOVAL AND INSTALLATION



CAUTION: A jumper wire must not be installed between the large round electrical terminal and the solenoid blade terminal at the starter. If done, voltage is generated to the solenoid by the spinning starter after release of the start key or button, causing the starter to remain engaged, resulting in failure.

(A) Permanent Magnet Starter

(B) Starter Motor Solenoid

(B+) 12 Volt Battery Supply Terminal

(C) Starter Cable

(D) B+ when relay is energized from ignition switch in crank position to “S” Terminal

(E) Nut

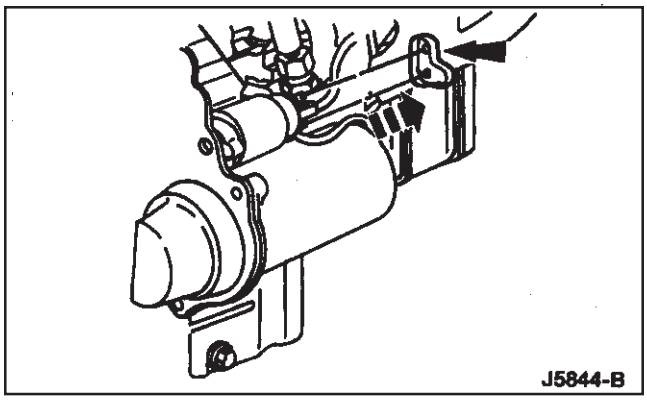
(F) Starter Solenoid Ignition Feed

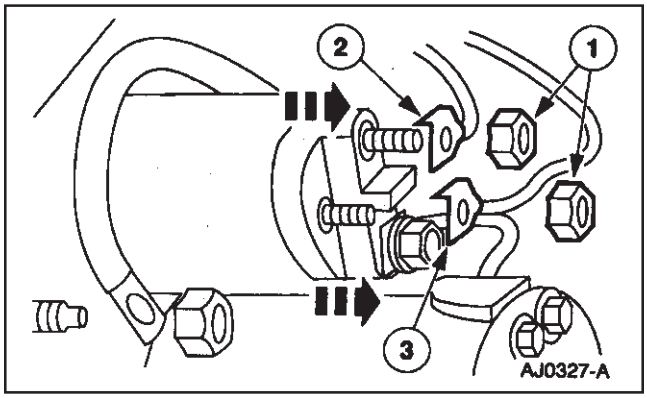
(G) Terminal Cover

Starter Motor - Removal

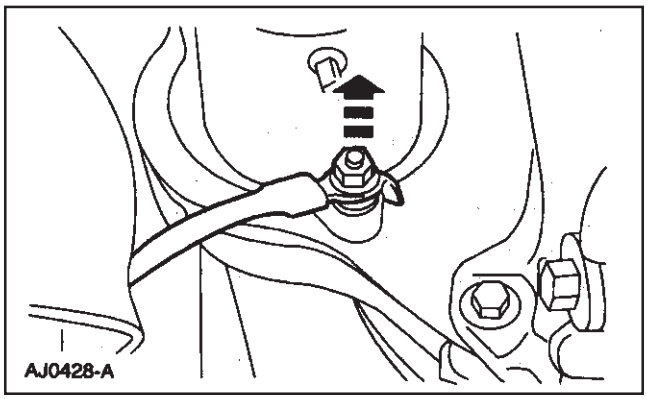
WARNING: WHEN CARRYING OUT MAINTENANCE ON THE STARTER SYSTEM BE AWARE THAT HEAVY GAUGE LEADS OR CONNECTED DIRECTLY TO THE BATTERY. MAKE SURE PROTECTIVE CAPS ARE IN PLACE WHEN MAINTENANCE IS COMPLETE. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

1. Disconnect the battery ground cable.
2. Raise and support the vehicle or equipment.
3. Remove the starter motor solenoid terminal cover (11N087).

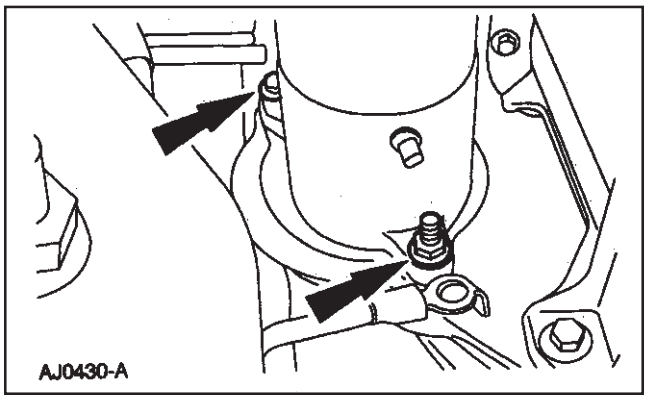




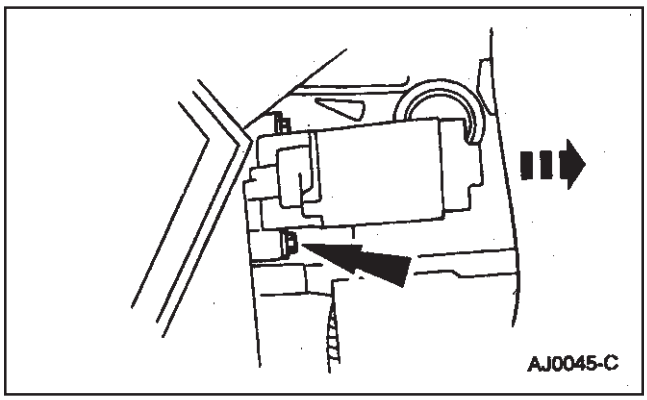
4. Disconnect the starter motor electrical connections.
   1. Remove the two nuts.
   2. Remove the battery cable.
   3. Remove the starter solenoid wire.



5. Remove the nut and the starter motor ground cable when equipped.



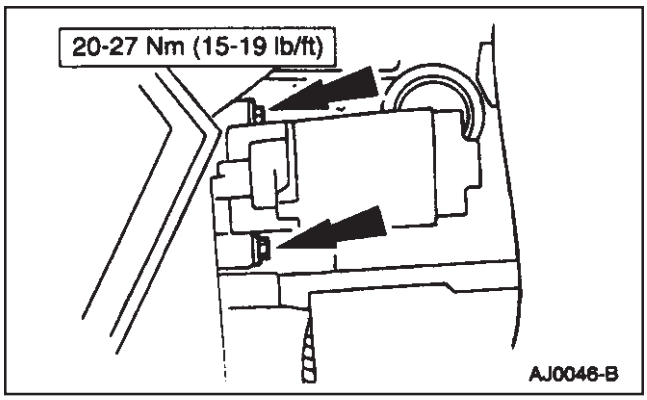
6. Remove the bolt and nut.



7. Remove the starter motor.

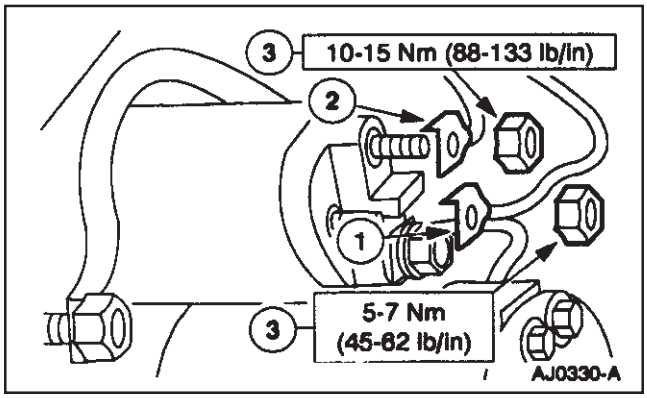
Starter Motor - Installation

WARNING: WHEN CARRYING OUT MAINTENANCE ON THE STARTER SYSTEM BE AWARE THAT HEAVY GAUGE LEADS ARE CONNECTED DIRECTLY TO THE BATTERY. MAKE SURE PROTECTIVE CAPS ARE IN PLACE WHEN MAINTENANCE IS COMPLETE. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

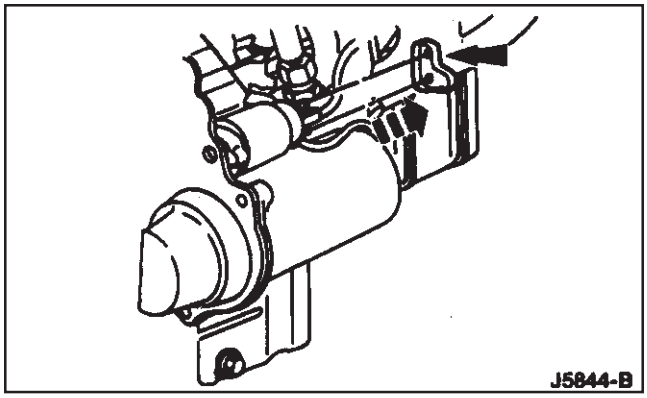


NOTE: It is recommended that wiring service kit F2PZ-11K162-A be used, which includes a 70 inch long #12 gauge wire, a terminal nut, a terminal cover, four tie wraps and insulation instructions.

1. Install the starter motor.
    1. Position the starter motor.
    2. Install the bolts.



2. Connect the starter motor electrical connections.
    1. Position the starter solenoid wire.
    2. Position the battery cable.
    3. Install the nuts.



3. Install the starter motor solenoid terminal cover.
4. Connect the battery ground cable.

SPECIFICATIONS

Torque Specifications

Description	Nm	Lb-In
Brush Plate Screw	2.3-3.4	20-30
Mounting Bolt	20.3-27	15-20 (Lb-Ft)
Solenoid Bolt	5.1-9.6	45-85
Starting Circuit Max. Voltage Drop (Engine Temp. Normal) Volts		0.5
Terminal Nut "S"	10-14	84-120
Terminal Nut "B"	10-14	84-120
Through-Bolt	5.0-9.5	45-84

Electrical Specifications

Voltage Drop	
Starting circuit maximum voltage drop (engine temp. normal)	0.5 volts

General Specifications

Starter Motor								Starter Brushes			
Motor Diameter		Current Draw Under Normal Load	Normal Engine Cranking Speed *	Min. Stall Torque @ 5 Volts		Max. Load	No Load	Mfg. Length		Spring Tension	
mm	Inches	Amps	RPM	Nm	Lb-Ft	Amps	Amps	mm	Inches	N	oz.
108	4	130-220	140-220	14.7	11.0	800	70 ± 10	16.8	0.66	18	64

Maximum commutator runout is 0.12mm (0.005 inch). Maximum starting circuit voltage drop (battery positive terminal to starter terminal) at normal engine temperature is 0.5 volt.

*NOTE: Engine may not start if cranking speed is below 140 RPM.

Special Tools

Rotunda Equipment

Tool Number	Description
105-R0057	Digital Volt/Ohm Meter (DVOM)

Special Service Tools called for by the procedures can be obtained by calling:
1-800-ROTUNDA (1-800-768-8632).