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Engine Cooling

Specifications

Fastener Tightening Specifications

Application	Specification	
	Metric	English
Coolant Outlet Bolt	19 N.m	14 lb ft
Coolant Recovery Pipe Mounting Bolt	14 N.m	124 lb in
Coolant Recovery Reservoir Mounting Bolt	6 N.m	53 lb in
Coolant Recovery Tank Mounting Bracket Bolt	30 N.m	22 lb ft
Fan Adapter to Water Pump Bolt	68 N.m	50 lb ft
Fan Shroud Bolt	6 N.m	53 lb in
Fan Clutch Nut	145 N.m	107 lb ft
Fan to Fan Clutch Bolt	21 N.m	16 lb ft
Radiator Hose Clamp	5 N.m	44 lb in
Radiator Support Brace Nut	55 N.m	41 lb ft
Radiator Support Side Mounting Bolt	65 N.m	48 lb ft
Radiator Support Top Cover Bolt	25 N.m	18 lb ft
Surge Tank Bolt	6 N.m	53 lb in
Tensioner Lock Nut	63 N.m	46 lb ft
Water Duct Bolt (M8)	19 N.m	14 lb ft
Water Duct Bolt (M16)	125 N.m	92 lb ft
Water Pump Bolt	19 N.m	14 lb ft

Engine Cooling System Specifications

Application	Specification	
	Metric	English
Pump Spindle Interferences		
Shaft to Pulley Center	0.048–0.078 mm	0.0019–0.0031 in
Shaft to Impeller	0.027–0.120 mm	0.0011–0.0047 in
Seal Height	11.0—11.6 N.m	0.433—0.457 in

Diagnostic Information and Procedures

Engine Overheating

Problem	Action
The engine temperature gauge is faulty.	Replace the engine temperature gauge. Refer to Body and Accessories.
The engine temperature gauge sensor is faulty.	Replace the engine temperature gauge sensor. Refer to *Engine Coolant Temperature Sensor Replacement* in Body and Accessories.
The operator exhibits poor driving habits.	Refer to the owner's manual.
The engine idling is prolonged.	Refer to the owner's manual.
The engine is lugging.	Refer to the owner's manual.
The brakes are dragging.	Adjust the brakes as needed. Refer to Brakes.
The engine coolant is frozen.	Allow the coolant to thaw.
The belt tension is incorrect.	Adjust the belt tension. Refer to Engine Mechanical.
The radiator is restricted.	Repair the restriction as needed. Refer to *Radiator Cleaning.*
The cooling fan is incorrect.	Install the correct fan. Refer to *Fan Replacement (Fan Blade).*
The exhaust is restricted.	Repair the restriction as needed. Refer to *Restricted Exhaust.*
The thermostat is incorrect.	Install the correct thermostat. Refer to *Thermostat Replacement.*
The water pump is faulty.	Replace the water pump. Refer to *Water Pump Replacement.*
The ignition timing is incorrect.	Adjust the ignition timing. Refer to Engine Mechanical.
The engine oil level is low.	Fill the engine oil to the correct level. Refer to *Approximate Fluid Capacities* in General Information.
The radiator grille is blocked.	Repair the grille as needed. Refer to *Radiator Cleaning.*
The radiator shroud or the baffles are missing.	Install the correct radiator shroud or the baffles. Refer to *Fan Shroud Replacement* or *Radiator Lower Mounting Panel Replacement.*
The thermostatic fan is faulty.	Replace the thermostatic fan clutch. Refer to Engine Mechanical.
The cooling fan is faulty.	Replace the fan. Refer to *Fan Replacement (Fan Blade).*
The engine thermostat is faulty.	Replace the thermostat. Refer to *Thermostat Replacement.*
The cooling system is plugged.	1. Repair the system as needed. 2. Drain the system. Refer to *Draining and Filling Cooling System (Draining).* 3. Flush the system. Refer to *Flushing.*

Loss of Coolant

Problem	Action
The coolant hoses are faulty.	Replace the hoses, as necessary. Refer to *Radiator Hose Replacement (Upper)* or *Radiator Hose Replacement (Lower).*
The drive belts are faulty.	1. Replace the belts. 2. Adjust the belt tension. Refer to Engine Mechanical.
The coolant hose clamps are faulty.	Replace the clamps, as necessary. Refer to *Radiator Hose Replacement (Upper)* or *Radiator Hose Replacement (Lower).*
The coolant drain plugs are loose.	Tighten the coolant drain plugs.
The radiator drain cock is loose.	Tighten the radiator drain cock as needed.
The radiator core is leaking.	Repair the radiator core as needed. Refer to *Radiator Replacement.*
The gaskets are leaking.	Repair or replace the gaskets as needed.
The radiator cap is faulty.	Replace the radiator cap.
The belt tension is incorrect.	Adjust the belt tension. Refer to Engine Mechanical.
The radiator is restricted.	Repair the restriction as needed. Refer to *Radiator Cleaning.*
The radiator grille is blocked.	Repair the grille as needed. Refer to *Radiator Cleaning.*
The radiator shroud or the baffles are missing.	Install the correct radiator shroud or baffles. Refer to *Fan Shroud Replacement* or *Radiator Lower Mounting Panel Replacement.*
The water pump is faulty.	Replace the water pump. Refer to *Water Pump Replacement.*
The cooling fan is faulty.	Replace the fan. Refer to *Fan Replacement (Fan Blade).*
The thermostatic fan clutch is faulty.	Replace the thermostatic fan clutch. Refer to Engine Mechanical.
The cooling system is plugged.	1. Repair the cooling system as needed. 2. Drain the system. Refer to *Draining and Filling Cooling System (Draining).* 3. Flush the system. Refer to *Flushing.*
The engine thermostat is faulty.	Replace the thermostat. Refer to *Thermostat Replacement.*
The engine thermostat is incorrect.	Install the correct thermostat. Refer to *Thermostat Replacement.*
The surge tank is faulty.	Repair or replace the surge tank. Refer to *Surge Tank (Diesel) Replacement.*
The heater hoses or the heater core is plugged.	Repair or replace the heater hoses of the heater core, as necessary.
The head gasket is leaking.	Repair or replace the head gasket, as necessary.
The engine temperature gauge sensor is faulty.	Replace the engine temperature gauge sensor. Refer to *Engine Coolant Temperature Sensor Replacement* in Body and Accessories.

Thermostat Diagnosis

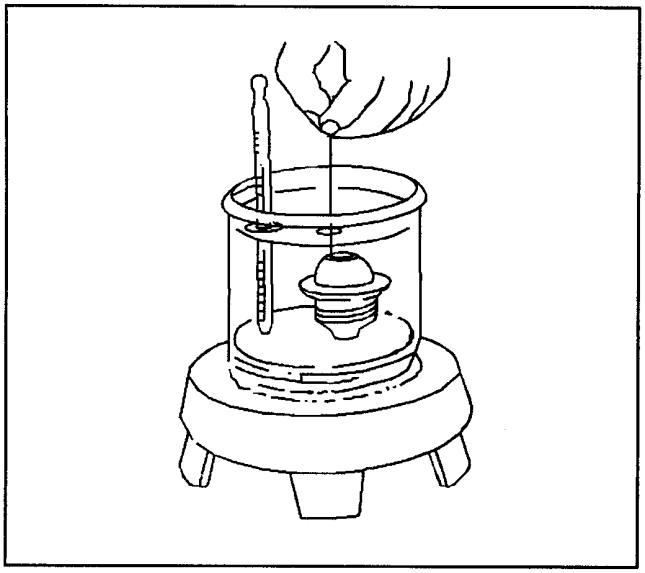
A thermostat that remains closed or only partially open restricts the flow of coolant in the system.

A faulty thermostat may cause the engine to overheat.

A thermostat that sticks in the full open position prevents the engine from reaching the normal operating temperature. Cold engine operation may cause a buildup of excess carbon deposits on the following components:

- The pistons
- The rings
- The valves

1. Remove the thermostat assembly.
   Refer to *Thermostat Replacement.*



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2. Suspend the thermostat and a thermometer in water. Place the thermostat near the thermometer.
3. Heat the water.
4. Record the temperature at which the thermostat begins to open.
5. Record the temperature at which the thermostat is open.
6. Compare the temperature readings with the Engine Thermostats.
7. Replace the thermostat and the gasket as needed.
   Refer to *Thermostat Replacement.*
8. Fill the cooling system.
9. Run the engine until the engine reaches normal operating temperature.
10. Inspect for coolant leaks around the thermostat housing and the gasket.
11. Inspect the coolant level. Add additional coolant as necessary.
12. Install the radiator cap.

Fan Clutch Diagnosis (Noise)

Fan noise may occur when the following normal conditions exist:

- The clutch is engaged for maximum cooling
- The fan has been running for 15–60 seconds.
  The clutch cannot redistribute the silicone fluid back to the normal disengaged operating condition (after overnight settling) for the first 15 seconds.

Fan noise or an excessive roar may occur continuously when the following conditions exist:

- The engine is operating at a high speed.
  A high speed is 2,500 RPM or more.
- The clutch assembly locks up due to an internal failure.

Replace the clutch if the following conditions exist:

- Rotating the fan by hand is impossible.
- A rough grating feeling exists while turning the fan.

Refer to *Fan Replacement (Fan Blade).*

Fan Clutch Diagnosis (Looseness)

Inspect a loose fan assembly for wear. Replace the fan assembly as necessary.

A visible lateral movement at the tip of the fan blade under is visible at various temperature conditions. Approximately 6.5 mm (1/4 in) maximum lateral movement, measured at the fan tip, is allowed. This movement is not cause for replacement.

Fan Clutch Diagnosis (Silicone Fluid Leaks)

The fan clutch operation is not affected by small fluid leaks which may occur around the bearing assembly. If the leakage appears excessive, replace the fan clutch.

Refer to *Fan Replacement (Fan Clutch).*

Fan Clutch Diagnosis (Engine Oveheating)

1. Verify that the engine is cool. A cool engine will ensure complete disengagement of the fan clutch.
2. Spin the clutch assembly by hand. The clutch assembly free-wheels if the assembly rotates more than five times.
3. If the fan and the clutch assembly free-wheel with no drag, replace the clutch.
4. If the clutch performs correctly with a slight drag, continue with the following procedure.

   Notice: Check for adequate clearance between the fan blades and the thermometer sensor before starting the engine, as damage could occur.
5. Place a thermometer between the fan blades and the radiator.

6. Insert the thermometer sensor through one of the existing holes in the fan shroud or place the thermometer between the radiator and the shroud.

   On some models, you may have to drill a 5 mm (3/16 in) hole in the fan shroud in order to insert the thermometer.
7. Cover the radiator grille in order to induce a high engine temperature.
8. Start the engine.
9. Turn on the air conditioning.
10. Operate the engine at 2,000 RPM.
11. Wait for 5–10 minutes for the clutch to engage.

    Observe the thermometer reading when the clutch engages.

    The following conditions indicate fan clutch engagement:
    - An increase or roar in the fan noise
    - A drop of 3–10 °C (5–15 °F) in the thermometer reading

    Important: Do not continue the test past a thermometer reading of 88 °C (190 °F). This action will prevent engine overheating.
12. Replace the unit if the following conditions exist:
    - The clutch does not engage between 65–90 °C (150–195 °F).

      Ensure that the fan clutch was disengaged at the start of the test.
    - No sharp increase in noise or no temperature drop was evident.
    - The fan noise level remained constantly high from the start of the test to 88 °C (190 °F).
13. As soon as the clutch engages, complete the following steps in order to assist in engine cooling:
    - Remove the radiator grille cover.
    - Turn off the air conditioning.
    - Run the engine at approximately 1,500 RPM.
14. Verify that the fan clutch disengages after several minutes.

    A reduction in fan speed and roar indicates disengagement.
15. Replace the fan clutch if the fan clutch fails to operate as described above.

Coolant Concentration Testing

Tools Required

- *J 26568* Coolant Tester (Centigrade)
- *J 23688* Coolant Tester (Fahrenheit)

Inspect the coolant for freeze protection and contamination.

The following fluids may cause contamination:

- Engine oil
- Automatic transmission fluid, if equipped

Inspect the following qualities of the coolant in order to detect contamination:

- The color
- The smell
- The feel

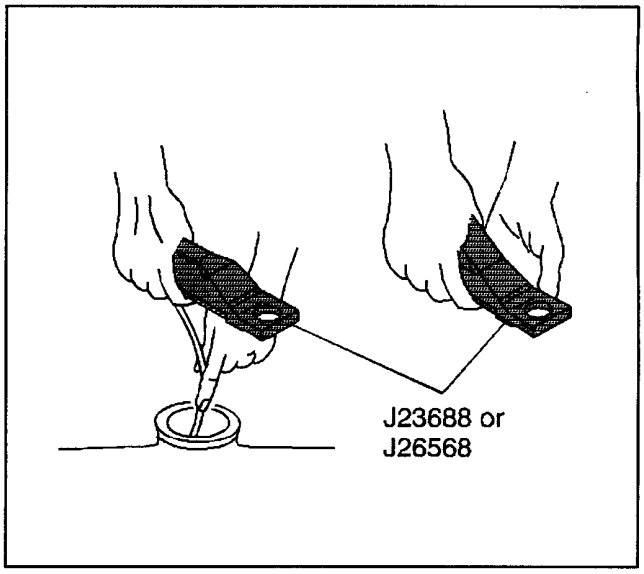
Diagnose and repair the cause of the contamination in order to prevent engine damage.

Use the *J 26568* or the *J 23688* in order to inspect the antifreeze protection of the coolant.

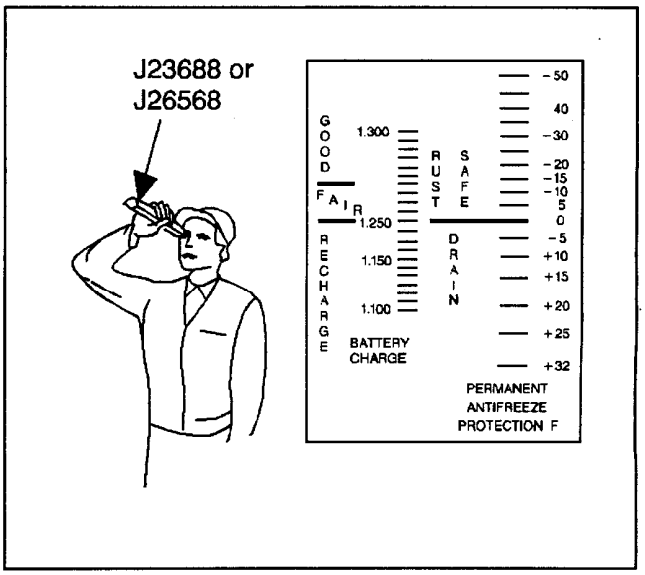
Ensure that the hydrometer markings are correct.

Unless the *J 26568* or the *J 23688* has a provision for temperature correction, test the temperature at which the *J 26568* or the *J 23688* calibrates. If the coolant is warmer or cooler, the reading may be incorrect.

Follow the manufacturer's directions for using the *J 26568* or the *J 23688*.



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Important:

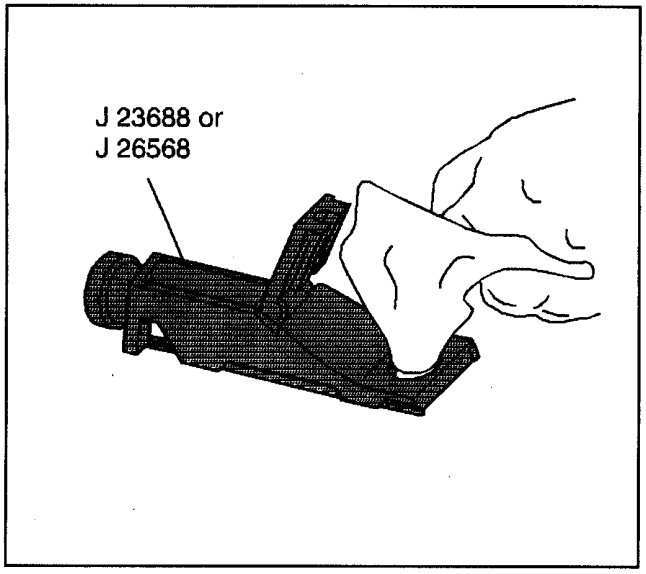
- Do not open the plastic cover when taking the readings.

  The coolant may evaporate. The evaporation may change the readings.
- If the readings are unclear, determine if the measuring surfaces were cleaned and dried.

  Wipe the measuring surfaces dry. Repeat the test.

Use the following procedure in order to clean the coolant tester:

1. Before each use, swing the plastic cover at the end of *J 26568* or *J 23688* in order to expose the measuring window at the bottom of the plastic cover.



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2. Wipe the measuring window dry with a tissue or a clean soft cloth.
3. Close the plastic cover.

Cooling System Leak Testing

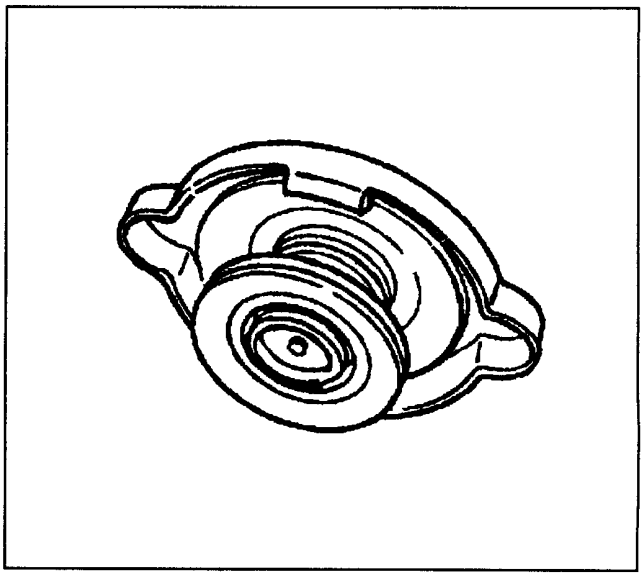
Tools Required

J 24460-01 Cooling System Tester

Caution: To avoid being burned, do not remove the radiator cap while the engine is at normal operating temperature. The cooling system will relieve scalding fluid and steam under pressure if the cap is removed while the engine and radiator are still hot, causing serious injury.

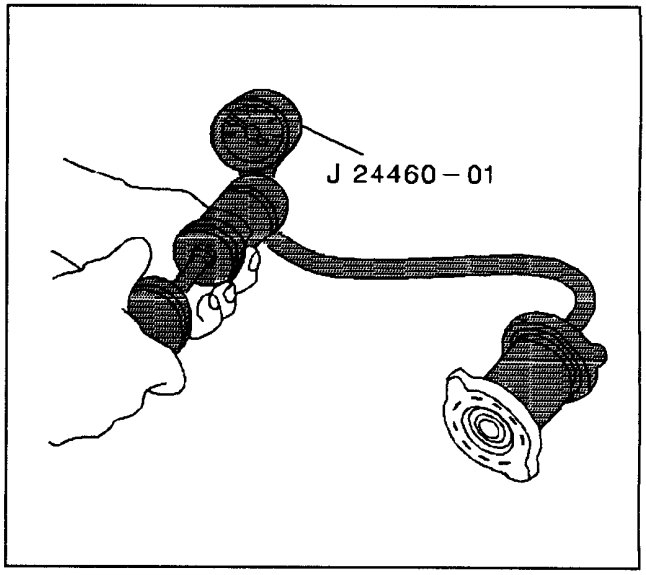
1. Test the radiator cap for correct opening and closing pressures.

   Correct opening and closing pressures ensure the safe, efficient operation of the cooling system. A pressure cap that cannot maintain pressure lowers the boiling point of the engine coolant. A lower boiling point causes the engine cooling system to operate at a higher than normal temperature.
2. Replace any faulty caps.



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3. Remove the radiator cap.
4. Wash off any sediment on the sealing surfaces of the radiator cap.
5. Wet the radiator cap gasket with coolant.



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6. Install the cap to the *J 24460-01*.
7. Operate the plunger handle of the *J 24460-01*.

   Pump up the pressure to the pressure that is stamped on the cap.
8. Note the rate of the decrease in pressure.

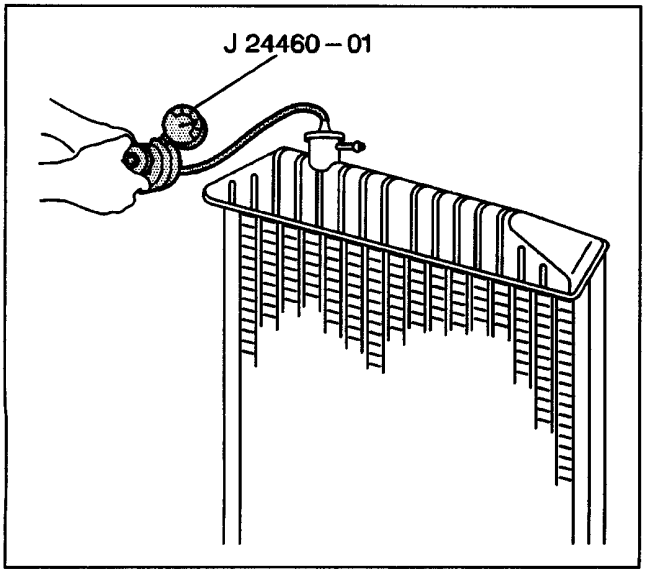
   Verify that the pressure reading remains within the corresponding pressure segment of the scale for about 10 seconds.
9. Replace the cap if the cap does not hold the pressure for 10 seconds.

Cooling System

Tools Required

J 24460-01 Cooling System Tester

1. Tighten the following components:
   - The radiator hose clamps
   - The heater hose clamps
2. Inspect the connections for leaks at the following locations:
   - The surge tank
   - The expansion tank
   - The air compressor coolant lines
3. Remove the filler cap.
4. Fill the cooling system to the level of the filler cap seat.



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5. Attach the *J 24460-01* to the filler neck.
6. Follow the instructions that are supplied with the *J 24460-01*.
7. Increase the pressure to 138 kPa (20 psi).

   Do not exceed 138 kPa (20 psi). The system should hold the pressure for about 2 minutes.

Off-Vehicle Pressure Testing

Notice: Do not use boil-out tanks or vats or other tanks that have been used for copper or brass radiators. The flux, acid, and caustic cleaners remaining in these tanks and will attack the aluminum and cause radiator failure. Use a separate test tank containing clean water for servicing aluminum/plastic radiators.

1. Install test fittings or rubber test caps in the inlet and the outlet necks.
2. Seal the oil cooler fittings with metal plugs.

   Sealing the fittings will protect the cooler and prevent fluid loss.
3. Attach the pressure tester.
4. Gradually apply air pressure until 138 kPa (20 psi) is attained.

   Do not exceed 138 kPa (20 psi).
5. Inspect the gauge in order to see if a pressure leak exists.
6. Run a mixture of water and mild detergent over the radiator.

   Inspect for bubbles in order to ensure that no leaks exist. Bubbles indicate leaks.

Repair Instructions

Draining and Filling Cooling System (Cooling System)

Notice: Two sealant pellets must be added to the radiator whenever the coolant system is drained and refilled with fresh coolant. Failure to use the correct sealant pellets may result in premature water pump leakage. Do not add pellets to the coolant recovery bottle since this may prevent the coolant system from operating properly.

Draining and Filling Cooling System (Draining)

Caution: To avoid being burned, do not remove the radiator cap while the engine is at normal operating temperature. The cooling system will relieve scalding fluid and steam under pressure if the cap is removed while the engine and radiator are still hot, causing serious injury.

1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
2. Place a drain pan under the radiator drain cock.
   Ensure that the capacity of the drain pan is at least 30 liters (32 quarts).
3. Ensure that the cooling system is cool.
4. Remove the radiator cap.
5. Open the drain cock. The drain cock is located at the bottom of the radiator. Allow the cooling system to drain until the coolant flow stops.
6. Open the following components:
   - The cylinder block
   - The accessory drain cocks
   - The plugs

   Allow the engine block to drain until the coolant flow stops.

   The radiator may drain more while the engine block drains.
7. Disconnect the coolant hose from the air compressor, if equipped.
8. Close the engine block drain plugs.
9. Close the radiator drain cock.

Draining and Filling Cooling System (Filling)

Do not use more than 70 percent antifreeze coolant solution or the coolant freeze point will begine to rise and the coolant will not be as effective. In order to avoid coolant loss, do not overfill the radiator.

1. Ensure that the radiator drain cock is closed.
2. Ensure that the engine drain plugs are tight.
3. Fill the cooling system with cooling solution.
4. Start the engine.
5. Run the engine for a few minutes in order to vent the air.
6. Add more coolant, if necessary.
7. Ensure that the engine is at normal operating temperature.
8. Fill coolant to the HOT LEVEL of the coolant recovery bottle, if equipped.
9. Fill the surge tank to the appropriate level.
   The system should hold approximately 30 liters (32 quarts).
   - If the engine is cold, fill the surge tank to the sight glass,
   - If the engine is warm, fill the surge tank to the filler neck.
10. Run the engine in order to remove air from the system.
11. Fill coolant to the HOT LEVEL of the coolant recovery bottle, if equipped.
12. Ensure that the coolant is sufficiently cool.
13. Ensure that pressure is off the system.
14. Remove the radiator cap.
15. Install the radiator cap.
16. Lower the cab.

Flushing

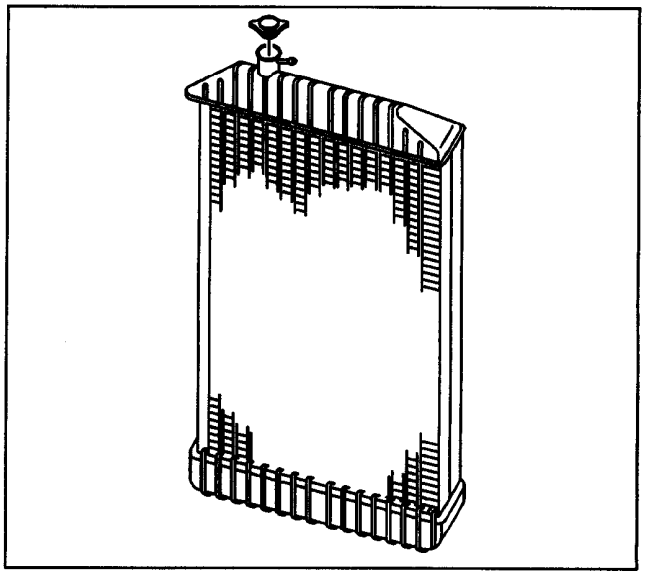
You can use various methods and equipment to flush the cooling system. If special equipment is used (such as a back flusher) follow the manufacturer's instructions. However, always remove the thermostat before flushing the system.

Radiator Cleaning

An engine may overheat when the following conditions exist:

1. The radiator core is dirty.
2. The radiator core is obstructed.
3. The radiator leaks.
4. Use any of the following materials in order to clean the outside of the radiator:
   - A soft bristle brush and clean hot water (or a mild detergent such as car wash or dishwashing liquid)
   - A common city water hose without the nozzle (in order to avoid damage to the fins)
5. Pressure flush the core tubes with clean hot water or a mild detergent in order to clean the inside of the tubes.
6. Use the following procedure in order to test for restrictions in the radiator:
   6.1. Turn on the engine in order to warm the engine.
   6.2. Turn off the engine.
   6.3. Feel the radiator.
   Verify that the following conditions exist:
   - The radiator is hot on the top.
   - The radiator is warm on the bottom.
   - The temperature rises evenly from the top to the bottom of the radiator.

   Cold spots in the radiator indicate clogged sections.

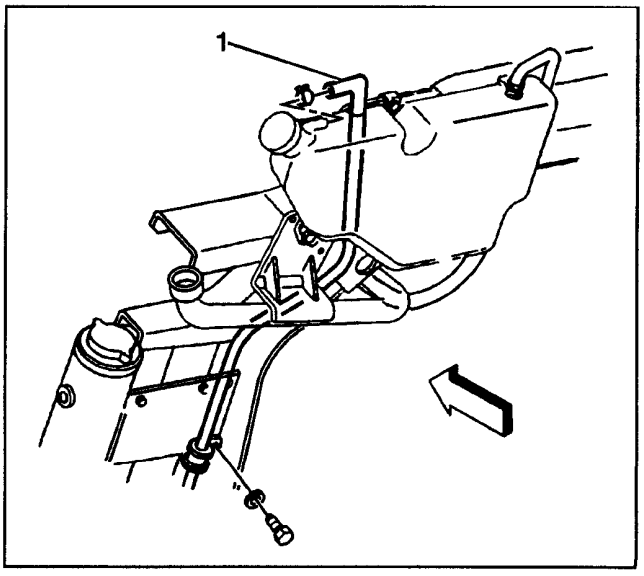


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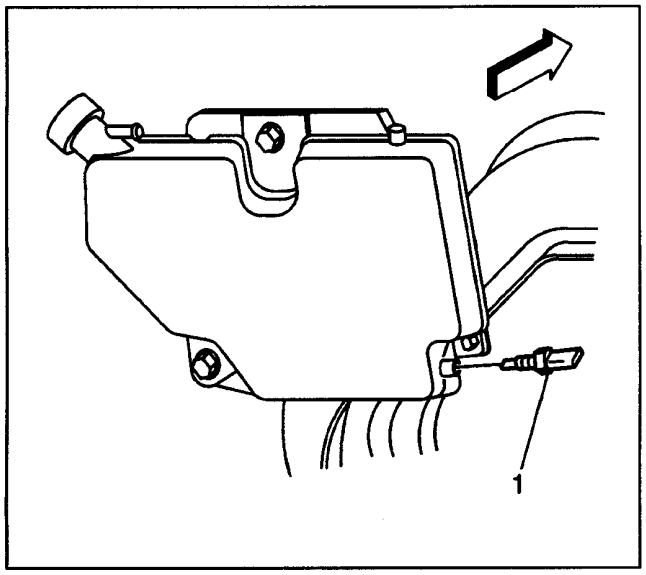
Surge Tank (Diesel) Replacement

Removal Procedure

1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Partially drain the cooling system.
   Refer to *Draining and Filling Cooling System (Draining)*.
4. Remove the following components:
   - The radiator surge tank inlet hose
   - The clamps
5. Remove the following components:
   - The radiator surge tank outlet hose (1)
   - The clamps
6. Remove the following components:
   - The surge tank overflow hose
   - The clamp

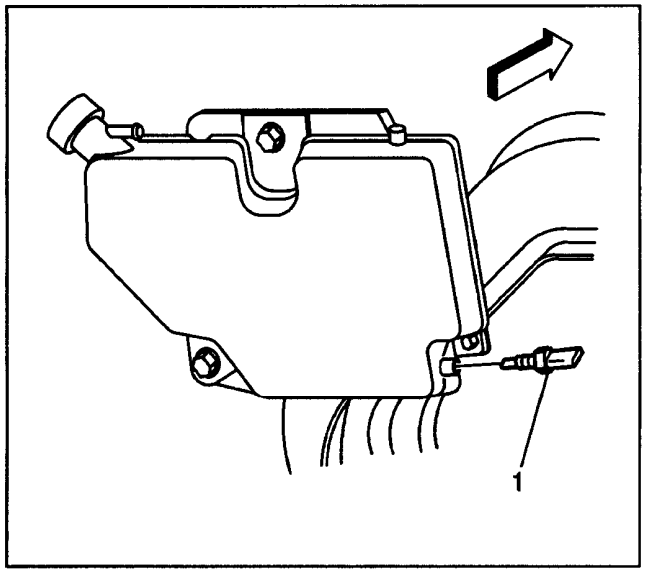


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7. Remove the low coolant sensor (1).
8. Remove the radiator surge tank cap.
9. Remove the radiator surge tank bolts.
10. Remove the radiator surge tank from the mount.
11. Inspect the radiator surge tank for cracks.
12. Replace the surge tank if the surge tank is damaged.



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Installation Procedure

1. Install the radiator surge tank to the mount.

   Notice: Refer to *Fastener Notice* in Caution and Notices.
2. Install the radiator surge tank bolts.

   Tighten

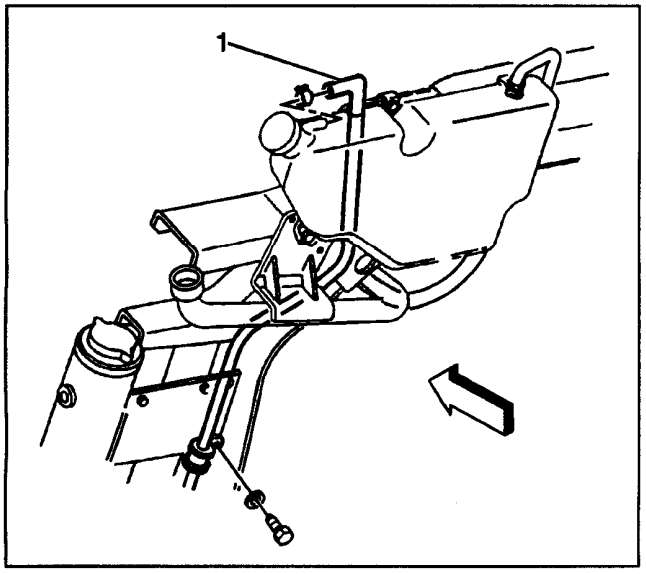
   Tighten the radiator surge tank bolts to 6 N·m (53 lb in).
3. Install the low coolant sensor (1).
4. Install the radiator surge tank inlet hose and the clamps.

   Tighten

   Tighten the clamps to 3 N·m (27 lb in).
5. Install the radiator surge tank outlet hose and the clamps.

   Tighten

   Tighten the clamps to 3 N·m (27 lb in).



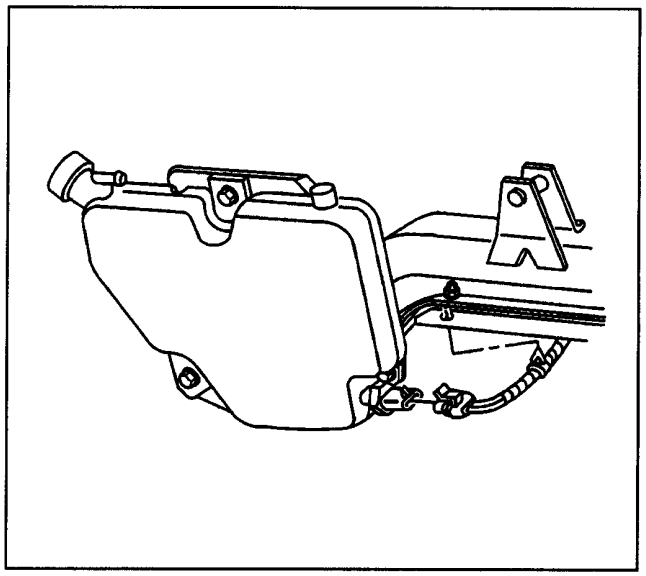
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6. Install the surge tank overflow hose (1) and the clamp.
7. Connect the negative battery cable.
8. Fill the cooling system.
9. Inspect the system for leaks.
10. Install the surge tank pressure cap.
11. Lower the cab.

Coolant Recovery Reservoir Replacement

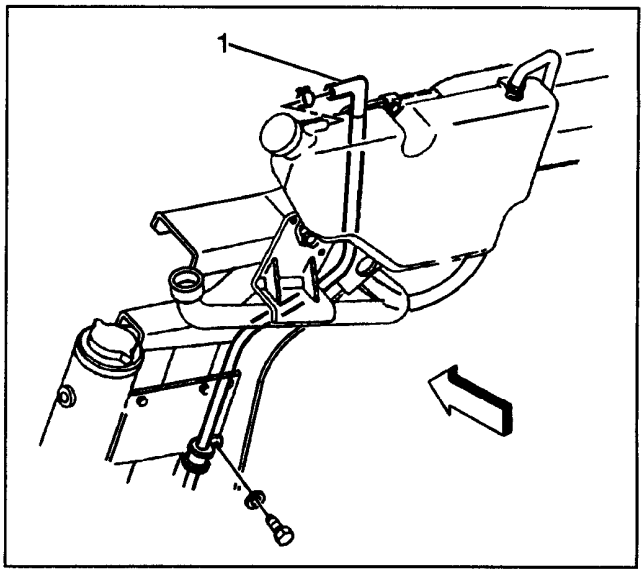
Removal Procedure

1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Partially drain the cooling system.
   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the following components:
   - The coolant recovery reservoir hose
   - The clamps



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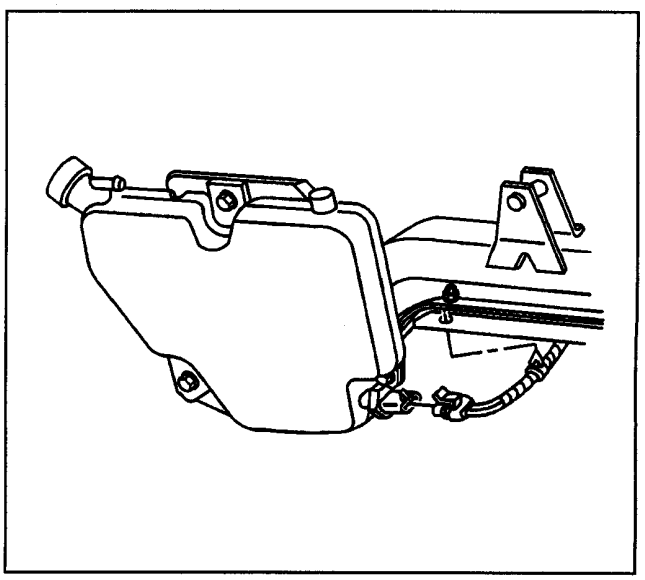
5. Remove the following components:
   - The recovery reservoir overflow hose (1)
   - The clamp
6. Remove the coolant recovery reservoir bolts.
7. Remove the coolant recovery reservoir.
8. Inspect the coolant recovery reservoir for the following conditions:
   - Cracks
   - Weak points
9. Replace the reservoir if the reservoir is damaged.
10. Inspect the recovery tank mounting bracket for cracks.
11. Replace the mounting bracket if necessary.



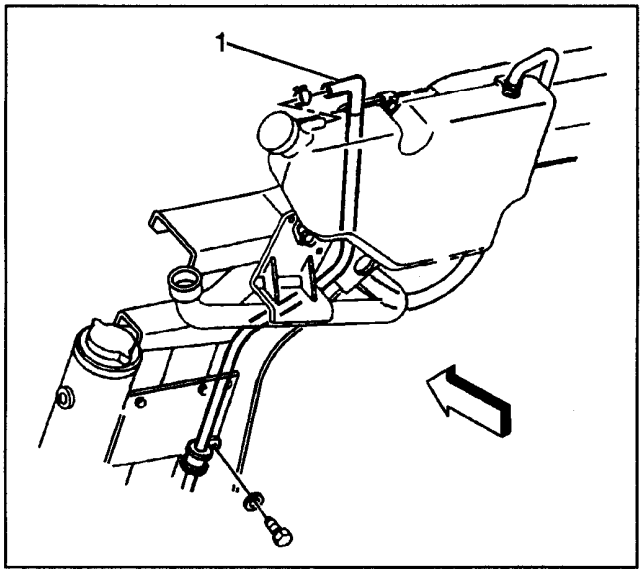
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Installation Procedure

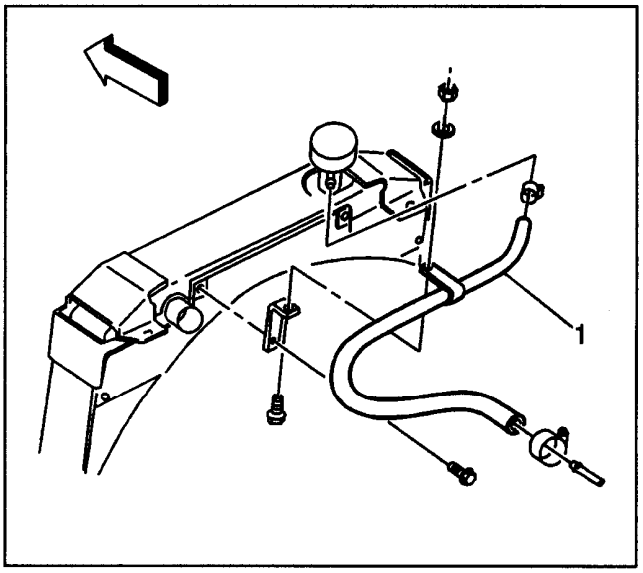
1. Install the coolant recovery reservoir to the mount.
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the coolant recovery reservoir bolts.
   Tighten
   Tighten the recovery reservoir bolts to 6 N·m (53 lb in).



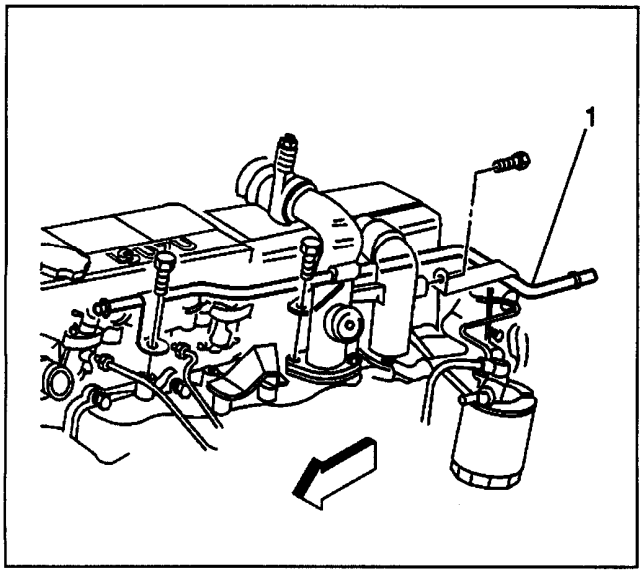
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3. Install the following components:
   - The recovery reservoir overflow hose (1)
   - The clamp

   Tighten

   Tighten the clamp to 3 N·m (27 lb in).
4. Install the following components:
   - The coolant recovery reservoir hose
   - The clamps

   Tighten

   Tighten the clamp to 3 N·m (27 lb in).
5. Connect the negative battery cable.
6. Fill the cooling system.
7. Inspect the system for leaks.
8. Lower the cab.

Coolant Recovery Pipe Replacement

Removal Procedure

1. Tilt the cab.

   Refer to *Cab Tilting* in General Information.

   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Partially drain the cooling system.

   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the following components:
   - The radiator recovery hose (1)
   - The clamp
5. Remove the following components:
   - The coolant recovery reservoir hose
   - The clamp
6. Remove the following components from the mounting brackets:
   - The bolts
   - The washers
7. Remove the radiator recovery pipe (1).
8. Inspect the following components for cracks, leakage and faulty conditions:
   - The radiator
   - The recovery reservoir
   - The hoses

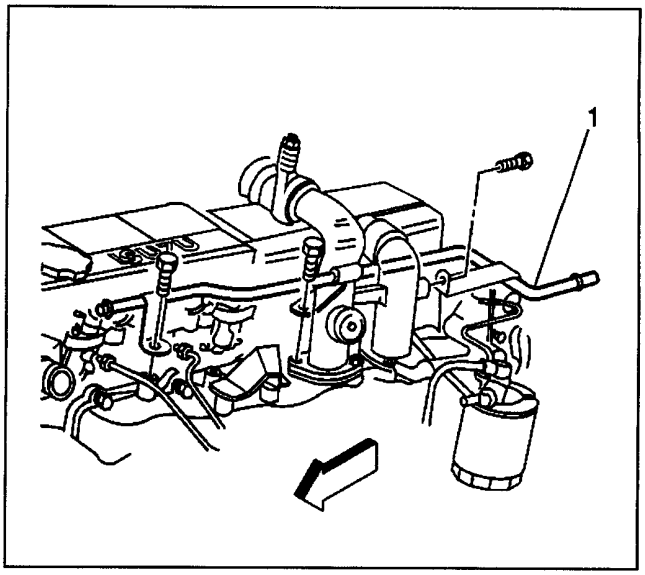
Installation Procedure

1. Install the radiator recovery pipe (1).

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the following components to the mounting brackets.
   - The bolts

     Tighten

     Tighten the mounting bolts to 14 N·m (124 lb in).
   - The washers



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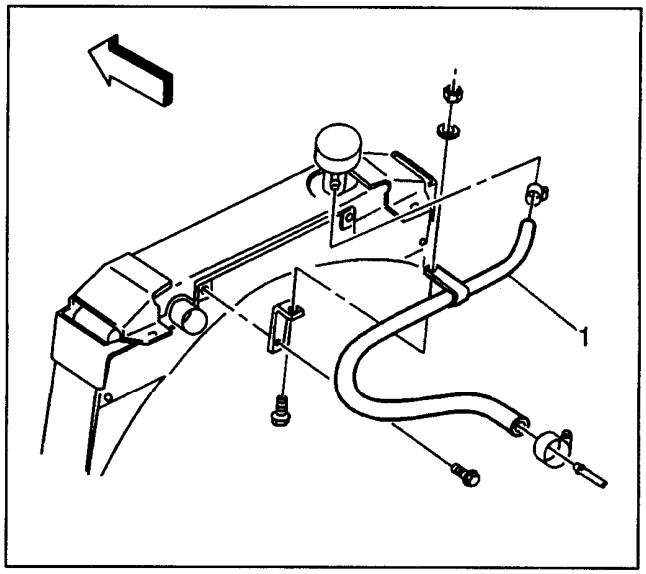
3. Install the following components:
   - The radiator recovery hose (1)
   - The clamp

     Tighten

     Tighten the clamps to 3 N·m (27 lb in).
4. Install the following components:
   - The coolant recovery reservoir hose
   - The clamp

     Tighten

     Tighten the clamp to 3 N·m (27 lb in).
5. Connect the negative battery cable.
6. Fill the cooling system.
7. Inspect the system for leaks.
8. Lower the cab.



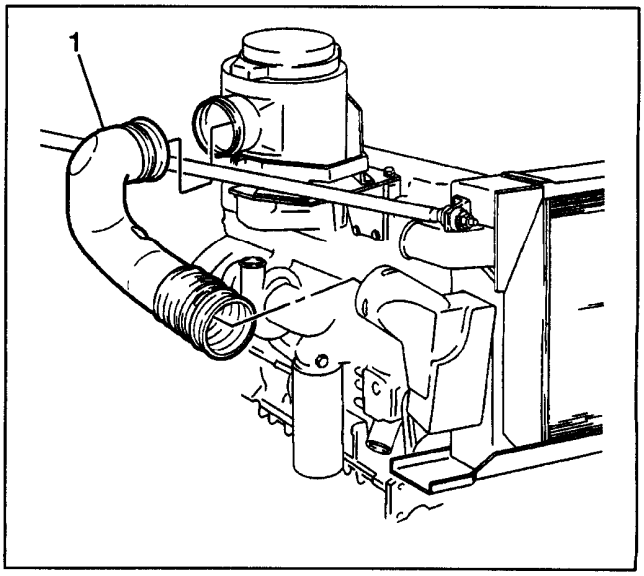
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Surge Tank Pipe Replacement - Inlet

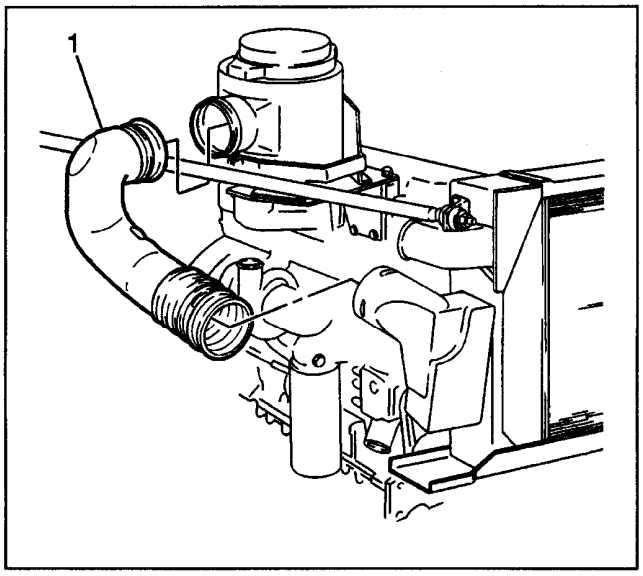
Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable.

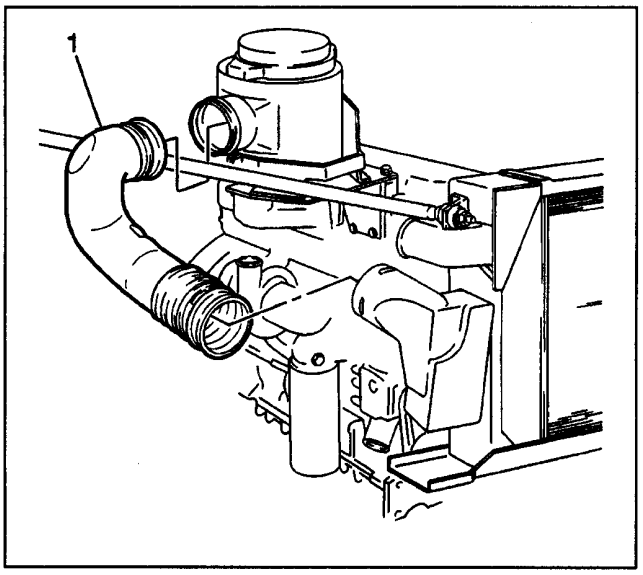
   Refer to *Battery Cable Replacement* in Engine Electrical.
2. Remove the front wheelhouse panel.
3. Remove the front intake air duct (1) from the air filter housing.
4. Drain the coolant. Refer to *Draining and Filling Cooling System (Draining).*
5. Remove the radiator surge tank inlet hose and the clamp.
6. Remove the surge tank inlet pipe.



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7. Inspect the following components for cracks or leaks:
   - The radiator
   - The surge tank
   - The pipes
   - The hoses

Installation Procedure

Notice: Refer to *Fastener Notice* in Cautions and Notices.

1. Install the surge tank inlet pipe.
   Tighten
   Tighten the flare nut on the 6.6L engine only to 35 N.m (26 lb ft).
2. Install the radiator surge tank inlet hose and the clamp.
   Tighten
   Tighten the radiator surge tank hose clamp to 3 N.m (27 lb in).
3. Install the front intake air duct (1) to the air filter housing.
4. Install the front wheelhouse panel.
5. Connect the negative battery cable.
6. Fill the cooling system. Refer to *Draining and Filling Cooling System (Draining).*
7. Check the system for leaks.

Surge Tank Pipe Replacement - Outlet

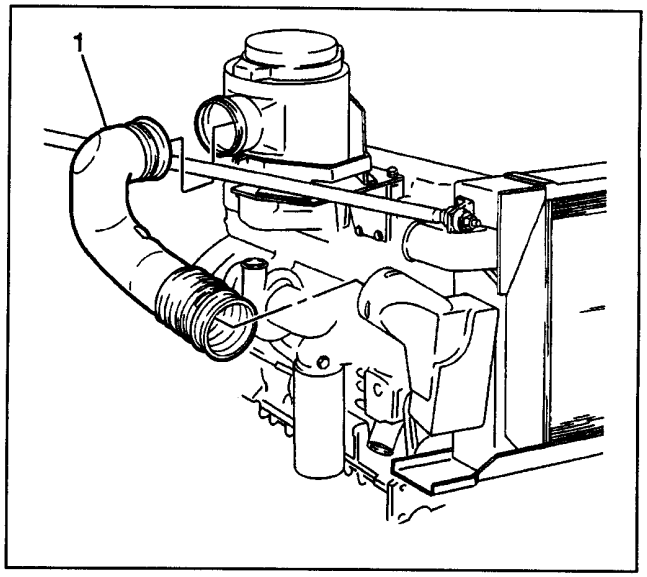
Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable.
   Refer to *Battery Cable Replacement* in Engine Electrical.
2. Remove the front wheelhouse panel.
3. Remove the front intake air duct (1) from the air filter housing.
4. Drain the coolant. Refer to *Draining and Filling Cooling System (Draining).*
5. Remove the radiator surge tank outlet hose and the clamp.
6. Remove the surge tank outlet pipe.
7. Inspect the following components for cracks or leaks:
   - The radiator
   - The surge tank
   - The pipes
   - The hoses

Installation Procedure

Notice: Refer to *Fastener Notice* in Cautions and Notices.

1. Install the surge tankoutlet pipe.
   Tighten
   Tighten the flare nut on the 7.2L engine only to 35 N·m (26 lb ft).
2. Install the radiator surge tank outlet hose and the clamp.
   Tighten
   Tighten the radiator surge tank hose clamp to 3 N·m (27 lb in).
3. Install the front intake air duct (1) to the air filter housing.
4. Install the front wheelhouse panel.
5. Connect the negative battery cable.
6. Fill the cooling system. Refer to *Draining and Filling Cooling System (Draining).*
7. Check the system for leaks.

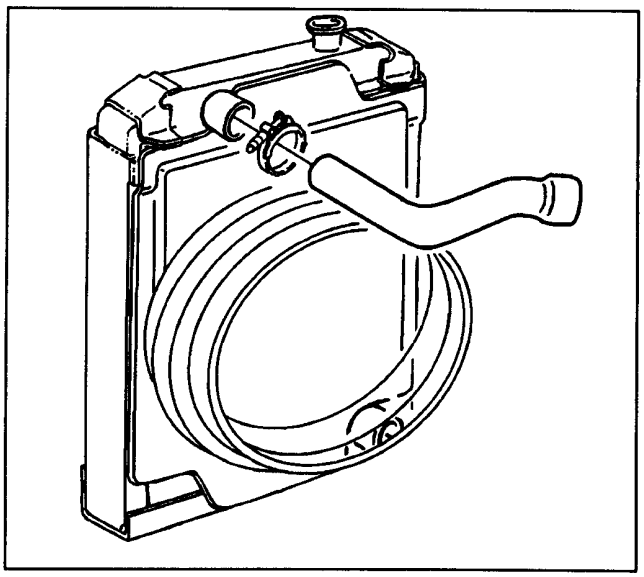


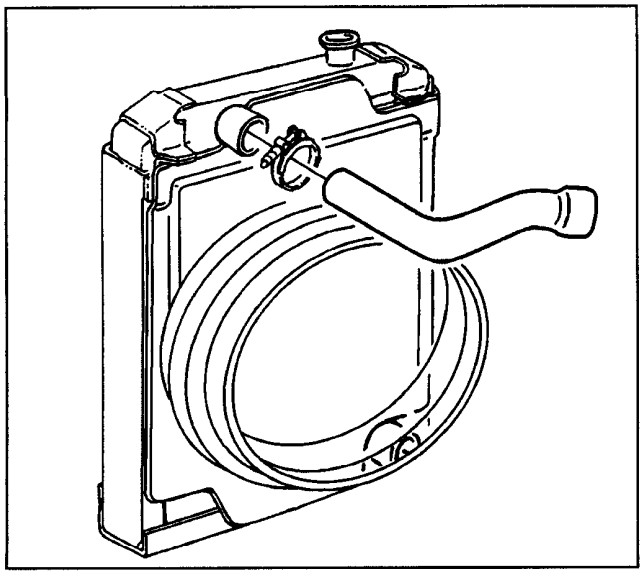
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Radiator Hose Replacement (Upper)

Removal Procedure

1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Drain the coolant.
   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the upper radiator hose.


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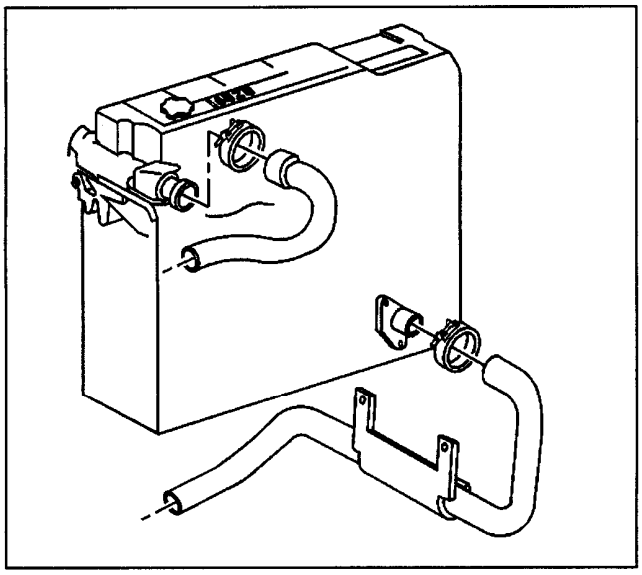


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Installation Procedure

Notice: Refer to *Fastener Notice* in Cautions and Notices.

1. Install the upper radiator hose.
   Tighten
   Tighten the clamps to 5 N.m (44 lb in).
2. Connect the negative battery cable.
3. Fill the cooling system.
4. Inspect the system for leaks.
5. Lower the cab.

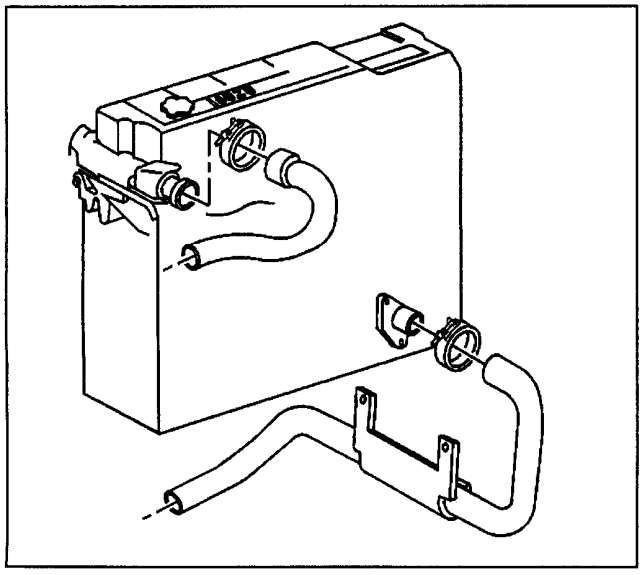


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Radiator Hose Replacement (Lower)

Removal Procedure

1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Drain the coolant.
   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the lower radiator hose.



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Installation Procedure

Notice: Refer to *Fastener Notice* in Cautions and Notices.

1. Install the lower radiator hose.
   Tighten
   Tighten the clamp to 5 N.m (44 lb in).
2. Connect the negative battery cable.
3. Fill the cooling system.
4. Inspect the system for leaks.
5. Lower the cab.

Fan Replacement (Fan Blade)

Removal Procedure

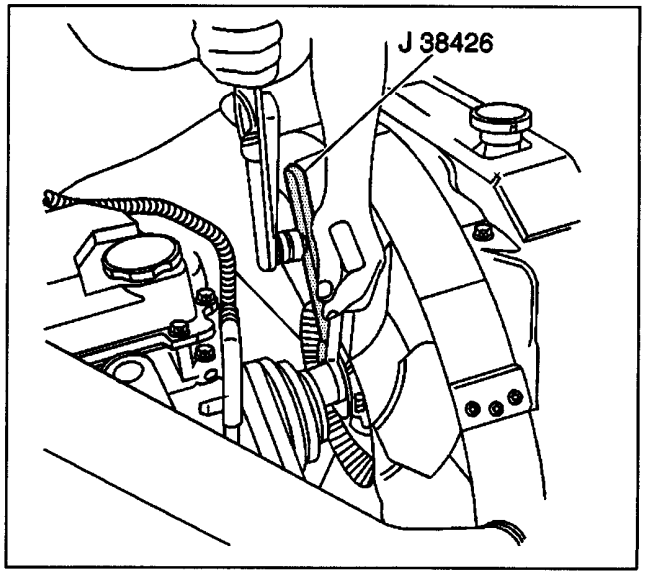
Tools Required
J 38425 Fan Hub Wrench

Notice: If a fan blade is bent or damaged, do not repair and use the damaged part. Replace a bent or damaged fan assembly with a new fan assembly. Using a fan with a different diameter, pitch, number of blades, or type of blade material may effect the cooling efficiency, performance and engine noise level.

Inspect the hub and the drive components if a fan assembly fails.

A fan assembly may fail due to an imbalance in the hub. The blades may not be the cause.

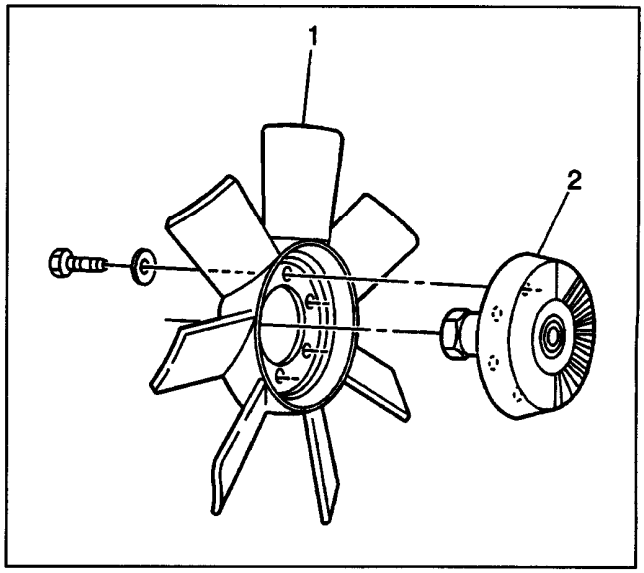
1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices
2. Disconnect the negative battery cable.
   Important: The fan clutch (2) has a left hand thread and must be rotated clockwise for removal.
3. Position wrench on shaft flats.
4. Insert the *J 38425* onto the fan hub.
5. Remove the fan (1) and the fan clutch (2).
6. Remove the following components:
   - The fan blade (1) to fan clutch bolts
   - The washers
7. Remove the fan blade (1) from the fan clutch (2).
8. Inspect the belts and the pulley for the following conditions:
   - Cracks
   - Distortion
   - Other damage
9. Replace the above components as necessary.



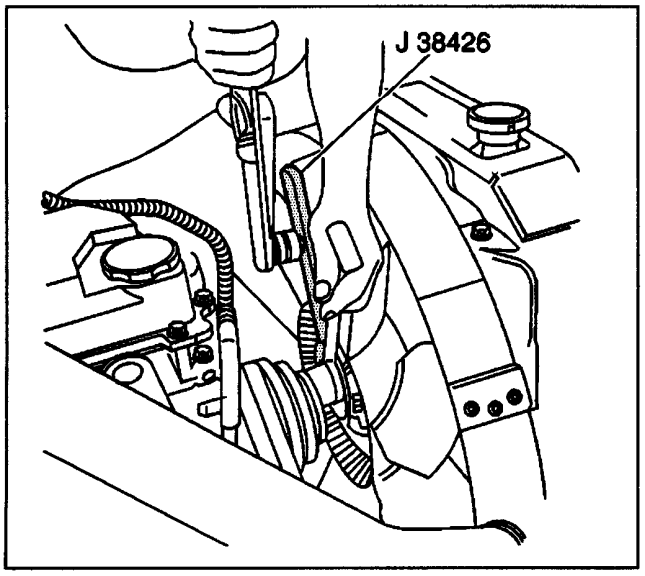
300348

Installation Procedure

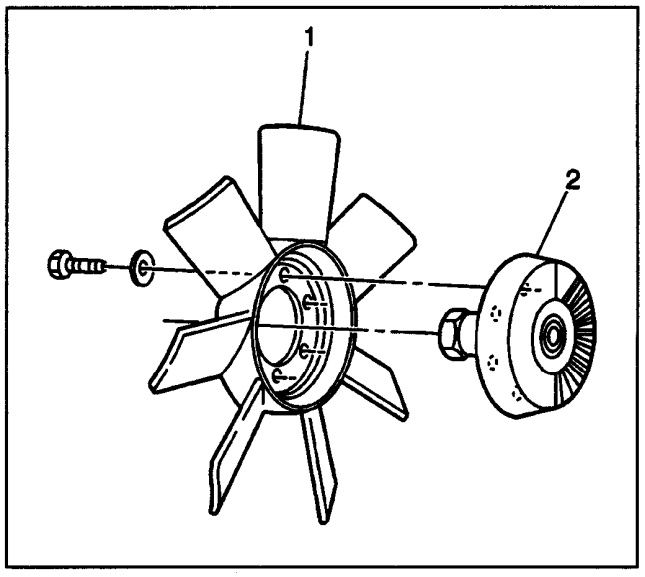
1. Install the fan (1) to the fan clutch (2).
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the fan blade to fan clutch bolts and the washers.
   Tighten
   Tighten the fan to fan clutch bolts to 21 N·m (16 lb ft).
3. Install the fan (1) and the fan clutch (2).
   Tighten
   Tighten the fan clutch nut to 145 N·m (107 lb ft).
4. Connect the negative battery cable.
5. Lower the cab.



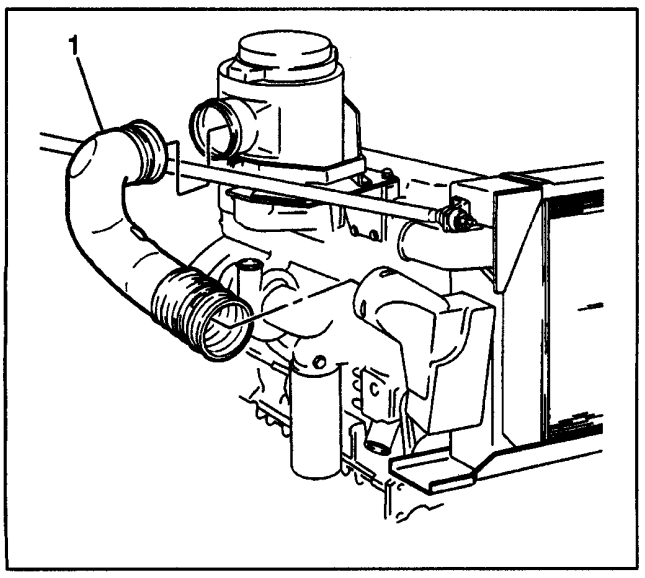
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Fan Replacement (Fan Clutch)

Tools Required

J 38425 Fan Hub Wrench

1. Tilt the cab.

   Refer to *Cab Tilting* in General Information.

   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Remove the fan and the fan clutch.

   Refer to *Fan Replacement (Fan Blade).*
4. Remove the following components:
   - The fan blade to fan clutch bolts
   - The washers
5. Remove the fan blade (1) from the fan clutch (2).
6. Inspect all of the components for smooth surfaces.

Installation Procedure

1. Install the fan (1) to the fan clutch (2).

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the following components:
   - The fan blade to fan clutch bolts

     Tighten

     Tighten the fan to fan clutch bolts to 21 N.m (16 lb ft).
   - The washers
3. Install the following components:
   - The fan (1)
   - The fan clutch (2)
4. Connect the negative battery cable.
5. Lower the cab.

Thermostat Housing Replacement

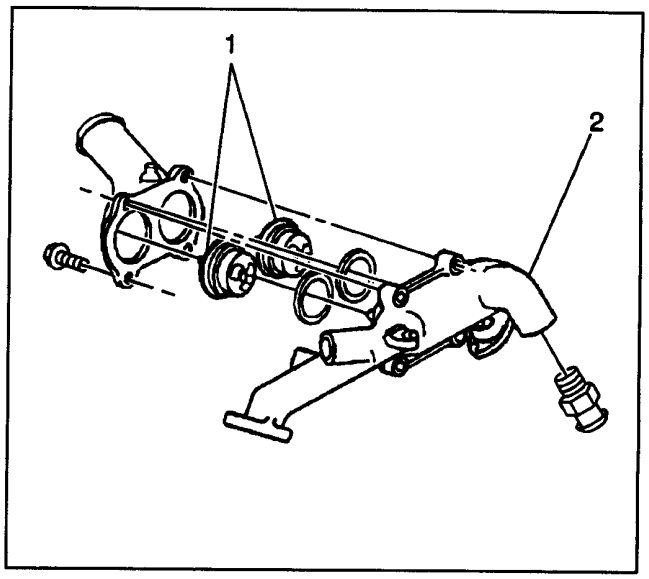
Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable.

   Refer to *Battery Cable Replacement* in Engine Electrical.
2. Remove the front wheelhouse panel.
3. Remove the front intake air duct (1) from the air filter housing.
4. Drain the coolant. Refer to *Draining and Filling Cooling System (Draining).*
5. Remove the upper radiator hose from the coolant outlet.
6. Remove the coolant outlet bolts.

7. Remove the coolant outlet.
8. Remove the thermostat housing.
9. Remove the coolant outlet gasket.
10. Clean the following components:
    - The surface of the coolant crossover manifold (2)
    - The coolant outlet
11. Inspect the coolant crossover manifold and the coolant outlet mating surfaces for the following conditions:
    - Pits
    - Cracks
    - Other damage that could cause leaks



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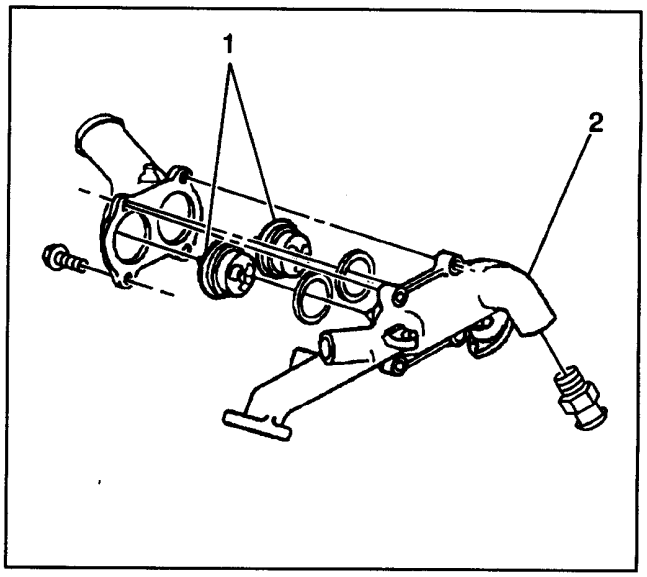
Installation Procedure

1. Install the thermostat housing (2).
2. Install the coolant outlet gasket.
3. Install the coolant outlet.

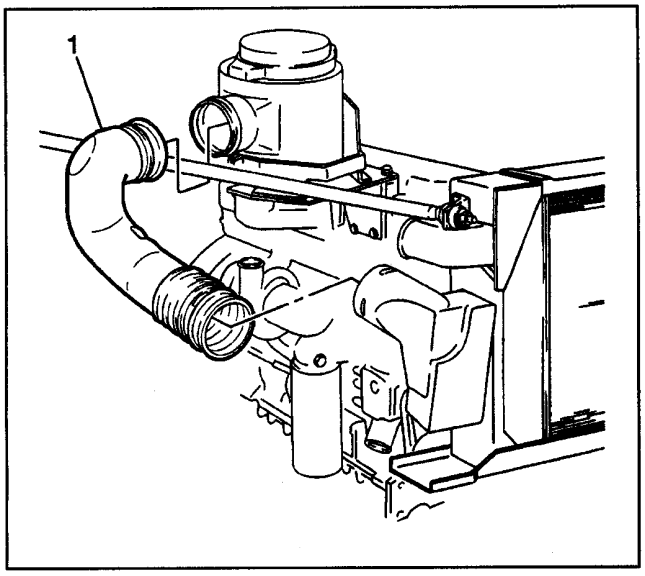
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
4. Install the coolant outlet bolts.

   Tighten

   Tighten the coolant outlet bolts to 42 N·m (31 lb ft).
5. Install the upper radiator hose to the coolant outlet.



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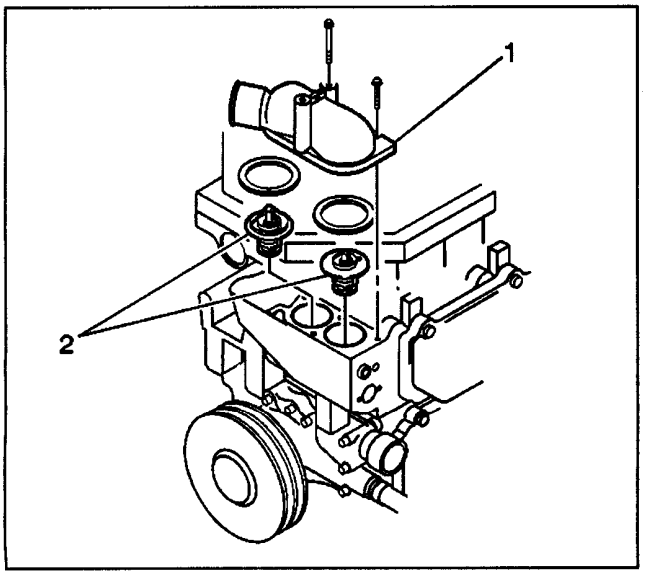
198949

6. Install the front intake air duct (1) to the air filter housing.
7. Install the front wheelhouse panel.
8. Connect the negative battery cable.
9. Fill the cooling system. Refer to *Draining and Filling Cooling System (Draining).*
10. Inspect the system for leaks.

Thermostat Replacement

Removal Procedure

1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Drain the coolant.
   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the upper radiator hose from the coolant outlet.
5. Remove the coolant outlet bolts.
6. Remove the coolant outlet (1).
7. Remove the thermostats (2).
8. Clean the following surfaces:
   - The inlet manifold
   - The coolant outlet
9. Inspect the coolant outlet for the following conditions:
   - Flat mating surfaces
   - Pits
   - Cracks
   - Other damage

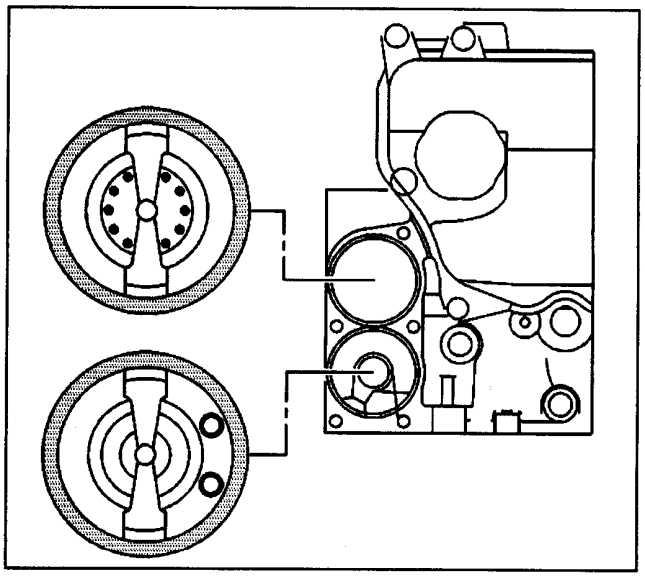


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Installation Procedure

Important: Place the thermostat with the jiggle valves on the left side.

1. Install the thermostats (2).



228198

2. Install the coolant outlet (1).

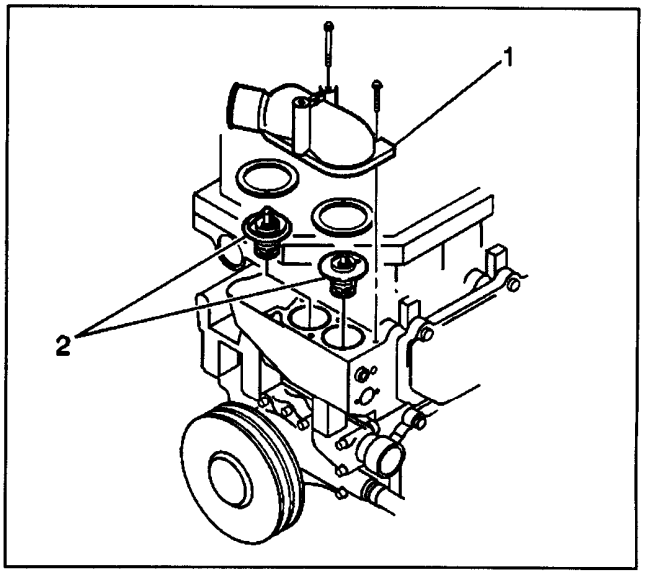
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
3. Install the coolant outlet bolts.

   Tighten

   Tighten the coolant outlet bolts to 19 N·m (14 lb ft).
4. Install the upper radiator hose to the coolant outlet.

   Tighten

   Tighten the clamp to 5 N·m (44 lb in).
5. Connect the negative battery cable.
6. Fill the cooling system.
7. Inspect the system for leaks.
8. Lower the cab.



228201

Water Pump Replacement

Removal Procedure

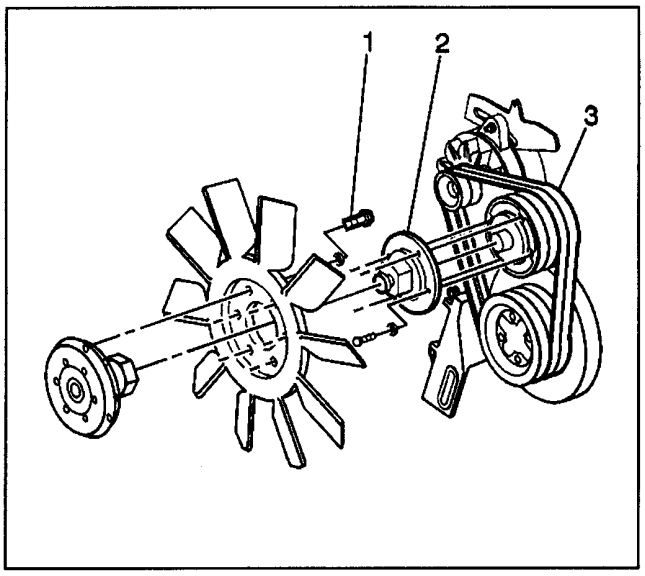
1. Tilt the cab.

   Refer to *Cab Tilting* in General Information.

   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Drain the coolant.

   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the drive belts.

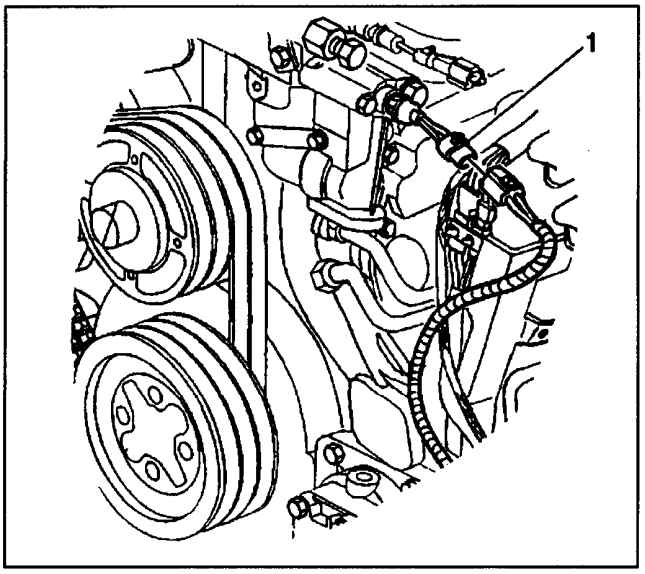
   Refer to Engine Mechanical.



228234

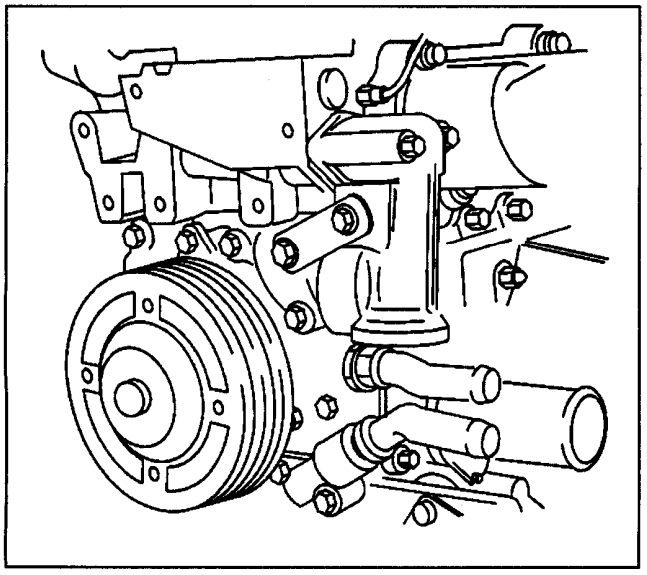
5. Remove the following components from the pump:
   - The fan clutch
   - The adapter (2)

   Refer to Fan Adapter.
6. Remove the following components from the water pump:
   - The clamp
   - The heater hose



228214

7. Remove the temperature sensor connector (1).

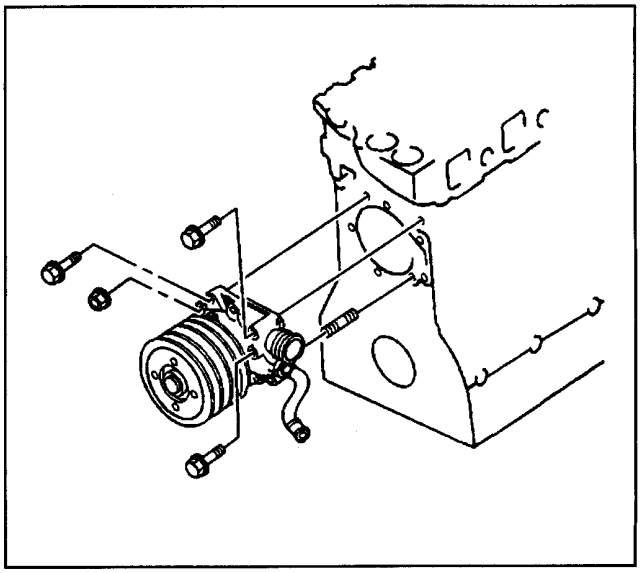


228206

8. Remove the bolts from the water duct.
9. Remove the following components:
   - The water duct
   - The O-ring

10. Remove the water pump bolts.
11. Remove the following components:
    - The water pump
    - The gaskets
12. Clean the following components:
    - The surface of the water pump
    - The surface of the engine block
    - The bolt threads
    - The water duct sealing surfaces
13. Inspect the following components for wear, deterioration or corrosion.

    Replace the components as necessary:
    - The clamps
    - The hoses
    - The water pump



228210

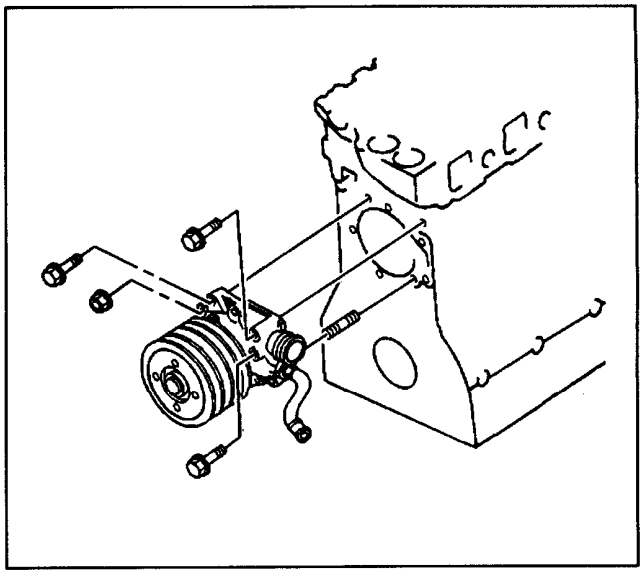
Installation Procedure

1. Install new gaskets to the water pump.
2. Install the water pump to the engine block.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
3. Install the water pump bolts.

   Tighten

   Tighten the water pump bolts to 19 N.m (14 lb ft).



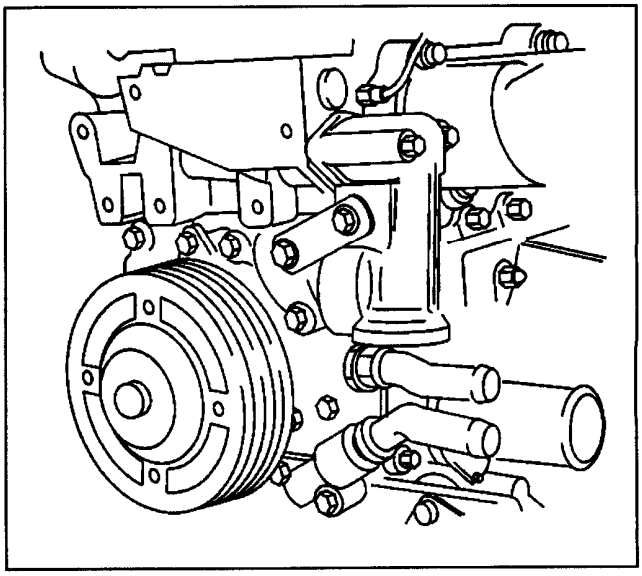
228210

4. Lube the O-ring with soap suds.
5. Install the following components:
   - The water duct
   - The O-ring
6. Install the water duct bolts.

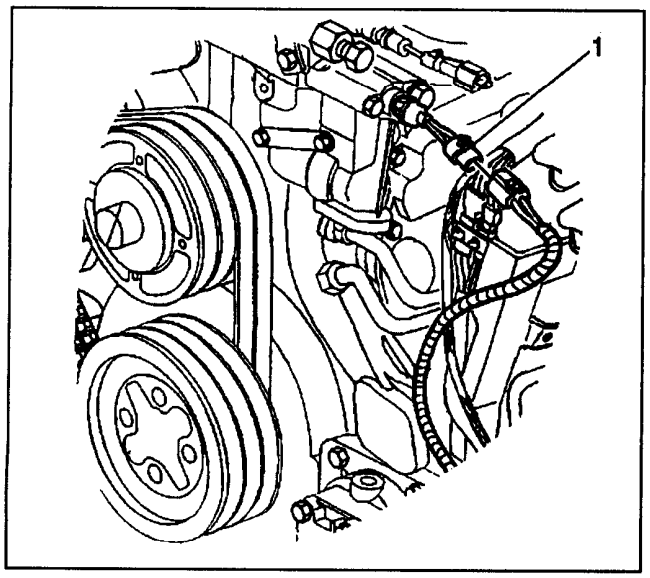
   Tighten

   6.1. Tighten the M8 bolt to 19 N.m (14 lb ft).

   6.2. Tighten the M16 bolt to 125 N.m (92 lb ft).



228206

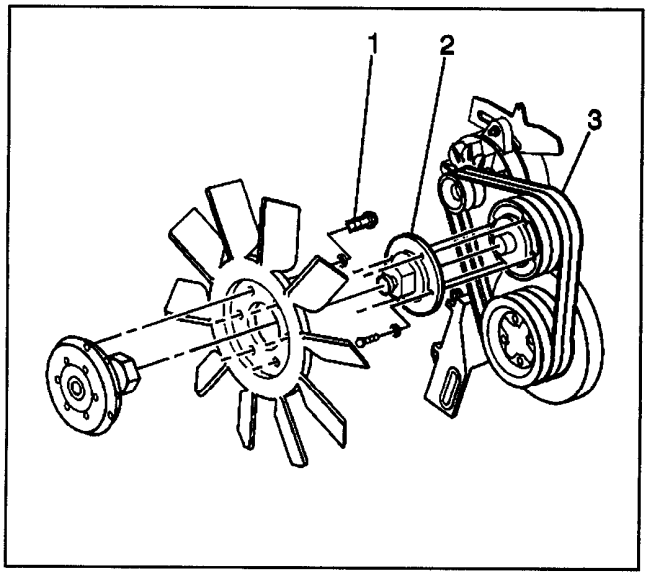


228214

7. Install the temperature sensor connector (1).
8. Install the following components to the water pump:
   - The heater hose
   - The clamp

   Tighten

   Tighten the clamp to 5 N·m (44 lb in).

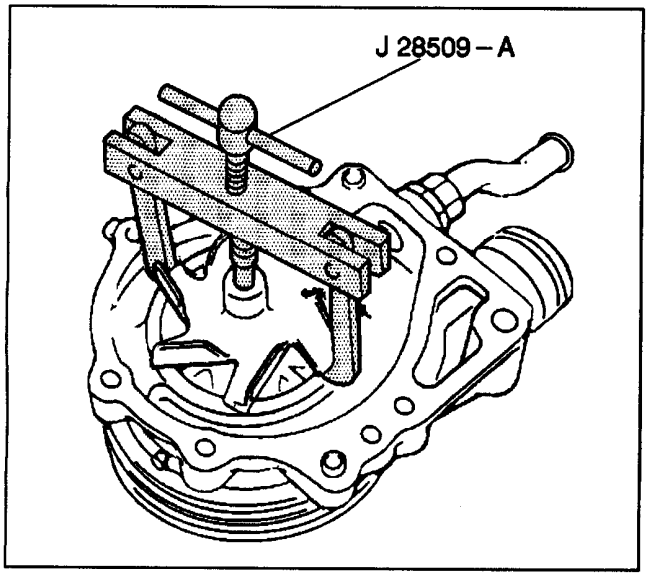


228234

9. Install the following components to the pump:
   - The adapter (2)

   Tighten

   Tighten the adapter bolts to 68 N·m (50 lb ft).
   - The fan clutch
10. Install the drive belts.
11. Connect the negative battery cable.
12. Fill the cooling system.
13. Inspect the system for leaks.
14. Lower the cab.



228725

Water Pump Overhaul

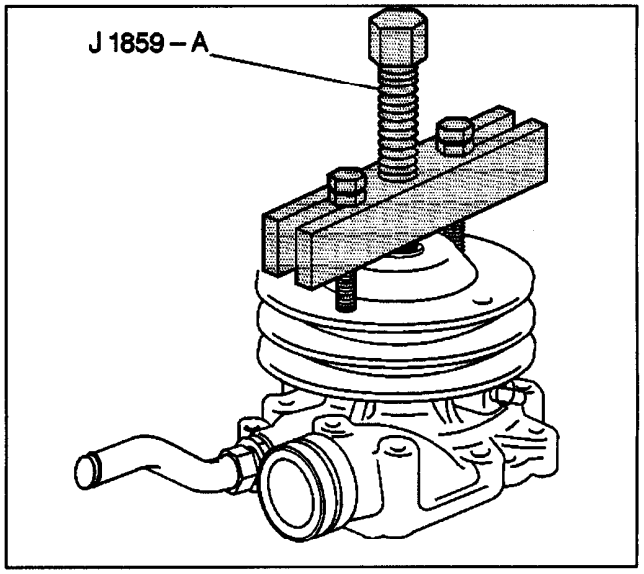
Disassembly Procedure

Tools Required

- *J 1859-A* Puller
- *J 28509-A* Bearing Remover

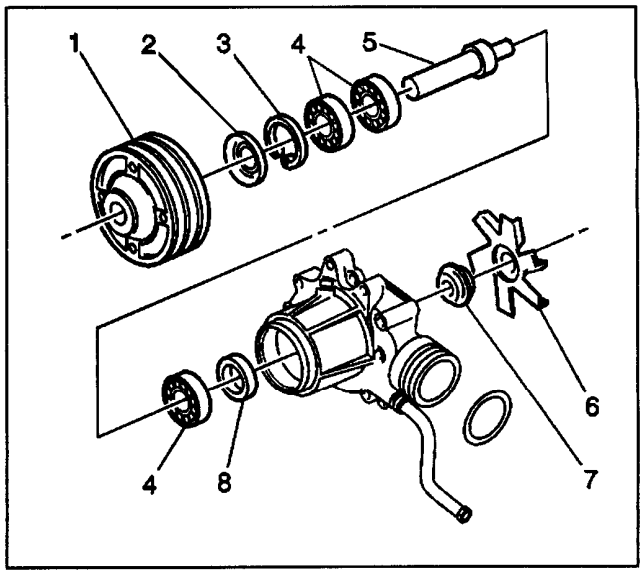
1. Use the *J 1859-A* in order to remove the impeller.

2. Use the *J 1859-A* in order to remove the pulley.



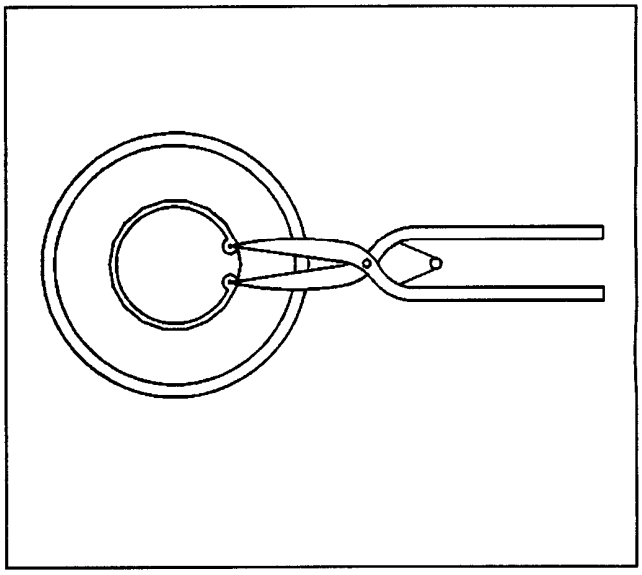
228727

3. Remove the dust thrower (2).

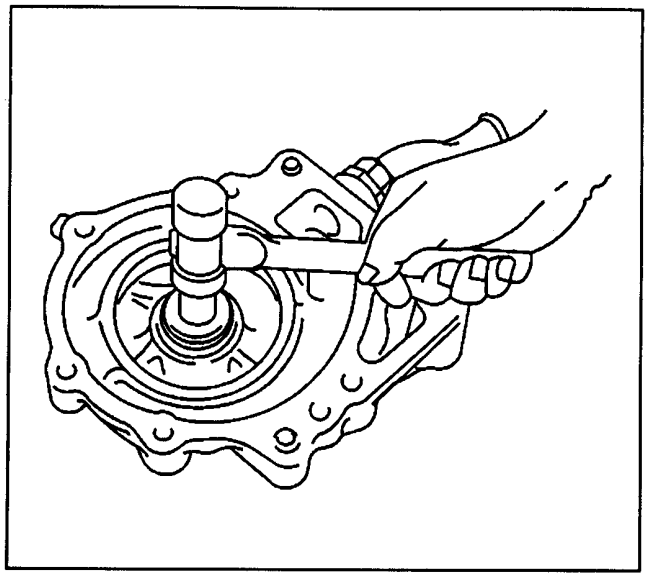


228730

4. Use snap ring pliers in order to remove the snap ring.

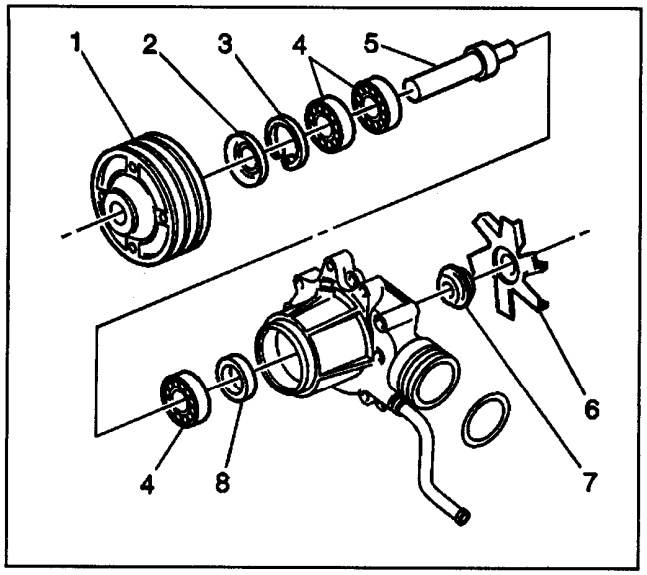


228723



228708

5. Remove the spindle. Use a plastic hammer in order to lightly tap the spindle free.
6. Remove the bearing.
7. Remove the spacer.



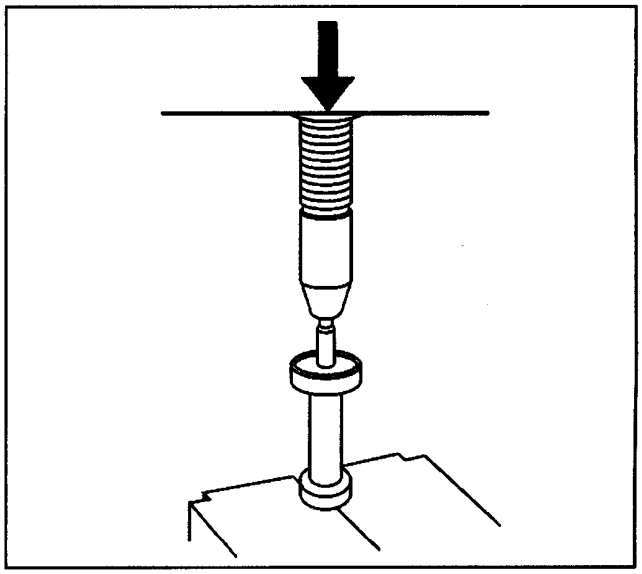
228730

8. Remove the front seal (8).
9. Use an arbor press and the *J 28509-A* in order to remove the seal unit (7).
10. Use an arbor press in order to remove the following components from the spindle (5):
    - The bearings
    - The spacer (4)
11. Inspect the above components for wear or damage.
12. Replace or repair the above components as necessary.
13. Inspect for proper fit of the shaft to the pulley center.
14. Inspect for proper fit of the impeller (6) and the pulley center to the pulley (1).
15. Inspect the housing for cracks or burrs.
16. Inspect the shaft for the following conditions:
    - Cracks
    - Burrs
    - Pitting

    Replace the shaft as necessary.

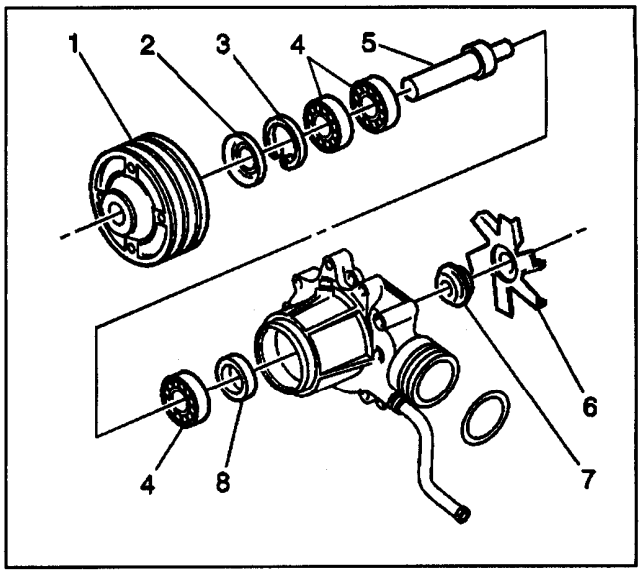
Assembly Procedure

1. Install the following components onto the spindle (5).
   - The bearings
   - The spacer (4)



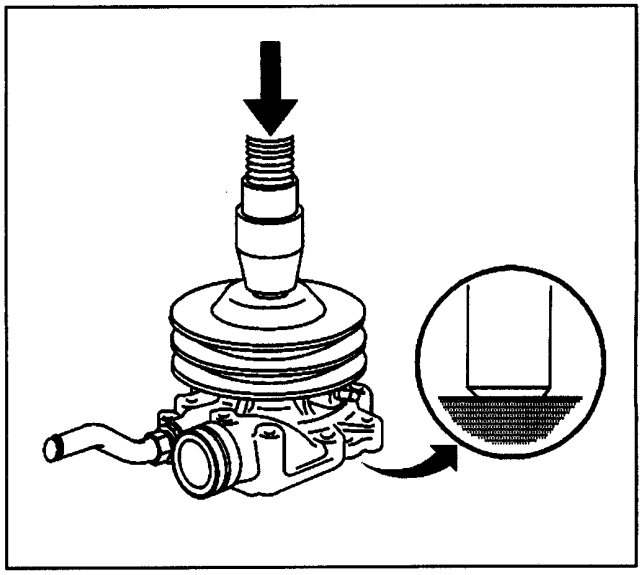
228705

2. Use an arbor press in order to install the following components onto the housing:
   - The spindle (5)
   - The bearings and spacer (4)
3. Apply multipurpose type grease to the lip seal.
4. Apply engine oil to the outer circumference of the lip seal.
5. Position the seal so that the lip of the seal faces forward.
6. Install the front seal (8).
7. Use snap ring pliers in order to install the snap ring (3).
8. Install the dust thrower (2).

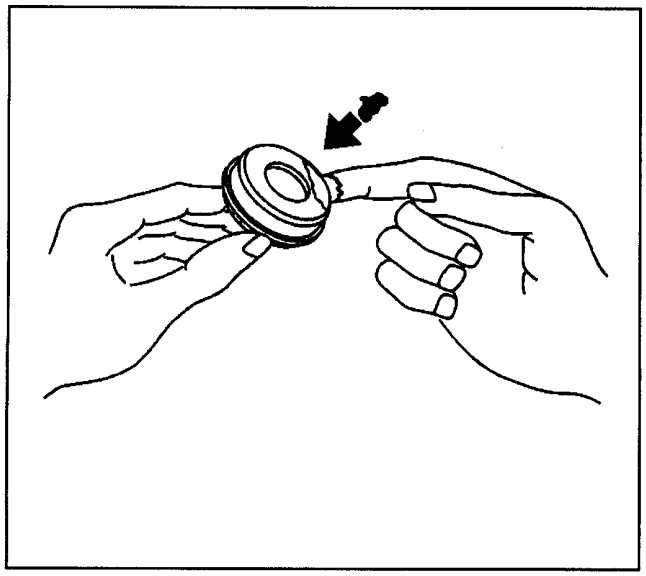


228730

9. Use a bench press in order to install the pulley.



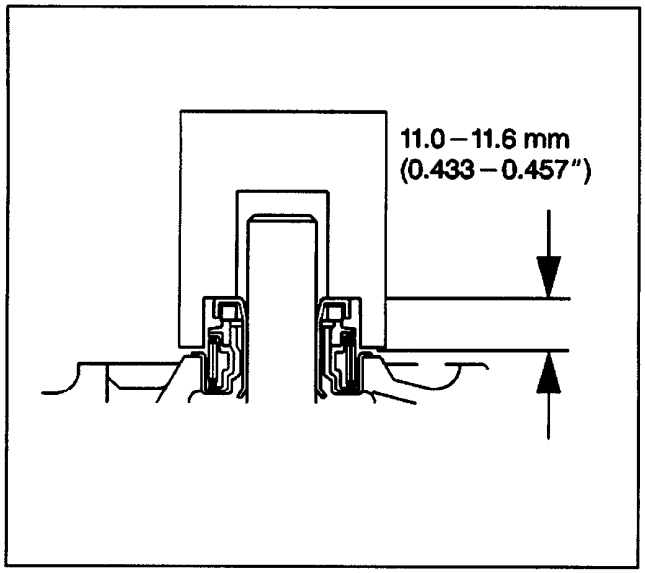
228720



228716

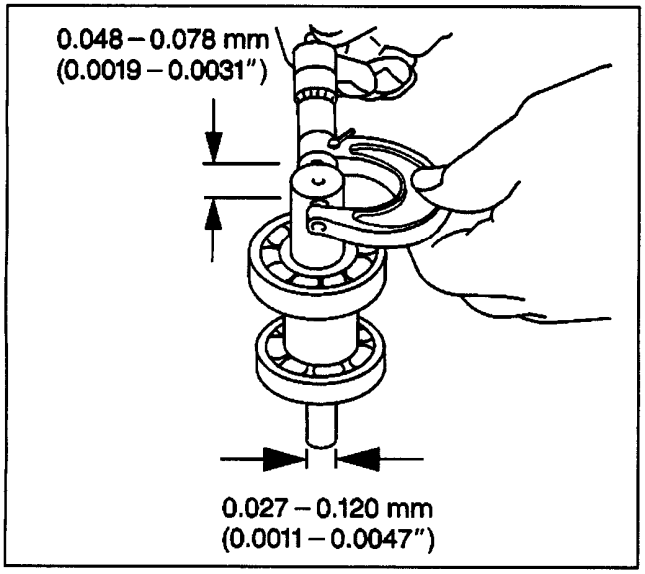
Caution: To protect the bearings and housing during this procedure, the press must contact the impeller side of the pump shaft and the pulley.

10. Apply a thin coat of liquid gasket (Three Bond 1104 or equivalent) to the seal.



228718

11. Use a bench press and an installer in order to install the seal unit to the housing.

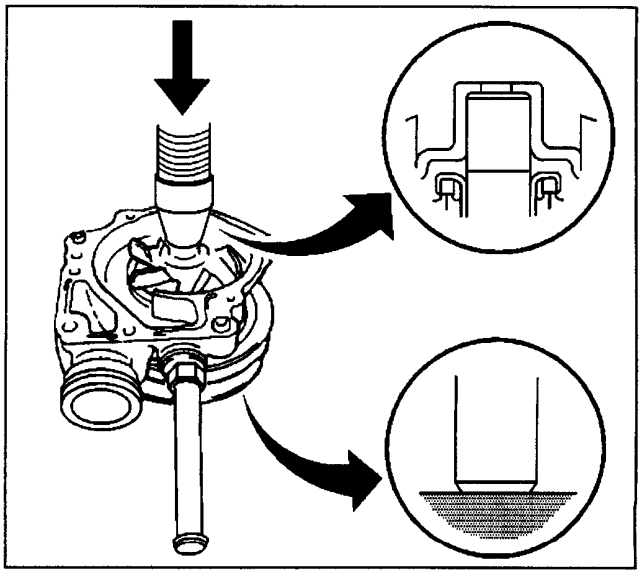


228688

12. Ensure that the seal height is between 11.0–11.6 mm (0.433–0.457 in).

Caution: To protect the bearings and housing during this procedure, the press must contact the impeller and the pulley.

13. Use a bench press in order to install the impeller to the shaft until the impeller bottoms out against the shaft.



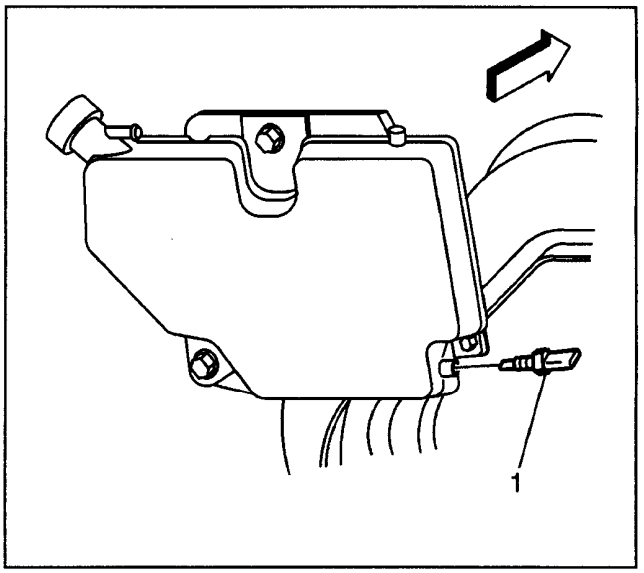
228712

Coolant Level Sensor Replacement

Removal Procedure

1. Disconnect the electrical connector from the probe.

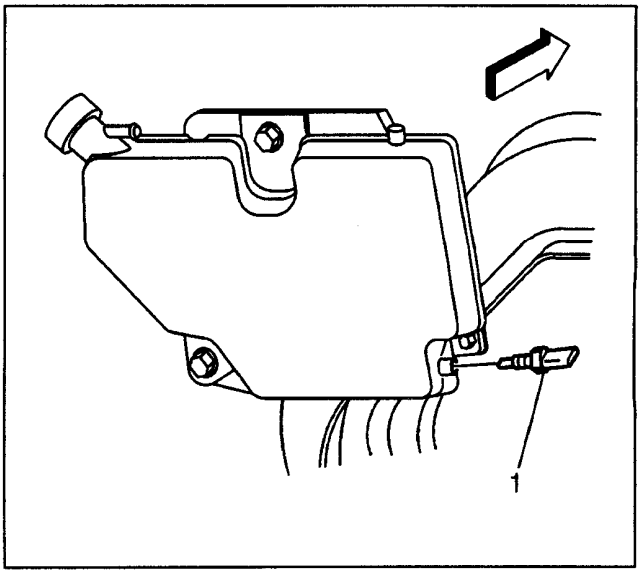
   Important: Catch any spilled coolant in a suitable container.
2. Remove the low coolant probe from the surge tank (1).



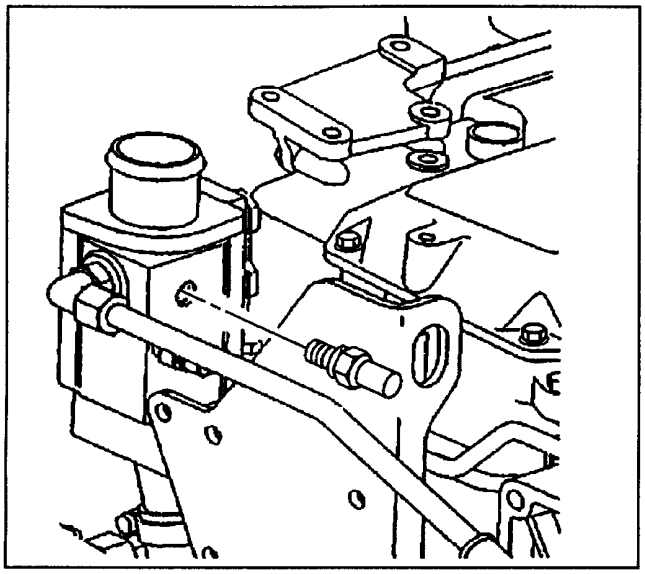
209252

Installation Procedure

1. Install the coolant probe into the surge tank (1).
2. Connect the electrical connector onto the probe.
3. Fill the engine coolant to the proper level.



209252

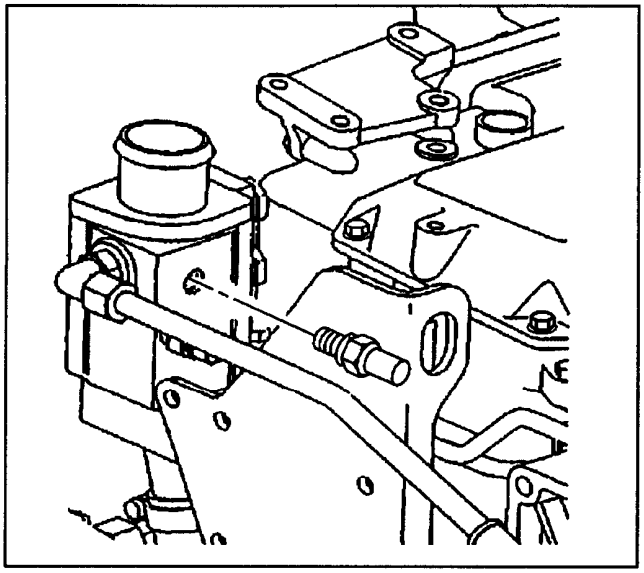


215566

Engine Coolant Temperature Sensor Replacement

Removal Procedure

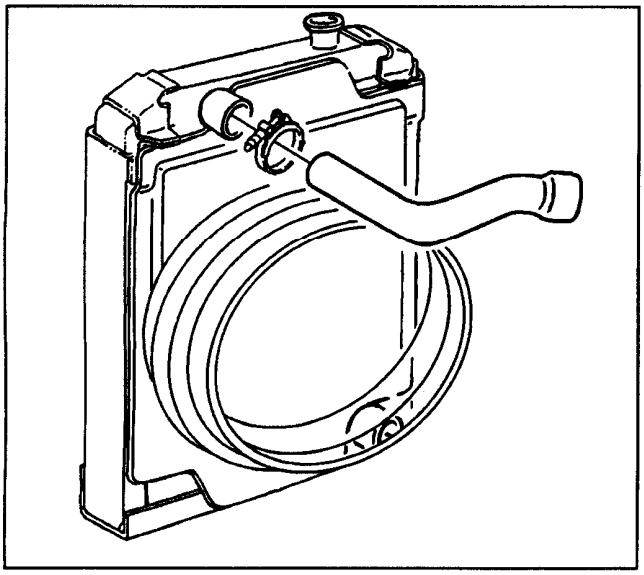
1. Drain the coolant.
2. Disconnect the electrical connector from the sensor.
3. Remove the sensor from the engine.



215566

Installation Procedure

1. Install the sensor to the engine.
2. Connect the electrical connector to the sensor.
3. Refill the coolant.



209225

Fan Shroud Replacement

Removal Procedure

1. Tilt the cab.

   Refer to *Cab Tilting* in General Information.

   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Remove the cooling fan.

   Refer to *Fan Replacement (Fan Blade).*
4. Partially drain the cooling system.

   Refer to *Draining and Filling Cooling System (Draining).*
5. Remove the upper radiator hose.
6. Remove the coolant recovery reservoir hose.
7. Remove the fan shroud bolts.
8. Remove the fan shroud.

9. Clean the fan shroud with a cloth in order to remove dirt and grease.
10. Inspect the fan shroud for cracks and warping.
11. Replace the fan shroud if the fan shroud is damaged.

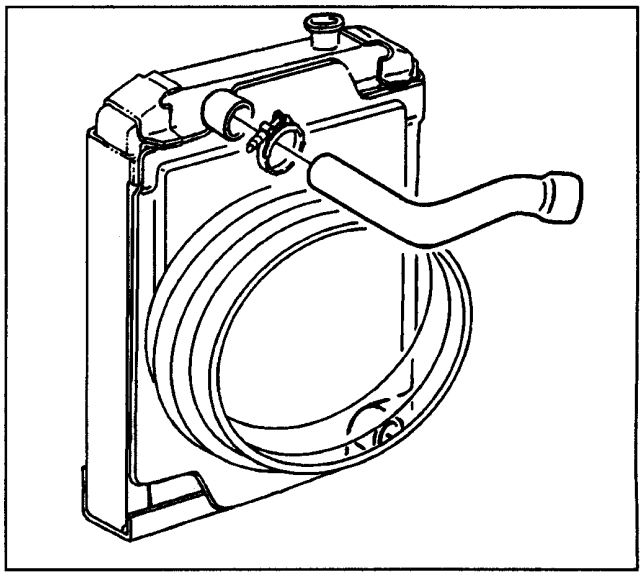
Installation Procedure

1. Install the fan shroud.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the fan shroud bolts.

   Tighten

   Tighten the fan shroud bolts to 6 N.m (53 lb in).
3. Install the coolant recovery reservoir hose.
4. Install the upper radiator hose.
5. Install the cooling fan.
6. Connect the negative battery cable.
7. Fill the cooling system.
8. Lower the cab.



209225

Radiator Replacement

Removal Procedure

Some assemblies may be equipped with an automatic transmission oil cooler in the bottom core tank. Before removing the automatic transmission oil cooler lines, provide a container in order to catch the oil that is drained from the automatic transmission cooler and the lines. Do not reuse the drained fluid. Fill the automatic transmission to the recommended level using clean, new fluid after completing the radiator installation.

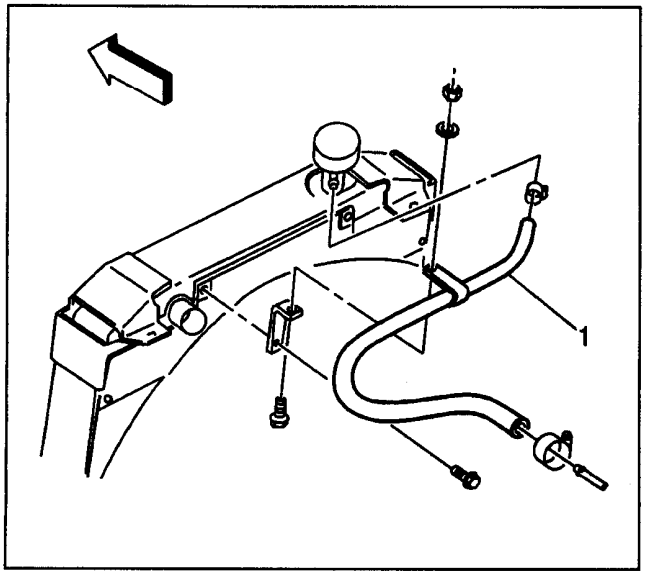
Refer to *Approximate Fluid Capacities* in General Information.

1. Tilt the cab.

   Refer to *Cab Tilting* in General Information.

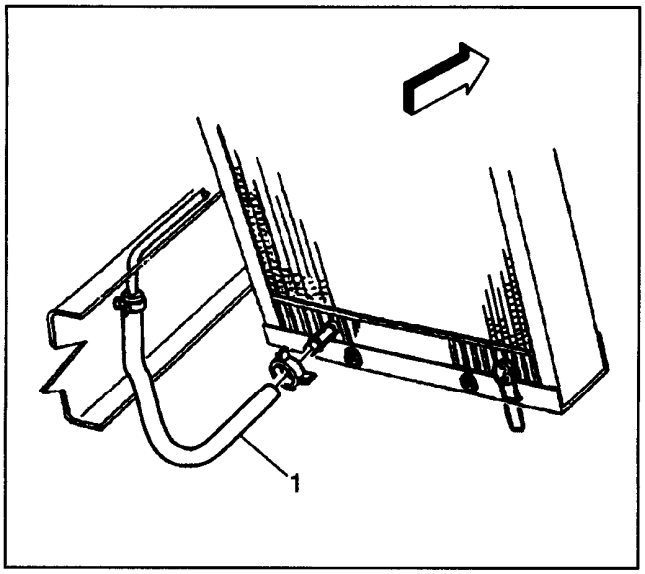
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Drain the coolant into a suitable container.

   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the upper radiator hose.



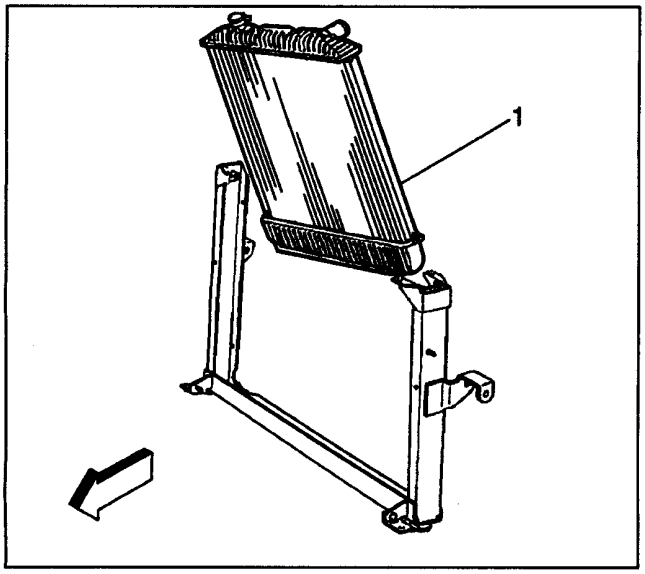
209213

5. Remove the coolant recovery hose (1) from the radiator.
6. Remove the automatic transmission oil cooler lines, if equipped.
7. Remove the lower radiator hose.



209207

8. Remove the heater hose (1).
9. Remove the radiator support top cover bolts.
10. Remove the radiator support top cover.



209210

11. Remove the radiator (1) from the support.
    Tilt the radiator in order to remove the radiator from the support.
12. Remove the radiator insulators.
13. Clean the radiator.
    Refer to *Radiator Cleaning*.
14. Inspect the following components:
    - The radiator
    - The hoses
    - The mounting hardware

    Replace the above components as necessary.

Installation Procedure

Important: Always install a new set of insulators when replacing the radiator.

Used insulators may wear out too large for the new radiator, which may cause the radiator to be loose.

1. Install the radiator insulators.
2. Install the radiator (1) to the support.
3. Install the radiator support top cover.

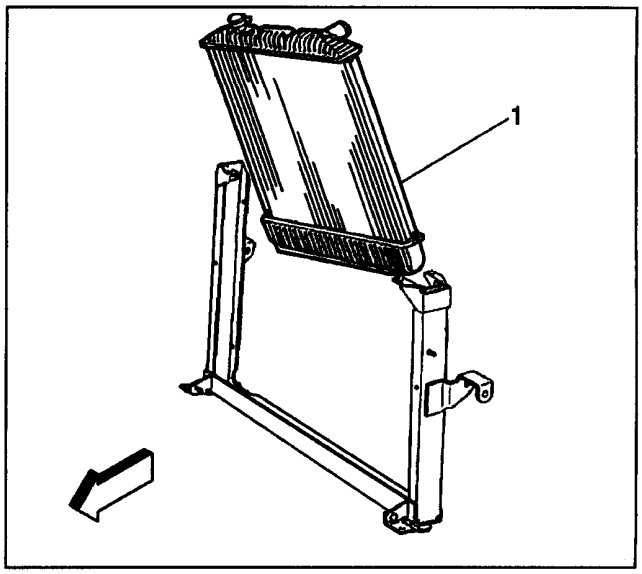
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
4. Install the radiator support top cover bolts.

   Tighten

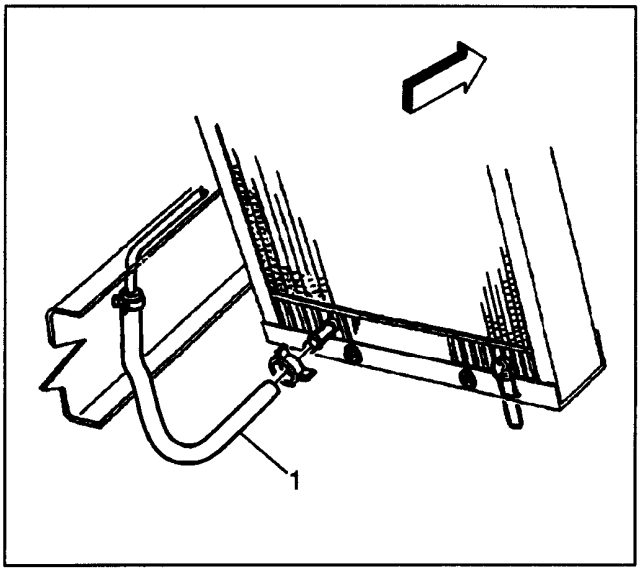
   Tighten the radiator support top cover bolts to 25 N.m (18 lb ft).
5. Install the automatic transmission oil cooler lines, if equipped.
6. Install the lower radiator hose.
7. Install the heater hose (1).

   Tighten

   Tighten the clamp to 5 N.m (44 lb in).



209210



209207

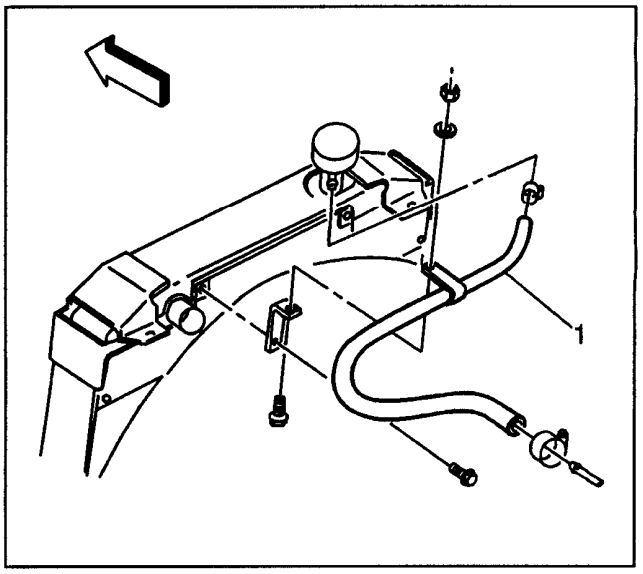
8. Install the coolant recovery hose (1) to the radiator.

   Tighten

   Tighten the clamp to 3 N.m (27 lb in).
9. Install the upper radiator hose clamp.

   Tighten

   Tighten the clamp to 5 N.m (44 lb in).
10. Connect the negative battery cable.
11. Fill the cooling system.
12. Fill the automatic transmission to the proper capacity, if equipped.
13. Inspect the system for leaks.
14. Lower the cab.

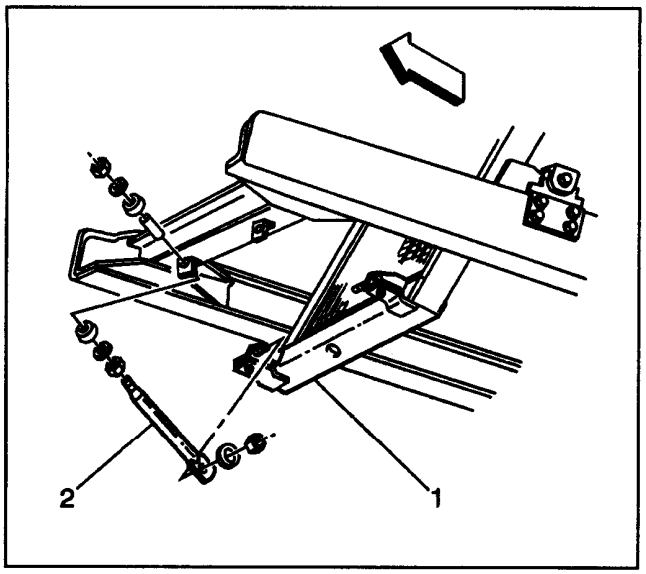


209213

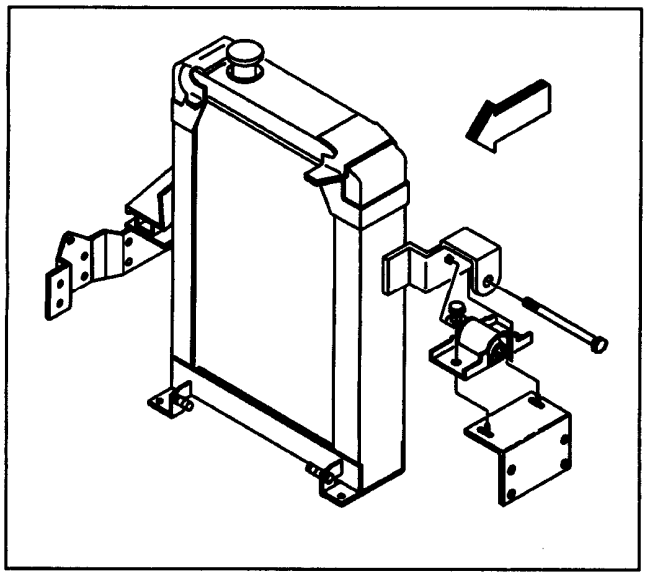
Radiator Lower Mounting Panel Replacement

Removal Procedure

1. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Drain the coolant.
   Refer to *Draining and Filling Cooling System (Draining).*
4. Remove the radiator.
   Refer to *Radiator Replacement.*
5. Remove the charge air cooler.
   Refer to Turbocharger.
6. Remove the radiator support brace nuts and the washers.
7. Disconnect the braces (2) from the radiator support (1).



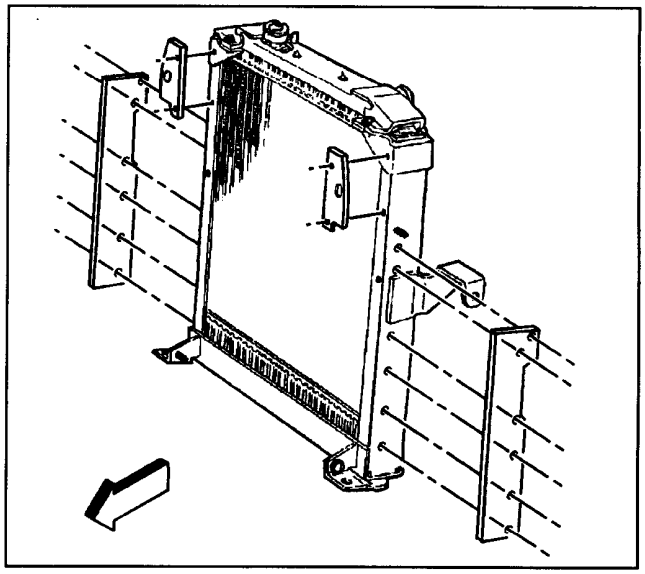
209230



209239

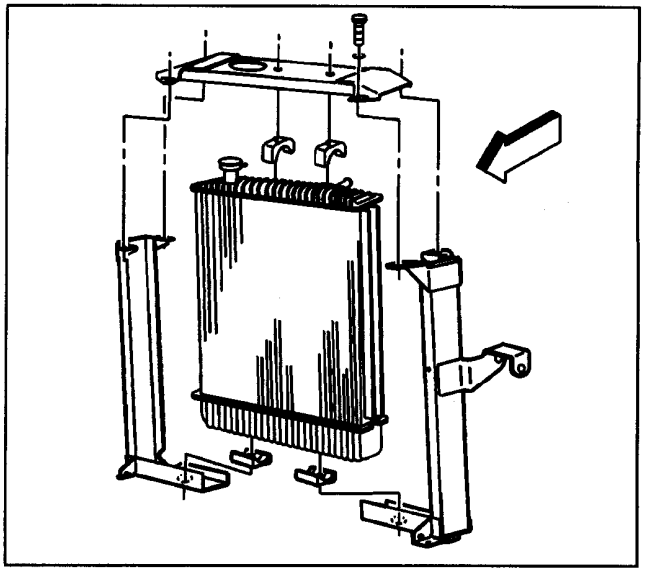
8. Remove the two side mounting bolts.
9. Remove the support from the vehicle.

10. Drill out the rivets for the radiator support side baffles.



209189

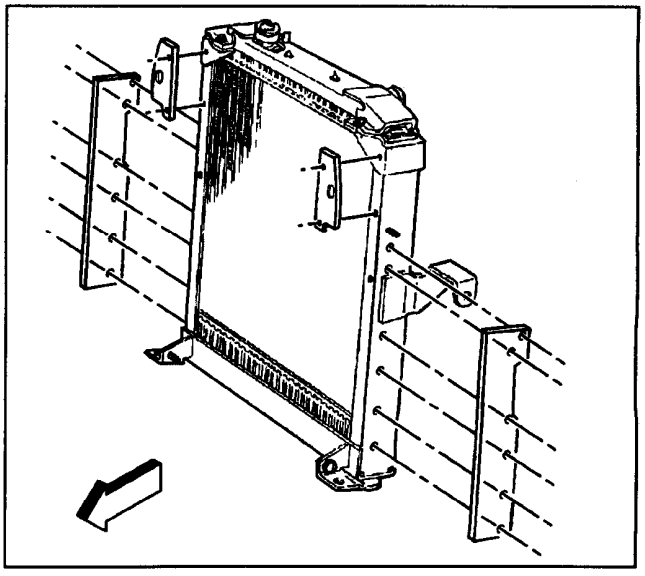
11. Remove the lower insulators from the radiator support.



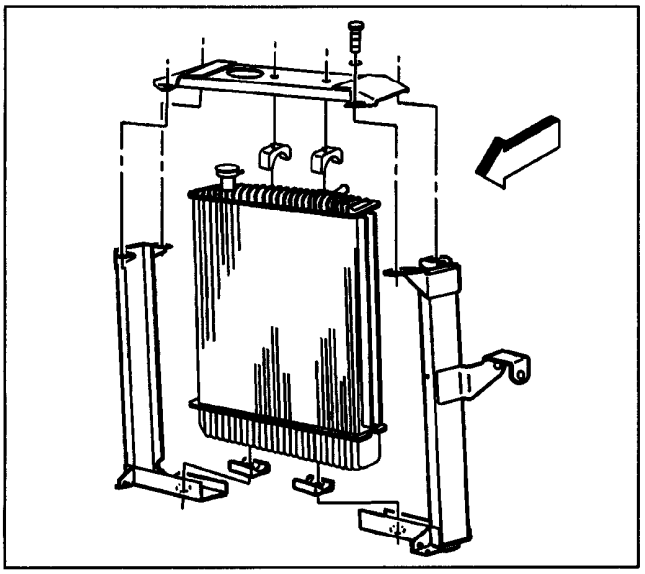
209216

Installation Procedure

1. Rivet the baffles to the radiator support.

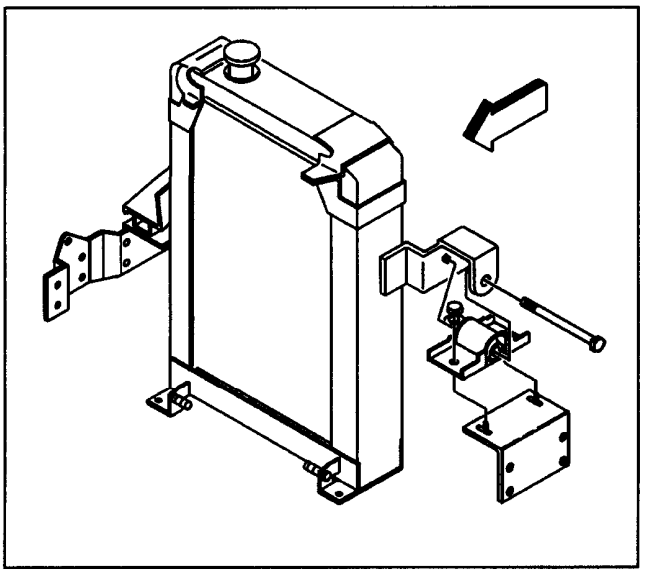


209189



209216

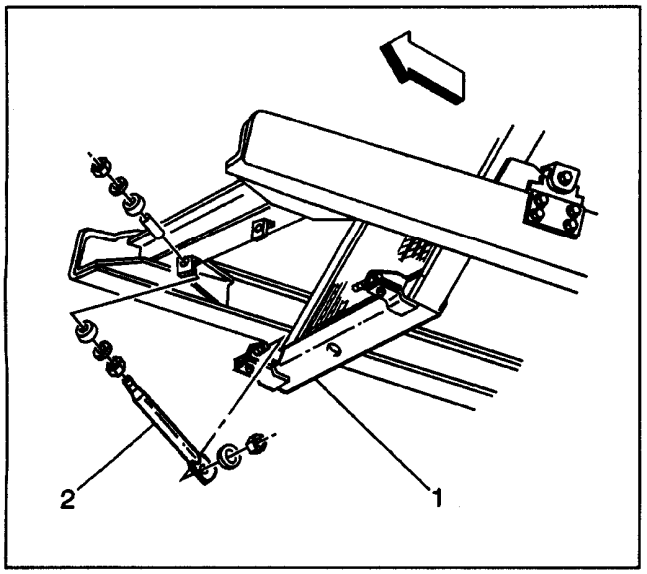
2. Install a new set of insulators.
3. Install the radiator support into the vehicle.



209239

Notice: Refer to *Fastener Notice* in Cautions and Notices.

4. Install the two side mounting bolts.
   Tighten
   Tighten the radiator support side mounting bolts to 65 N.m (48 lb ft).



209230

5. Connect the braces (2) to the radiator support (1).
6. Install the radiator support brace nuts and the washers.
   Tighten
   Tighten the radiator support brace nuts to 55 N.m (41 lb ft).
7. Install the charge air cooler.
8. Install the radiator.
9. Fill the cooling system.
10. Lower the cab.

Description and Operation

Cooling System Description

The engine cooling system uses a coolant solution of DEX-COOL™ and clean, drinkable water. The system carries excess heat away from the engine block and the air compressor, if equipped. A belt driven water pump moves the solution through the engine cooling system. The heated coolant flows through the radiator, where heat is transferred to the outside air. The cooled fluid then flows back to the engine block.

The coolant dissipates heat as the coolant passes through the radiator tubes and the radiator. Radiators transfer heat from the coolant to the outside air. The engine cooling fan pulls outside air past the radiator fins and the tubes.

The fan draws the air through the radiator fins in order to cool the radiator and the coolant. A fan shroud and rubber baffles direct air flow. The rubber baffles are mounted to the under side of the cab. The fan shroud and the rubber baffles form a seal at the top of the radiator. Together the fan shroud and the baffles prevent air from re-circulating around the radiator. Missing or misaligned baffles may cause overheating.

A thermostatic fan clutch from the engine crankshaft belt drives the fan. The thermostatic fan clutch controls the torque that transmits from the engine crankshaft to the fan blades. The clutch allows more torque to engage on the fan when the following conditions exist:

- Increasing engine temperature
- Low driving speeds

The fan turns faster and draws more air through the radiator with more torque. The thermostatic fan clutch disengages when the following conditions exist:

- Decreasing engine temperature
- Higher driving speeds

Thermostats regulate the engine operating temperature. The thermostats are located in the coolant outlet at the front of the engine. When the engine reaches a predetermined temperature, the thermostats open and allow the coolant to flow through to the radiator. The thermostats close as the engine cools down in order to restrict coolant flow. The thermostats also control the amount of coolant that flows through the engine.

The cooling system operates under pressure in order to increase the efficiency of the cooling system. Operating the system under pressure causes the following actions:

- Reduces boiling at high engine coolant temperatures
- Reduces boiling at high altitudes
- Prevents cavitation
- Raises the boiling point of the coolant

The pressure cap on the radiator or on the surge tank regulates the cooling system pressure. The pressure cap is designed with two normally closed valves. The pressure relief valve opens when the coolant temperature and the pressure exceed the pressure valve spring tension. The pressure relief valve allows coolant or air to escape. The pressure relief valve is set for 62 kPa (9 psi). The vacuum valve opens when the coolant is cooling and when ambient pressure overcomes the vacuum valve spring. The vacuum valve allows the coolant in the recovery reservoir or the surge tank to re-enter the system. The vacuum valve also prevents the collapse of the hoses or other components that are not internally supported.

The coolant recovery reservoir or the surge tank is mounted behind the cab. Coolant recovery reservoirs or surge tanks compensate for coolant fluid expansion. Coolant recovery reservoirs or surge tanks also help remove air from the cooling system.

Radiator Assembly Description (Radiator)

This radiator uses an aluminum core with plastic core tanks. The lower core tank houses the transmission oil cooler, if equipped. The drain cock is located in the lower tank. The drain cock is serviceable.

Radiator Assembly Description (Core)

The core is made of aluminum. The core is the downflow design. The core uses large tubes that resist plugging. The core attaches to the side tanks by clinched tabs on the core. Replace the core under the following conditions:

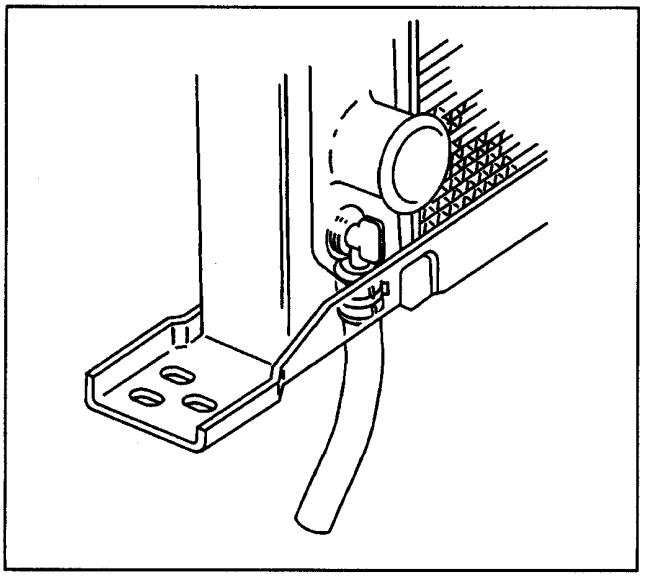
- More than three tabs are broken on one side.
- Two adjacent tabs are broken.

Radiator Assembly Description (Tanks)

The tanks are fastened to the core by clinched tabs. Clinched tabs attach to the sides of the core. The clinched tabs may bend backward in order to remove the tank from the core if necessary. Bend back the tabs only enough in order to remove the tank. Overbending weakens the tabs.

A high temperature rubber gasket seals the mating surface between the core and the tank. Replace the gasket when removing a tank from the core.

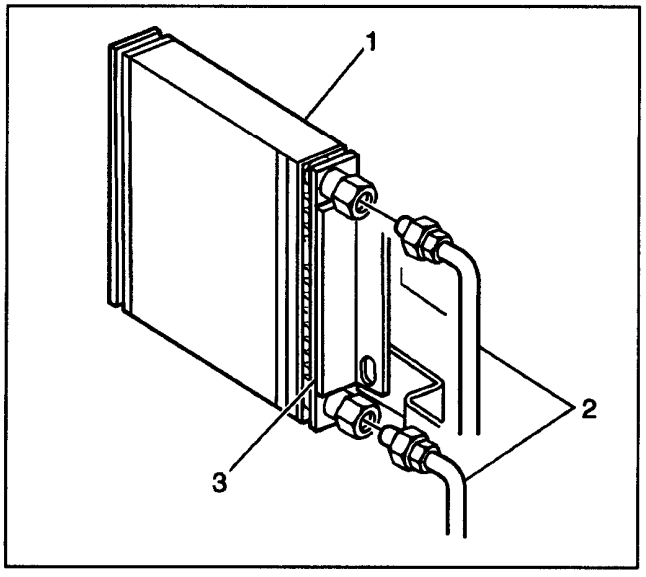
Radiator Assembly Description (Drain-Cock)



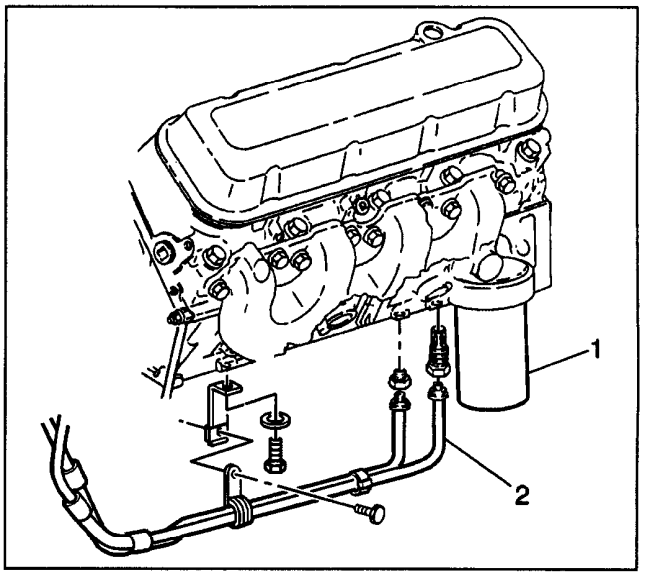
198896

The aluminum/plastic radiator uses a two-piece plastic drain cock and a rubber seal. The drain cock is serviceable.

Engine Oil Cooler Description



198899



198903

The engine oil cooler on all of the other models is located in the left radiator side tank.

Oil circulates through the following components in the system:

1. The engine oil pump
2. The engine oil cooler lines (2)
3. The engine oil cooler
4. The oil filter
5. The engine main oil passage

Flush the oil cooler and replace the oil filter in order to prevent premature engine wear under the following conditions:

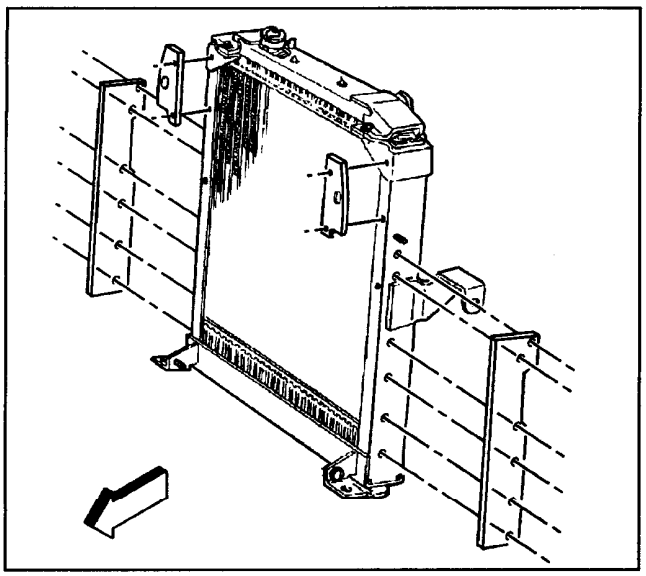
- Foreign material is present in the oil cooler.
- The engine is damaged internally.

Transmission Oil Cooler Description

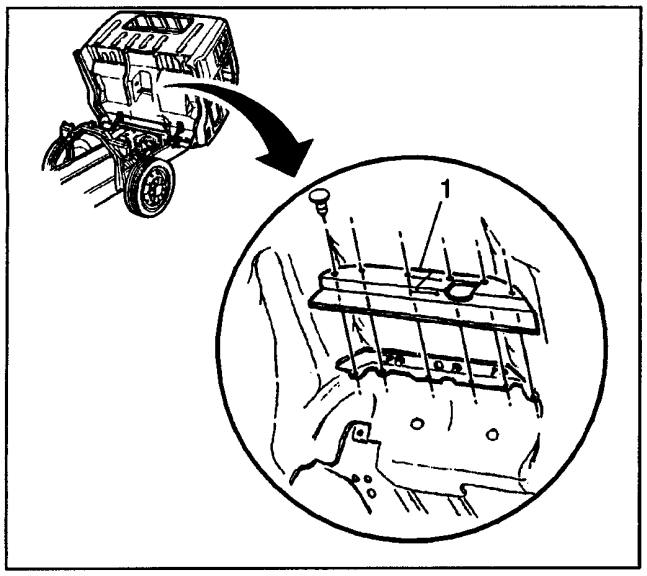
Remove the tank from the core in order to replace the transmission oil cooler.

Removing the tank from the core is not necessary when replacing a leaking transmission oil cooler gasket.

Air Baffles and Seals Description



209189



209184

Inspect for missing or misaligned baffles. Baffles that are missing or misaligned allow air to re-circulate around the radiator. Re-circulation causes the engine to overheat. Repair the baffles as needed.

Coolant Description

Newly developed engine coolant DEX-COOL™ was developed to last for 241 350 km (150,000 miles) or 5 years, whichever occurs first. Follow the instructions in *Draining and Filling Cooling System (Draining)*. Ensure that only DEX-COOL™ is added when coolant is added or changed.

A 50/50 mixture of DEX-COOL™ and clean, drinkable water provides the following conditions:

- Freezing protection to -37°C (-34°F)
- Boiling protection to 129°C (265°F)
- Rust and corrosion protection
- Helps keep the proper engine temperature
- Allows the warning lights and the gauges to operate as designed

Special Tools and Equipment

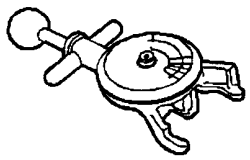
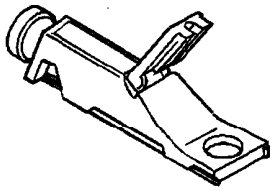
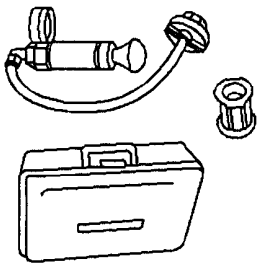
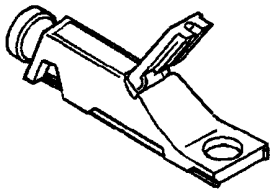
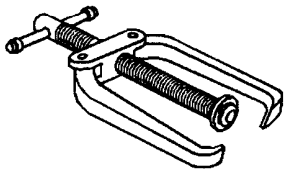
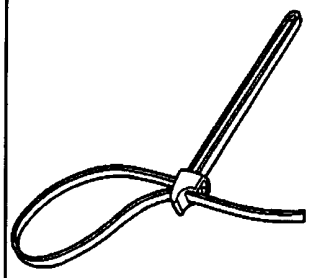
Illustration	Tool Number/ Description
 802	J 1859 Steering Wheel Puller
 48868	J 23600-B Belt Tension Gauge
 1409	J 23688 Coolant Tester Fahrenheit
 1405	J 24460-01 Cooling System Tester

Illustration	Tool Number/ Description
 12869	J 26568 Coolant Tester Centigrade
 48445	J 28509-A Counter Gear Bearing Remover
 199544	J 38425 Fan Hub Wrench
 340773	J 38426 Pulley Strap Wrench

Engine Electrical

Specifications

Fastener Tightening Specifications

Application	Specification	
	Metric	English
Accessory Mounting Bracket to Engine Bolt	50 N·m	37 lb ft
Air Conditioning Compressor Mounting Bolt	39 N·m	29 lb ft
Battery Top Bar Nut	17 N·m	13 lb ft
Battery Top Post Terminal Nut	17 N·m	13 lb ft
Buss Bar to Glow Plug Nut	2 N·m	18 lb in
Generator Ground Strap to Frame Bolt	30 N·m	22 lb ft
Generator Ground Strap to Generator Bolt	6 N·m	53 lb in
Generator Ground Strap to Generator Bolt	11 N·m	97 lb in
Generator Indicator Terminal Nut	2 N·m	18 lb in
Generator Mounting Bolt	88 N·m	65 lb ft
Generator Output Terminal Nut	12 N·m	100 lb in
Generator Relay Terminal Nut	2 N·m	18 lb in
Generator Shaft Nut	100 N·m	75 lb ft
Generator Top Mounting Bracket to Engine Bottom Bolt	19 N·m	14 lb ft
Generator Top Mounting Bracket to Engine Top Bolt	38 N·m	28 lb ft
Glow Plug to Cylinder Head	25 N·m	18 lb ft
Negative Battery Cable to Frame Bolt	30 N·m	22 lb ft
Negative Cable to Engine, Engine Side Bolt	18 N·m	13 lb ft
Negative Cable to Engine Cable, Frame Side Bolt	28 N·m	21 lb ft
Positive Cable to Maxi-Fuse® Block Bolt	9 N·m	80 lb in
Positive Battery Cable to Starter Nut	21 N·m	16 lb ft
Starter Motor Mounting Nut	82 N·m	60 lb ft
Starter Relay Mounting Bolt	23 N·m	17 lb ft
Starter Solenoid Bolt	4 N·m	35 lb in

General Specifications

Battery Temperature and Minimum Voltage

Estimated Temperature (Metric)	Estimated Temperature (English)	Minimum Voltage
21°C	70°F	9.6 V
10°C	50°F	9.4 V
0°C	32°F	9.1 V
-10°C	15°F	8.8 V
-18°C	0°F	8.5 V
Below -18°C	Below 0°F	8.0 V

Generator Output

Rated Output Amps	Cold Output Amps	Cold Output RPM
160	45	1600
160	150	5000
100	60	1600
100	100	6500
130	57	1600
130	130	6500

Battery Usage

A battery has the following two ratings:

- Reserve capacity
- Cold cranking amperage

Reserve Capacity

The reserve capacity estimates how long the vehicle can drive without generator output under the following conditions:

- With the headlamps turned on.
- With minimum electrical load (most of the accessories are turned off).

Reserve capacity is the maximum amount of time (in minutes) necessary for a charged battery to reach a terminal voltage of 10.5 volts. The battery must have been discharged at a constant rate of 25 amperes and a constant temperature of 27°C (80° F). The following factors affect the life of a battery when the vehicle drives without generator output:

- Other temperatures or current draws
- The state of charge
- The condition of the battery

Cold Cranking Amperage

The Cold Cranking Amperage (CCA) indicates the battery's ability to crank the engine at cold temperatures. The battery must maintain the minimum amperage rating for 30 seconds at -18°C (0°F) at 7.2 V. A battery's performance will vary depending on the actual temperature.

Battery Specifications

Catalogue Number	Cold Cranking Amperes Rating	Reserve Capacity (Minutes)	Load Test Amperes
1110	750	160	370
1150	625	180	310
31-900CT	900	160	450

Generator Usage

21-SI 200 Generator Specifications

Part Number	Field-Ohms 27°C (80°F)	Field Current 27°C (80°F) AMPS	Field Current 27°C (80°F) VOLTS	Cold Output AMPS	Cold Output RPM	Rated Output AMPS
19010110	1.7–1.8	6.7–7.1	12	45	1600	160
19010110	1.7–1.8	6.7–7.1	12	150	5000	160
19010112	1.7–1.8	6.7–7.1	12	60	1600	100
19010112	1.7–1.8	6.7–7.1	12	100	6500	100
19010113	1.7–1.8	6.7–7.1	12	57	1600	130
19010113	1.7–1.8	6.7–7.1	12	130	6500	130

Generator Output Specifications

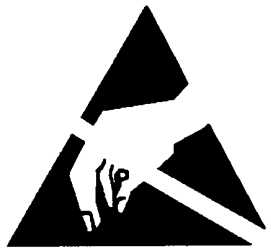
Engine	Option Code	Generator Model	Rated Output	Load Test
Diesel Engines	KW1	21SI	160 A	112 A
Diesel Engines	KG8	21SI	130 A	91 A
Diesel Engines	K60	21SI	100 A	70 A

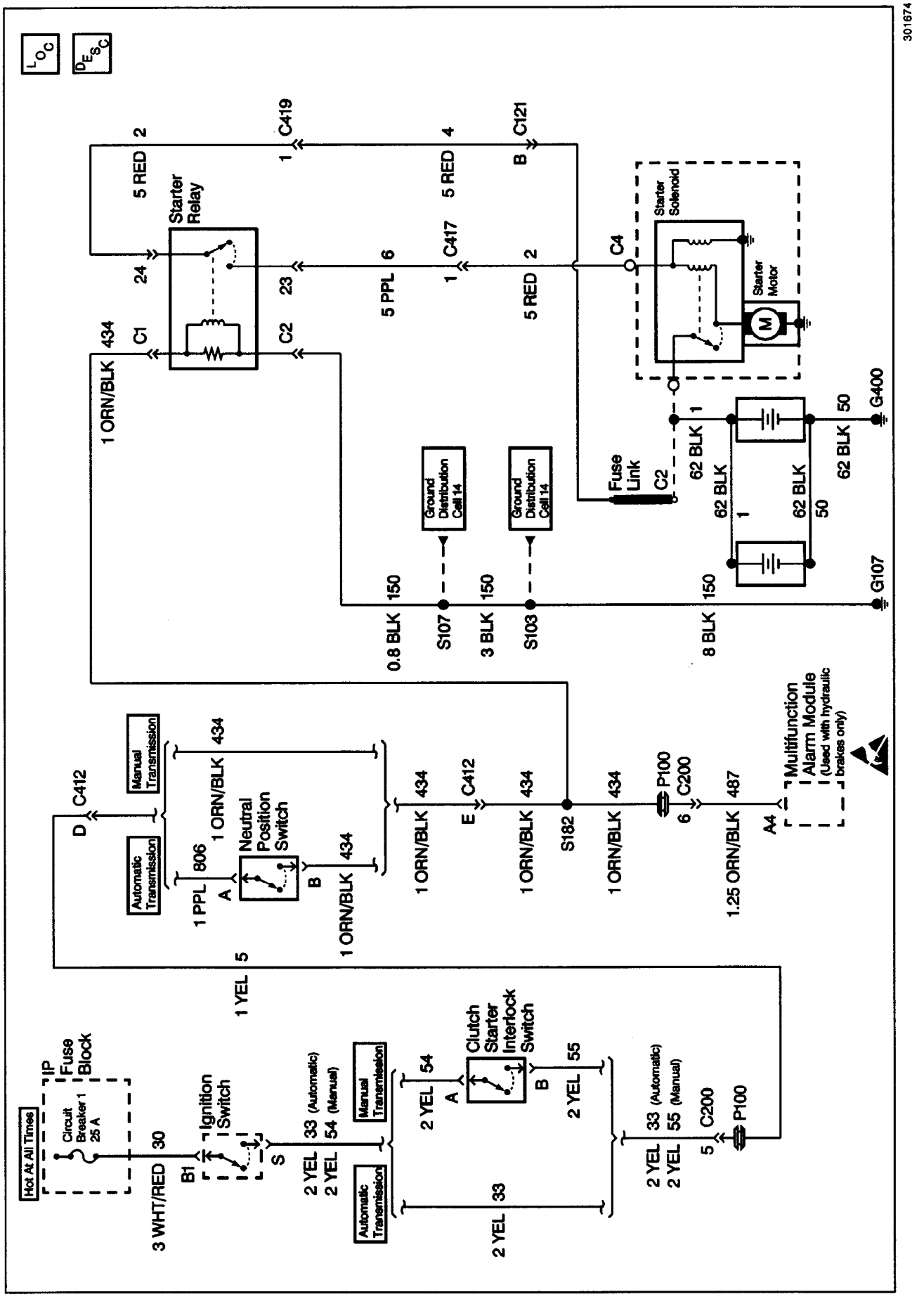
Schematic and Routing Diagrams

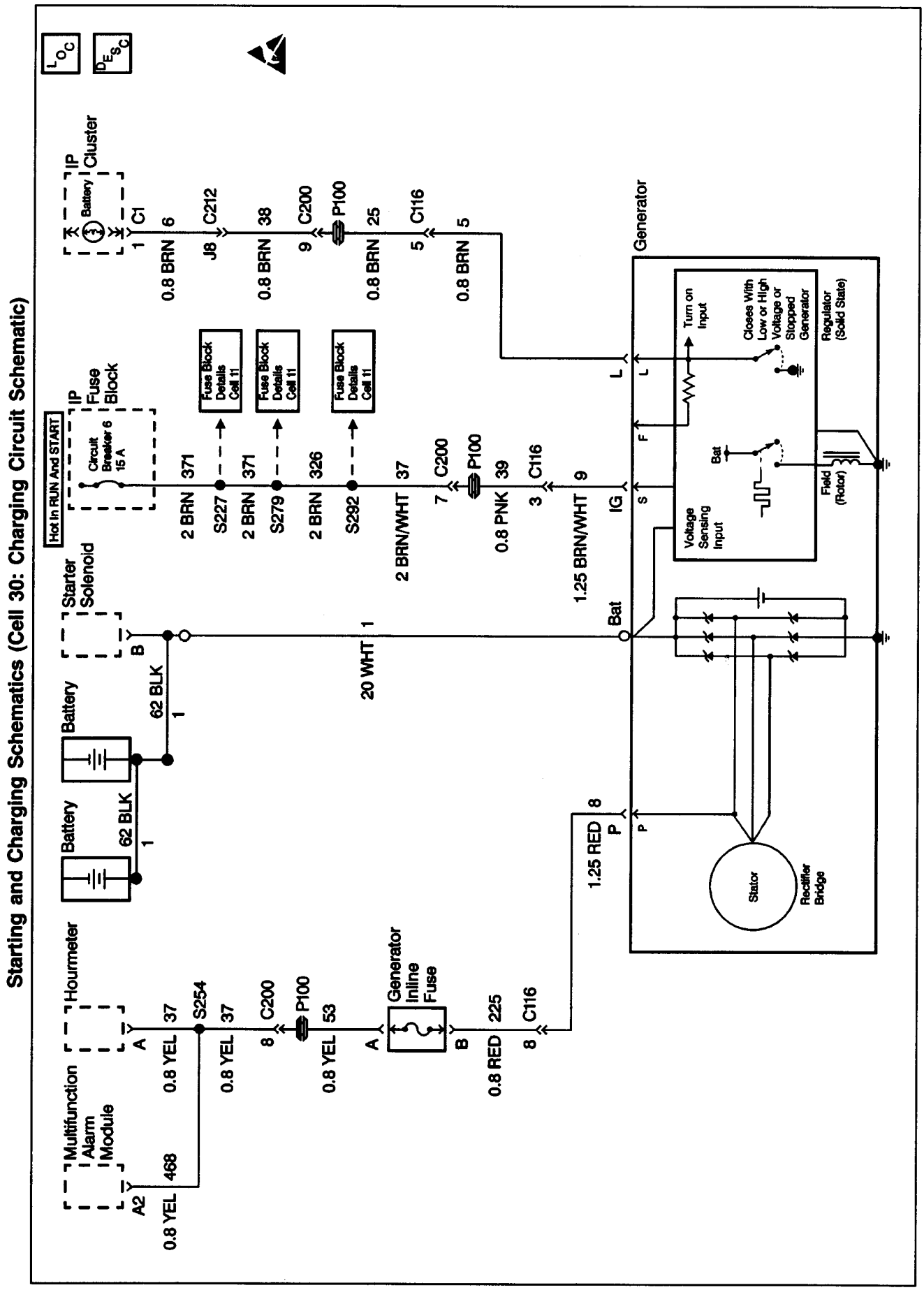
Starting and Charging Schematic References

Reference on Schematic	Section Number - Subsection Name
Audible Warning Cell 76	8—Instrument Panel and Console
Fuse Block Details Cell 11	8—Wiring Systems
Ground Distribution Cell 14	8—Wiring Systems
Headlights: Daytime Running Lights Cell 102	8—Lighting Systems
Power Distribution Cell 10	8—Wiring Systems

Starting and Charging Schematic Icons

Icon	Icon Definition
 19384	Refer to *ESD Notice* in Cautions and Notices.

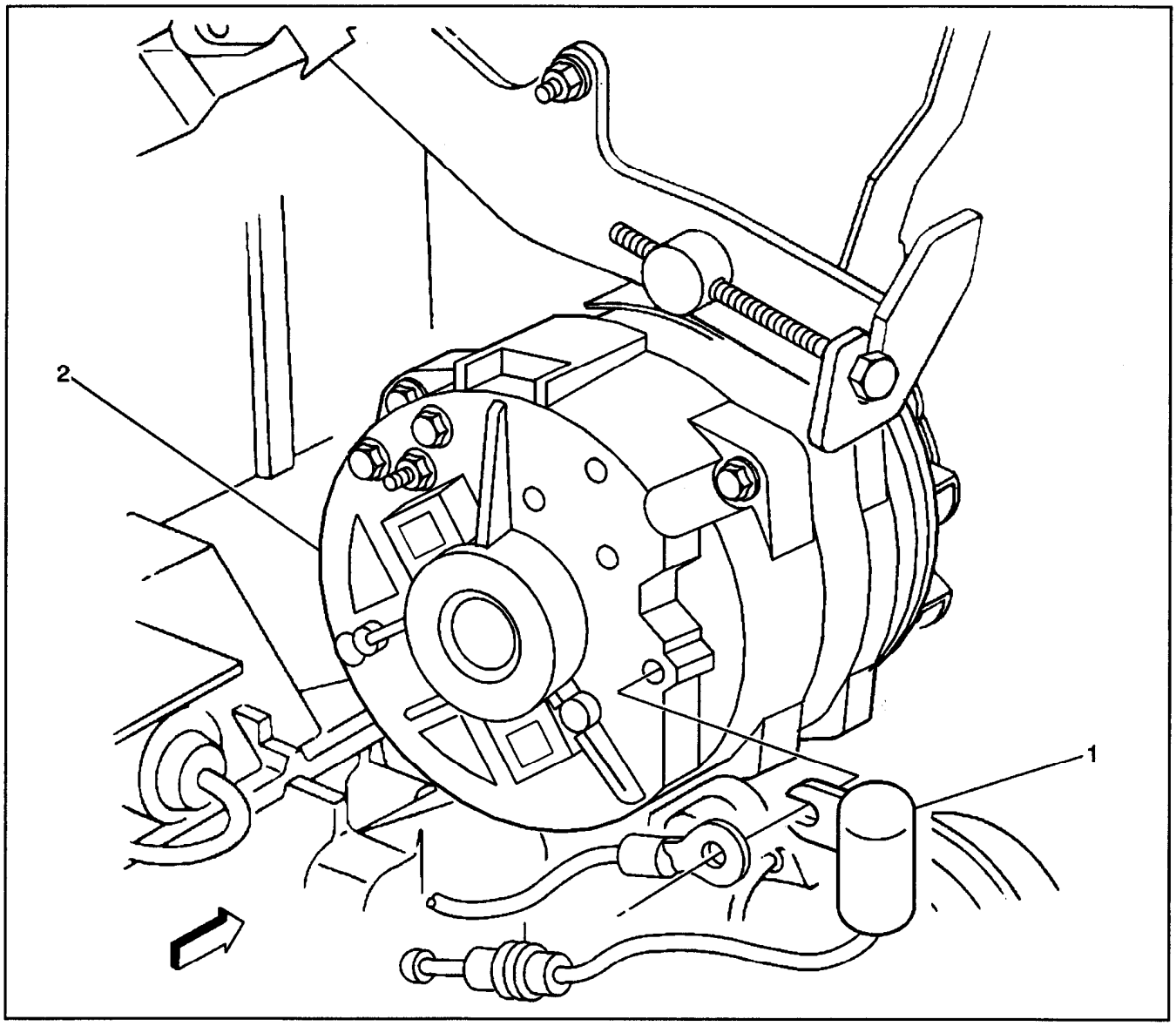

Starting and Charging Schematics (Cell 30: Starter Circuit Schematic)
301674
L O C
D E S C
Starter Relay
Starter Solenoid
Starter Motor
Fuse Link
Ground Distribution Cell 14
Ground Distribution Cell 14
Manual Transmission
Automatic Transmission
Neutral Position Switch
Clutch Starter Interlock Switch
Ignition Switch
Circuit Breaker 1 25 A
IP Fuse Block
Hot At All Times
Multifunction Alarm Module (Used with hydraulic brakes only)
1 ORN/BLK 434
5 RED 2
5 RED 4
5 PPL 6
1 PPL 806
1 YEL 5
3 WHT/RED 30
2 YEL 33 (Automatic)
2 YEL 54 (Manual)
2 YEL 54
2 YEL 55
2 YEL 33
0.8 BLK 150
3 BLK 150
8 BLK 150
62 BLK 1
62 BLK 50
1.25 ORN/BLK 487
C1
C2
C4
C121
C412
C417
C419
C200
P100
S107
S103
S182
G107
G400


Starting and Charging Schematics (Cell 30: Charging Circuit Schematic)
301675
Multifunction Alarm Module
Hourmeter
Battery
Battery
Starter Solenoid
Hot In RUN And START
IP Fuse Block
Circuit Breaker 6 15 A
IP Cluster
Battery
Generator Inline Fuse
Fuse Block Details Cell 11
Fuse Block Details Cell 11
Fuse Block Details Cell 11
Generator
Turn on Input
Closes With Low or High Voltage or Stopped Generator
Regulator (Solid State)
Voltage Sensing Input
Bat
Field (Rotor)
Stator
Rectifier Bridge
A2
A
B
C1
J8
S227
S279
S292
S254
C200
P100
C116
L
F
S
IG
P
Bat
0.8 YEL 468
0.8 YEL 37
0.8 YEL 37
0.8 YEL 53
0.8 RED 225
62 BLK 1
62 BLK 1
20 WHT 1
0.8 BRN 6
2 BRN 371
2 BRN 371
2 BRN 326
2 BRN/WHT 37
0.8 PNK 39
1.25 BRN/WHT 9
1.25 RED 8
0.8 BRN 38
0.8 BRN 25
0.8 BRN 5

Component Locator

Starting and Charging Component Views

Generator, Rear View

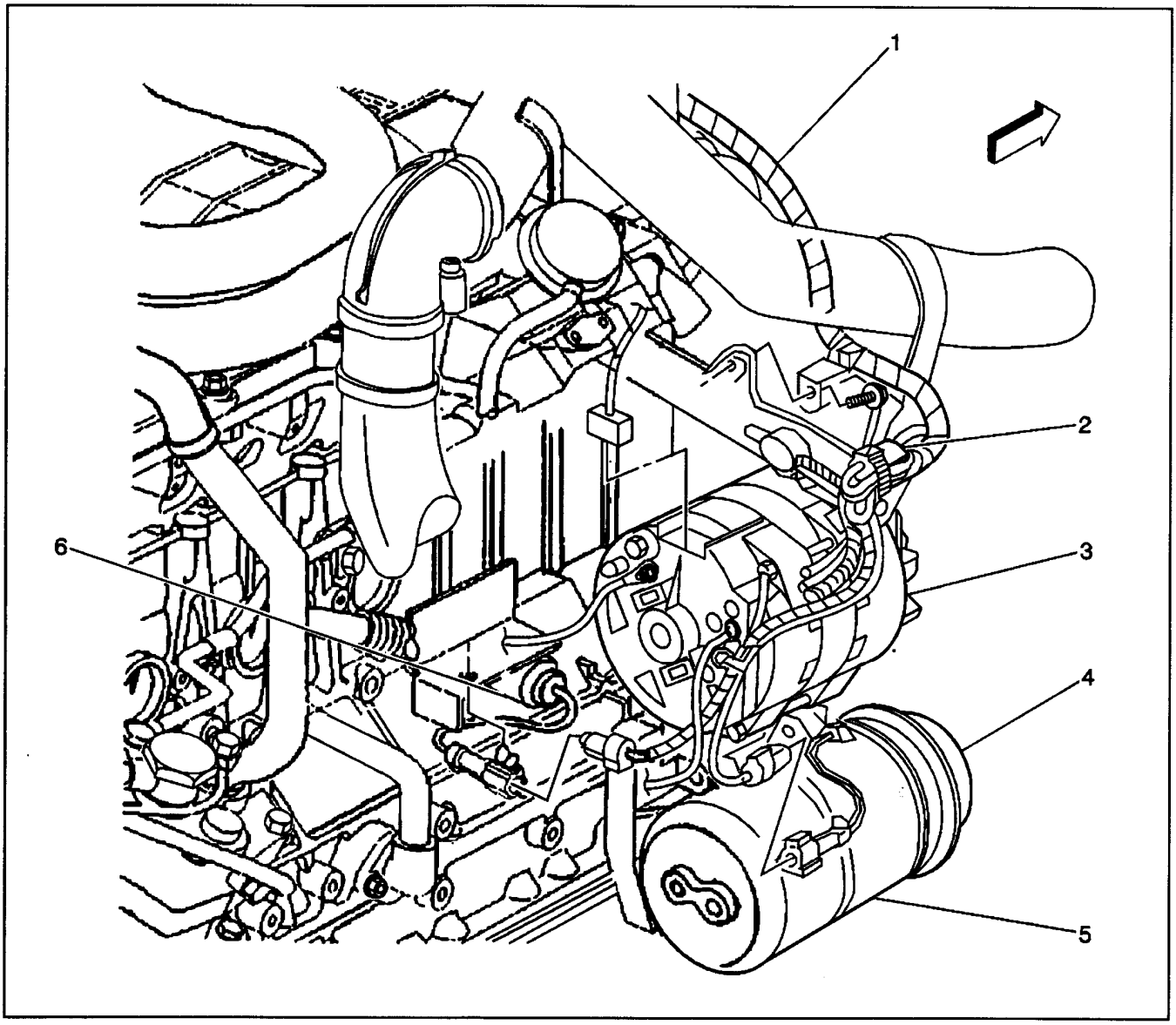


228810

Legend

(1) Generator Capacitor
(2) Generator

Engine Harness to RH Side of Engine, RH Rear View

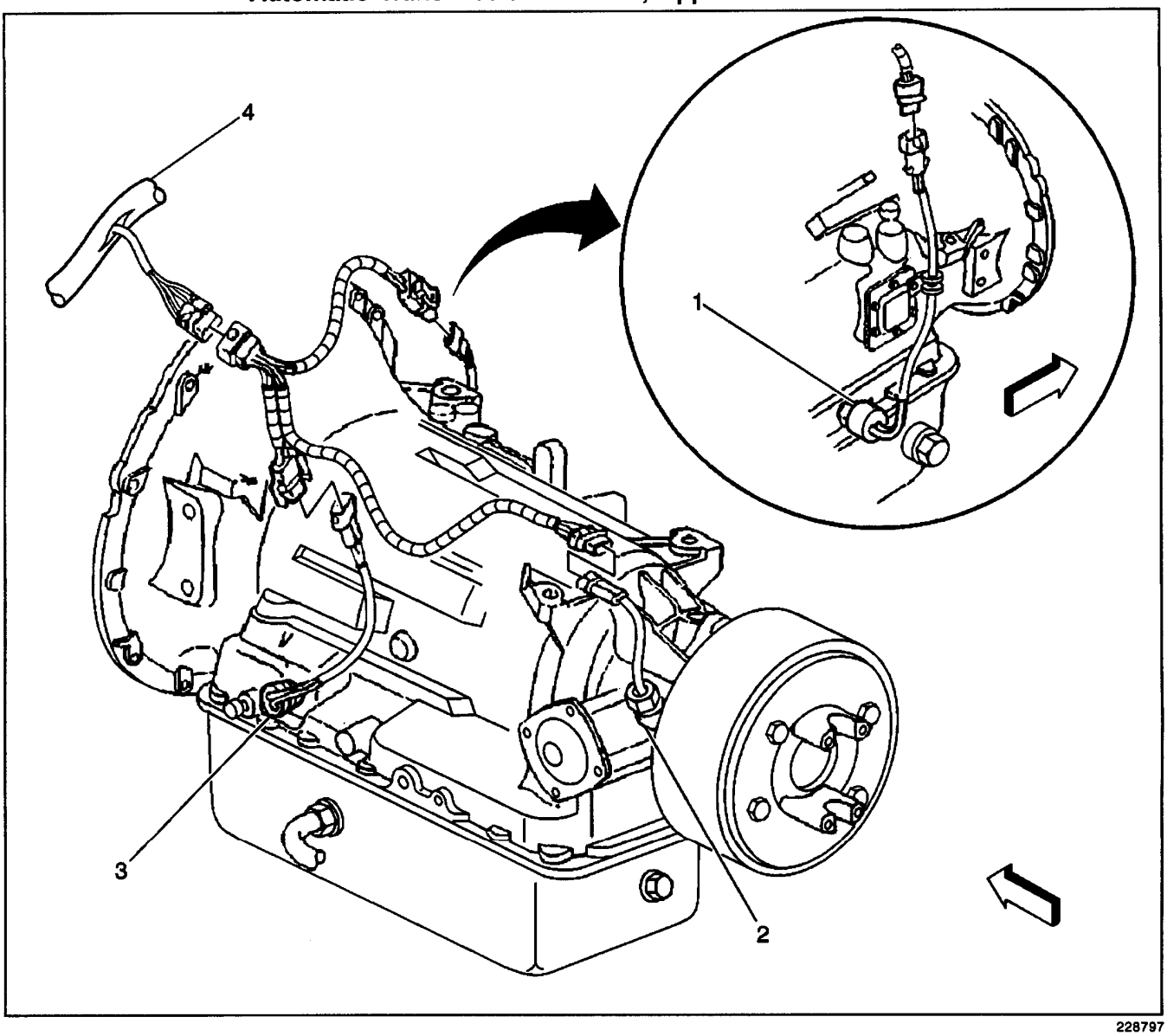


228805

Legend

(1) Engine Harness
(2) Generator Fuse
(3) Generator
(4) A/C Compressor Clutch
(5) A/C Compressor
(6) Engine Oil Pressure Gauge Sensor

Automatic Transmission Harness, Upper Left Rear View

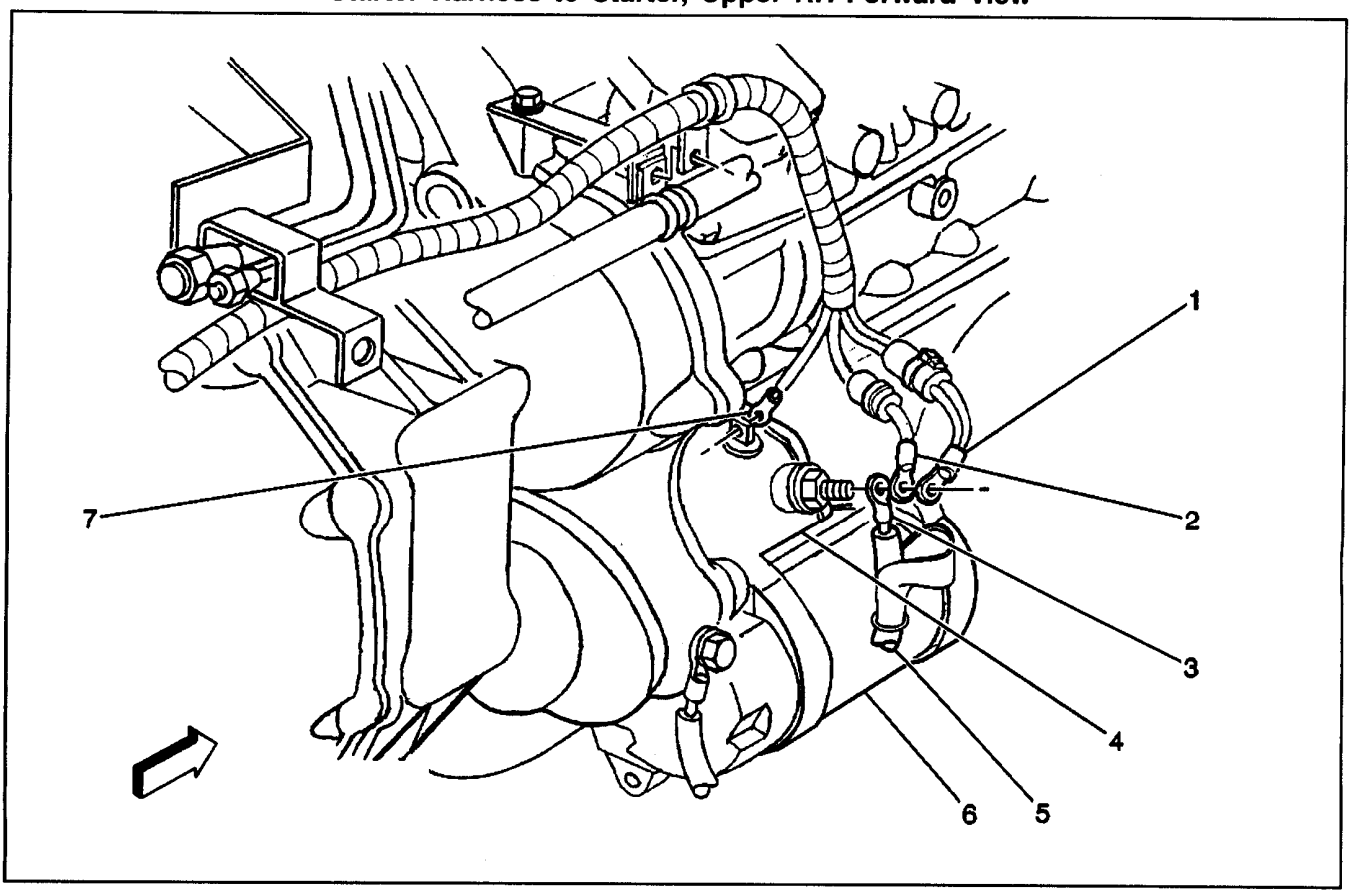


228797

Legend

(1) Backup Lamps Switch
(2) Vehicle Speed Sensor (VSS)
(3) Neutral Switch
(4) Front Chassis Harness

Starter Harness to Starter, Upper RH Forward View

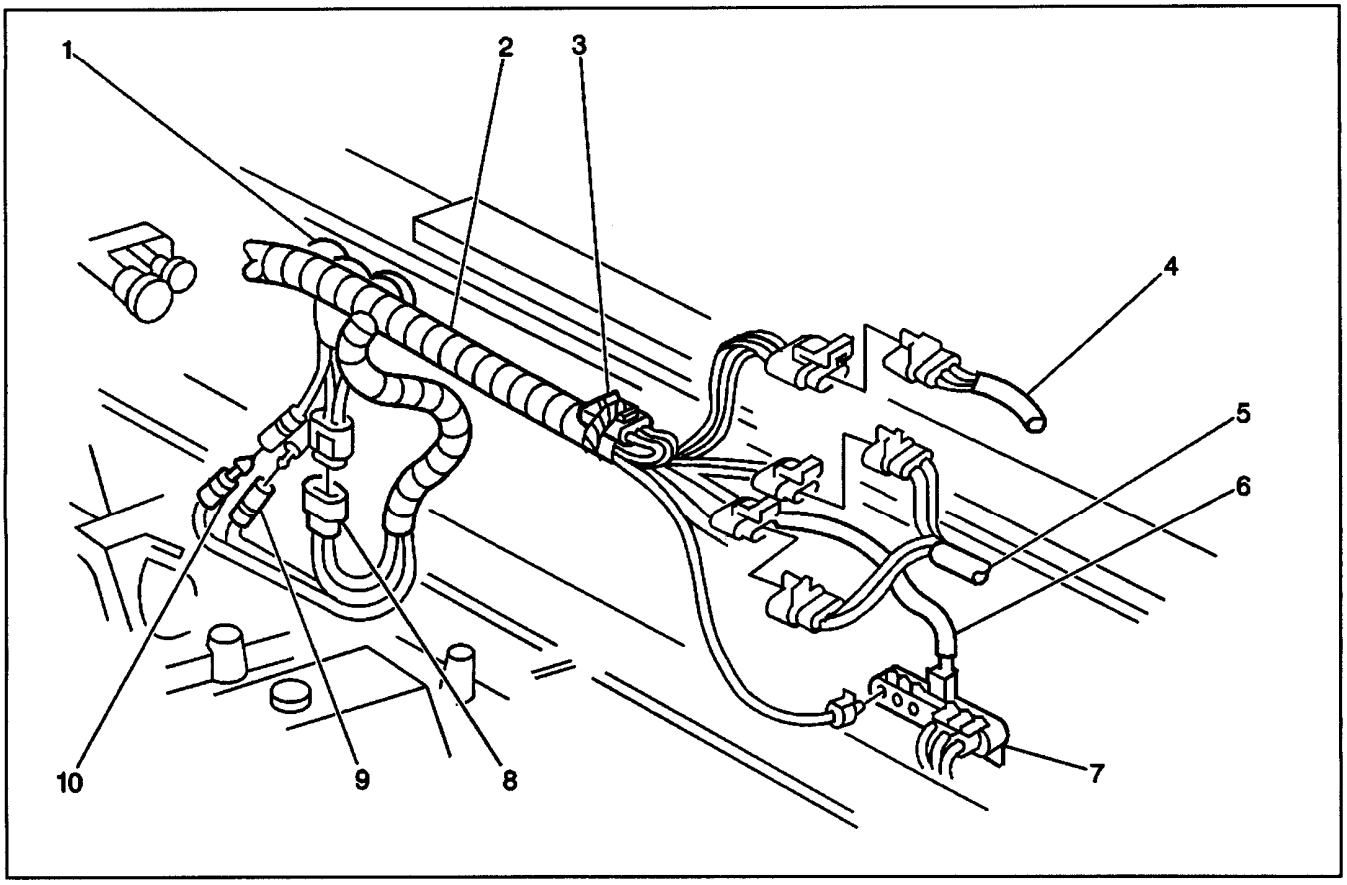


228771

Legend

(1) Engine Harness to Starter Solenoid Connector C3 (Ring Terminal)
(2) Engine Harness to Starter Solenoid Connector C2 (Ring Terminal)
(3) Positive Battery Cable to Starter Solenoid Connector C1 (Ring Terminal)
(4) Starter Solenoid
(5) Positive Battery Cable
(6) Starter Motor
(7) Engine Harness to Starter Solenoid Connector C4 (Ring Terminal)

Front Chassis Harness to RH Frame, LH Forward View



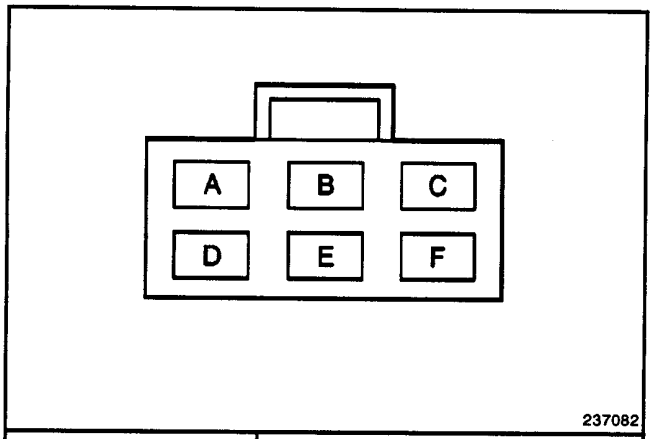
228778

Legend

(1) Starter Relay
(2) Front Chassis Harness
(3) Body Builder Connector(s)
(4) Trailer Harness
(5) Rear Chassis Harness
(6) Negative Battery Cable
(7) Ground Block (Part of Negative Battery Cable, 6 cavities)
(8) Starter Relay Connector C3 (2 cavities)
(9) Starter Relay Connector C2 (1 cavity)
(10) Starter Relay Connector C1 (1 cavity)

Starting and Charging Connector End Views

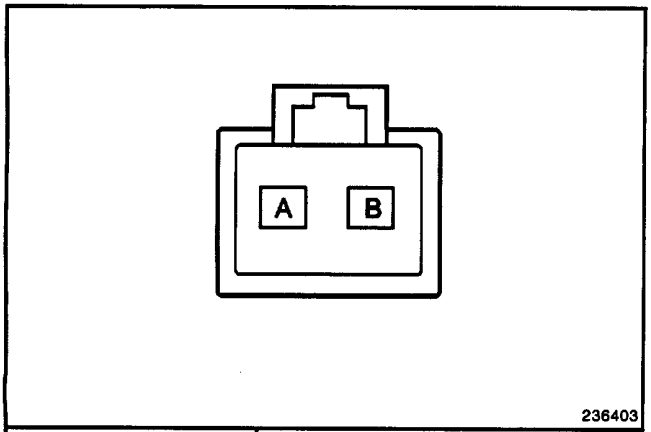
Automatic Transmission Selector Control (AT Transmission)



237082

Connector Part Information	• 6 Way F • (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	RED/GRN	41	Illumination
B	RED	37	Fuse Output Ignition
C	BLK/WHT	40	Transmission Park/Neutral Signal
D	BLK/RED	46	Interior Lamp Dimming Buss
E	RED/BLU	38	Select Lever Back Lamp
F	BLK/RED	39	Neutral Signal

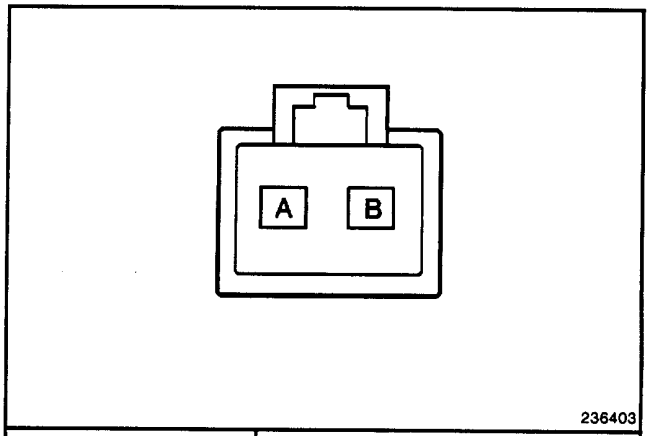
Clutch Switch



236403

Connector Part Information	• 2 Way • Female		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	PNK	276	Fuse Output-Ignition
B	BLU/YEL	277	ECM Pin-7

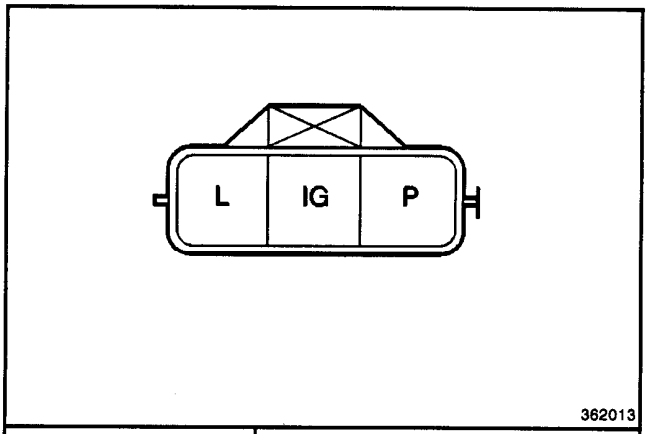
Clutch Starter Interlock Switch (Manual)



236403

Connector Part Information	• 2 Way • Female		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	YEL	54	Ignition Switch
B	YEL	55	Starter Relay

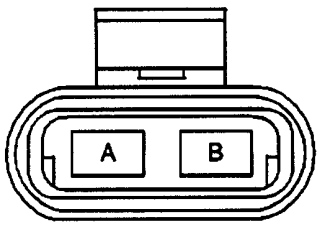
Generator



362013

Connector Part Information	• 3 Way • Female		
Pin	**Wire Color**	**Circuit No.**	**Function**
L	BRN	5	Generator (Charge Indicator Lamp Output)
IG	BRN/WHT	9	Generator
P	RED	8	Generator Output-Regulator Refence Voltage

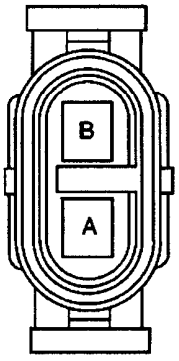
Generator In-Line Fuse



62489

Connector Part Information		• 12066681 • 2 Way F Metri-Pack 630 Series, Pull to Seat (BLK)	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	YEL	53	Fuse Output-Generator-Tachometer Pulse
B	RED	225	Alternator Output-Regulator Reference Voltage

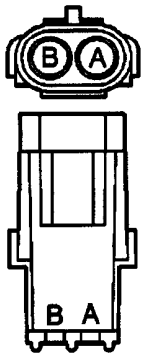
Neutral Position Switch



38554

Connector Part Information		• 12124819 • 2 Way F Metri-Pack 280 Series, Sealed (BLK)	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	PPL	806	Fuse Output-Crank
B	ORN/BLK	434	Transmission Mounted Neutral Safety Switch Signal

Starter Relay



258174

Connector Part Information		• 12162878 • 2 Way M 305 Series (NAT)	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	PPL	6	Starter Solenoid Feed
B	RED	2	Fuse Output-Battery

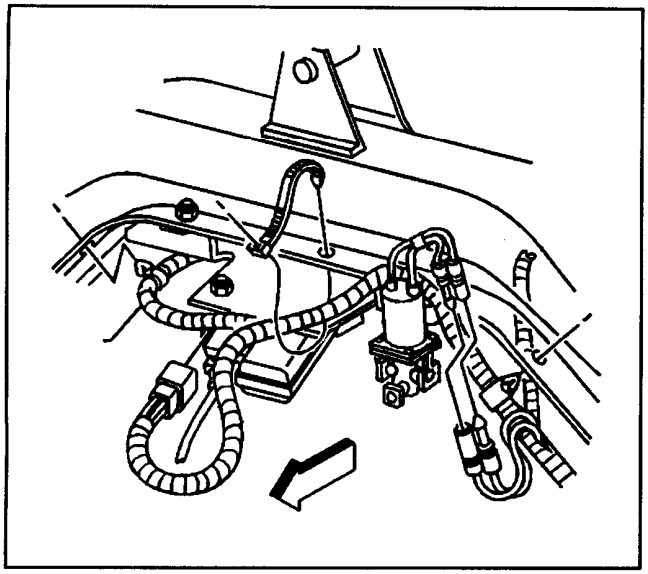
Diagnostic Information and Procedures

Starting System Check

Notice: Do not operate the starter motor continuously for more than 30 seconds without pausing to allow it to cool at least 2 minutes. Overheating from excessive cranking will seriously damage the starting motor.

Tools Required

- *J 39200* Digital Multimeter
- *J 35590* Inductive Current Clamp



240794

Disconnect the fuel stop control actuator in order to prevent the engine from starting which could cause serious injury while performing the following inspection procedures.

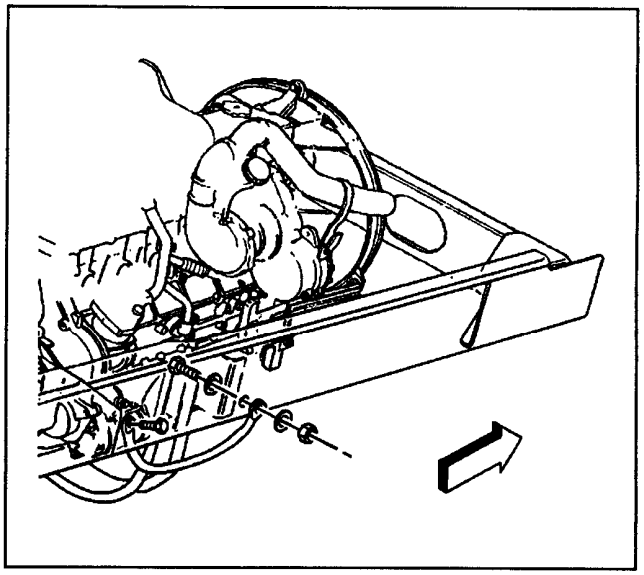
Testing the starter motor against the specifications while the starter motor is on the vehicle is impossible.

Use the following procedure in order to test for excessive resistance in the starting circuit:

1. Ensure that the vehicle is at room temperature. Colder weather causes higher resistance in the circuit.
2. Ensure that the battery is fully charged.
3. Remove the surface charge if the battery was recently charged.
4. Perform a load test. Refer to *Charging System Check (Battery Testing).*
5. Connect *J 39200* across the battery. The *J 39200* should show at least 12 volts.
6. Crank the engine.
7. Measure the voltage.

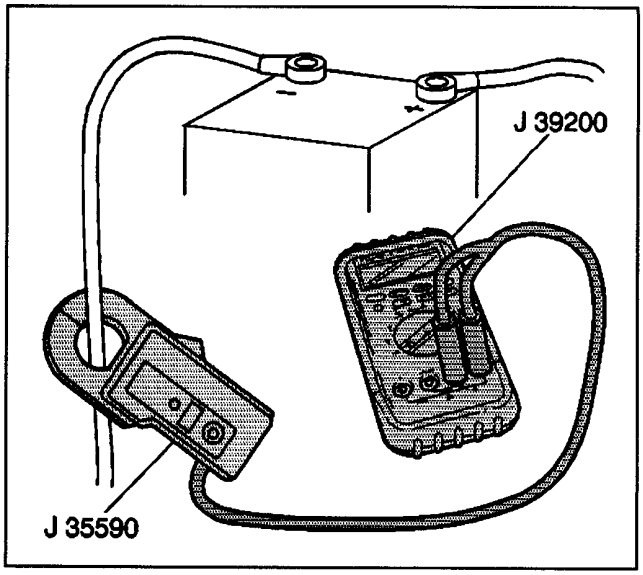
   Excessive resistance exists in the circuit if the voltage drops more than 2 volts.

8. Inspect the ground circuit for the following conditions:
   - Loose connections
   - Corroded connections
   - Dirty connections
   - Frayed cables



240793

9. Inspect the starter ground.



105066

10. Connect *J 39200* from the negative terminal of the battery to the ground stud on the engine block near the starter motor.
11. Crank the engine.
12. Measure the voltage.

    J 39200 should read about 0.2 volt.

    Excessive resistance exists in the ground circuit if the reading is 0.5 volt or higher.

13. Remove the starter motor for repair if excessive resistance exist but the following components are in proper condition:
    - The circuit wires
    - The connections
    - The ground circuit

Charging System Check

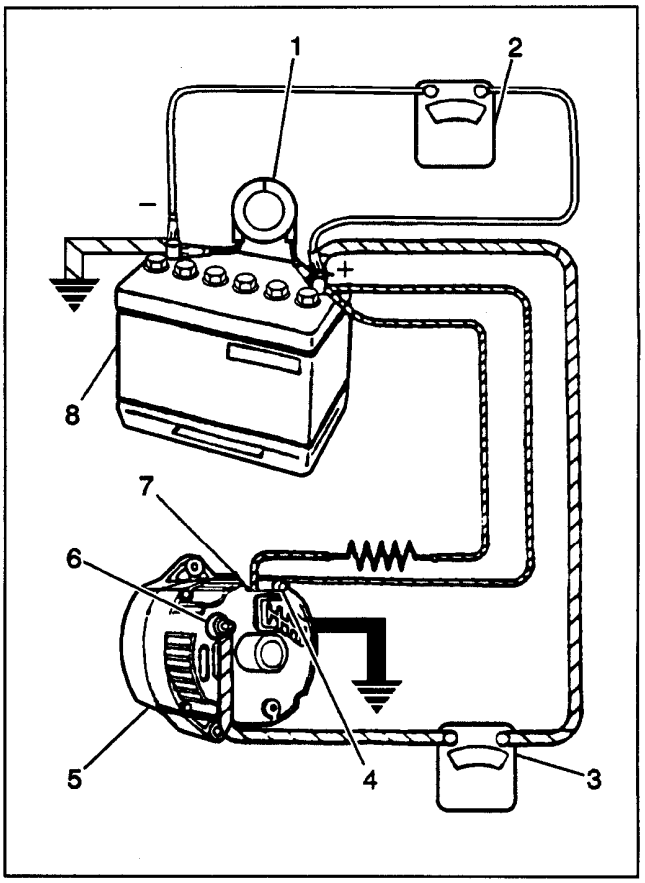
Tools Required

- *J 39200* Digital Multimeter
- *J 35590* Inductive Current Clamp

Using the Digital Multimeter:

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable. Refer to Negative Battery Cable Removal in *Battery Cable Replacement.*
2. Connect an ammeter in series between the BAT terminal of the generator and the output lead.
3. Connect the negative battery cable. Refer to Negative Battery Cable Installation in *Battery Cable Replacement.*
4. Start the engine.
5. Turn ON the following components:
    - The radio
    - The windshield wipers
    - The headlamps (high beam)
    - The blower motor (high speed)



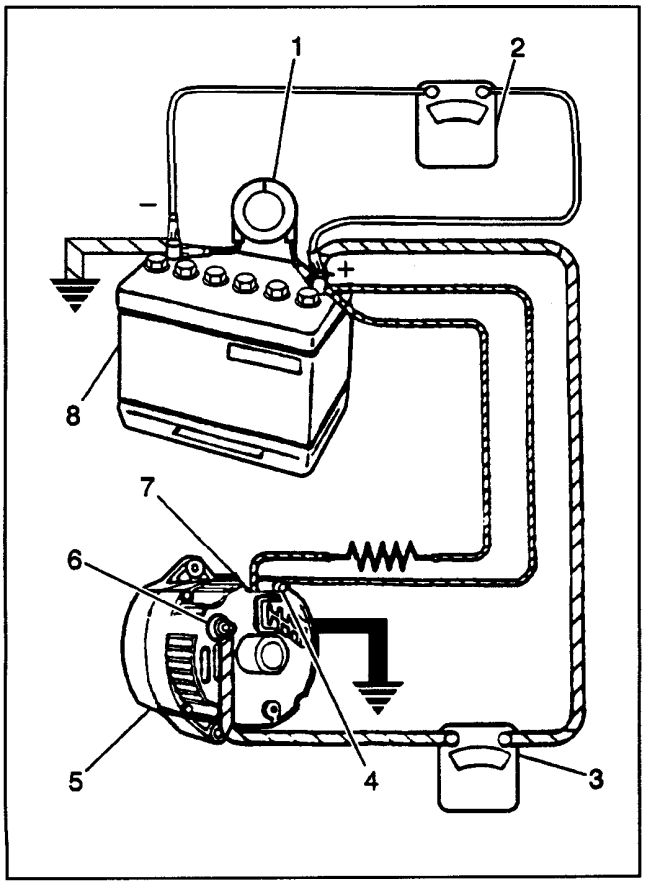
203666

6. Connect a carbon pile across the battery.
7. Operate the engine at 2500 RPM.

   Important: Residual magnetism in the rotor causes the initial voltage buildup. Increase the engine speed as necessary in order to obtain the maximum current output.
8. Adjust the carbon pile as necessary in order to obtain the maximum current output.
9. If the ampere output is within 10 amperes of the rated output stamped on the generator frame, the generator functions properly.
10. If the ampere output is not within 10 amperes of the rated output stamped on the generator frame, repair the generator. Refer to *Generator Replacement.*

Using the Inductive Current Clamp:

1. Install the *J 35590.*
2. Start the engine.
3. Turn ON the following components:
    - The radio
    - The windshield wipers
    - The headlamps (high beam)
    - The blower motor (high speed)



203666

4. Connect a carbon pile across the battery.
5. Operate the engine at 2500 RPM.

   Important: Residual magnetism in the rotor causes the initial voltage buildup. Increase the engine speed as necessary in order to obtain the maximum current output.
6. Adjust the carbon pile as necessary in order to obtain the maximum current output.
7. If the ampere output is within 10 amperes of the rated output stamped on the generator frame, the generator functions properly.
8. If the ampere output is not within 10 amperes of the rated output stamped on the generator frame, repair the generator. Refer to *Generator Replacement.*

Charging System Check (Battery Testing)

Tools Required

- Battery Terminal Adapters
- *J 39200* Digital Multimeter

Perform the following procedures in order to test batteries.

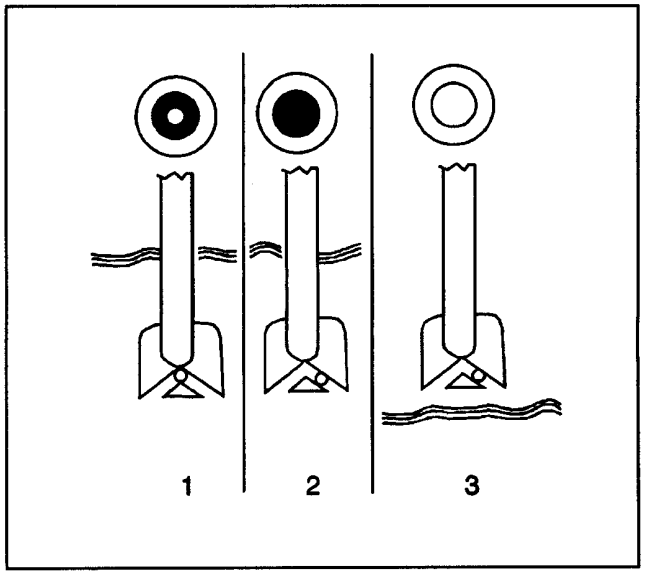
Visual Inspection Procedure

1. Inspect for obvious damage that may permit the loss of electrolyte.

   A cracked or broken battery case is an example of the above damage.
2. Determine the cause of the damage.
3. Correct the damage as necessary.

   If no obvious damage exists, proceed to the Hydrometer Inspection.

Hydrometer Inspection



181056

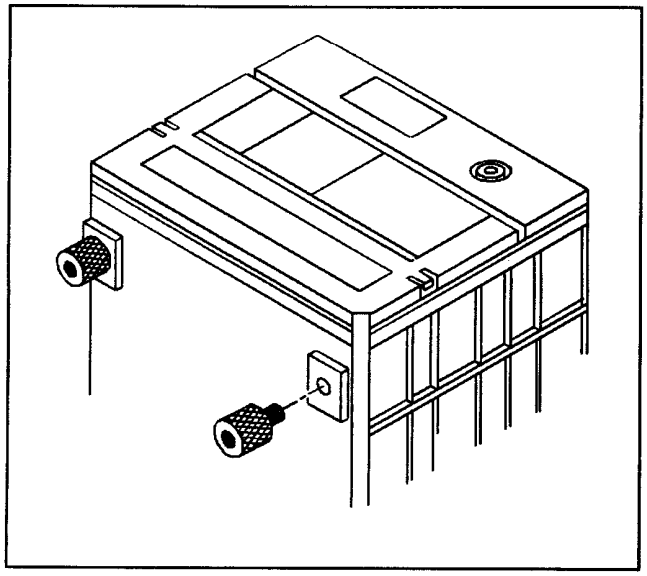
1. Inspect for green dot visibility (1).

   If the green dot is visible (1), proceed to Battery Load Testing.
2. Inspect for darkness (2). (The green dot is not visible.)

   If the hydrometer is dark (2), charge the battery. Refer to *Battery Charging.* Proceed to Battery Load Testing.
3. Inspect for a clear or yellow color (3).

   If a clear or yellow color exists (3), replace the battery.

Battery Load Testing



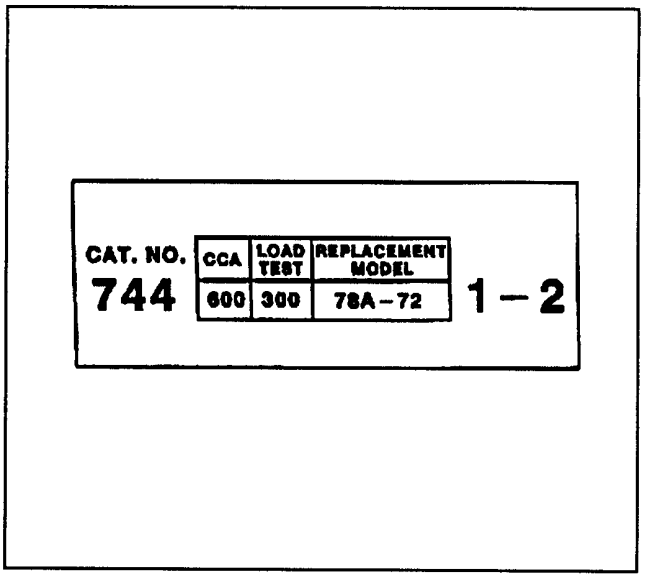
42433

1. Use battery side terminal adapters in order to ensure a proper connection during battery load testing.
2. Inspect the battery in order to ensure that the battery is not frozen.

   If the battery is frozen do not load test the battery. Replace the battery.
3. Turn all of the electrical loads off.
4. Use the *J 39200* in order to measure the voltage across the battery terminals.

   When the green dot appears in the hydrometer, the voltage should equal or exceed 12 volts. Replace the battery if the voltage is less than 12 volts, unless the battery has just been discharged (such as by load testing or cranking the engine).
5. With the *J 39200* attached, connect a battery load tester across the battery terminals.

   Important: Do not perform this step if the battery has not been recently charged.
6. Apply a 300 ampere load for 15 seconds to the battery in order to remove the surface charge from the battery.
7. Wait 15 seconds in order to allow the battery to recover.



106519

8. Apply the specified amperage load to the battery. The battery specification label determines the appropriate voltage.
9. Load the battery for 15 seconds. Read the voltage and remove the load.
10. If the voltage remains above the minimum value, the battery is good and should be returned to service. Refer to Battery Temperature and Minimum Voltage in *General Specifications*. Estimate the battery temperature by feel, and the temperature that the battery has been exposed to for the preceding few hours.
11. Replace the battery if the voltage drops below the listed minimum value.

Starter Solenoid Does Not Click

Step	Action	Value(s)	Yes	No
1	1. Ensure that the battery voltage is appropriate for the temperature. Refer to *General Specifications.* 2. Connect a test lamp from CKT 2 (RED) at starter solenoid terminal S to chassis ground. 3. Place the transmission in the PARK position. 4. Place the ignition switch in the START position. Does the test lamp light?	—	Go to *Step 2*	Go to *Step 4*
2	1. Clean the following components: • The starter mounting bolts • The starter motor • The starter motor ground • The mounting surface 2. Connect a test lamp from CKT 2 (RED) at starter solenoid terminal S to chassis ground. 3. Place the transmission in the PARK position. 4. Place the ignition switch in the START position. Does the test lamp light?	—	Go to *Step 3*	Go to *Step 4*
3	Replace the starter motor. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 4*	System OK
4	1. Connect a test lamp from starter relay terminal 23 to chassis ground. 2. Place the ignition switch in the START position. Does the test lamp light?	—	Go to *Step 5*	Go to *Step 6*
5	Locate and repair the open in CKT 6 (PPL) or CKT 2 (RED) between the starter relay and the starter solenoid. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 6*	System OK
6	Connect a test lamp from starter relay terminal 24 to chassis ground. Does the test lamp light?	—	Go to *Step 8*	Go to *Step 7*
7	Locate and repair the open in CKT 2 (RED) between the starter relay and the fusible link at the starter motor. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 8*	System OK
8	1. Connect a test lamp from CKT 434 (ORN/BLK) at starter relay connector C1 to chassis ground. 2. Place the ignition switch in the START position. Does the test lamp light?	—	Go to *Step 10*	Go to *Step 9*
9	Is the vehicle equipped with an automatic transmission?	—	Go to *Step 13*	Go to *Step 19*
10	1. Connect a jumper wire from CKT 150 (BLK) at starter relay connector C2 to chassis ground. 2. Place the ignition in the START position. Does the engine crank?	—	Go to *Step 11*	Go to *Step 12*
11	Locate and repair the open in CKT 150 (BLK) between the starter relay and G107. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 13*	System OK

Starter Solenoid Does Not Click (cont'd)

Step	Action	Value(s)	Yes	No
12	Replace the starter relay. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 13*	System OK
13	1. Connect a test lamp from neutral switch terminal B to chassis ground. 2. Place the ignition switch in the START position and hold. Does the test lamp light?	—	Go to *Step 14*	Go to *Step 15*
14	Locate and repair the open in CKT 434 (ORN/BLK) between the neutral switch and the starter relay. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 15*	System OK
15	1. Connect a test lamp from neutral switch terminal A to chassis ground. 2. Place the ignition switch in the START position and hold. Does the test lamp light?	—	Go to *Step 16*	Go to *Step 19*
16	Inspect the neutral switch for proper adjustment. Is an adjustment necessary?	—	Go to *Step 17*	Go to *Step 18*
17	Adjust the neutral switch as necessary. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 18*	System OK
18	Replace the neutral switch. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 19*	System OK
19	1. Connect a test lamp from transmission harness connector C412 terminal D to chassis ground. 2. Place the ignition switch in the START position. Does the test lamp light?	—	Go to *Step 20*	Go to *Step 23*
20	Is the vehicle equipped with a manual transmission?	—	Go to *Step 21*	Go to *Step 22*
21	Locate and repair the open in CKT 5 (YEL) or CKT 434 (ORN/BLK) between C412 and the starter relay. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 23*	System OK
22	Locate and repair the open in CKT 5 (YEL) or CKT 806 (PPL) between C412 and the neutral position switch. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 23*	System OK
23	1. Connect a test lamp from CKT 33 (YEL) at terminal S of the ignition switch to chassis ground. 2. Place the ignition switch in the START position and hold. Does the test lamp light?	—	Go to *Step 24*	Go to *Step 25*
24	Locate and repair the open in CKT 33 (YEL) or CKT 5 (YEL) between the ignition switch and transmission harness connector C412. Does the engine still not crank and does the starter solenoid still not click?	—	Go to *Step 25*	System OK

Starter Solenoid Does Not Click (cont'd)

Step	Action	Value(s)	Yes	No
25	Connect a test lamp from CKT 30 (WHT/RED) at terminal B1 of the ignition switch to chassis ground. Does the test lamp light?	—	Go to *Step 26*	Go to *Step 27*
26	Replace the ignition switch. Does the engine still not crank and does the starter solenoid still not click?	—	—	System OK
27	Locate and repair the open in CKT 30 (WHT/RED) between the ignition switch and the IP fuse block. Does the engine still not crank and does the starter solenoid still not click?	—	—	System OK

Starter Solenoid Clicks, Engine Does Not Crank

Step	Action	Value(s)	Yes	No
1	1. Disconnect the connector at the engine shutoff solenoid. 2. Connect a voltmeter to one of the battery's positive and negative terminals. 3. Place the ignition switch in the START position and hold for 15 seconds. 4. Observe the voltmeter indication. 5. Place the ignition switch in the OFF position. Does the voltage exceed the specified value?	9.6 V	Go to*Step 2*	Go to *Step 3*
2	1. Connect a voltmeter to the other battery's positive and negative terminals. 2. Place the ignition switch in the START position and hold for 15 seconds. 3. Observe the voltmeter indication. 4. Place the ignition switch in the OFF position. Does the voltage exceed the specified value?	9.6 V	Go to *Step 5*	Go to *Step 3*
3	Perform the battery load test.[1] Refer to *Charging System Check (Battery Testing)* Does the battery pass the load test?	—	Go to *Step 5*	Go to *Step 4*
4	Replace the battery and/or the auxiliary battery. Does the starter solenoid still click and does the engine still not crank or crank slowly?	—	Go to *Step 5*	System OK
5	1. Connect a voltmeter between the battery negative terminal and the engine block. 2. Place the ignition switch in the START position. 3. Observe the voltage. Does the voltage exceed the specified value?	0.5 V	Go to *Step 6*	Go to *Step 7*
6	Locate and repair the high resistance in negative cable 50 (BLK) between the battery and G400. Does the starter solenoid still click and does the engine still not crank or crank slowly?	—	Go to *Step 7*	System OK
7	1. Connect a voltmeter between the positive battery terminal and starter solenoid terminal S. 2. Place the ignition switch in the START position. 3. Observe the voltage. Does the voltage exceed the specified value?	0.5 V	Go to *Step 8*	Go to *Step 9*

Starter Solenoid Clicks, Engine Does Not Crank (cont'd)

Step	Action	Value(s)	Yes	No
8	Locate and repair the high resistance in positive cable 1 (BLK) between the battery and the starter. Does the starter solenoid still click and does the engine still not crank or crank slowly?	—	—	System OK
9	Repair or replace the starter motor. Does the starter solenoid still click and does the engine still not crank or crank slowly?	—	—	System OK
[1]This vehicle is equipped with dual batteries. Test the batteries individually.				

Starter Motor Noise Diagnosis

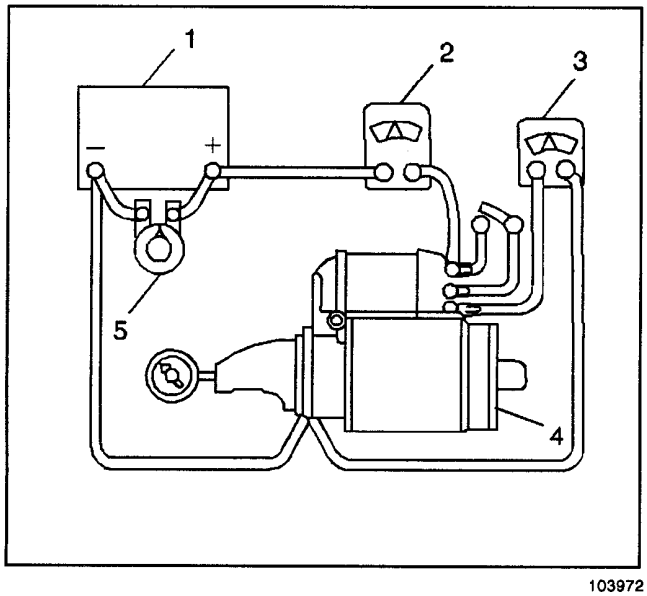
Loud Cranking Noise

Problem	Action
DEFINITION: A loud noise occurs while cranking the engine after the engine fires but while the starter remains engaged.	
The starter motor clutch is worn.	Remove the starter motor for repair.

Rumble, Growl or Knock

Problem	Action
DEFINITION: After starting the engine, a rumble, growl or (in severe cases) a knock is heard as the starter coasts down to a stop.	
A starter armature may be bent or unbalanced.	Remove the starter motor for repair. Refer to Unit Repair.

Starter No Load Test



103972

1. Connect a voltmeter from the motor terminal to the motor frame.
   On starter motors with ground terminals, connect the voltmeter to the ground terminals rather than the frame.
2. Use an RPM indicator in order to measure pinion speed.
3. Connect the motor and an ammeter in series with the following components:
   - A fully charged battery of the specified voltage
   - A switch in the open position from the solenoid battery terminal to the solenoid switch terminal.
4. Close the switch.
5. Compare the following measurements with the no load test specified values. Refer to Starter Motor Usage.
   - RPM
   - Current
   - Voltage
6. Evaluate the measurements by understanding that it is not necessary to obtain the exact voltage specified. A good reading may be made by understanding that if the voltage is slightly higher, the RPM will be slightly higher and the current will remain basically unchanged
7. Use the following procedure in order to obtain the exact specified voltage (if desired):
   7.1. Connect a carbon pile across the battery.
   7.2. Compare the reduced voltage with the no load test specified values. Refer to Starter Motor Usage.
8. Disconnect the circuit only with the switch open.

9. Use the following information in order to interpret the test results:
   - Rated current draw and no-load speed indicate normal condition of the starter motor.
   - Low free speed and high current draw indicate the following conditions:
     - Excessive friction

       Tight, dirty, or worn bearings, a bent armature shaft or loose pole shoes allow the armature to drag.
     - A shorted armature

       Inspect a shorted armature on a growler after disassembly.
     - Grounded armature fields

       Verify the grounded armature after disassembly.
   - Failure to operate with high current draw indicates the following conditions:
     - A direct ground

       A direct ground exists in the terminal or fields.
     - Seized bearings

       Seized bearings should have been noted by hand turning the armature by hand.
   - Failure to operate with no current draw indicates the following conditions:
     - An open field circuit

       An open field circuit can be checked after disassembly by inspecting the internal connections and tracing the circuit with a self-powered test lamp.
     - Open armature coils

       Inspect the commutator for badly burned bars.
     - Broken brush springs, worn brushes

       High insulation between the commutator bars or other causes which would prevent proper contact between the brushes and the commutator.
   - Low no-load speed and low current draw indicate a higher internal resistance due to the following conditions:
     - Poor connections
     - Defective leads
     - A dirty commutator
     - An open field circuit
     - Open armature coils
     - Broken brush springs, worn brushes
   - High free speed and high current draw indicate shorted fields. If shorted fields are suspected, replace the field coil assembly and inspect for improved performance.

Starter Motor Relay Test

Tools Required

J 39200 Digital Multimeter

The starter relay is located near the battery box on the inner side of the right frame rail.

Refer to *Starting System Circuit Description* and *Starting System Check*.

1. Disconnect the engine stop control actuator in order to prevent the engine from starting while performing these checks.
2. Place the transmission in the NEUTRAL position.
3. Block the wheels.

Battery Common Causes of Failure (Common Causes)

With the proper care, the battery will provide many years of service.

The following factors may reduce the battery performance level:

- Vehicle accessories remain ON overnight.
- Insufficient driving time in order to recharge the battery.

  Short trips may cause insufficient charging time.
- Insufficient driving speed.

  Slow average driving speeds for long periods of time may cause insufficient charging.
- The vehicle's electrical load is greater than generator output.

  The addition of aftermarket equipment often causes the above condition.
- The following charging system conditions:
  - Poor ground circuits
  - Electrical shorts
  - A slipping drive belt
  - A faulty generator
- The following methods of improper installation of aftermarket equipment affect the generator:
  - Structural failure of aftermarket mounting brackets.
  - Misaligned pulleys.
  - Loose belts.
- Failure to keep the battery cable terminals clean and tight.
- Operating the battery with a loose battery hold-down.
- Pinched wires or a cracked battery case resulting from a collision may cause improper mechanical conditions in the electrical system.

  Inspect the outside of the battery periodically for damage, such as a cracked cover or case.

Battery Common Causes of Failure (Electrolyte Freezing)

The freezing point of electrolyte depends on the specific gravity of the electrolyte. Maintaining the battery in a fully charged condition can protect the electrolyte against freezing. If the green dot appears in the built-in hydrometer, the battery will not freeze unless the temperature drops below -32 °C (-25 °F). A fully charged battery will not freeze unless the temperature drops below -54 °C (-65 °F).

Battery Common Causes of Failure (Carrier and Hold-Down)

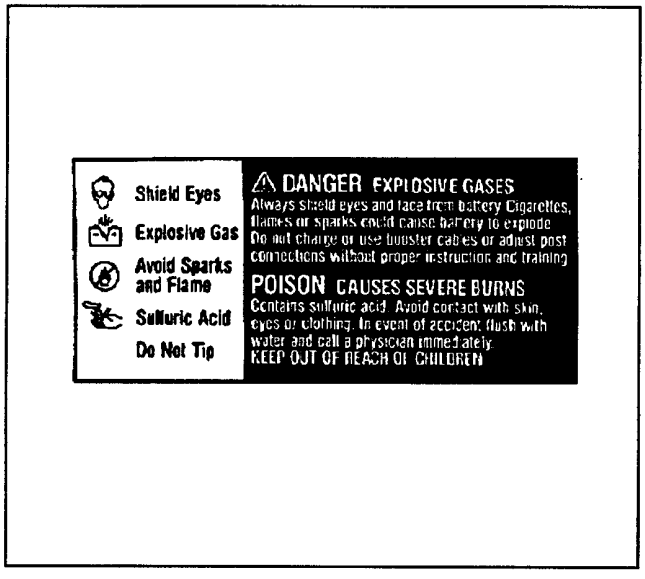
Ensure that the battery carrier and the battery hold-down(s) are in the following condition before installing the battery:

- Clean
- Free from corrosion

Ensure that the carrier is in proper condition because the carrier will hold the battery securely and keep the battery level. Ensure that no loose items are in the carrier before installing the battery.

Tighten the hold-down bolts to the specified values in order to prevent the battery from shaking in its carrier. Refer to *Fastener Tightening Specifications*.

Battery Common Causes of Failure (Battery Protect During Storage)



106521

Caution: Follow all safety precautions on the battery. Failure to do so may result in personal injury.

Some electronic devices on the vehicle impose small continuous current drains on the battery. This condition is commonly called parasitic current drain. If the vehicle is not used for an extended time, these parasitic loads can discharge and eventually cause permanent damage to the battery. Discharged batteries can also freeze in cold weather. Refer to *Battery Common Causes of Failure (Electrolyte Freezing)*.

Notice: Always turn off the engine control switch when connecting or disconnecting battery cables, battery chargers, or jumper cables. Failure to do so may damage the Powertrain Control Module (PCM) or other electronic components.

Perform the following actions if the vehicle is likely to be stored for over 30 days:

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

- Verify that the built-in hydrometer's green dot is visible, then disconnect the negative battery cable from the battery. This action will protect the battery from being discharged by parasitic current drain from the vehicle's electrical system.
- If the battery cable cannot be disconnected, establish a regular schedule of recharging the battery every 20–45 days in order to maintain a high state of charge. Any time a battery is found with the green dot not visible in the hydrometer, promptly recharge the battery.
- Use a battery charger that is capable of providing a charging voltage of at least 16 volts in order to maintain a low charge time. Charge rates of 50 amps or more will not damage original equipment maintenance free batteries if the battery does not exhibit the following conditions:
  - Excessive gassing of electrolyte from the vents
  - Excessive battery temperature

    Any temperature over 52 °C (125 °F) is excessive.
- Inspect the battery being charged every 45–60 minutes. Stop or reduce the charge rate as necessary. Stop charging within one hour after the green dot appears in the hydrometer in order to avoid overcharging the battery.
- Allow ample charging time. Refer to *Battery Charging*.

  A battery that remains in a discharged state for a long period of time will be difficult to recharge. The battery may even be permanently damaged if the battery remains discharged.

Use the following procedure when reconnecting the battery:

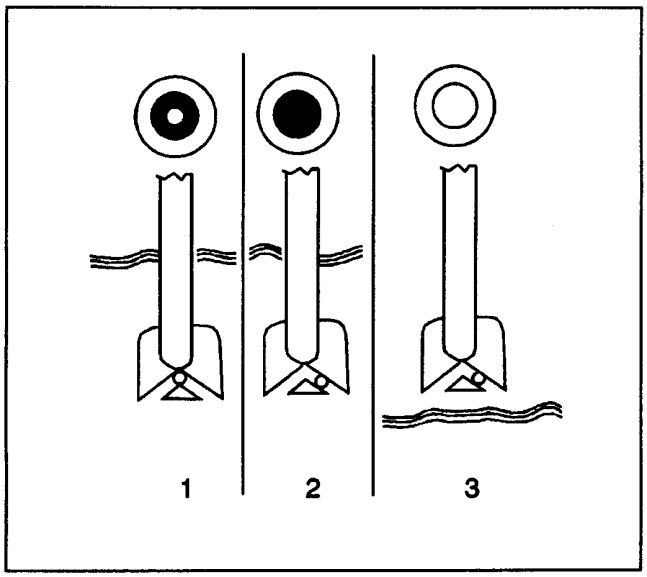
1. Use a wire brush in order to lightly clean any oxidation from the contact face of the battery terminal before reattaching the cable.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Tighten the battery cable.

   Tighten

   Tighten the top post terminal nut to 17 N.m (13 lb ft).
3. Reset the clock, push-button radio tuning, etc., before the vehicle returns to service.

Battery Common Causes of Failure (Built-In Hydrometer)



181056

A built-in temperature compensated hydrometer is molded into the top of the maintenance-free battery. The hydrometer is an indicator of the battery's state of charge. Use this hydrometer with the following diagnostic procedure.

When observing the hydrometer, ensure that the battery has a clean top. A light may be required in some poorly-lit areas.

Under normal operation one of the following three indications can be observed:

Green Dot Visibility

Any green appearance in the hydrometer is interpreted as a green dot (1). The presence of a green dot indicates that the battery's state of charge is 65 percent or more. The battery is ready for testing.

Dark Dot or Lack of Green Dot Visibility

Lack of green dot visibility (dark dot) (2) indicates that the battery's state of charge is below 65 percent. Test the charging system output and the electrical system for excessive draws.

Yellow Dot or Clear Dot Visibility

A yellow or clear dot (3) indicates that the electrolyte level is low. This electrolyte level is also too low for diagnosis. The following conditions may have caused the reduced electrolyte levels:

- Excessive or prolonged charging
- A broken case
- Excessive tipping of the battery

  Batteries having the above conditions may indicate excessive charging voltages, caused by a faulty charging system. Inspect the charging and the electrical systems. Replace the battery.

Battery Electrical Drain/Parasitic Load (Battery Electrical Drain)

Inspect the electrical system for excessive electrical drain (parasitic current drain) if the vehicle battery meets one of the following conditions:

- The battery is low or dead after an overnight period.
- The battery discharges over a period of 2–3 days.

Inspect the vehicle for excessive parasitic current drain if a battery needs recharging and no obvious cause exists.

Failure of one or more of the on-board solid state control modules, such as the PCM, may cause a high parasitic drain on the vehicle's battery. After the circuit continuity is restored, disconnecting the battery in order to install an ammeter or in order to test for excessive current drain may not continue. Cycling the engine control switch to the ON position and then to the LOCK position may cause such a drain to recur. Unless the vehicle's systems are reactivated in a road test, some drains will not recur.

Do not rotate the engine control switch to the following positions with an ammeter installed between the battery terminal and the battery cable:

- The ACCY position
- The ON position
- The START position

Use a current drain test tool in order to test the battery for parasitic current drain. Refer to *Battery Electrical Drain/Parasitic Load (Current Drain Test).*

Battery Electrical Drain/Parasitic Load (Current Drain Test)

Tools Required

- Terminal Adapters
- *J 38758* Parasitic Draw Test Switch
- *J 39200* Digital Multimeter

Perform the following procedure before starting the battery electrical drain/parasitic load test:

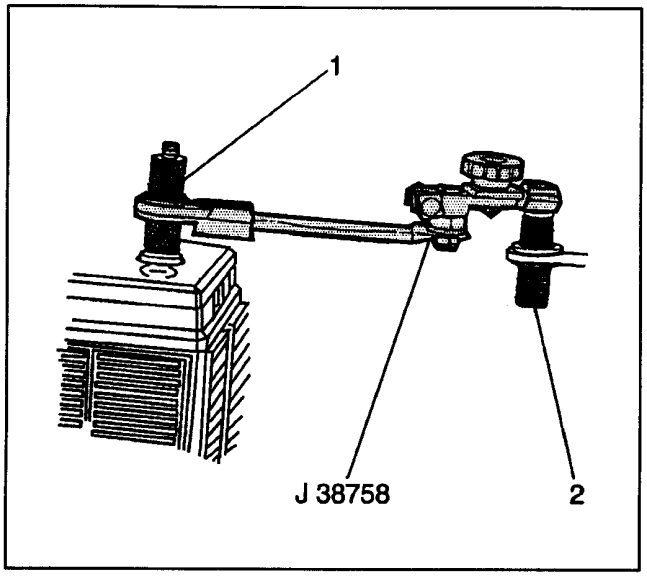
1. Turn the engine control switch to the LOCK position.
2. Turn off all electrical accessories.
3. Close the vehicle's doors.

Notice: J 38758 should never be turned to the OFF position, with the engine running or damage could occur to the vehicle's electrical system.

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Remove the negative battery cable at the main battery. Refer to Negative Battery Cable in *Battery Cable Replacement.*

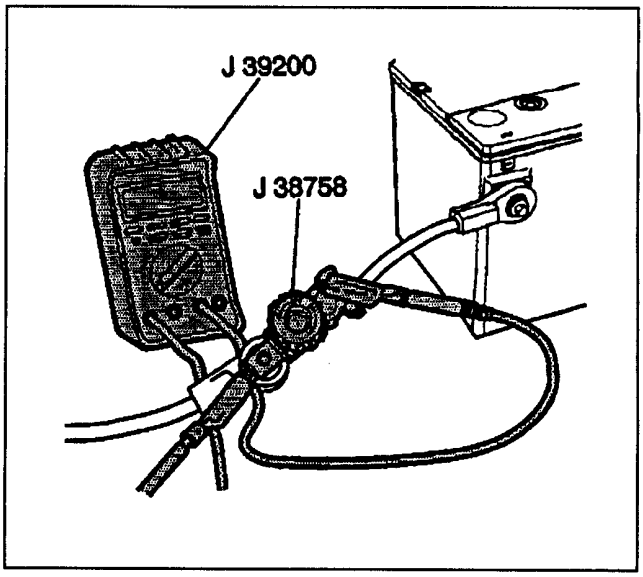
   The main battery will be wired from the positive battery terminal to the starter motor.



181057

Important: Ensure that the bottom of the adapter firmly contacts the pad or base of the battery post.

2. Use the following procedure in order to install the male end of *J 38758* to the negative battery terminal:
   2.1. Remove the terminal bolt from the battery cable end of the test switch.
   2.2. Thread a terminal adapter (1) onto the negative terminal post of the battery.
   2.3. Place the battery cable end of *J 38758* over the threaded end of the terminal adapter.
   2.4. Thread a second terminal adapter over the first terminal adapter.
   2.5. Turn the knob of the *J 38758* to the OFF position.
   2.6. Use a set of terminal adapters in order to install the negative battery cable to the female end of the *J 38758.*
3. Turn the knob on the *J 38758* to the OFF position.
4. Install the negative battery cable to the female end of *J 38758.*
5. Turn the test switch to the ON position.
6. Road test the vehicle and activate all accessories including the radio and air conditioning.
7. Turn the ignition switch to the OFF position and remove the key.



106017

Important: Electrical continuity in the ground circuit to the battery must be maintained from this point forward. Use the *J 38758* (in the ON position) or the ammeter in order to maintain electrical continuity.

8. Some components, including PCMs, have timers that draw several amps of current when the components cycle down. This condition may cause an incorrect parasitic current drain reading. Wait 15 minutes in order to allow the above components to power down before continuing the test.

   Important: If using a digital multimeter other than the *J 39200* , ensure that the vehicle does not have excessive current drain. Excessive current drain may damage the multimeter when the multimeter is installed.
9. Use the following procedure in order to test the current drain level:
   9.1. Connect a jumper wire with an in-line 10 amp fuse to the *J 38758* terminals.
   9.2. Turn the *J 38758* to the OFF position.
   9.3. Wait 10 seconds.
   9.4. Inspect for a blown fuse.
   If the fuse does not blow, the current draw is less than 10 amps and the *J 39200* may operate safely.
   9.5. Turn the *J 38758* to the ON position.
   Turning the *J 38758* to the ON position before installing the *J 39200* maintains continuity in the electrical system.
   9.6. Remove the fused jumper wire.
   9.7. Install the *J 39200.*

10. Set the *J 39200* to the 10 amp scale and connect the multimeter to the *J 38758*.
11. Turn the *J 38758* to the OFF position. Current now flows through the *J 39200* only.
12. Wait at least 60 seconds in order to observe the current reading.

    If the current reading is at or below 2 amps, turn the test switch to the ON position (in order to maintain continuity in the electrical system) and switch the *J 39200* to the 2 amp scale for a more accurate reading.
13. Turn the *J 38758* to the ON position.
14. Measure the reading in milliamps, if necessary.
15. Refer to Battery Specifications in *Battery Usage* in order to determine the reserve capacity of the battery.
16. Divide the reserve capacity value by 4 and compare the result to the *J 39200* reading.

    The current drain reading should not exceed the value determined above. Example: If a battery has a reserve capacity of 100 minutes, the current drain should not exceed 25 milliamps.

    Notice: Always turn the test switch knob to the ON position before removing each fuse in order to maintain continuity in the electrical system and to avoid damaging the digital multimeter due to accidental overloading, such as opening a door to change a fuse.
17. If the current draw is excessive, remove the system fuses one at a time until the draw returns to a value less than or equal to the specified value.

    In order to protect the *J 39200* without disrupting electrical continuity, turn the test switch to the ON position before opening the door.
18. Start with fuses that are hot at all times. Refer to Fuse Block Details Schematics in Wiring Systems.
19. Remove the courtesy lamp fuse and observe the *J 39200* reading.
20. If the parasitic load remains excessive perform the following steps:
    - 20.1. Removing the other fuses, one at a time.
    - 20.2. Leave the courtesy lamp fuse out during diagnosis so the vehicle door can be left open.
    - 20.3. Observe the *J 39200* reading each time a fuse is removed.
21. The PCM fuse should cause a drop of less than 10 milliamps when removed.
22. If the drop is more than 10 milliamps, inspect the PCM wiring for a short to ground. Also, inspect the components connected to the wires. Refer to the related schematics for the system being worked on.
23. Repeat the parasitic current drain test after the condition has been located and repaired. The vehicle could have more than one parasitic current drain.
24. When the cause of the excessive current draw has been located and repaired, remove the *J 39200*, the *J 38758* and the terminal adapters.
25. Reconnect the negative battery cable.

Battery Is Undercharged or Overcharged

Step	Action	Value(s)	Yes	No
1	1. Disconnect the generator connector. 2. Place the ignition switch in the RUN position. 3. Connect a voltmeter from CKT 5 (BRN) at the generator connector to chassis ground. 4. Observe the reading on the voltmeter. Does a battery voltage exist?	—	Go to *Step 5*	Go to *Step 2*
2	Inspect the condition of the indicator bulb. Is the indicator bulb in proper condition?	—	Go to *Step 4*	Go to *Step 3*
3	Replace the indicator bulb. Is the battery still undercharged or overcharged?	—	Go to *Step 4*	System OK
4	Locate and repair the open in the BRN wire between the instrument cluster and the generator. Is the battery still undercharged or overcharged?	—	Go to *Step 5*	System OK

Battery Is Undercharged or Overcharged (cont'd)

Step	Action	Value(s)	Yes	No
5	*Connect a voltmeter* from battery terminal 1 (RED) at the generator connector to chassis ground. Does the voltmeter read a battery voltage?	—	Go to *Step 7*	Go to *Step 6*
6	Locate and repair the open in CKT 1 (RED) between the generator and the MaxiFuse® Block. Is the battery still undercharged or overcharged?	—	Go to *Step 7*	System OK
7	1. Reconnect the generator connector. 2. Turn off all accessories. 3. Run the engine at a fast idle. 4. Connect a voltmeter from battery terminal 1 (RED) at the generator to chassis ground. Does the voltmeter give a reading within the specified range?	13–16 V	Go to *Step 8*	Go to *Step 9*
8	Perform a battery load test. Refer to *Charging System Check (Battery Testing).* Is the battery still undercharged or overcharged?	—	Go to *Step 9*	System OK
9	Perform a generator bench test. Refer to *Charging System Check (Battery Testing)* Is the generator in need of repair or replacement?	—	Go to *Step 10*	Go to *Step 11*
10	Repair or replace the generator. Is the battery still undercharged or overcharged?	—	—	System OK
11	Perform a battery load test. Refer to *Charging System Check (Battery Testing)* Is the battery still undercharged or overcharged?	—	—	System OK

Indicator - Charge Always On

Step	Action	Value(s)	Yes	No
1	1. Stop the engine. 2. Disconnect CKT 5 (BRN) to the generator. Does the BAT indicator lamp remain illuminated?	—	Go to *Step 3*	Go to *Step 2*
2	Replace the generator. Does the BAT indicator lamp remain illuminated with the engine running?	—	Go to *Step 3*	System OK
3	1. Disconnect the connector at the instrument cluster. 2. Connect a self-powered test lamp between generator connector terminal A1 and chassis ground. Does the test lamp light?	—	Go to *Step 4*	Go to *Step 5*
4	Locate and repair the short to ground in the BRN wire between the instrument cluster and the generator. Does the BAT indicator lamp remain illuminated with the engine running?	—	—	System OK
5	Replace the instrument cluster. Does the BAT indicator lamp remain illuminated with the engine running?	—	—	System OK

Indicator - Charge Inoperative

Step	Action	Value(s)	Yes	No
1	1. Ensure that the battery is charged. 2. Disconnect CKT 5 (BRN) at the generator. 3. Connect a fused wire between generator harness connector terminal C and chassis ground. 4. Place the ignition switch in the RUN position. Does the battery indicator light?	—	Go to *Step 2*	Go to *Step 5*
2	Inspect the generator mechanical grounding. Are the grounding connections in need of repair?	—	Go to *Step 3*	Go to *Step 4*
3	Repair the grounding connections. Does the BAT indicator lamp still not light with the ignition switch in the RUN position and the engine stopped?	—	Go to *Step 4*	System OK
4	Replace the generator. Does the BAT indicator lamp still not light with the ignition switch in the RUN position and the engine stopped?	—	Go to *Step 5*	System OK
5	1. Ensure that the jumper is still connected. 2. Disconnect the 15 way IP harness connector at the instrument cluster. 3. Connect a test lamp from CKT 6 (BRN) at instrument cluster connector terminal A1 to chassis ground. Does the test lamp light?	—	Go to *Step 7*	Go to *Step 6*
6	Locate and repair the open in CKT 6 (BRN) between the instrument cluster and the generator. Does the BAT indicator lamp still not light with the ignition switch in the RUN position and the engine stopped?	—	Go to *Step 7*	System OK
7	Connect a test lamp from CKT 1 (BRN) at instrument cluster connector terminal A6 to chassis ground. Does the test lamp light?	—	Go to *Step 9*	Go to *Step 8*
8	Locate and repair the open in CKT 1 (BRN) between the instrument cluster and S243. Does the BAT indicator lamp still not light with the ignition switch in the RUN position and the engine stopped?	—	Go to *Step 9*	System OK
9	Inspect for an open filament in the BAT indicator lamp. Is the filament good?	—	Go to *Step 11*	Go to *Step 10*
10	Replace the BAT indicator lamp. Does the BAT indicator lamp still not light with the ignition switch in the RUN position and the engine stopped?	—	—	System OK
11	Replace the instrument cluster. Does the BAT indicator lamp still not light with the ignition switch in the RUN position and the engine stopped?	—	—	System OK

Noisy Generator

The following conditions may cause the generator to emit noise:

- Insufficient fan clearance to bolts or structures
- Dirty or worn bearings
- A worn diode or stator

If the pulley and mounting bolts are snug and the noise continues, remove the generator for inspection and repair. Refer to *Generator Replacement.*

A loose drive pulley or loose generator mounting bolts may also cause a generator to emit noise. In some cases, the generator has been relocated in order to mount aftermarket equipment. Inspect the generator brackets for structural failure or misaligned pulleys. Observe the generator with the engine running in order to ensure that the following conditions do not exist:

- Excessive vibration
- Excessive motion
- Squealing or other abnormal noises

Verify the following conditions before performing the diagnostic procedures on the vehicle:

- The system wiring is in the proper condition.
- The generator belt is not slipping.
- The battery must be fully charged for a valid test of the charging system.

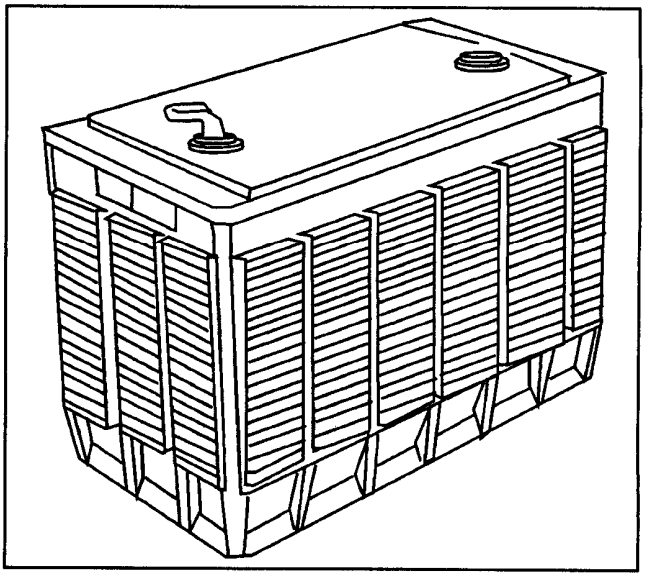
  Refer to *Charging System Check (Battery Testing)* for detailed diagnosis and repair.

Notice: To avoid damaging the vehicle's electrical system, observe the following precautions:

- Do not polarize the generator.
- Do not short across or ground any of the terminals in the charging circuit, except as specifically instructed herein.
- NEVER operate the generator with the output terminal open-circuited.
- Make sure the generator and battery have the same ground polarity.
- When a connecting charger or booster battery to the vehicle's battery, connect the negative to negative and the positive to positive.

Faulty operation of the charging system will appear as one or more of the following conditions:

- Unusual operation of the charging indicator lamp on vehicles without gauges



181055

- An undercharged battery

  Slow cranking or a dark battery hydrometer indicates an undercharged battery. Refer to *Battery Is Undercharged or Overcharged.*
- An overcharged battery

  Excessive gassing of electrolyte from the battery vents indicates an overcharged battery. Refer to *Battery Is Undercharged or Overcharged.*

Charging System Indicator Lamp Operation

Generator Electrical Test

Step	Action	Value(s)	Yes	No
1	1. Turn the ignition to the ON position. Do not start the engine. 2. Observe the charging system indicator lamp. Does the indicator lamp turn ON?	—	System OK	*Go to Step 3*
2	1. Turn the ignition to the ON position. 2. Start the engine. 3. Observe the charging system indicator lamp. Does the indicator lamp turn OFF?	—	System OK	*Go to Step 3*
3	Perform the Charging System Check in order to identify the malfunction. Refer to *Charging System Check (Charging System Check).* Perform any necessary repairs. Is the system operating properly?	—	System OK	—

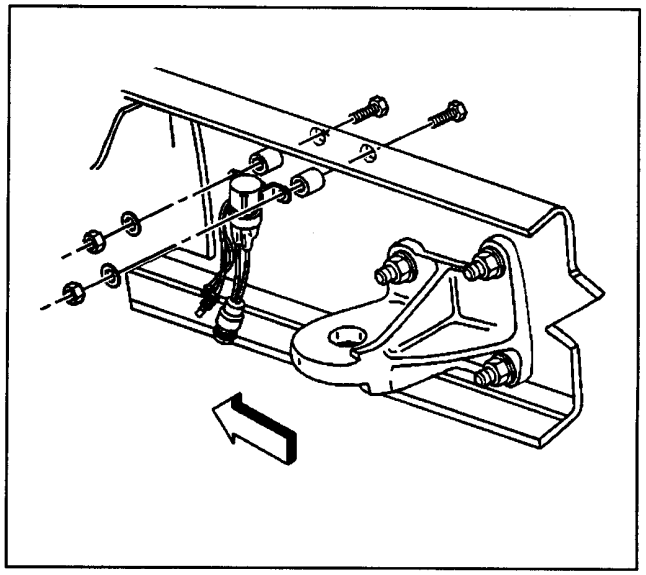
Repair Instructions

Starter Motor Relay Replacement

Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

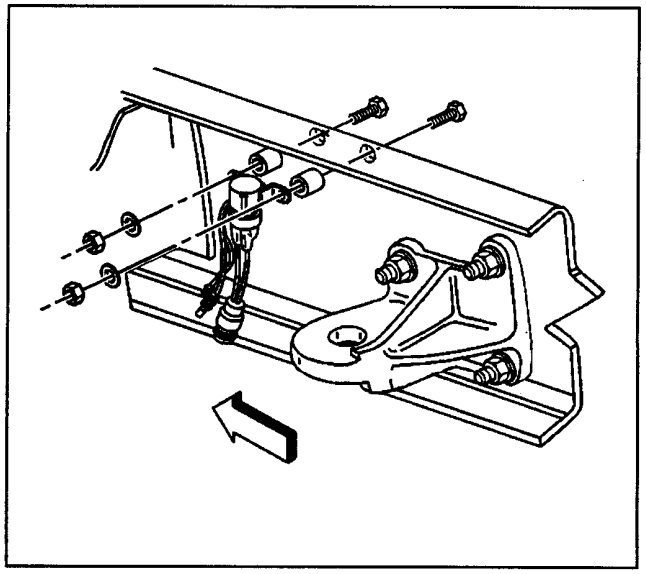
1. Disconnect the negative battery cable.
2. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
3. Disconnect the electrical connectors to the starter relay.
4. Remove the starter relay mounting bolts.
5. Remove the starter relay from the frame.



240820

Installation Procedure

1. Connect the starter relay to the frame.
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the starter relay mounting bolts.
   Tighten
   Tighten the starter relay mounting bolts to 23 N·m (17 lb ft).
3. Connect the electrical connectors to the starter relay.
4. Connect the negative battery cable.
5. Lower the cab.



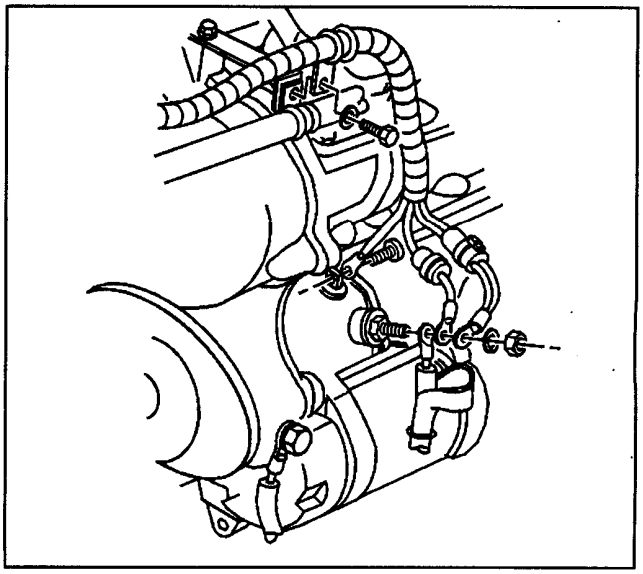
240820

Starter Motor Replacement

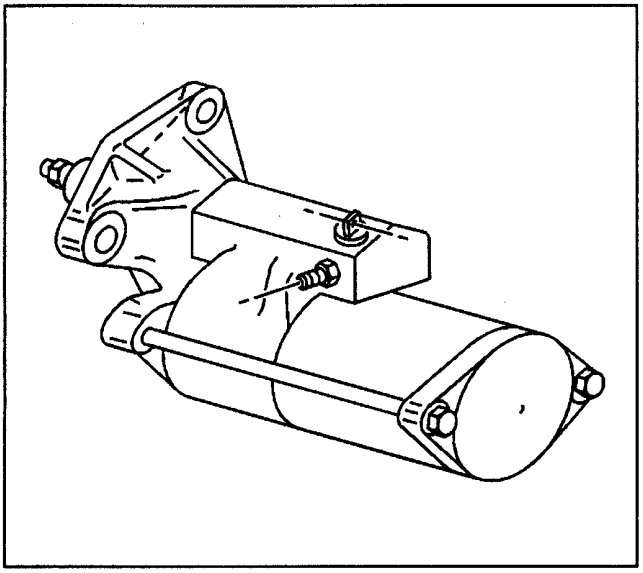
Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable.
2. Tilt the cab.
   Refer to *Cab Tilting* in General Information.
3. Disconnect the electrical connectors from the starter motor.
4. Remove the nuts and the washers that attach the starter motor to the engine.

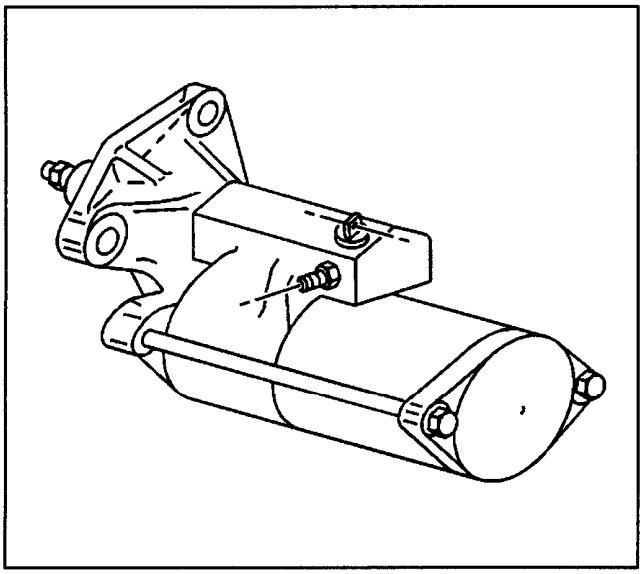


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240816

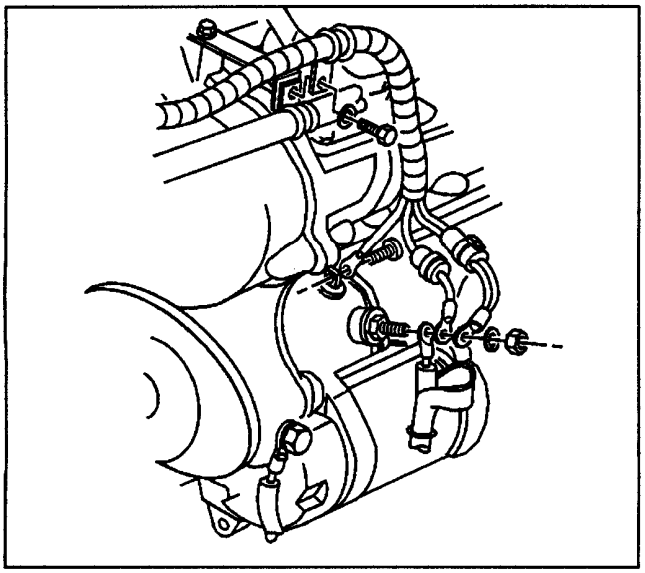
5. Remove the starter motor from the engine.
6. Clean the following components:
   - The starter motor terminals
   - The electrical connectors
7. Inspect the pinion gear teeth for wear and damage.



240816

Installation Procedure

1. Connect the starter motor to the engine.



240818

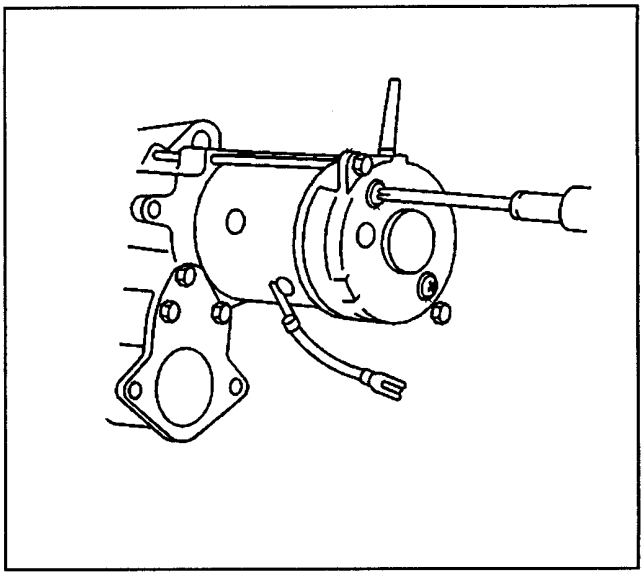
Notice: Refer to *Fastener Notice* in Cautions and Notices.

2. Install the nuts and the washers that attach the starter motor to the engine.
   Tighten
   Tighten the starter motor mounting nuts to 82 N.m (60 lb ft).
3. Connect the electrical connectors to the starter motor.
4. Hold the hex-shaped base of the stud while tightening the positive battery cable nut.
   Tighten
   4.1. Tighten the positive battery cable nut to 21 N.m (16 lb ft).
   4.2. Tighten the solenoid bolt to 4.0 N.m (35 lb ft).
5. Lower the cab.
6. Connect the negative battery cable.

Starter Motor Overhaul

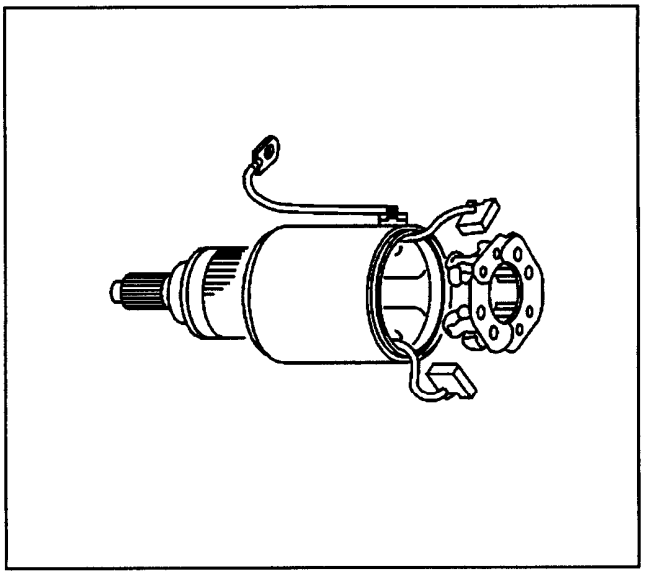
Disassembly Procedure

1. Disconnect the lead wire.
2. Remove the magnetic switch assembly and gasket.
3. Loosen the brush holder screws at the rear bracket.



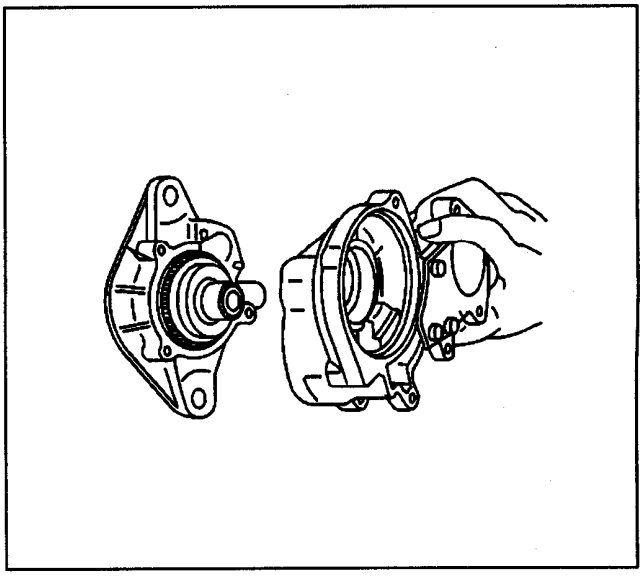
316329

4. Remove the through bolt.
5. Remove the rear bracket.
6. Remove the brush.
7. Remove the brush holder and spring.
8. Remove the yoke assembly
9. Disassemble the armature using the following procedure:
   - 9.1. the brush holder
   - 9.2. the yoke assembly
   - 9.3. the armature assembly

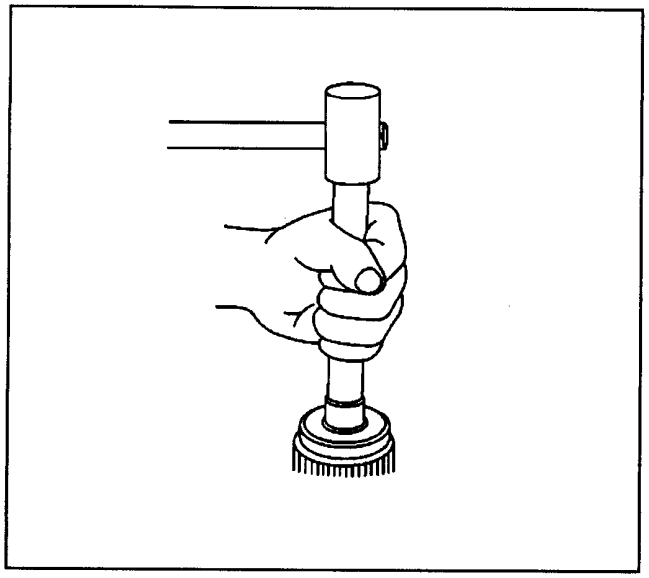


316338

10. Remove the front bracket.
11. Remove the center bracket using the following procedure.
    - 11.1. Loosen the bolts holding the front bracket to the center bracket.
    - 11.2. Remove the front bracket from the center bracket.

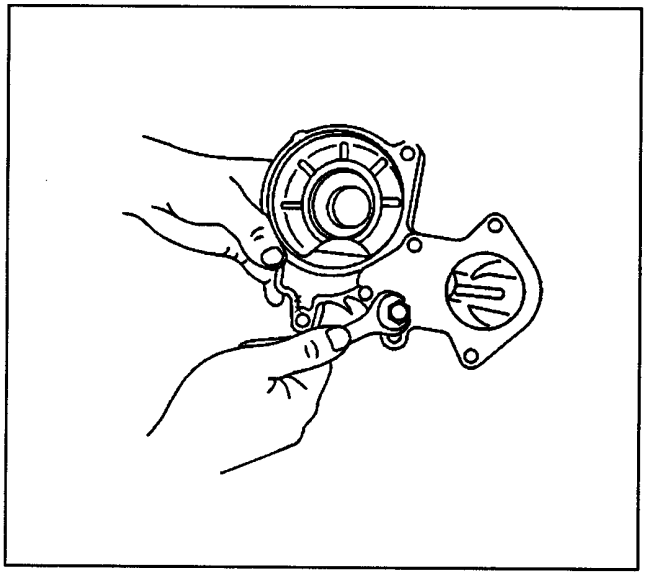


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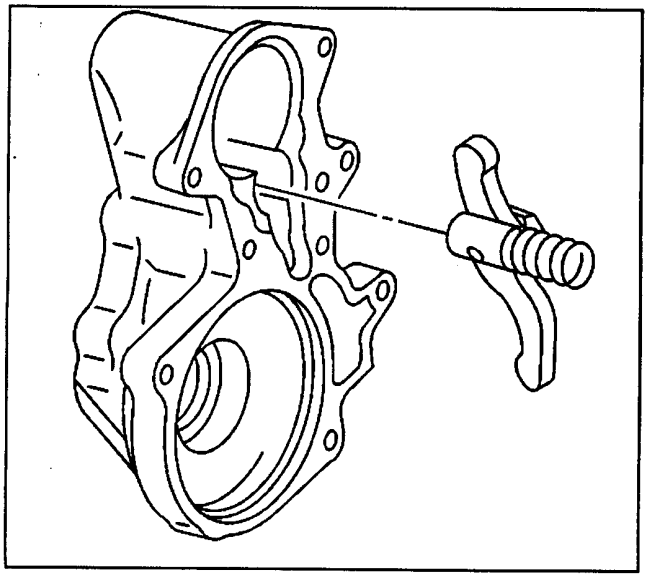
316344

12. Remove the pinion stopper clip.
13. Remove the cup ring from the right end of the over running clutch.
14. Remove the return spring.
15. Remove the pinion stopper from the right end of the over running clutch.
16. Drive out the pinion.



316348

17. Remove the over running clutch
18. Remove the plate and gasket.
19. Remove the shift lever using the following procedure:
    19.1. Loosen the plate bolts.
    19.2. Remove the shift lever from the center bracket.



316406

Reassembly Procedure

1. Install the center bracket.
2. Install the shift lever.
    2.1. Apply molybdenum disulfide grease to the shift lever pin.
    2.2. When installing the shift lever, pay attention to its installing direction as illustrated.

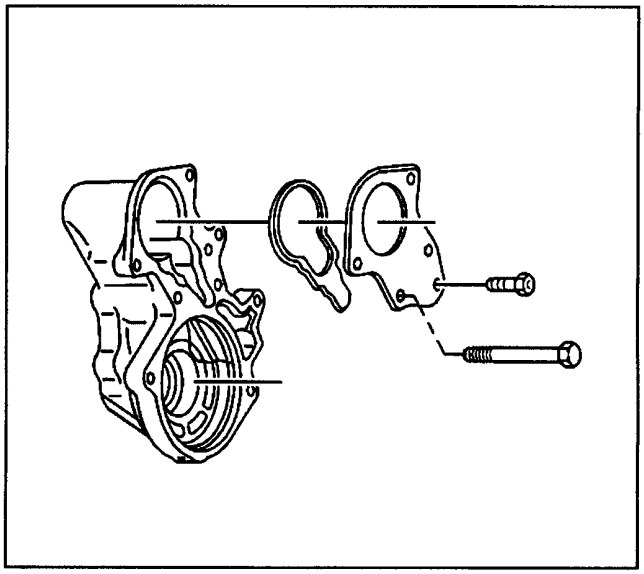
3. Install the plate and gasket using the following procedure:
   3.1. Install the plate and gasket to the center cover.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.

   3.2. Install the plate bolts.

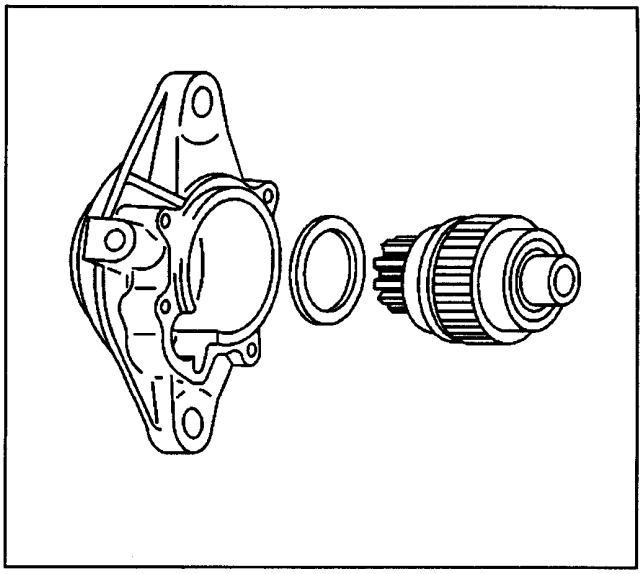
   Tighten

   Tighten the bolts to 9 N.m (78 lb in).



316410

4. Install the over running clutch.
5. Install the pinion.
6. Install the pinion stopper.
7. Install the return spring.
8. Install the cup ring.
9. Install the pinion stopper clip.



316415

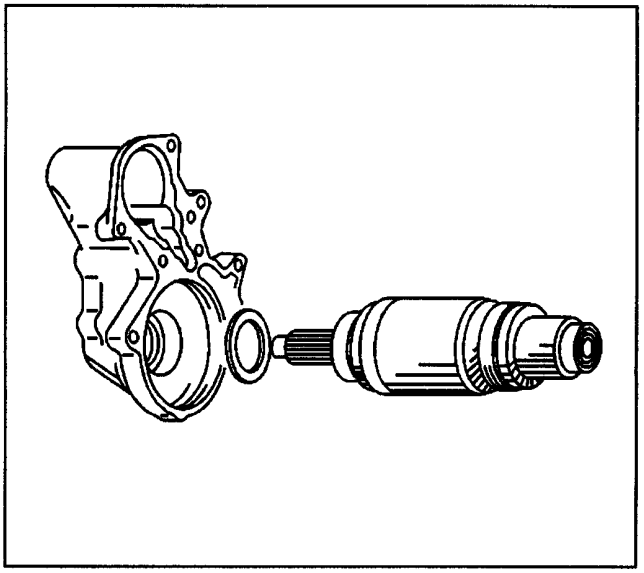
10. Adjust the over running clutch front bracket and bearing clearance with the adjusting washer so that the clearance may become as specified.

    Front Bracket and Bearing Clearance

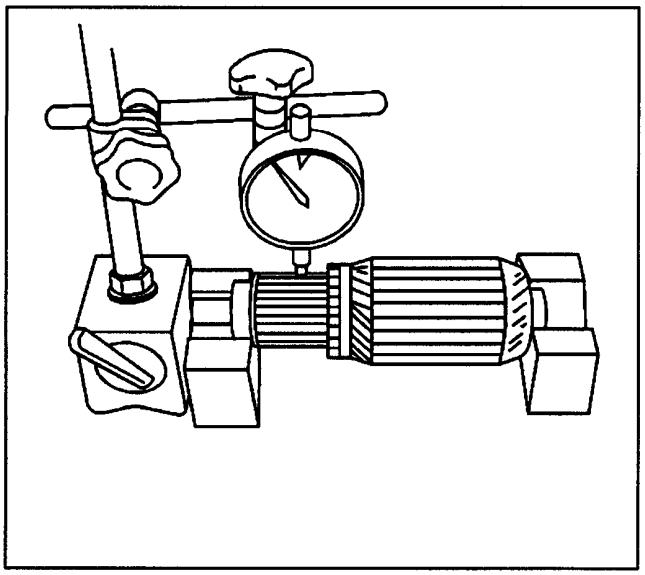
    The clearance should be 0.2–0.8 mm (0.008–0.031 in).
11. Install the yoke assembly.
12. Install the brush holder and spring.
13. Adjust the armature center bracket and bearing clearance with the adjusting washer so that the clearance may become as specified:

    Center Bracket and Bearing Clearance

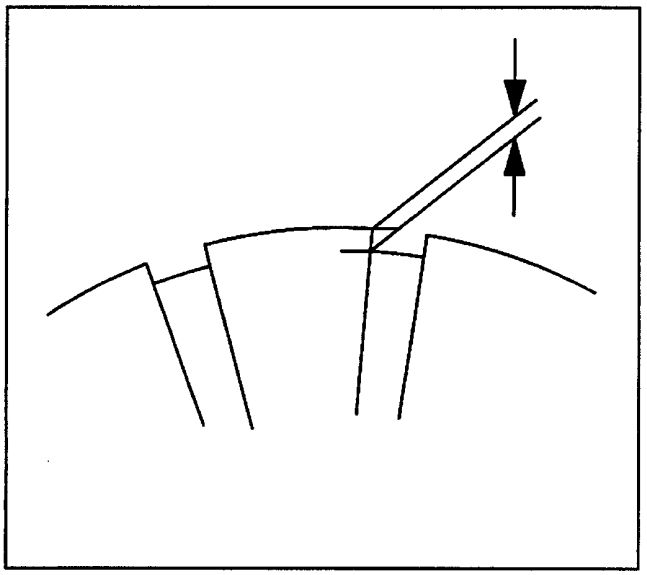
    The clearance should be 0.2–0.8 mm (0.008–0.031 in).
14. Install the brushes.
15. Install the rear bracket.
16. Install the brush holder screw.



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316357



316360

17. Install the through bolt.
    Tighten
    Tighten the bolt to 9 N·m (78 lb in).
18. Install the magnetic switch assembly using the following procedure:
    18.1. Install the magnetic switch assembly to the center bracket.
    18.2. Install the magnetic switch assembly bolts.
    Tighten
    Tighten the bolt to 9 N·m (78 lb in).
19. Connect the lead wire.

Starter Motor Inspection

Inspection and Repair

Perform the necessary adjustments, repairs, and part replacements if excessive wear or damage is discovered during inspection.

It is important that electrical components be kept clean and dry at all times.

Always visibly check the fusible links, the fuses, and the indicator lights for damage as the first step in the inspection and repair procedure.

Armature

Commutator Face

1. Check the commutator face for roughness.
2. If necessary, dress the commutator face with fine sandpaper (#500 or #600).
3. Be absolutely sure that there are no metal filings in the segment gaps.

Commutator Run-Out

1. Mount the armature assembly on V-blocks.
2. Use a dial indicator to measure the commutator run-out. If the run-out is greater than the specified standard but less than the specified limit, the commutator may be turned on a lathe to correct it. If the run-out exceeds the specified limit, the armature assembly must be replaced.
   Commutator Run-Out
   The standard is 0.06 mm (0.002 in) or less. The limit is 0.1 mm (0.004 in).

Commutator Segment Groove Depth

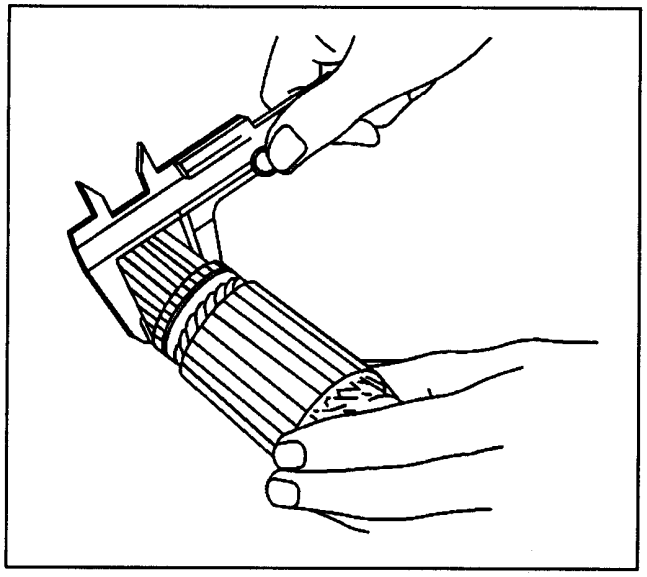
1. Use the V-blocks and the dial indicator to measure the depth of each of the commutator segment grooves.
2. Replace the armature assembly if the commutator segment groove depth is less than the specified limit.
   Commutator Segment Groove Depth
   The standard is 0.5–0.8 mm (0.020–0.031 in) or less. The limit is 0.2 mm (0.008 in).

Commutator Outside Diameter

1. Use a vernier caliper to measure the commutator outside diameter.
2. If the commutator outside diameter is less than the specified standard but greater than the specified limit, the commutator may be turned on a lathe to correct it.
3. Replace the armature assembly if the commutator outside diameter is less than the specified limit.

   Commutator Outside Diameter

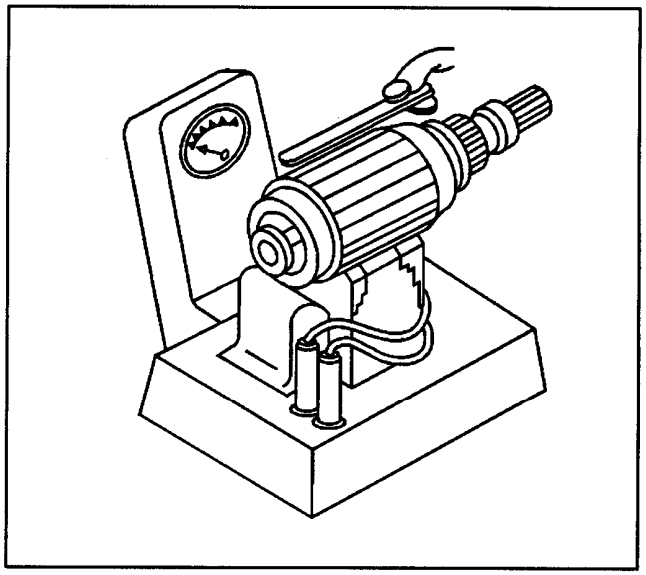
   The standard is 36 mm (1.42 in) or less. The limit is 35 mm (1.38 in).



316363

Armature Coil

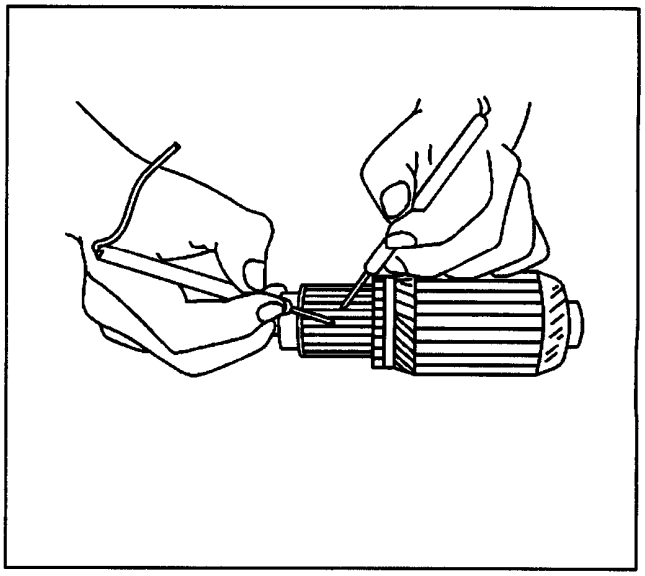
1. Place the armature in a growler tester.
2. Hold a hacksaw blade against the armature core. Slowly rotate the armature. If the armature is shorted, the hacksaw blade will vibrate. Replace the armature assembly if it is shorted.



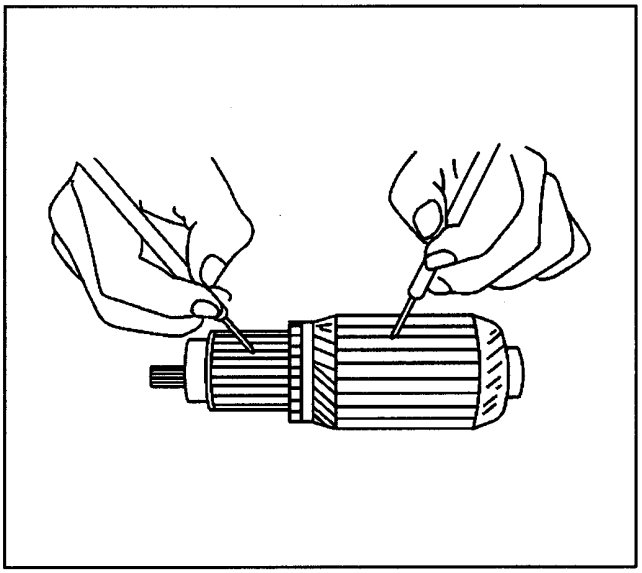
316364

Armature Continuity

1. Use a circuit tester to check for continuity between the commutator segments.
2. If there is no continuity between any two points on the commutator, the armature assembly must be replaced.



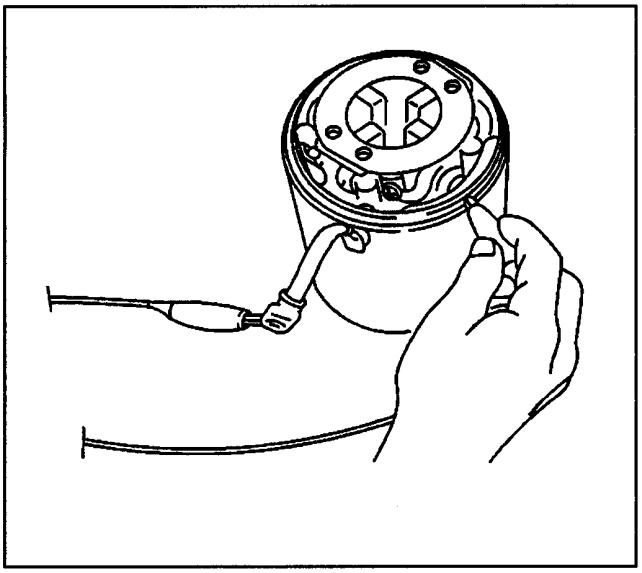
316369



316372

Armature Insulation

1. Use a circuit tester to check that there is no continuity between the commutator segments and the coil core.
2. If there is continuity between the commutator segments and the coil core, the armature assembly is defective and must be replaced.

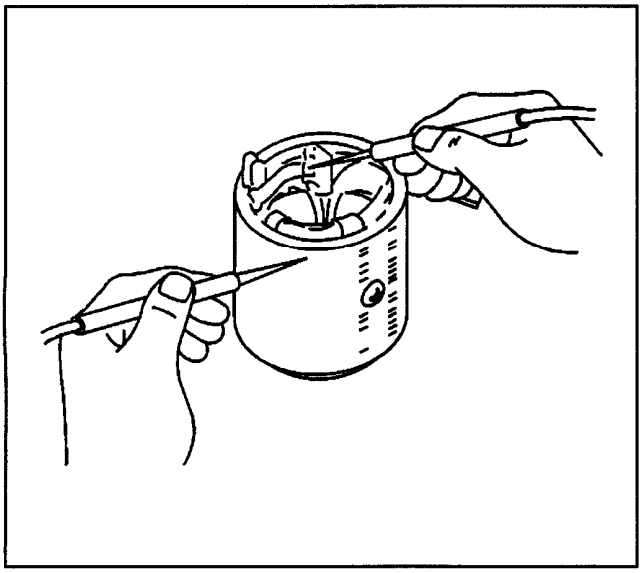


316376

Yoke

Field Coil Continuity

1. Use a circuit tester to check for continuity between the connecting leads and the brushes.
2. Replace the yoke assembly if there is no continuity at any point.



316377

Yoke Insulation

1. Use a circuit tester to check that there is no continuity between the field coil and the yoke body.
2. If there is continuity between the field coil and the yoke body, the yoke assembly is defective and must be replaced.

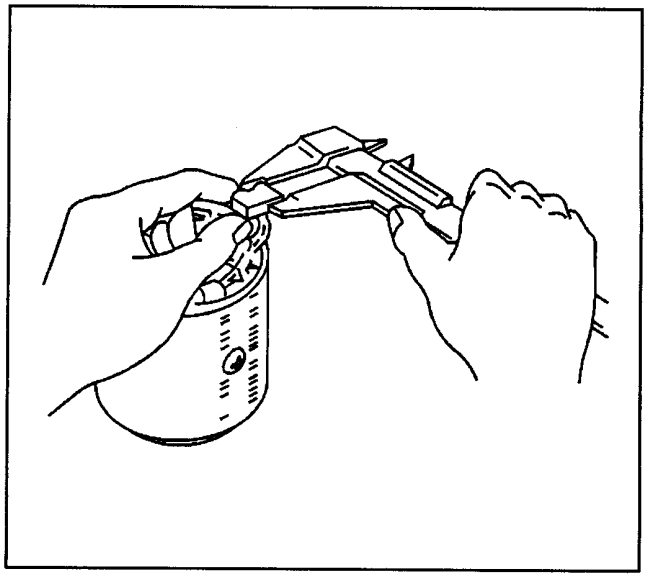
Brush and Brush Holder

Brushes

1. Use a vernier caliper to measure the brush lengths (four brushes).
2. Replace the brushes as a set if one or more of the brush lengths is less than the specified limit.

   Brush Length

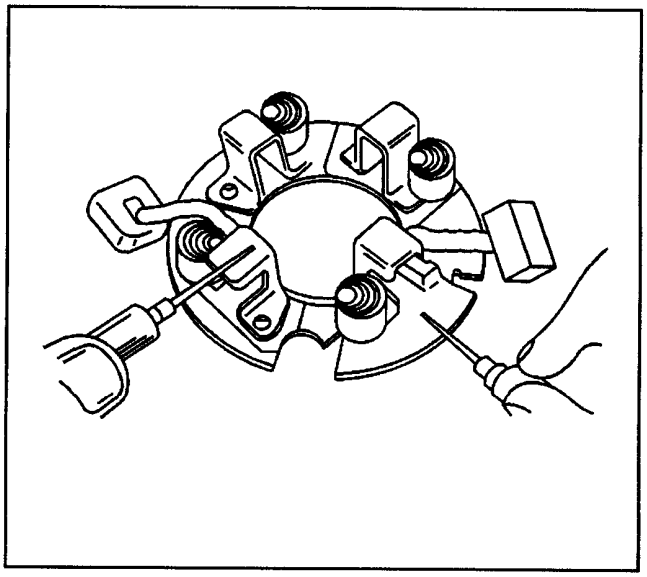
   The specified length limit is 12 mm (0.47 in).



316381

Brush Holder Insulation

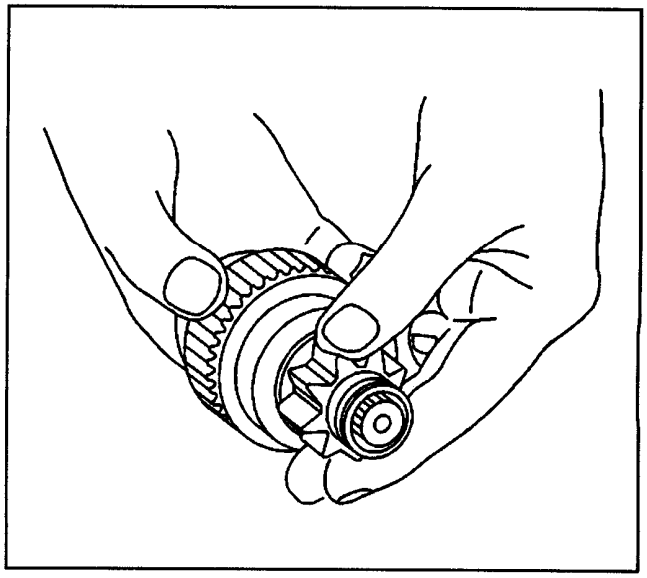
1. Use a circuit tester to check that there is no continuity between the battery side brush cages and the holder plate.
2. If there is continuity between the battery side brush cages and the holder plate, the brush holder assembly is defective and must be replaced.



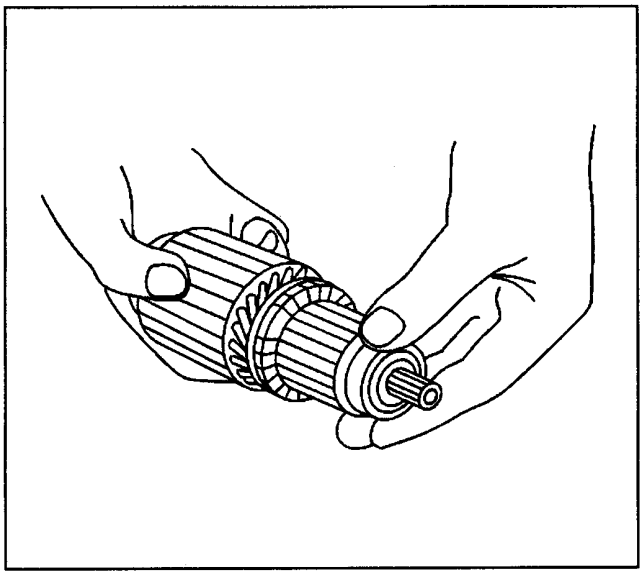
316387

Pinion Clutch

1. Clean the pinion clutch with a clean rag.
2. Check the pinion clutch and pinion gear for excessive wear and damage.
3. Turn the pinion gear clockwise. The gear should turn smoothly with no resistance. If the gear does not turn smoothly, the pinion clutch assembly must be replaced.
4. Turn the pinion gear counterclockwise. The gear should lock up firmly. If the gear does not lock firmly, the pinion clutch assembly must be replaced.

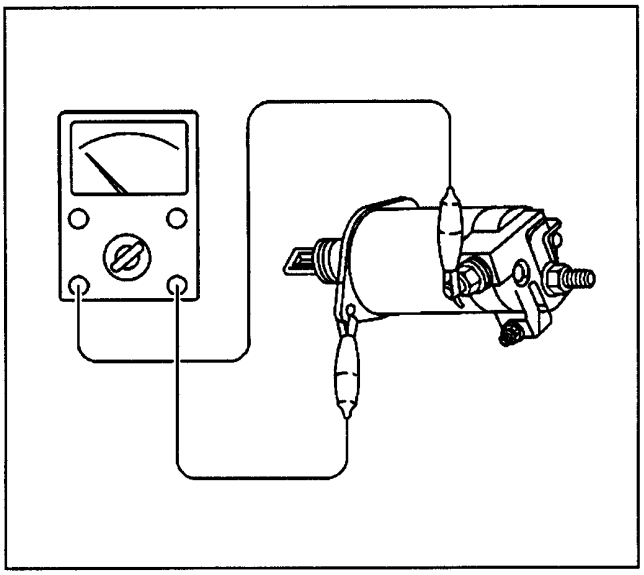


316390



316393

Bearing
Inspect the bearings for excessive wear and damage. Replace the bearings if necessary.

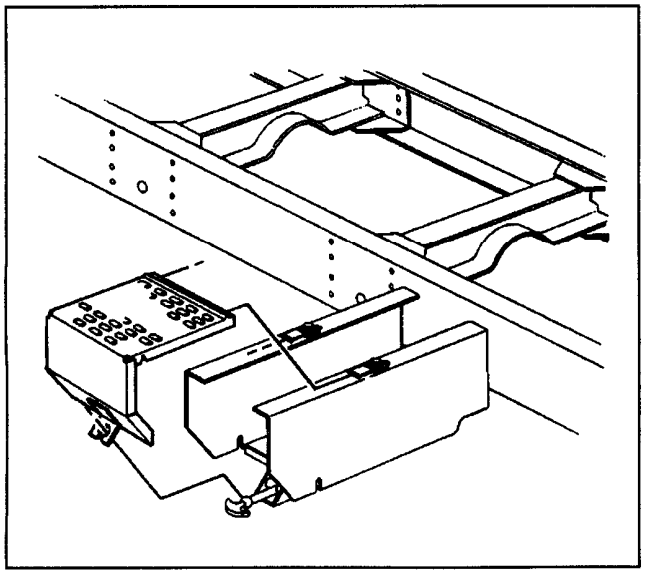


316395

Magnetic Switch

Caution: Do not apply the operating test to the magnetic switch as a single unit.

Inspect the continuity between the M terminal and the case of the magnetic switch using a circuit tester.



215008

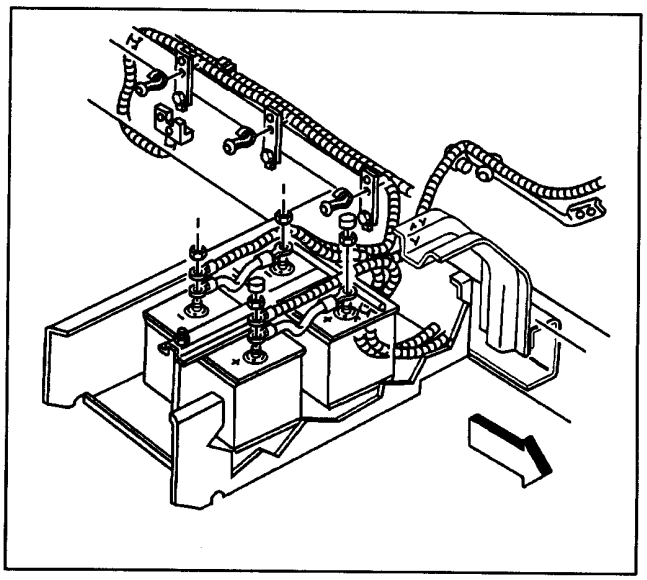
Battery Replacement

Removal Procedure

1. Remove the battery carrier cover.

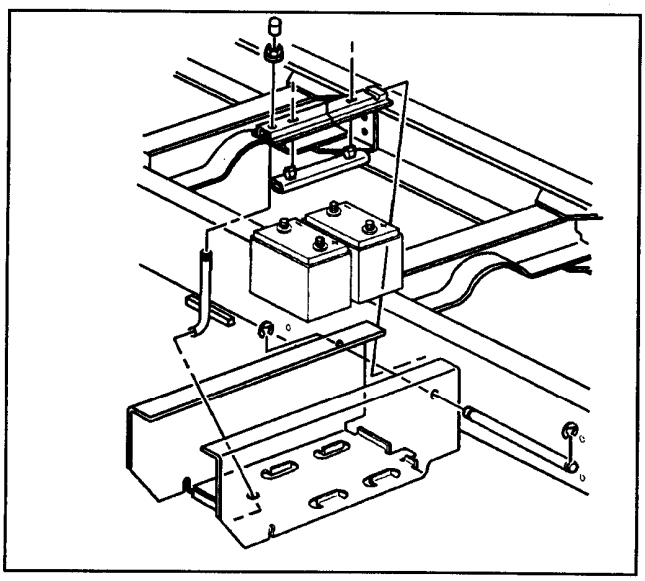
Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

2. Remove the negative cable from the negative battery terminal
3. Remove the positive cable from the positive battery terminal.



204729

4. Remove the battery hold-down retainer.
5. Remove the battery from the carrier.
6. Inspect the following components for damage:
   6.1. The battery
   6.2. The cables and the connectors
   6.3. The carrier
7. Clean the components as necessary.
   Correct any evident damage.



204720

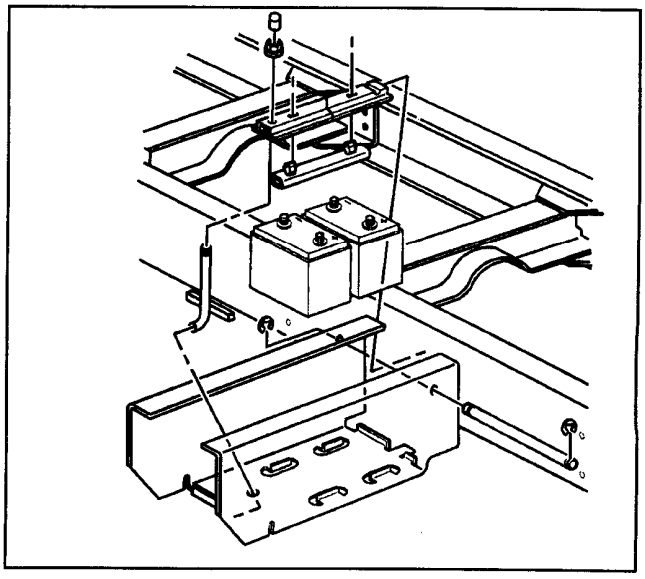
Installation Procedure

1. Install the battery into the cleaned carrier.

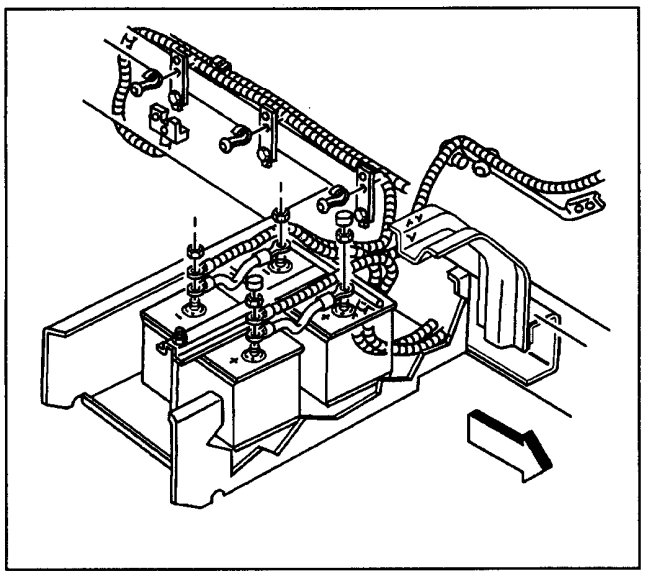
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the battery hold-down retainer or top bar and nut.

   Tighten

   Tighten the top bar nut to 17 N.m (13 lb ft).



204720

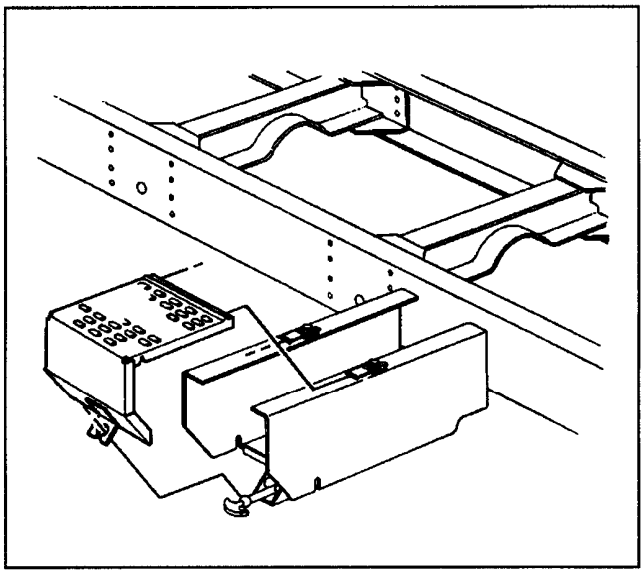


204729

3. Connect the positive cable to the positive battery terminal.
4. Connect the negative cable to the negative battery terminal.

   Tighten

   Tighten the top post terminal nut to 17 N·m (13 lb ft).



215008

5. Install the battery carrier cover.

Battery Charging

Follow these rules when charging the battery:

- Use a charger with an end charge voltage of 16 volts and a charger that is equipped with a voltmeter that is accurate within 1 percent.
- The surrounding temperature should be 15–38 °C (60–100 °F). A battery that is extremely cold may not accept measurable current for several hours after starting the charger.
- The charging area should be well ventilated.
- Do not charge the battery if the built-in hydrometer has a clear or yellow light.
- Do not charge a frozen battery. Replace the battery.
- Do not charge a battery with a green dot showing in the hydrometer unless the battery has just been discharged (such as by cranking the engine).

Caution: Always turn off the engine control switch when connecting or disconnecting battery cables, battery chargers, or jumper cables. Failure to do so may result in personal injury and damage to the Powertrain Control Module or other electronic components.

Tighten the adapters against the lead terminals of the battery in order to keep resistance between the adapter and the battery terminals to a minimum.

1. Clean and tighten all charger connections.
2. Use the 12 volt setting that gives the highest charging rate in order to charge the battery. Charge the battery until the green dot appears. Do not use the charger settings for jump starting a vehicle in order to charge the battery. Refer to the charger manufacturer's instructions. Inspect the battery periodically while charging. Tap the hydrometer lightly on the top in order to dislodge any air bubbles that may prevent a correct indication.
3. Discontinue charging the battery or reduce the charging rate if one of the following conditions occurs:
   - The battery feels hot, over 52 °C (125 °F).
   - Violent gassing of electrolyte through the vent holes occurs.
4. Test the battery after charging. Refer to *Charging System Check (Battery Testing)*.

The time required to change a battery depends on the following factors:

- Size of the battery

  A completely discharged heavy duty battery requires more than twice the recharging time than a completely discharged light duty battery.
- Temperature

  Recharging a cold battery takes more time. When a fast charger connects to a cold battery, the current accepted by the battery will be very low at first. The battery will accept a higher charging rate as the battery warms up.
- Charger capacity

  It takes less time to charge the battery that has a higher charger amperage.
- State of charge

  More than twice as much charge is required in order to charge a completely discharged battery than is needed to charge a one-half charged battery. The battery's current is low at first because the electrolyte is nearly pure water and is a poor conductor in a completely discharged battery. As the charging current causes the electrolyte acid content to increase, charging current will also increase.

  A battery that is discharged by parasitic current drain, and then allowed to stand in this condition for a period of time, may not accept a charge readily. However, if recharged long enough, many batteries will return to a usable condition.

  The battery can become permanently damaged if the battery remains in an extremely discharged condition for a prolonged period. Changes in temperature may accelerate this damage. Batteries that are extremely discharged can freeze at temperatures as high as -7 °C (20 °F) and be permanently damaged.

  Disconnect the negative battery cable in order to remove the constant drain on the battery if the vehicle will not operate within a 30 day period. This will prevent battery damage and recharging problems. If performing the above precaution is not possible, recharge the battery periodically (every 30–45 days) until the green dot is visible.

Charging Low or Completely Discharged Battery

Use the following procedure in order to recharge a very low or completely discharged battery. Unless the procedure is properly followed, a perfectly good battery may be needlessly replaced.

Tools Required:
J 39200 Digital Multimeter

1. Use the *J 39200* in order to measure the voltage at the battery terminals. If voltage is below 11 volts, the charge current will be very low and the battery may take longer to accept current in excess of a few milliamps.
2. Set the battery charger on the high setting.
3. Connect the charger leads to the battery terminals correctly because some chargers feature polarity protection circuitry that prevents charging. A completely discharged battery may not have enough voltage to activate this circuitry, even though the leads are connected properly. It will appear that the battery will not accept charging current. Follow the charger manufacturer's instructions in order to bypass or override the circuitry. This action will turn on the charger and charge a low-voltage battery.

4. Battery chargers vary in the amount of voltage and current the chargers provide. The following times are required for the battery in order to accept measurable charger current at various voltages:
   - 16.0 volts or more up to 4 hours
   - 14.0–15.9 volts up to 8 hours
   - 13.9 volts or less up to 16 hours

   Important: If the charge current is not measurable at the end of the above charging times, replace the battery.

   If the charge current is measurable during the charging time, the battery is good. Complete the charging in the normal manner.
5. Recharge a completely discharged battery for a sufficient number of ampere hours (AH) in order to restore the battery to a useable state. Use the reserve capacity rating of the battery in order to determine the amount of time necessary in order to completely recharge the battery. For capacity ratings, refer to Battery Specifications in *Battery Usage*. Divide the reserve capacity rating by the amount of ampere charge in order to determine how many hours of charging are needed. (Rating divided by amps = hours).

   For example: A battery with a reserve capacity rating of 75, charged at a rate of 10 amperes, will take 7.5 hours to fully recharge (75 divided by 10 = 7.5). The same battery, charged at a rate of 25 amperes, will take 3 hours to fully recharge (75 divided by 25 = 3).
6. Batteries recharged by this procedure should be load tested in order to determine serviceability. Refer to *Charging System Check (Battery Testing)*.

Jump Starting in Case of Emergency

Caution: Batteries produce explosive gasses. Batteries contain corrosive acid. Batteries supply levels of electrical current high enough to cause burns. Therefore, to reduce the risk of personal injury while working near a battery:

- ***Always shield your eyes.***
- ***Avoid leaning over the battery whenever possible.***
- ***Do not expose the battery to open flames or sparks.***
- ***Do not allow battery acid to contact the eyes or the skin.***
    1. ***Flush any contacted areas with water immediately and thoroughly.***
    2. ***Get medical help.***
- ***Follow each step in the jump starting instructions, exactly.***

Notice: Do not push or tow the vehicle to start it. Under some conditions this may damage the catalytic converter or other parts of the vehicle. Also, since this vehicle has a 12–volt negative ground electrical system, make sure the vehicle or equipment used to jump start the engine has a 12–volt negative ground electrical system. Use of any other type system may damage the vehicle's electrical components.

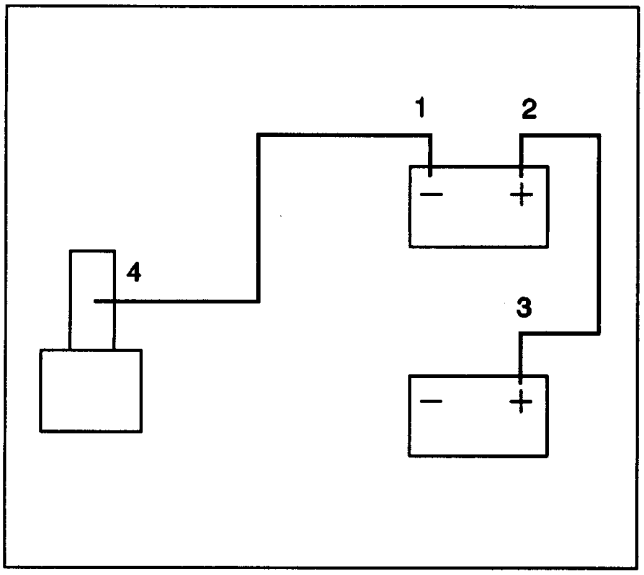
Do not jump start a vehicle under the following conditions:

- You do not know the voltage or ground of the other vehicle.
- The voltage or ground of the other vehicle are different than the voltage or ground of your vehicle.

Follow the procedure outlined below when using jumper cables. Treat the booster battery and the discharged battery carefully when using jumper cables. Do not cause sparks.

1. Position the vehicle equipped with the charged battery so that the jumper cables will reach the discharged battery.

   DO NOT allow the vehicles to touch.
2. Turn OFF the following components:
    - The engine control switch
    - The lights
    - Any other unnecessary electrical loads
3. Apply the parking brake.
4. Place the transmission in the NEUTRAL position.
5. Block the wheels.
6. Do not use the jumper cables if the insulation is loose or missing.
7. Inspect the built-in battery hydrometer of the vehicle equipped with the dead battery. If the hydrometer is clear or light yellow, do not jump start the battery. Replace the battery.



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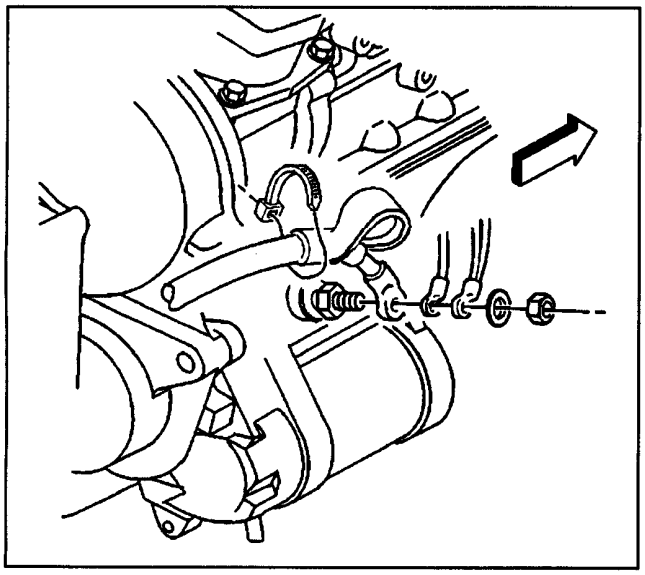
8. Attach one jumper cable end to the positive terminal (2) of the booster battery.
9. Attach the other end of the same cable to the positive terminal (3) of the discharged battery.
10. Attach one negative jumper cable end to the negative terminal (1) of the booster battery.
11. Connect the jumper negative cable end to a solid ground (4) (such as an A/C compressor bracket), at least 450 mm (18 in) from the battery of the vehicle being started.
12. Start the engine of the vehicle that provides the jump start.
13. Start the engine of the vehicle with the discharged battery.
14. Perform the following steps in order to remove the jumper cables:
    14.1. Remove the negative cable from the metal ground (4).
    14.2. Remove the negative cable from the booster battery (1).
    14.3. Remove the positive cable from the booster battery (2).
    14.4. Remove the positive cable from the jumped battery (3).

Battery Cable Replacement

When you replace a battery cable, use a replacement cable that has the following specifications that are equal to the specifications of the original cable:

- Type
- Diameter
- Length

Additional feed wires sometimes attach to positive cables. Additional ground leads sometimes attach to negative cables. Route the replacement cable in the same manner as the original cable was routed.



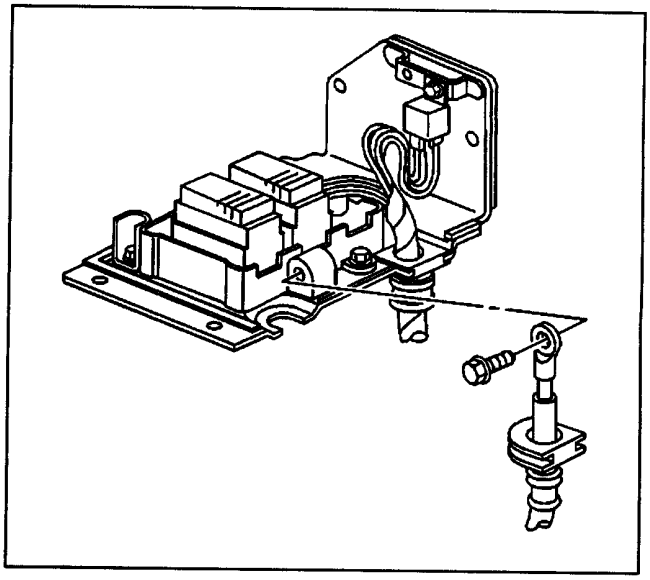
227242

Positive Cable Removal Procedure

1. Tilt the cab. Refer to *Cab Tilting* in General Information.

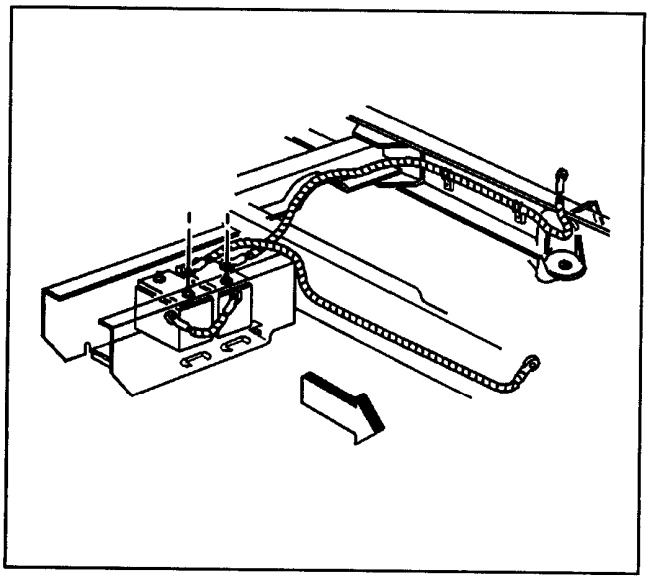
   Caution: Refer to Battery Disconnect Caution in Cautions and Notices.
2. Disconnect the negative battery cable.
3. Disconnect the positive cable from the starter solenoid.

4. Disconnect the positive cable from the Maxi-Fuse® block.



215054

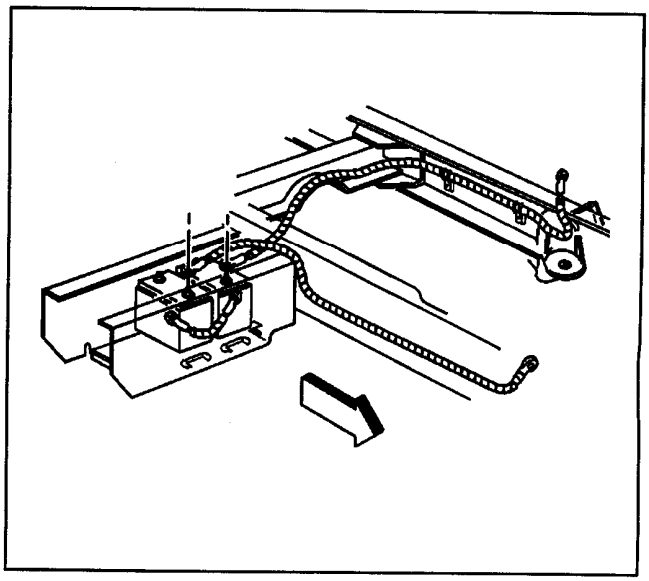
5. Remove the following components:
   - The positive cable clamps
   - The tie downs
6. Remove the positive cable.



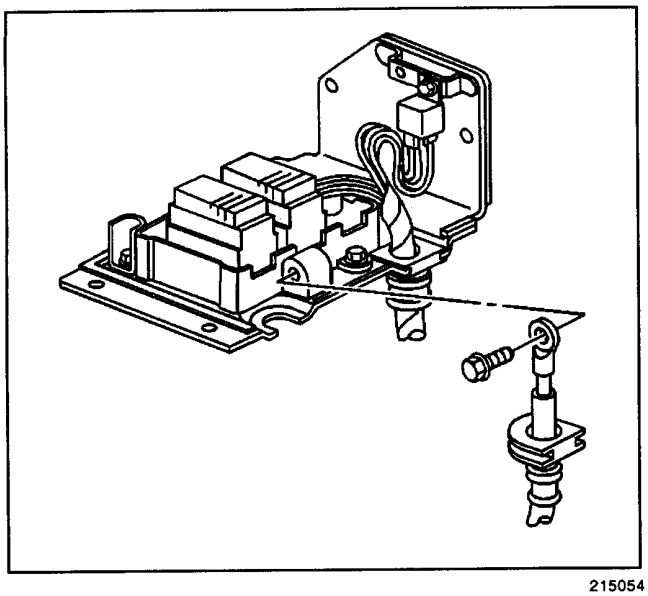
215049

Positive Cable Installation Procedure

1. Install the positive cable.
   Ensure that the positive cable is installed to the original positive cable routing.
2. Install the following components:
   - The positive cable clamps
   - The tie downs



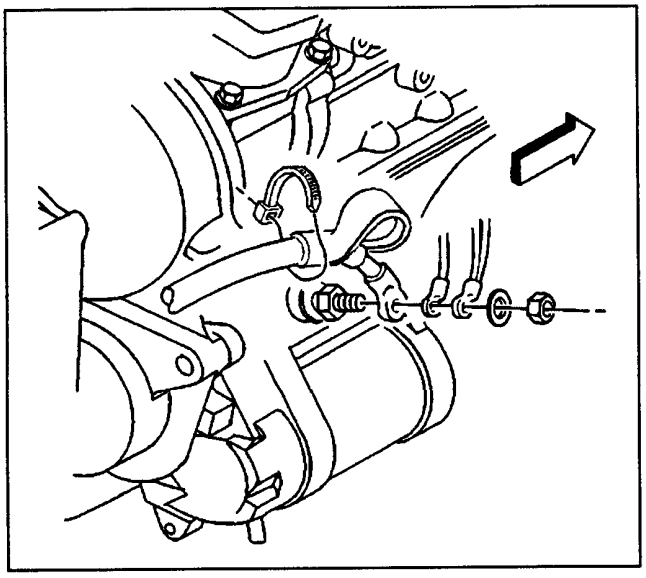
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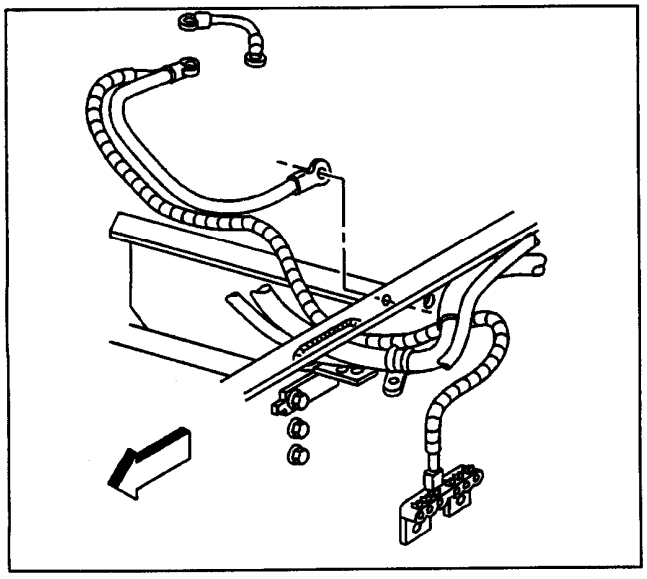
Notice: Refer to *Fastener Notice* in Cautions and Notices.

3. Connect the positive cable to the Maxi-Fuse® block.
   Tighten
   Tighten the positive cable to Maxi-Fuse® block bolt to 9 N.m (80 lb in).



227242

4. Connect the positive cable to the starter solenoid.
   Tighten
   Tighten the positive cable starter nut to 21 N.m (16 lb ft).
5. Connect the negative battery cable.
   Tighten
   Tighten the top post terminal nut to 17 N.m (13 lb ft).
6. Lower the cab.



204733

Negative Cable to Frame Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable from the battery.
2. Connect the negative battery cable from the frame.
3. Disconnect the wires from the negative junction block.
4. Remove the negative junction from the frame.

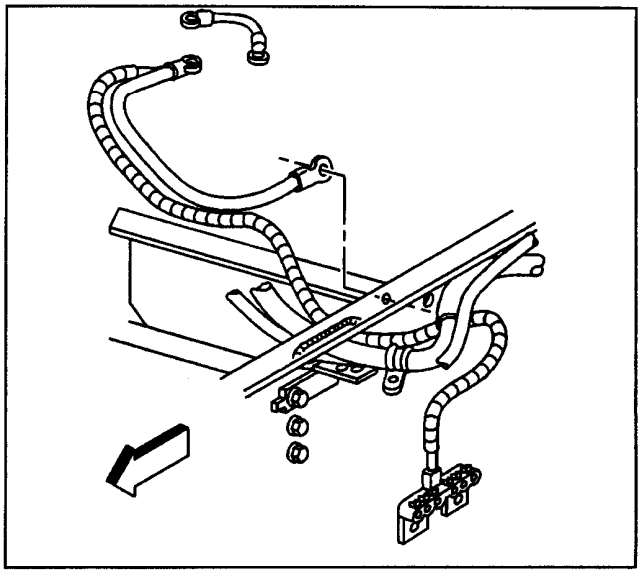
Negative Cable to Frame Installation Procedure

1. Install the negative junction to the frame.
2. Connect the wires to the negative junction block.
3. Connect the negative battery cable to the frame.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
4. Connect the negative battery cable to the battery.

   Tighten

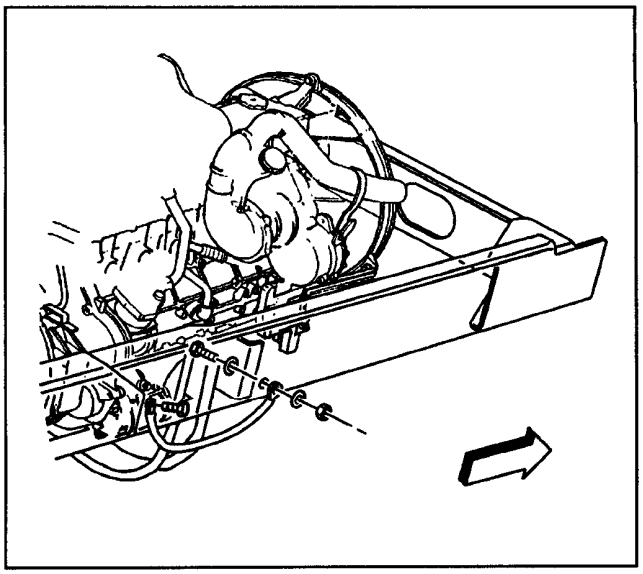
   - Tighten the top post terminal nut to 17 N.m (13 lb ft).
   - Tighten the negative cable bolt to frame to 30 N.m (22 lb ft).



204733

Negative Cable to Engine Removal Procedure

1. Disconnect the negative cable from the frame.
2. Disconnect the negative cable from the engine.



204739

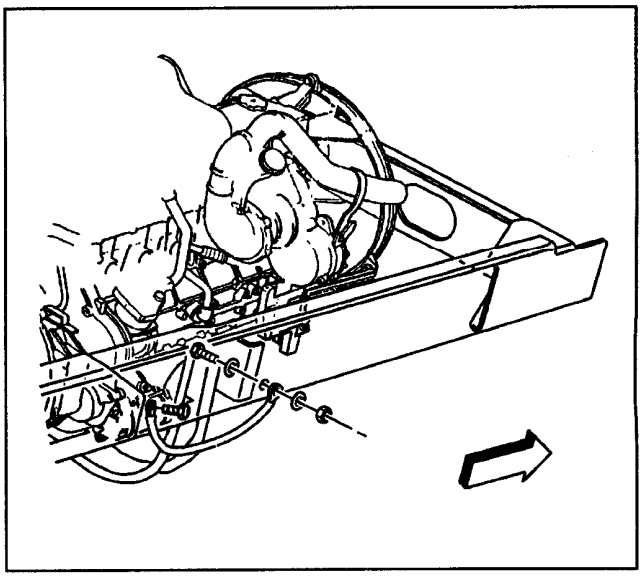
Negative Cable to Engine Installation Procedure

1. Connect the negative cable to the engine.

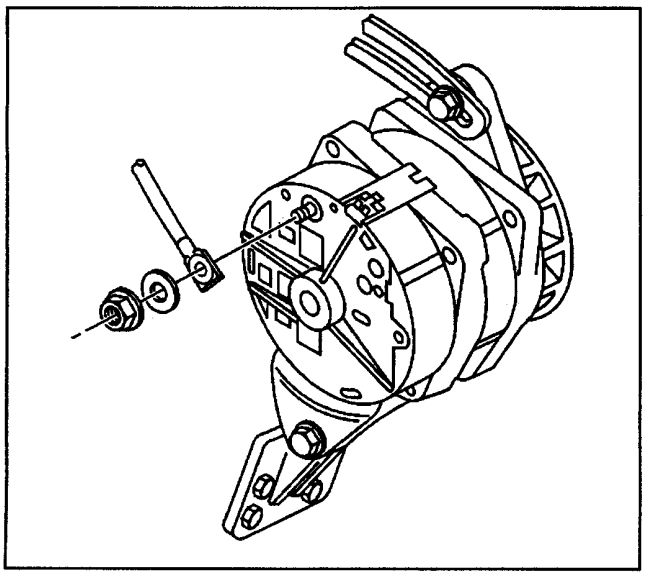
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Connect the negative cable to the frame.

   Tighten

   - Tighten the negative cable to frame bolt to 28 N.m (21 lb ft).
   - Tighten the negative cable to engine bolt to 18 N.m (13 lb ft).



204739

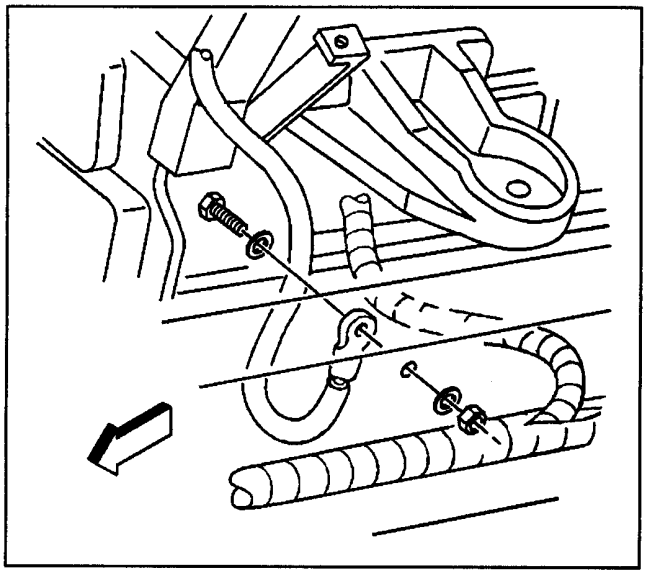


227237

Ground Strap Replacement

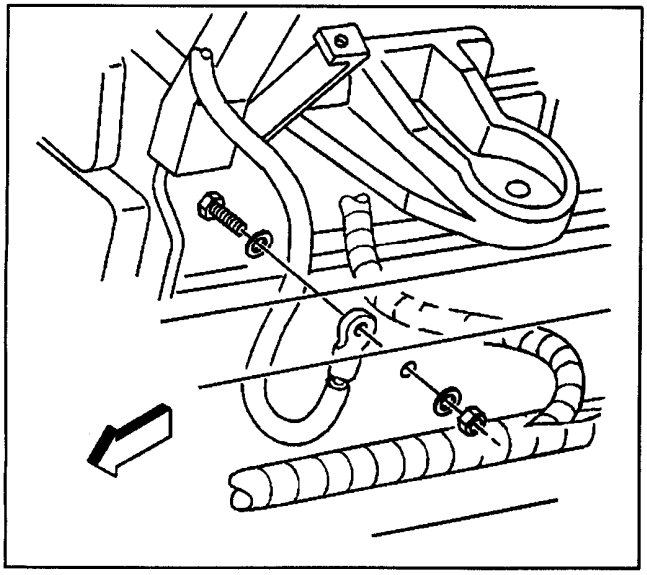
Removal Procedure

1. Tilt the cab. Refer to *Cab Tilting* in General Information.
2. Disconnect the ground strap from the generator.



227251

3. Disconnect the ground strap from the front engine harness.
4. Remove the ground strap from the left side frame rail.
5. Remove the ground strap from the front engine harness.



227251

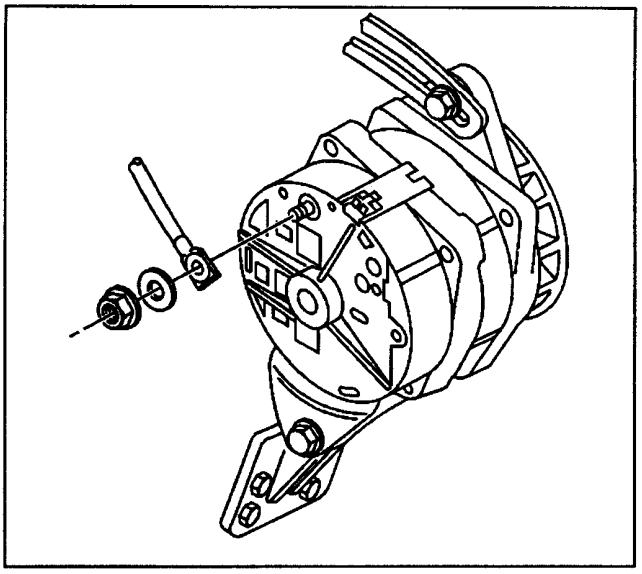
Installation Procedure

1. Install the ground strap.

   Route the ground strap to the original routing in the front engine harness.
2. Connect the ground strap to the left side frame rail.

Notice: Refer to *Fastener Notice* in Cautions and Notices.

3. Connect the ground strap to the generator.
   Use additional ground straps in order to connect the body and the frame to the engine and the transmission. Connect all of the ground straps in order to ensure a proper ground path to the battery from all of the electrical components.
   Tighten
   - Tighten the ground strap bolt to generator to 11 N.m (97 lb in).
   - Tighten the ground strap bolt to frame rail to 30 N.m (22 lb ft).
4. Lower the cab.



227237

Generator Bracket Replacement (Top Mounting Bracket)

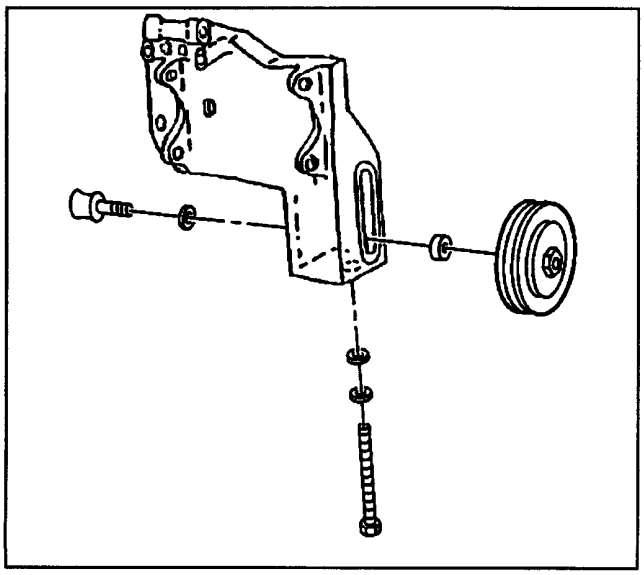
Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

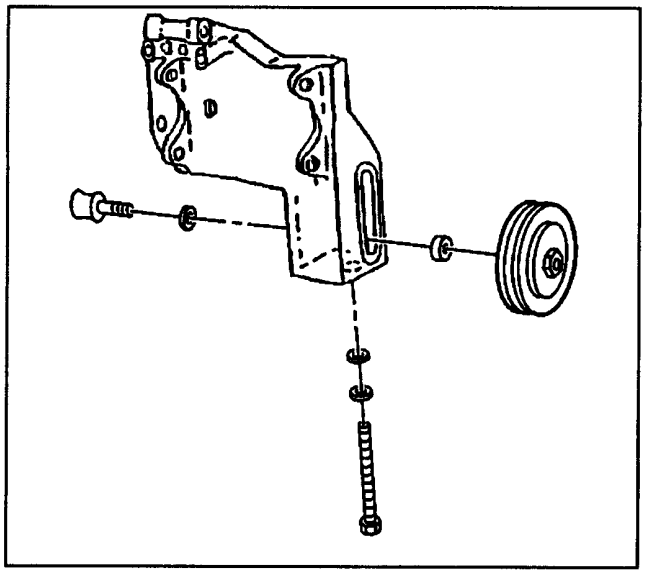
1. Disconnect the negative battery cable. Refer to *Battery Cable Replacement.*
2. Tilt the cab. Refer to *Cab Tilting* in General Information.
3. Remove the belts. Refer to Belt Tension Adjustment in Engine Mechanical.
4. Remove the generator top mounting bolt.
5. Remove the wire harness clamp.
6. Remove the mounting bracket bolts.
7. Remove the mounting bracket.

Installation Procedure

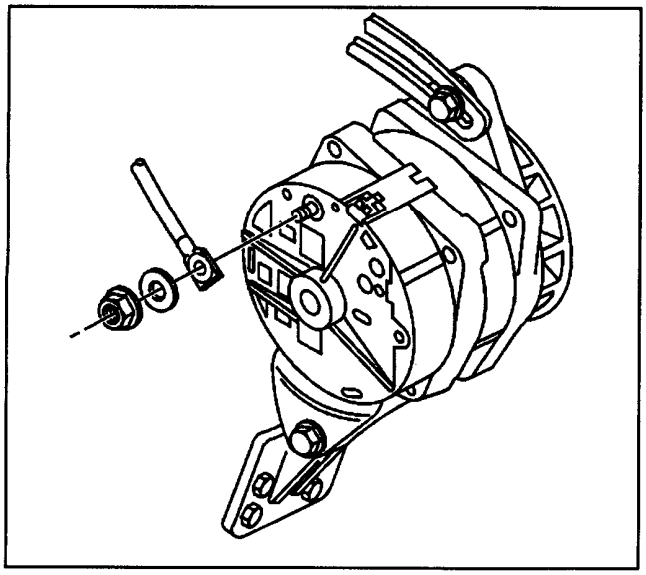
1. Install the mounting bracket.
   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the mounting bracket bolts.
   Tighten
   - Tighten the mounting bracket to engine top bolt to 38 N.m (28 lb ft).
   - Tighten the mounting bracket to engine bottom bolts to 19 N.m (14 lb ft).
3. Install the wire harness clamp.
4. Install the belts.
5. Install the generator mounting bolts.
   Tighten
   Tighten the generator mounting bolts to 88 N.m (65 lb ft).
6. Lower the cab.
7. Connect the negative battery cable.



227233



227233



227237

Generator Bracket Replacement (Accessory Mounting Bracket)

Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable. Refer to *Battery Cable Replacement* .
2. Tilt the cab. Refer to *Cab Tilting* in General Information.
3. Remove the generator. Refer to *Generator Replacement.*
4. Remove the air conditioning belt, if equipped. Refer to Belt Tension Adjustment in Engine Mechanical.
5. Remove the air conditioning compressor mounting bolts, if equipped.
6. Remove the accessory mounting bracket bolts.
7. Remove the accessory mounting bracket.

Installation Procedure

1. Install the accessory mounting bracket.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the accessory mounting bracket bolts.

   Tighten

   Tighten the accessory mounting bracket bolts to 50 N.m (37 lb ft).
3. Install the air conditioning compressor mounting bolts, if equipped.

   Tighten

   Tighten the air conditioning compressor mounting bolts to 39 N.m (29 lb ft).
4. Install the air conditioning belt, if equipped.
5. Install the generator.
6. Lower the cab.
7. Connect the negative battery cable.

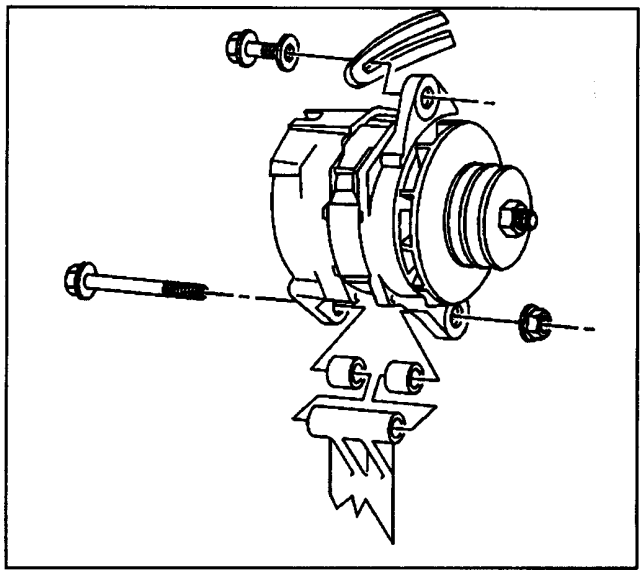
Generator Replacement

Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

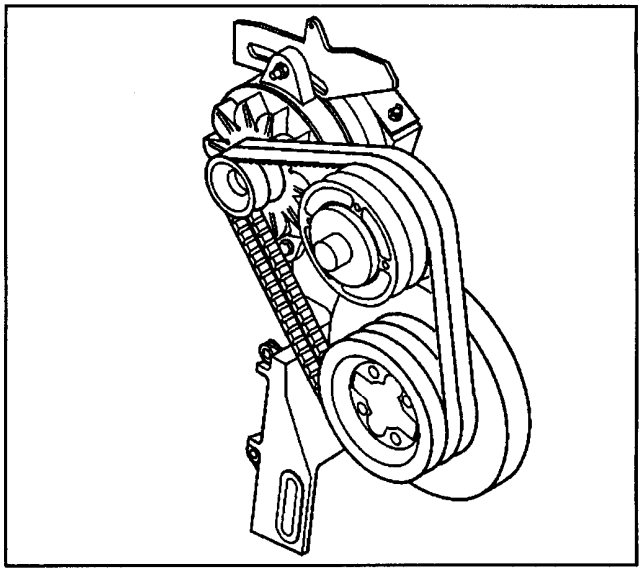
1. Disconnect the negative battery cable. Refer to *Battery Cable Replacement.*
2. Tilt the cab. Refer to *Cab Tilting* in General Information.
3. Disconnect the wiring connectors from the back of the generator.
4. Remove the ground strap.
5. Remove the drive belt. Refer to Belt Tension Adjustment in Engine Mechanical.

6. Remove the generator mounting bolts.
7. Remove the generator.



227236

8. Remove the generator pulley.



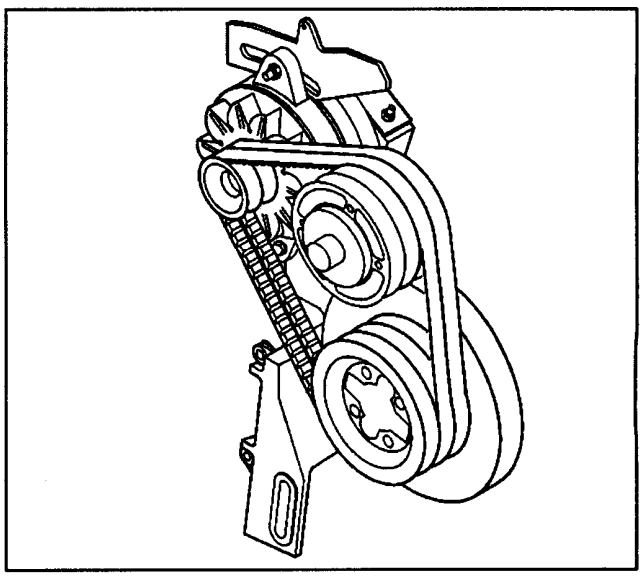
227240

Installation Procedure

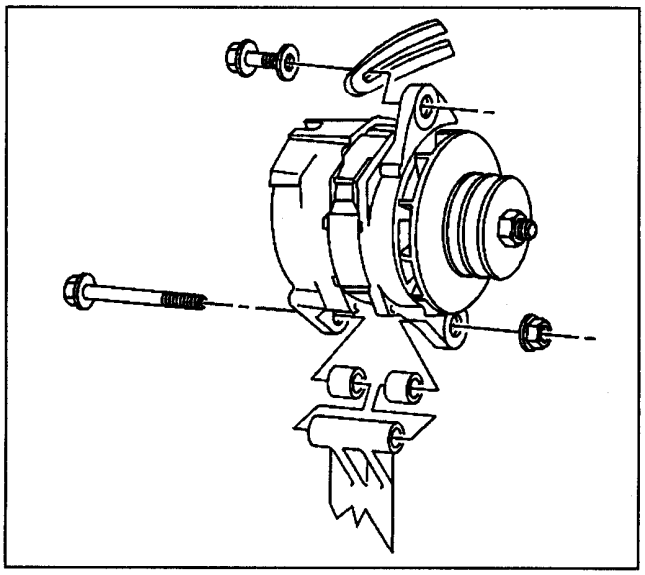
Important: Replace the pulley of the new generator, if the pulley diameter of the new pulley is not exactly equal to the diameter of the old pulley.

Notice: Refer to *Fastener Notice* in Cautions and Notices.

1. Install the generator pulley.
   Tighten
   Tighten the generator shaft nut to 100 N.m (75 lb ft).

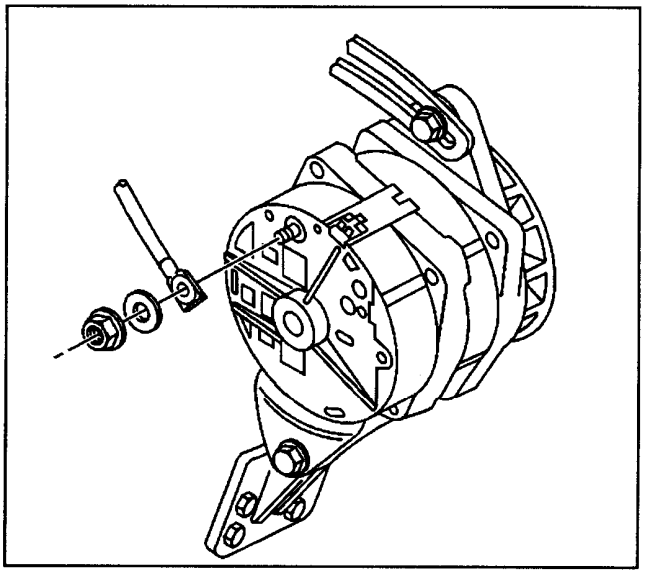


227240



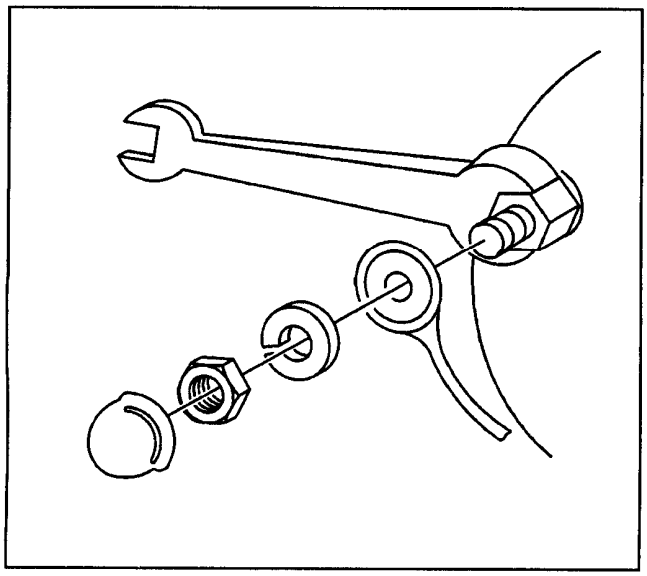
227236

2. Install the generator to the mounting bracket.
   Use mounting bolts in order to secure the generator.



227237

3. Install the ground strap.
   Tighten
   Tighten the ground strap bolt to 6 N·m (50 lb ft).
4. Install the drive belt.



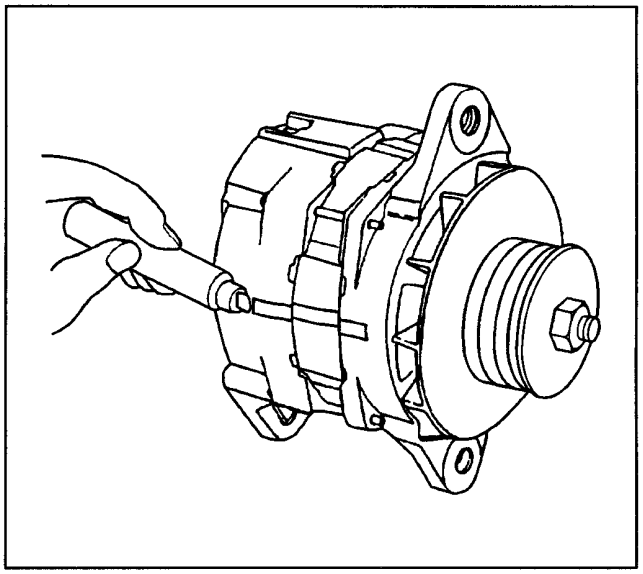
206221

5. Tighten the generator mounting bolts.
   Tighten
   - Tighten the top mounting bolts to 88 N·m (65 lb ft).
   - Tighten the mounting bolts to 88 N·m (65 lb ft).
6. Connect the wiring connectors to the back of the generator.
   Hold the hex-shaped base on the output terminal when you tighten the nuts.
   Tighten
   - Tighten the generator output terminal nut to 12N·m (100 lb in).
   - Tighten the relay terminal nut to 2 N·m (20 lb in).
   - Tighten the indicator terminal nut to 2 N·m (20 lb in).
7. Lower the cab.
8. Connect the negative battery cable.

Generator Overhaul

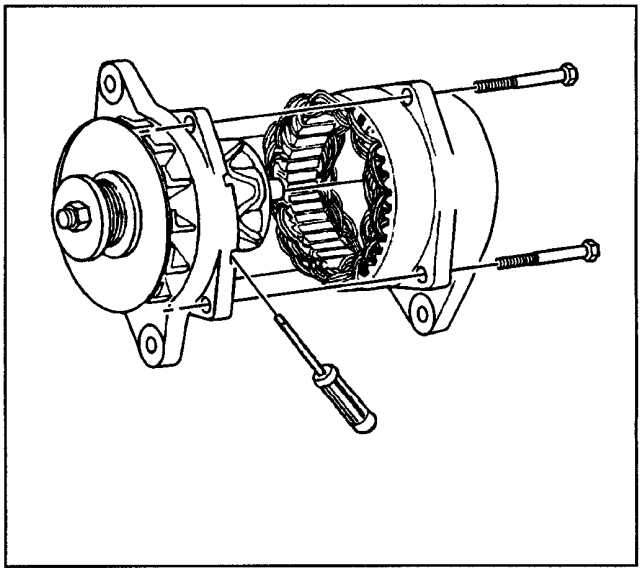
Slip Ring End Frame Disassembly

1. Hold the generator in a vise.
2. Clamp the generator lengthwise onto one mounting lug.
3. Scribe a mark onto the generator frame end parts in order to ensure correct assembly.



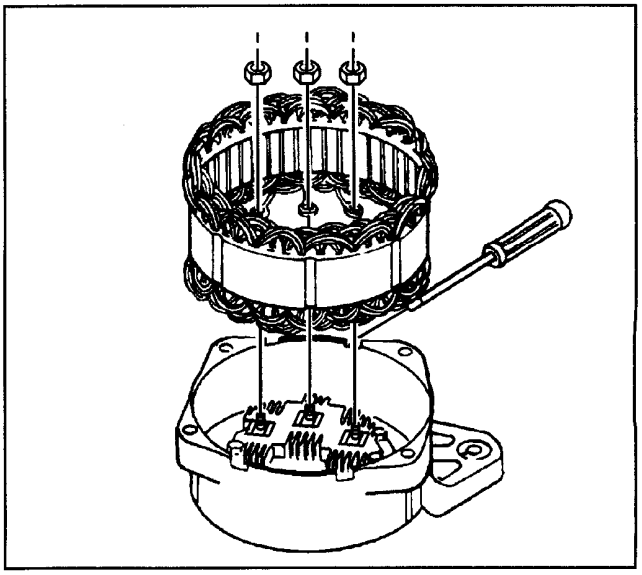
203690

4. Remove the four through-bolts.
5. Use a screwdriver at the stator slots, if necessary, in order to remove the slip ring end frame from the following components:
   - The drive end frame
   - The rotor assembly

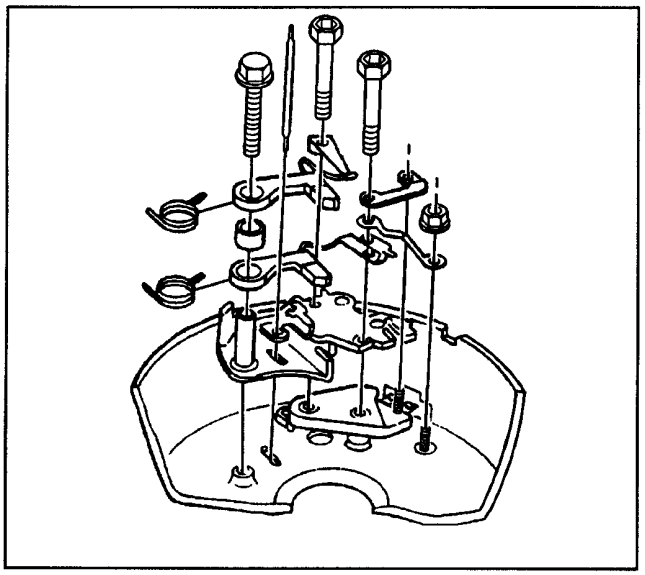


203693

6. Remove the three rectifier bridge nuts in order to disconnect the stator.
7. Carefully use a screwdriver, if necessary, in order to remove the stator from the slip ring end frame.
8. Remove the nut from the relay terminal connecting strap.
9. Remove the following components from the inside of the frame:
   - The connecting strap
   - The washer
10. Remove the threaded relay terminal from the outside of the frame.
11. Remove the following parts from the regulator:
    - The two insulated screws
    - The one ground screw

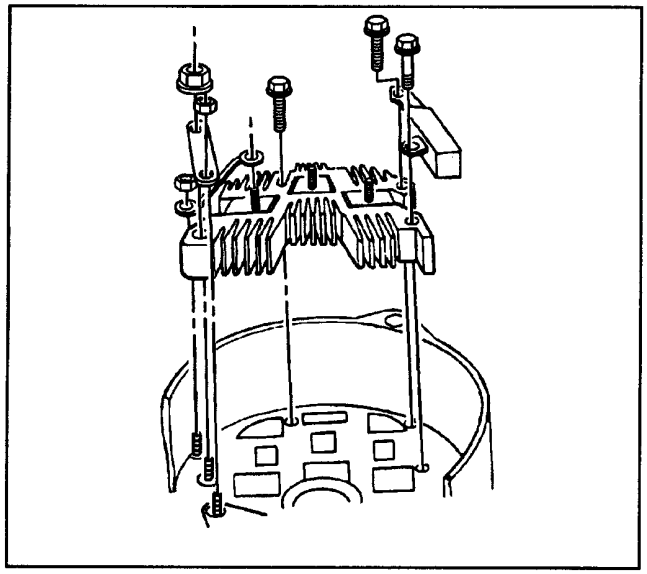


203706



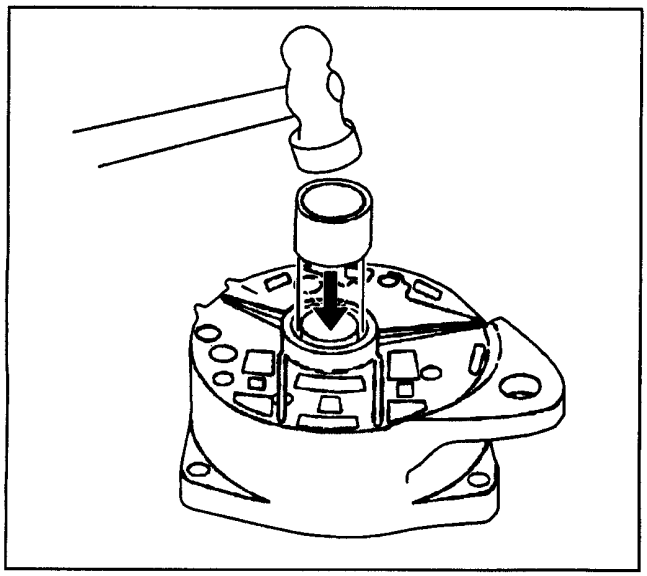
203713

12. Remove the following components from the brush holder.
    - The screw
    - The washer
13. Remove the following parts from the end frame:
    - The regulator
    - The brush holder
    - The diode trio



203711

14. Remove the screws holding the capacitor to the following components:
    - The slip ring end frame
    - The rectifier bridge
15. Remove the following parts on the BAT terminal from the rectifier bridge:
    - The ground screw
    - The ground screw washer
    - The ground screw nut
16. Remove the rectifier bridge from the end frame.
17. Remove the following parts from the outside of the frame.
    - The BAT terminal
    - The BAT terminal shield



203716

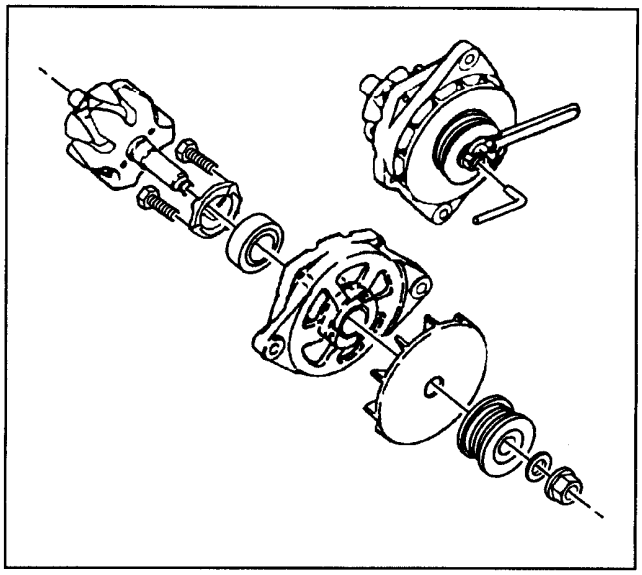
18. Use the following procedure in order to remove the bearing from the slip ring end frame:
    18.1. Support the slip ring end frame from the inside.
    18.2. Obtain a tube that has an outside diameter slightly smaller than the bearing.
    18.3. Use the tube from outside the frame in order to press the bearing in.

Drive End Frame Disassembly

1. Use the following procedure in order to remove the pulley nut:
   1.1. Use the 5/16 inch hex-head wrench in order to hold the end of the shaft.
   1.2. Turn the wrench to the left in order to remove the pulley nut.
   1.3. If a 5/16 inch hex-head wrench is not available, take the following steps:
      1.3.1. Wrap the rotor in a shop cloth.

      Notice: The rotor may be distorted if the vise is overtightened.

      1.3.2. Place the rotor in a vise.
      1.3.3. Tighten the vise in order to hold the rotor while removing the pulley nut.
2. Remove the washer.
3. Remove the pulley.
4. Remove the fan.
5. Use a puller, if necessary, in order to remove the drive end frame from the rotor shaft.
6. Remove the rotor from the vise.
7. Remove the three retainer bolts.
8. Remove the retainer.
9. Use the following procedure in order to remove the bearing from the drive end frame:
   9.1. Use a metal tube that has an inside diameter slightly larger than the outside diameter of the bearing in order to support the drive end frame from the inside.
   9.2. Use a second metal tube against the inner race of the bearing in order to press the bearing from the drive end frame.

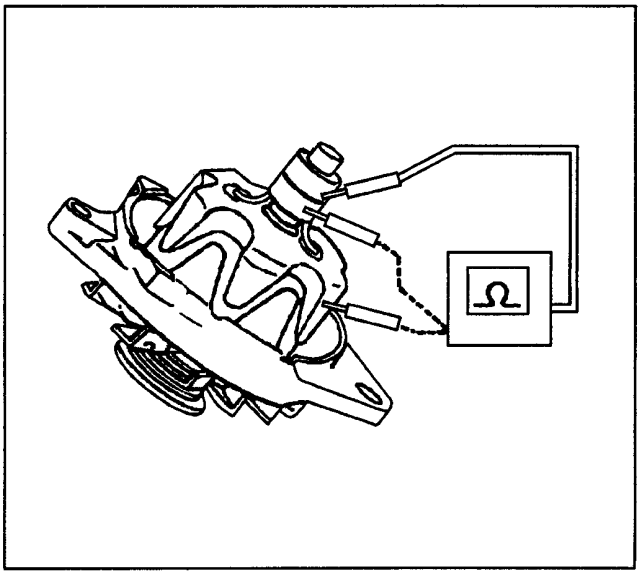


203718

Cleaning and Inspection Procedure

1. Clean all of the metal components except for the following components in a suitable solvent:
   - The voltage regulator
   - The rectifier bridge
   - The stator
   - The rotor
   - The bearing assemblies
2. Use one of the following methods in order to dry the components:
   - Wipe the components.
   - Blow the components.
3. Inspect the brush holder.
4. Inspect the insulating sleeves on the brush holder retaining screws.
5. Inspect the brushes.

   If the brushes are worn more than halfway, replace the brush assembly.



203719

6. Inspect the brush springs for the following conditions:
   - Discoloration
   - Weakness
7. Inspect the bearing seals.

   If the felt seal in the drive end bearing retainer plate exhibits one of the following conditions, replace the retainer assembly:
   - Hardness
   - Wear
8. Inspect the bearings for grease.

   Use the following standard in order to replace the bearing:
   - If the slip ring end bearing grease supply is exhausted, replace the bearing.
   - If the slip ring end bearing grease supply is not exhausted, relubricate the bearing. Refer to Lubrication in order to use the correct type of lubricant.
9. Replace the rotor and the stator windings if any of the following conditions exist:
   - Burnt insulation
   - Cracked insulation
   - Broken wires
   - Broken connectors
10. Inspect the rotor slip rings.

    Notice: The rotor must be rotated so that the slip rings will be cleaned evenly. Cleaning the slip rings by hand without spinning the rotor may result in flat spots on the slip rings, causing brush noise.

    10.1. If the slip rings are dirty, use the following procedure in order to clean the slip rings:
        10.1.1. Obtain a polishing cloth with a grain of 400 or finer.
        10.1.2. Spin the rotor.
        10.1.3. Hold the polishing cloth against the slip rings until the slip rings are clean.

    10.2. If the slip rings are rough or out of round, use the following procedure in order to true the rings:
        10.2.1. Use a lathe in order to true the slip rings to 0.05 mm (0.002 in) maximum indicator reading.
        10.2.2. Remove only enough material in order to make the rings smooth and round.
        10.2.3. Use a polishing cloth with a grain of 400 or finer in order to finish the rings.
        10.2.4. Blow away all of the dust.

11. Perform electrical tests on the following components.
    - The rotor
      Refer to Rotor Field Winding Tests.
    - The stator windings
      Refer to Stator Tests.
12. Inspect the drive end housing for damage.
13. Inspect the slip ring end housing for damage.

Rotor Field Winding Tests

Use a self-powered test lamp or an ohmmeter on the low range scale in order to perform an electrical test the rotor.

Open Circuit Test

1. Connect the test lamp or the ohmmeter to each slip ring in order to test for opens.
2. The winding is open if the lamp fails to light or if the ohmmeter reading is high (infinite).

Short Circuit or Resistance Test

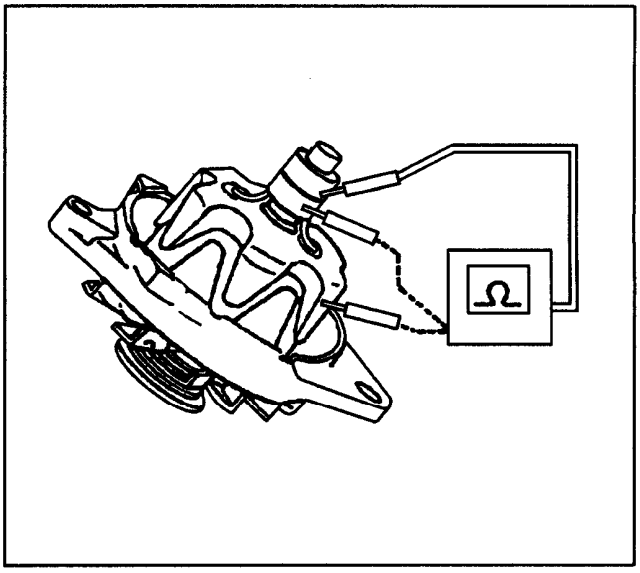
1. Use one of the following two methods in order to test the winding for short-circuits or excessive resistance:

   Using an Ammeter

   1.1. Connect a 12 volt battery and an ammeter in series with the edges of the two slip rings.
   1.2. Compare the reading on the ammeter to the specified values for 21-SI 200 generators. Refer to *Generator Usage.*
   1.3. Use the following procedure in order to identify a short circuit or excessive resistance.
   - If the ammeter reading is above the specified value, then the windings are shorted.
   - If the ammeter reading is below the specified value, then the resistance is excessive.

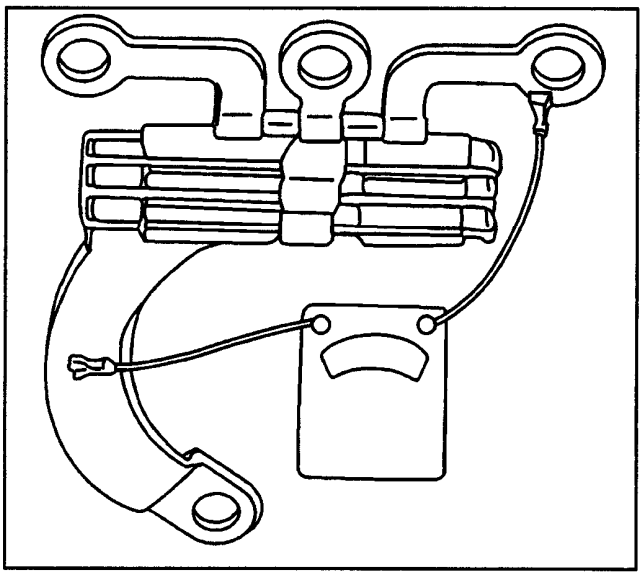
   Using an Ohmmeter

   1.1. Connect an ohmmeter to the two slip rings.
   1.2. Compare the reading on the ohmmeter to the specified values for 21-SI 200 generators. Refer to *Generator Usage.*
   1.3. If the resistance reading is below the value specified value, then the resistance is excessive.



203719

2. Use the following guides in order to diagnose winding malfunctions:
   - The winding resistance and ammeter readings will vary slightly according to temperature changes in the winding.
   - If the rotor is good but the generator fails to supply the rated output, then the problem is in one of the following components:
     - The diode trio
     - The rectifier bridge
     - The stator
     - The regulator
   - Use the following procedure in order to test for grounds:
     2.3.1. Connect the ohmmeter as shown.
     2.3.2. Replace the rotor if the reading is less than infinite.
3. Replace the rotor if the results of the rotor tests are not within specifications.



203721

Diode Trio Test

Use an ohmmeter with a 1.5 volt cell set to the lowest range scale in order to test the diode trio. Use the following procedure:

1. Place the negative lead of the ohmmeter on the regulator strap.
2. Use the positive lead of the ohmmeter in order to test for continuity between each of the three rectifier bridge straps.
3. Ensure that all three readings indicate continuity.
4. Reverse the ohmmeter leads.
5. Perform the test again.
6. Ensure that all three readings indicate open circuits.
7. Replace the diode trio if any of the readings are wrong.

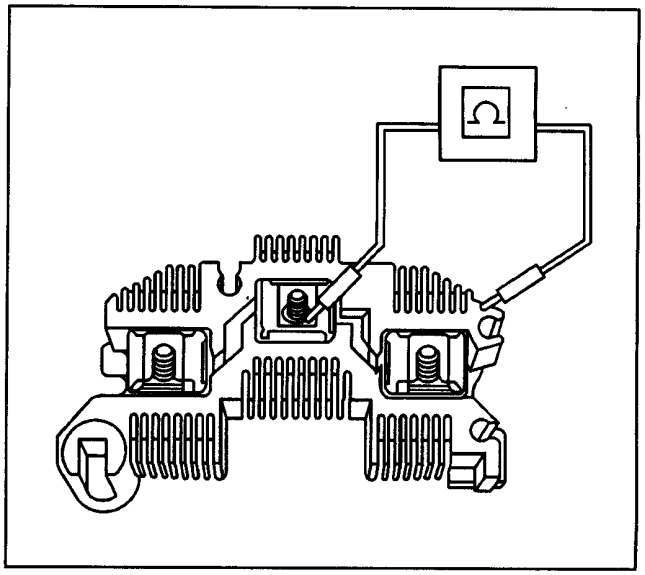
The ohmmeter test of the diode trio is a valid and accurate test. Do not replace the diode trio unless at least one pair of readings is the same.

Rectifier Bridge Test

Use an ohmmeter with a 1.5 volt cell set to the lowest range scale in order to test the rectifier bridge. Use the following procedure:

1. Connect an ohmmeter to the following components in order to test the rectifier bridge:
   - The grounded heat sink
   - One of the three flat metal connectors

   Do not bend the flat metal clips.
2. Observe the ohmmeter reading.
3. Reverse the lead connections to the grounded heat sink and the same flat metal connector.
4. A good rectifier bridge will show one high reading and one low reading. If both readings are the same, then replace the rectifier bridge.
5. Repeat the above test procedure between the grounded heat sink and the other two connectors.
6. Repeat the above test procedure between the insulated heat sink and each of the three connectors.
7. Complete a total of six tests using two readings for each test.



203722

The ohmmeter test of the rectifier bridge is a valid and accurate test. Do not replace the rectifier bridge unless at least one pair of readings is the same.

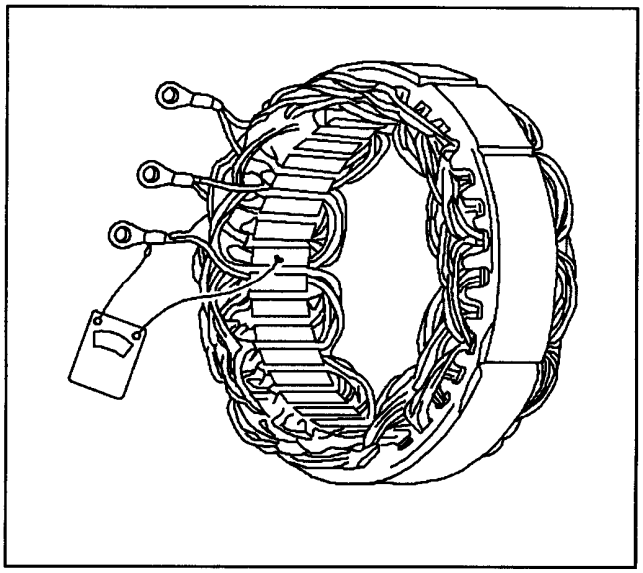
Stator Tests

1. Use a self-powered test lamp or an ohmmeter in order to test the stator windings.
2. If the test lamp lights or if the meter reading is low when connected from any stator lead to the frame, then the windings are grounded. Refer to *Generator Usage*.
3. If the windings are grounded, replace the stator.

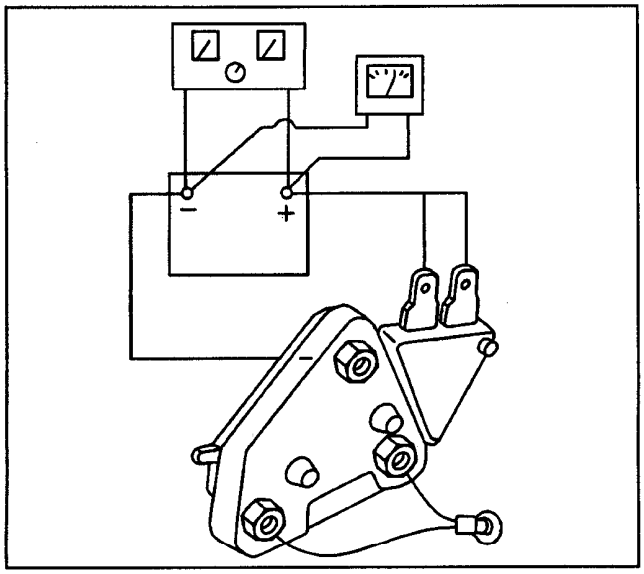
Locating an open or a short circuit in the delta stator windings is difficult without using laboratory test equipment. Locating an open or a short circuit in the delta stator windings is difficult because of the low resistance of the windings. The following conditions indicate shorted or open delta windings:

- All other electrical test are normal.
- The generator does not produce within 15 amps of the rated output.

If the above conditions exist, replace the stator.



17205



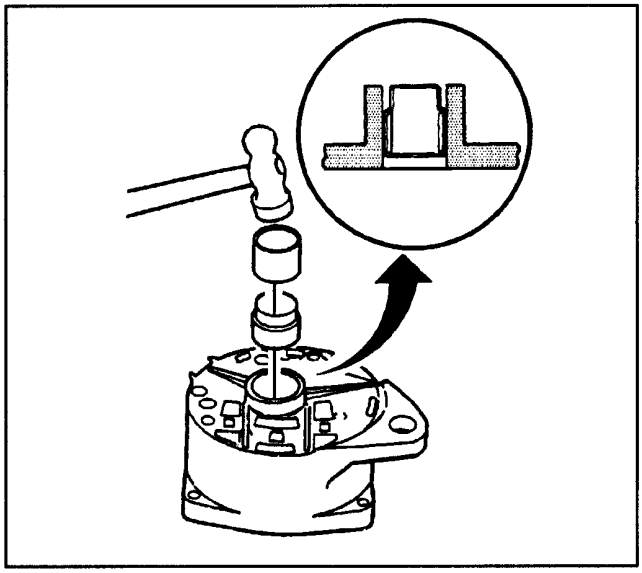
203725

Testing the Regulator

1. Connect the following items to the 12 volt battery
   - The voltmeter
   - The fast charger
2. Connect the following components:
   - The regulator
   - The test lamp
3. Observe the polarity of the battery.
4. Verify that the test lamp is ON.
5. Turn ON the fast charger.
6. Slowly increase the charge rate.
7. Observe the voltmeter.
8. Verify that the lamp turns OFF at the voltage regulator setting.
9. Verify that the voltage regulator setting is a minimum of 13.5 volts and a maximum of 15.5 volts.

The test lamp connects into the circuit exactly as the rotor is when the regulator is inside the generator. The regulator shuts off the current to the test lamp when the voltage reaches the regulator setting.

If you cannot test the regulator, and the regulator is questionable after testing the other components, replace the regulator with a new or a known good regulator.



203739

Generator Assembly

1. Use the following procedure in order to install the bearing into the slip ring end frame:
   1.1. Support the inside of the frame.
   1.2. Use a thin wall tube in the space between the grease cup and the housing in order to push the bearing in flush with the housing.
2. Use the following procedure in order to install the bearing into the drive end frame:
   2.1. Support the drive end frame on a flat surface.
   2.2. Use a tube against the outer race of the bearing in order to press the bearing in.
3. Install the retainer.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
4. Install the three retainer screws.

   Tighten

   Tighten the three retainer screws to 3 N·m (26 lb in).

5. Install the drive end frame onto the rotor shaft.
6. Install the fan.
7. Install the pulley.
8. Install the washer.
9. Install the pulley nut.

   Notice: Too much pressure applied against the rotor will distort it.
10. Place the rotor in a vise.

    Tighten the vise only enough to tighten the pulley nut.

    Tighten

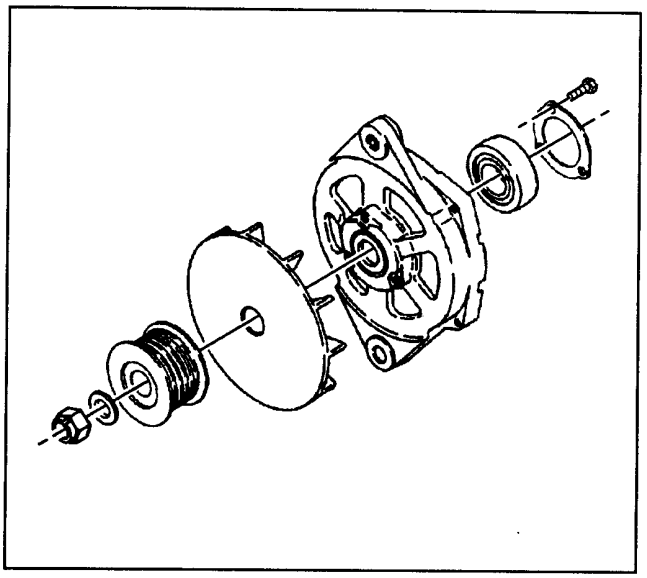
    Tighten the pulley nut to 100 N·m (74 lb ft).
11. Remove the assembly from the vise.
12. Install the following components onto the slip ring end frame:
    - The rectifier bridge
    - The capacitor
13. Use the following components in order to secure the rectifier bridge and the capacitor to the slip ring end frame:
    - Two ground screws
    - One insulated screw

    Tighten

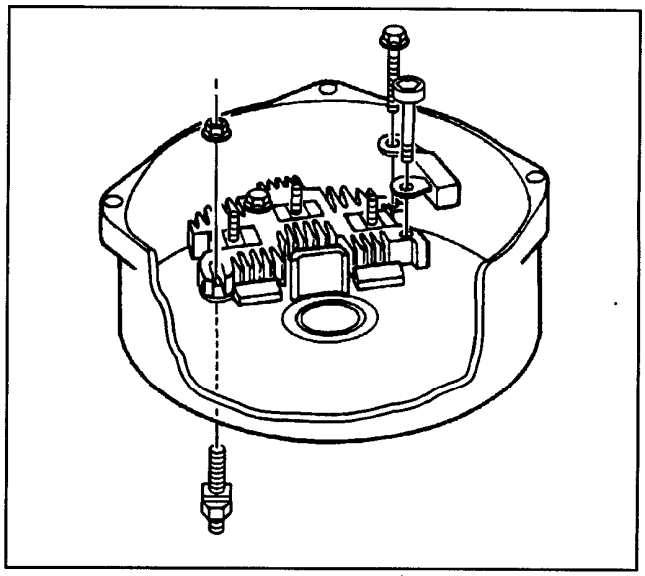
    - Tighten the ground screws to 3 N·m (25 lb in).
    - Tighten the insulated screw to 2.5 N·m (22 lb in).
14. Install the BAT terminal from the outside of the slip ring end frame.
15. Install the nut onto the BAT terminal stud.

    Tighten

    Tighten the nut to 5.5 N·m (50 lb in).



203744

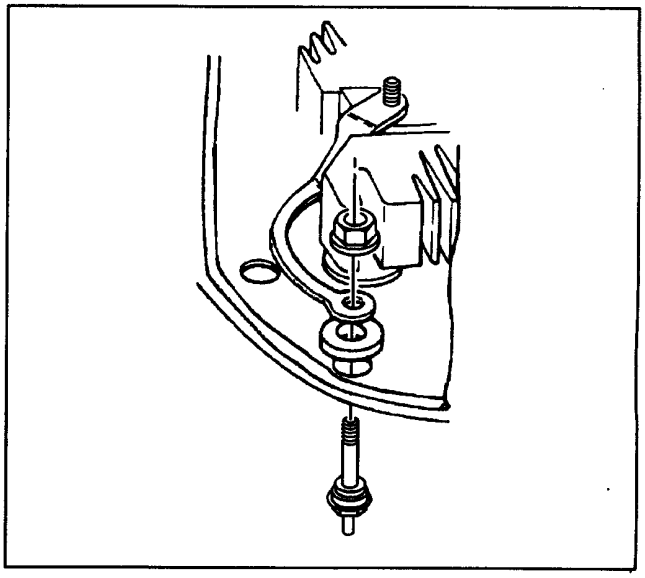


203746

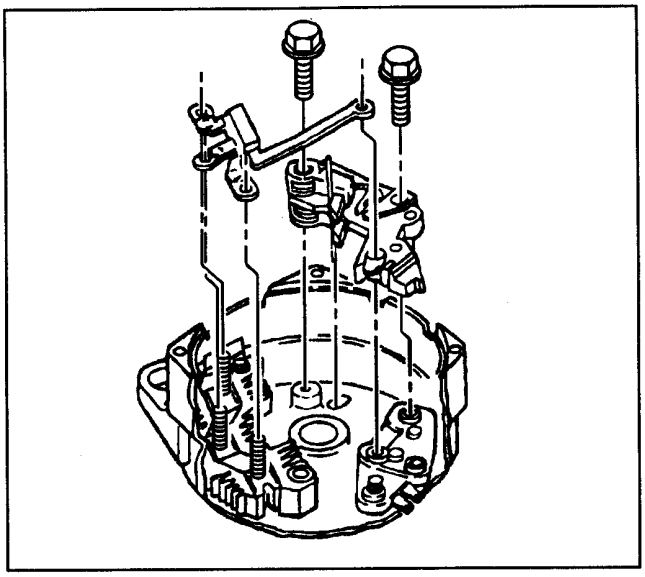
16. Install the relay terminal from the outside of the slip ring end frame.
17. Use the copper nut in order to secure the insulated washer and the attaching strap from the rectifier bridge to the relay terminal.

    Tighten

    Tighten the copper nut to 2.5 N·m (22 lb in).
18. Install the brushes into the brush holder assembly.
19. Use a retainer in order to retain the brushes.
20. Ensure that the long end of the retainer extends through the end frame in order that you are able to remove the retainer after you install the rotor and the drive end frame.

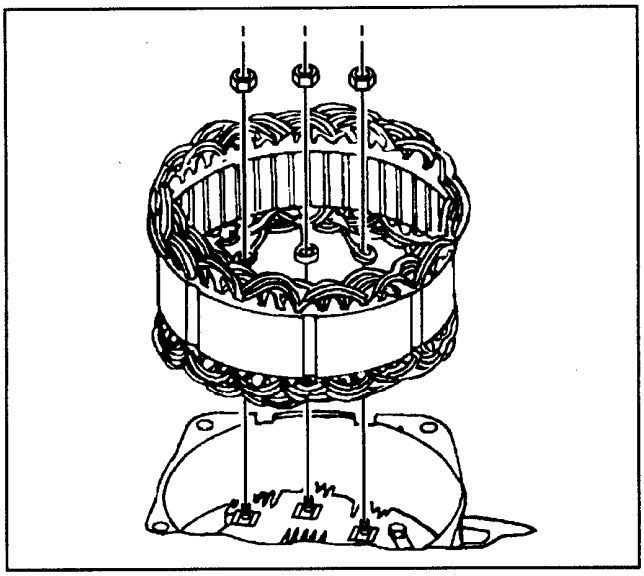


203749



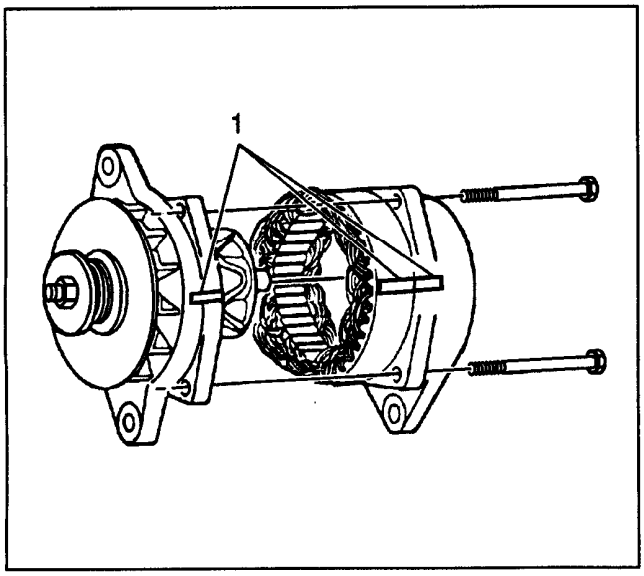
203755

21. Install the following components to the end frame:
    - The regulator
    - The brush holder assembly
    - The diode trio
22. Use the following components in order to secure the regulator, the brush holder assembly and the diode trio to the end frame:
    - The ground screw
    - The insulated screws
23. Install the nut onto the stud on the regulator:
    Tighten
    Tighten the nut to 2.5 N·m (22 lb in).
24. Install the stator to the following components:
    - The slip ring end frame
    - The three rectifier bridge terminals



203766

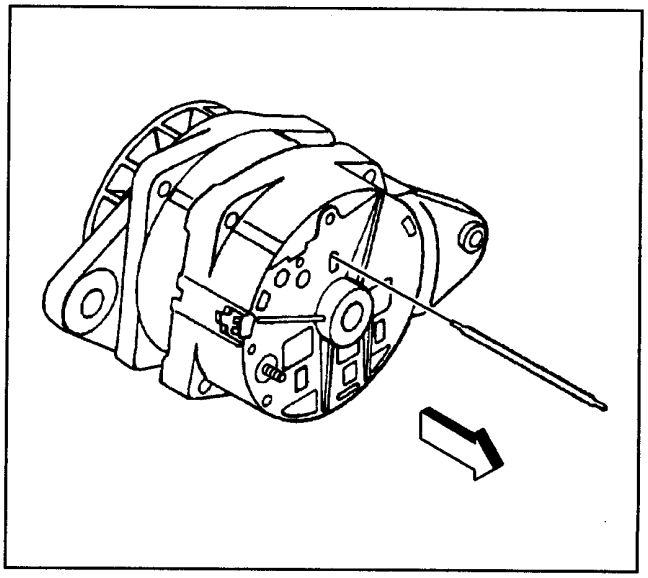
25. Use the three terminal nuts in order to secure the following components to the rectifier bridge:
    - The stator leads
    - The diode trio leads
    Tighten
    Tighten the nuts to 2.5 N·m (22 lb in).
26. Use the scribe mark in order to line up the following components to the slip ring end frame:
    - The drive end frame
    - The rotor assembly



203771

27. Use the four through-bolts in order to secure the following components to the slip ring end frame:
    - The drive end frame
    - The rotor assembly
    Tighten
    Tighten the through-bolts to 5.5 N·m (50 lb in).

28. Remove the brush retainer from the end frame.
29. Test the generator output. Refer to *Charging System Check.*



203775

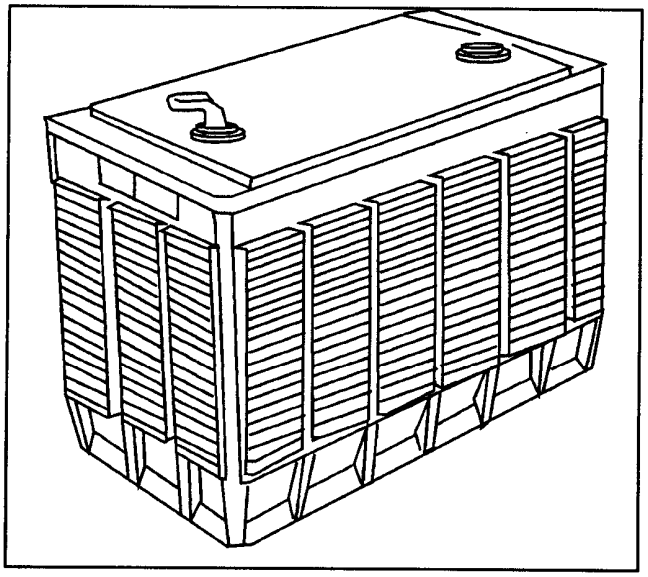
Description and Operation

Battery

The battery performs the following operations in the electrical system:

- Provides a source of energy in order to crank the engine
- Acts as a voltage stabilizer for the electrical charging system
- Provides energy when the vehicle's electrical load exceeds the output of the generator.

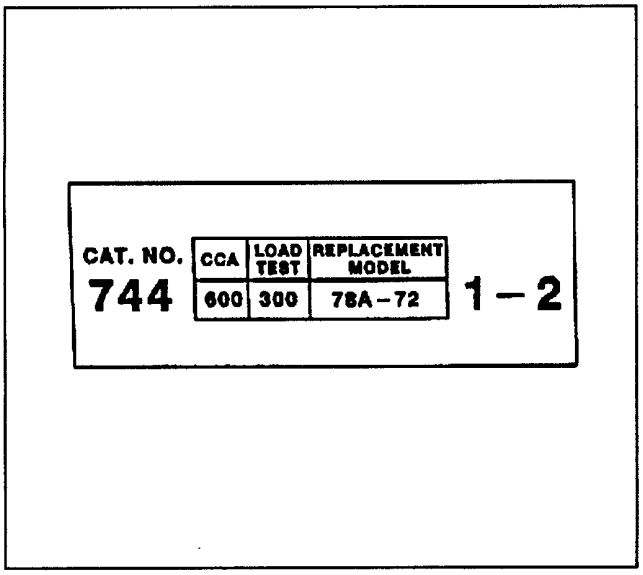
  The battery can only provide this energy for a limited amount of time.



181055

The maintenance-free battery is standard on all vehicles with top terminals. The battery is completely sealed except for two small vent holes. The vent holes are located near the top of the battery on two sides. The vent holes allow the release of a small amount of electrolyte gassing that is produced in the battery.

The battery carrier mounts on the outboard side of the right frame rail under the cab. The two 12-volt batteries are installed into the battery carrier.



106519

The battery specification label contains the following information that is pertinent to servicing the battery:

- Cold cranking amps
- Load test ratings
- Original equipment
- Recommended replacement part numbers

Refer to *General Specifications* for the above information.

Starting System Description

The cranking circuit consists of the following components:

- The battery
- The starter motor
- The engine control switch
- The starter relay
- Related electrical wiring

Vehicles that are equipped with automatic transmissions have a neutral start switch in the circuit.

Some vehicles are equipped with electronically-controlled automatic transmissions. Electronically-controlled automatic transmission vehicles do not have a separate neutral start switch in the cranking circuit. The switch is built into the Vehicle Interface Module (VIM).

Refer to component location.

Refer to *Starting System Circuit Description* for a detailed circuit description.

The starter is a reduction gear drive model with a direct acting solenoid. The solenoid works through the overrunning clutch. The gear housing and the armature end bearing housing are aluminum. The bearings on the armature are sealed ball bearings. The brush assembly brushes are replaceable. The ball bearings on the clutch assembly are serviced as part of the entire clutch assembly. The commutator bars are mica insulated and are undercut.

The shift lever mechanism and the solenoid plunger are within the drive housing. The drive housing protects the shift lever mechanism and the solenoid plunger from exposure to the following conditions:

- Dirt
- Ice
- Splash

The solenoid operates when the engine control switch is turned to the START position (the automatic transmission is in neutral). When the solenoid energizes the main contacts close, completing the electrical circuit between the battery and the starter motor. Energizing the solenoid also shifts the plunger and the shift lever. The pinion gear then engages in order to mesh with the engine flywheel ring. Engine cranking then takes place.

The pinion overriding clutch protects the armature from excessive speed when the engine starts. Releasing the engine control switch enables the following actions:

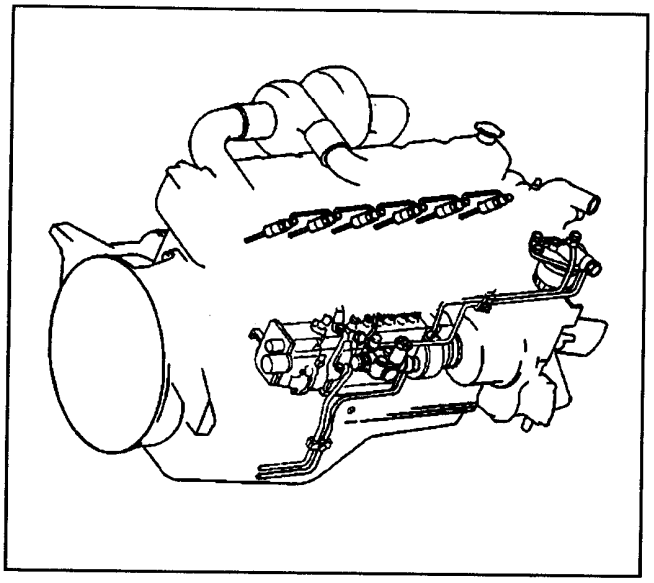
- The solenoid main contacts open
- The plunger return spring disengages the pinion

Release the key immediately after engine starts in order to prevent damage to the starter.

Starting System Operation (Glow Plugs)

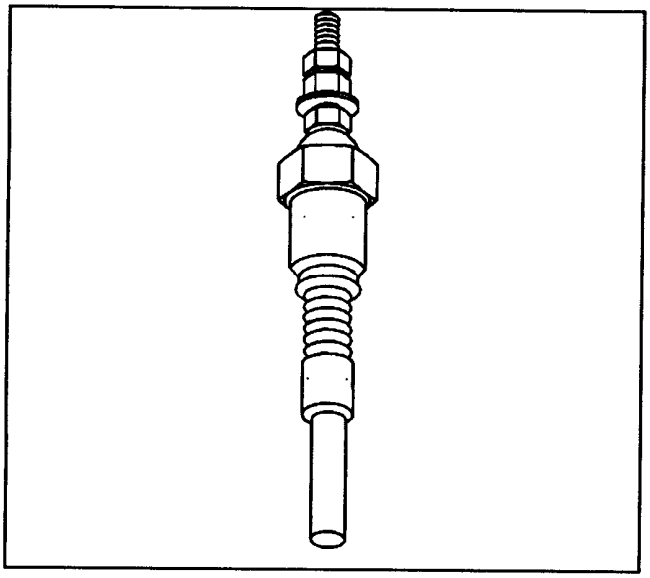
Notice: Never manually spray starting aid fluids into the air intake where the fluid may come in contact with the heater element. This could result in an explosion and/or fire.

Diesel engines rely on the heat of compression in order to initiate combustion. Cold engine start-ups may require extra engine cranking time in order to create the necessary heat needed in order to ignite the diesel fuel.



227701

Glow plugs are one of the devices available in order to aid in cold starting the diesel engine. Six glow plugs are used in order to preheat the combustion chambers as an aid to starting.



227706

The glow plugs are 10.5 volt heaters that are operated at 12 volts when the engine control switch turns to the H position. The glow plugs provide a pre-heat feature to the combustion chamber. The glow plugs also improve cold weather engine start ups.

Starting System Operation (Starting Procedure)

Use the following procedure in order to initiate glow plug operation:

1. Turn the engine control switch to the H position.
2. Wait until the glow plug indicator glows.
3. Crank the engine.
4. Fully depress the accelerator pedal.
5. Release the accelerator pedal.
6. Turn the engine control switch to the START position.

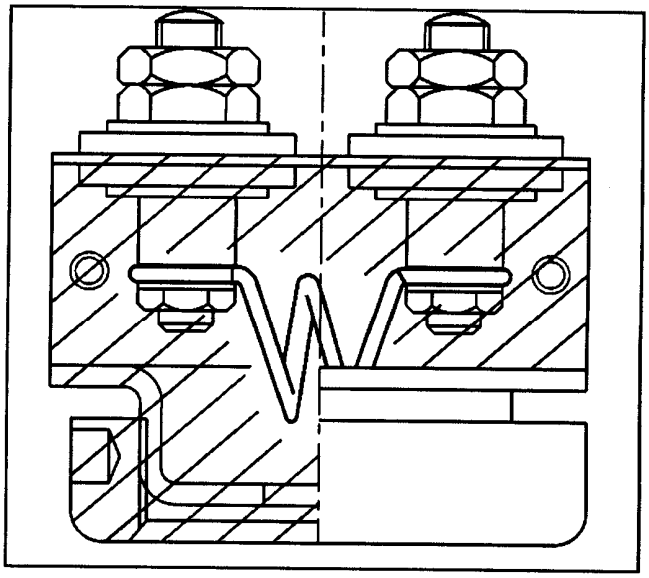
   Release the switch when the engine starts.
7. If the engine does not start after 15 seconds of cranking, repeat the procedure until the engine starts.

Starting System Operation (Glow Plug Operation)

Current flows through the following components when the engine control switch turns to the H position:

- The glow plug relay
- The thermal resistor
- The glow plugs

The current heats the glow plugs to 800°C (1472°F). The glow plugs take 20–25 seconds to heat when the ambient temperature is about 0°C (32°F).



227717

The temperature of the control resistor heats at the same rate as the glow plugs. As the resistor temperature reaches 1000°C (1832°F) the resistor glows red. A glowing red resistor indicates the following conditions:

- The glow plugs are hot.
- The engine control switch can turn to the START position.

Inspect the components and the connections under the following conditions:

- The resistor does not light
- The glow plugs do not heat

Refer to Control Resistor Check.

Starting System Circuit Description

CKT 30 (WHT/RED) from the 25 Amp circuit breaker in the IP fuse block provides battery voltage at the ignition switch at all times. CKT 2 (RED) from the fusible link on the starter provides battery voltage to the starter relay contacts at all times.

When you turn the ignition to the START position, the contacts close in order to apply voltage on CKT 5 (YEL) to the neutral switch (automatic transmission). If the automatic transmission is in the NEUTRAL position, voltage applies to CKT 434 (ORN/BLK) to the starter relay coil. CKT 150 (BLK) grounds the starter relay coil at ground G107.

When voltage applies to the coil, the starter relay energizes. CKT 6 (PPL) then applies voltage to the starter solenoid winding terminal S. CKT 1 (BLK) at starter solenoid terminal B also provides battery voltage at all times.

When battery voltage applies at starter solenoid terminal S, current flows through the hold-in winding to the mechanical ground at the solenoid. Simultaneously, current flows through the pull-in winding and the starter motor to the starter motor's mechanical ground. The combined force of these windings overcomes the force of the return spring. This force pulls the starter's plunger in order to engage the starter with the flywheel drive assembly through the shift lever. The engine turns over. The actuation of the plunger also operates a contact in the starter solenoid. This contact closes in order to apply battery voltage directly to the starter motor. With battery voltage applied directly to the starter motor, the pull-in winding no longer has a voltage drop across the coil. Current ceases to flow. The current flow through the hold-in winding enables the starter solenoid to remain engaged.

The starter motor operates until the ignition switch returns to the RUN position. With the ignition switch in the RUN position, voltage exits through starter solenoid terminal S. However, voltage remains at terminal B. CKT 1 (BLK) energizes both the hold-in winding and the pull-in winding. The forces from these windings now oppose one another. The operation of the return spring returns the plunger to the disengaged position. This action operates the contact in order to remove battery voltage from the starter motor. This action stops the motor. Both windings also de-energize. This plunger operation also retracts the starter from the flywheel drive assembly. The engine operates on the engine's own power.

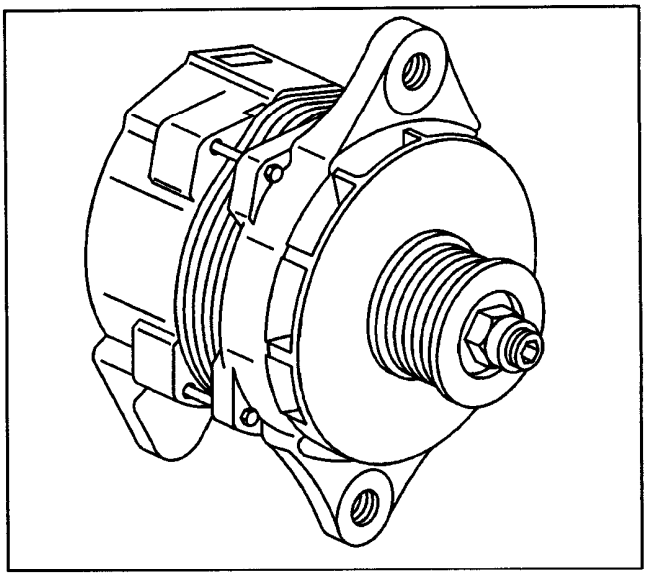
Charging System Description

The charging system consists of the following components:

- The battery
- The generator
- The regulator
- The voltmeter and charging system indicator lamp circitry

The generator supplies electrical power in order to charge the battery and operate the accessories. This vehicle uses the 21-SI 200 generator.

These generators are of the SI (Systems Integral) series. SI generators have a built-in regulator.



203654

The solid state regulator and the brush holder assembly attach to the slip ring end frame. The regulator voltage setting is not adjustable.

The regulator is equipped with the following terminals:

- The R (Relay) terminal.

  The R terminal operates auxiliary equipment in some circuits, such as the tachometer.
- The I (Indicator) terminal.

  The I terminal feeds an indicator lamp or a gauge.

The rotor bearings contain enough grease in order to eliminate the need for periodic lubrication. Two brushes carry current through the two slip rings to the field coil. The field coil mounts on the rotor. Under normal operating conditions, the field coil provides long periods of attention-free service.

The stator windings are assembled on the inside of a laminated core that forms part of the generator frame. A rectifier bridge that connects to the stator windings contains six diodes. The rectifier bridge electrically changes the stator AC voltages to DC voltage. This DC voltage appears at the generator output BAT terminal. A diode trio that connects to the stator windings supplies the generator field current. A capacitor or a condenser mounted to the end frame protects the rectifier bridge and diode trio from high voltages. The capacitor or the condenser also suppresses radio noise.

Charging System Description

The generator provides voltage in order to operate the vehicle's electrical system. The generator also provides voltage in order to charge the battery. The generator operates as an alternator in order to generate Alternating Current (AC) electricity which rectifies to Direct Current (DC) electricity.

A belt drives the generator. The generator rotates as the engine runs. The regulator induces an excitation magnetic field in the generator's rotor. The generator's rotation causes the excitation field to move through the stator windings. The motion of the field through the stator conductors induces an alternating magnetic field to be generated in the stator. Diodes in the rectifier bridge allow stator current to flow as a result of this alternating magnetic field. Stator current only flows in the one direction that charges the battery. The generator's internal solid state voltage regulator regulates the pulse width of the excitation field in order to regulate the voltage generated at the BAT terminal at 14 V, nominally.

The excitation field is present in the generator only when the ignition switch is in the RUN position or the START position. The generator does not contain permanent magnetism of sufficient strength in order to produce a useable excitation magnetic field. The generator's Turn On input is present from CKT 25 (BRN). CKT 25 (BRN) connects the generator to the instrument cluster. Voltage is present to the instrument cluster from circuit breaker 25 in the IP fuse block. The BAT indicator lamp only illuminates when sufficient current flow exists in order to cause the lamp filament to emit light. The resistor allows the slight current flow used by the generator in normal operations. The resistor bypasses the indicator lamp. Thus, an open filament in the lamp does not prevent generator operations.

The generator controls the BAT indicator lamp in the instrument cluster. Internal logic at the generator closes an internal contact to ground the indicator lamp circuit when the generator is not rotating or when the sensed generator output voltage is either too high or too low. The indicator lamp circuit is only powered when the ignition switch is in the RUN or START position.

Special Tools and Equipment

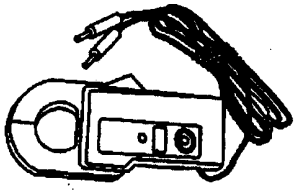
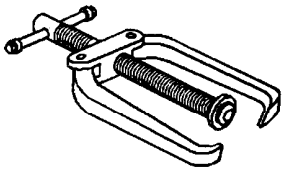
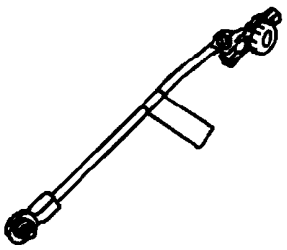
Illustration	Tool Number/ Description
 95591	J 35590 Current Clamp
 3430	J 39200 Digital Multimeter
 48445	J 28509-A Bearing Remover

Illustration	Tool Number/ Description
 3429	J 24642-F Module Tester
 3432	J 38758 Parasitic Draw Test Switch

Engine Controls - 7.8L

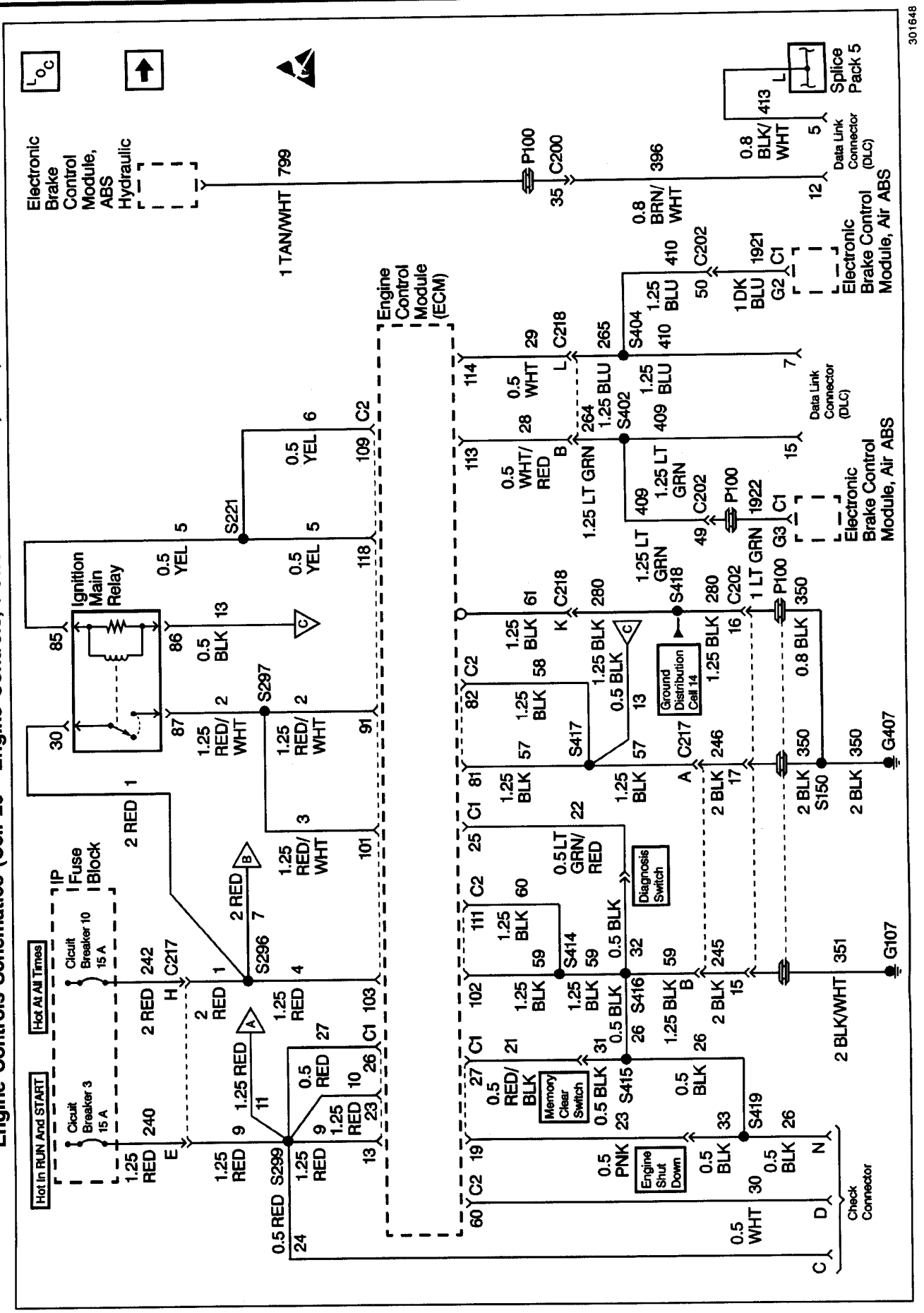
Schematic and Routing Diagrams

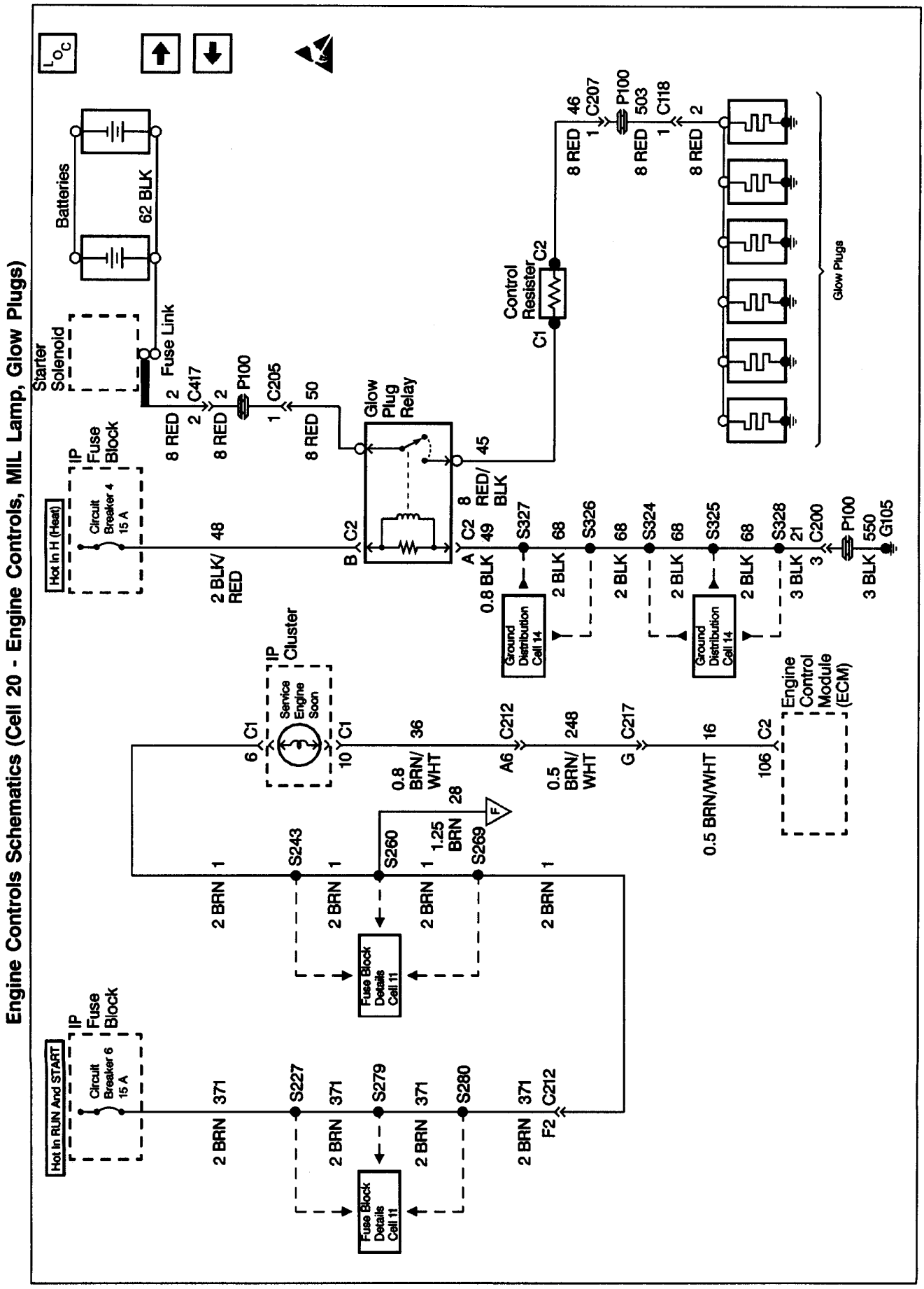
Engine Controls Schematic References

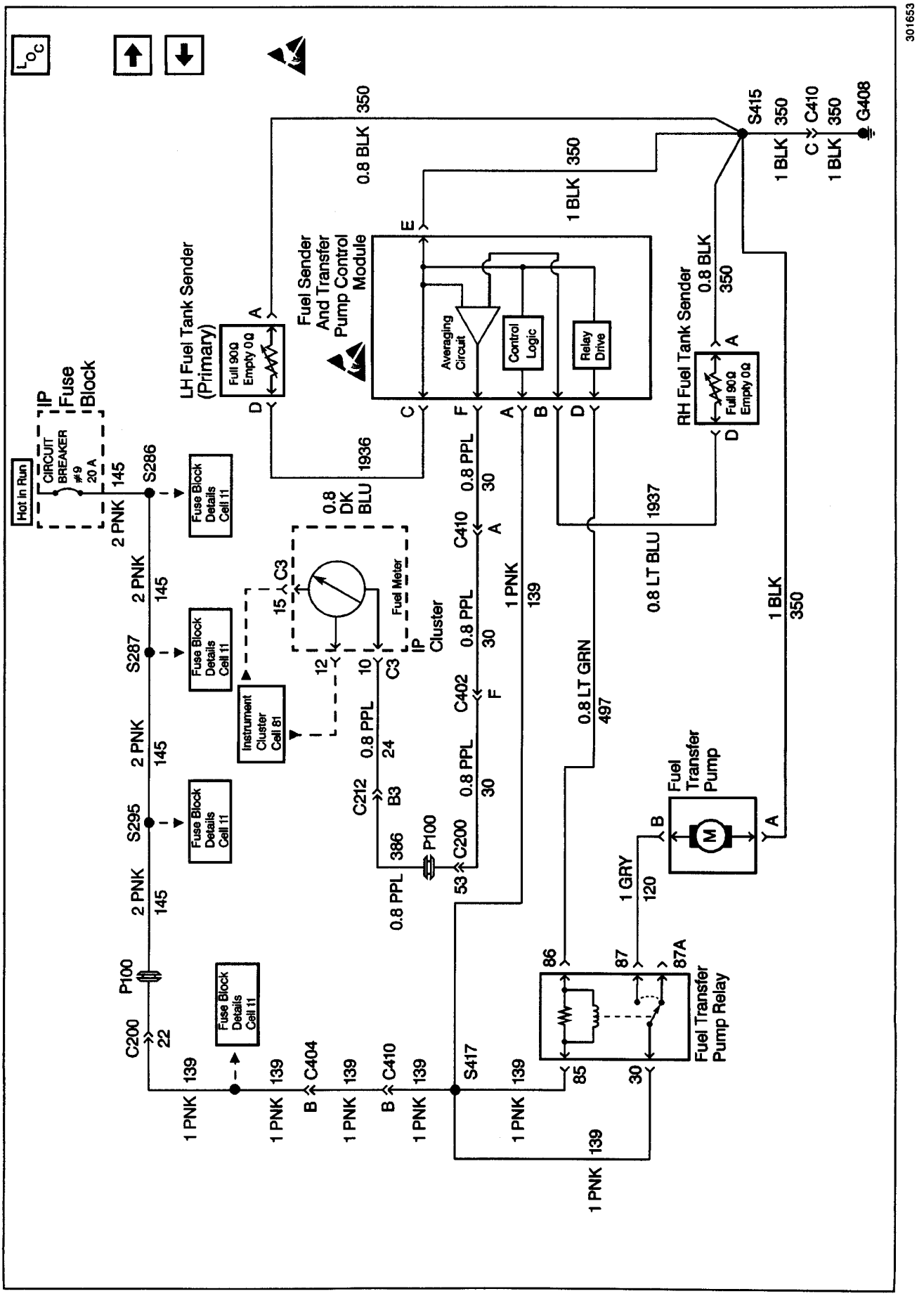
Reference on Schematic	Section Number - Subsection Name
Fuse Block Details Cell 11	8—Wiring Systems
Ground Distribution Cell 14	8—Wiring Systems

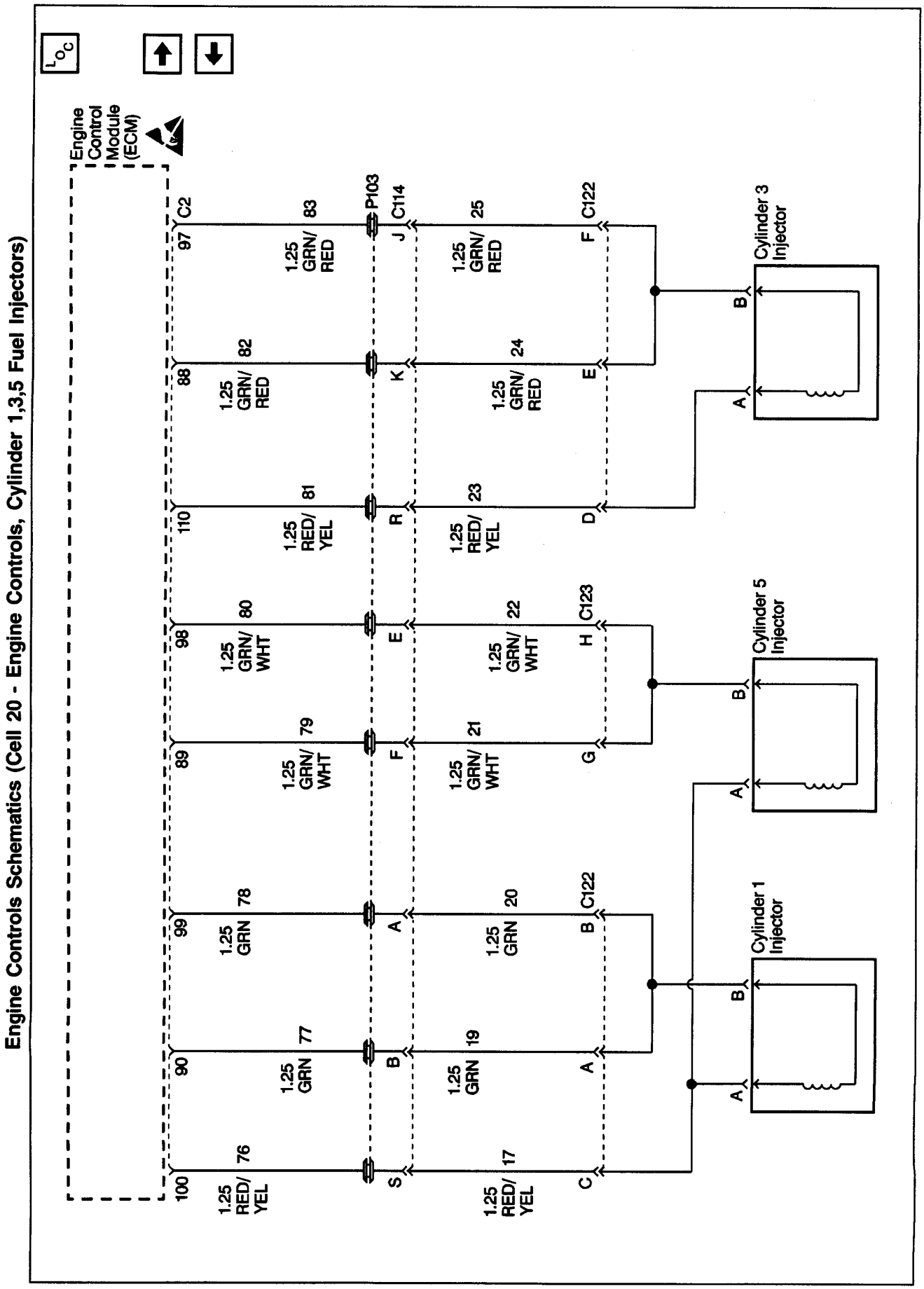
Engine Controls Schematic Icons

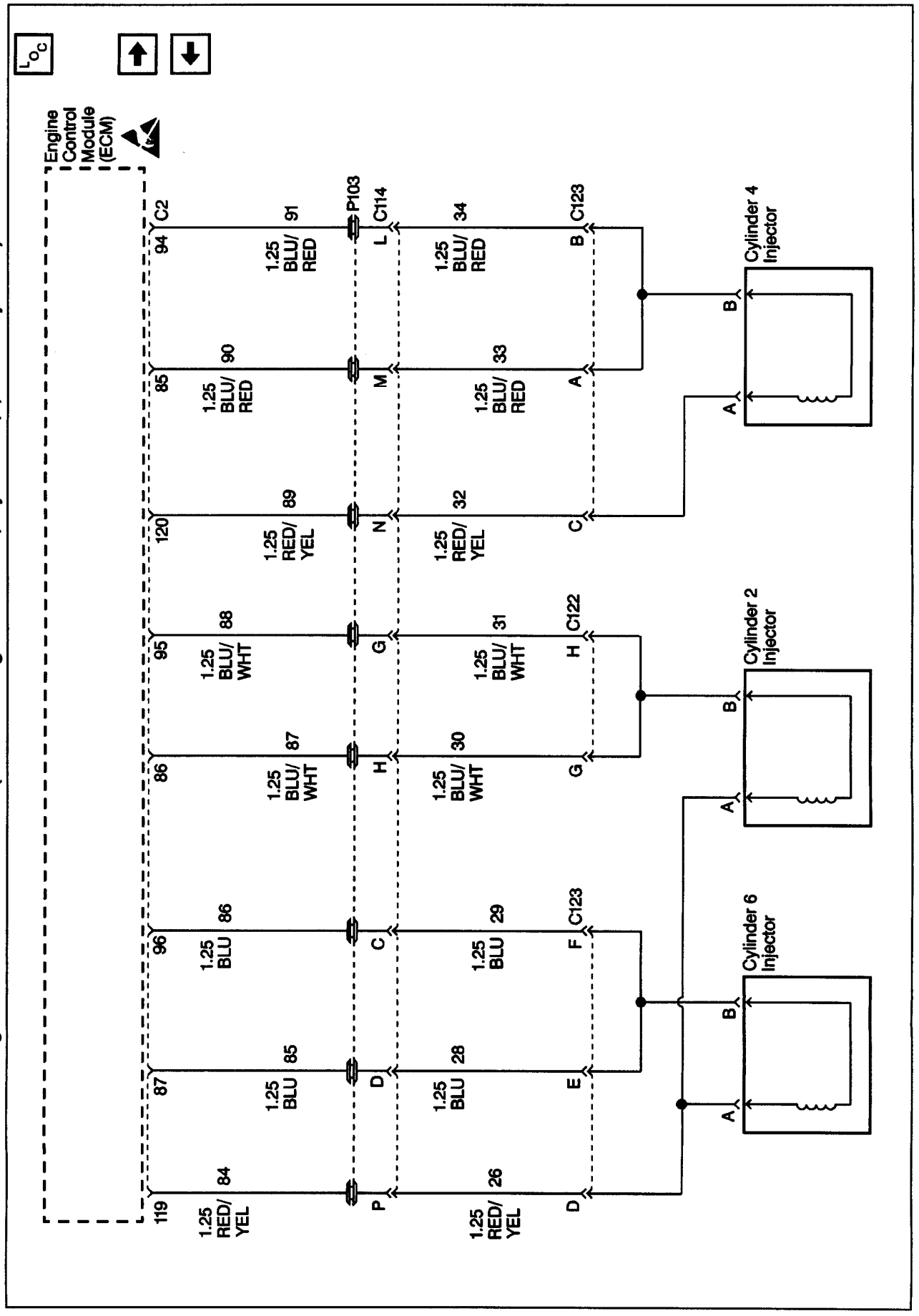
Icon	Icon Definition
 19384	Refer to *ESD Notice* in Cautions and Notices.

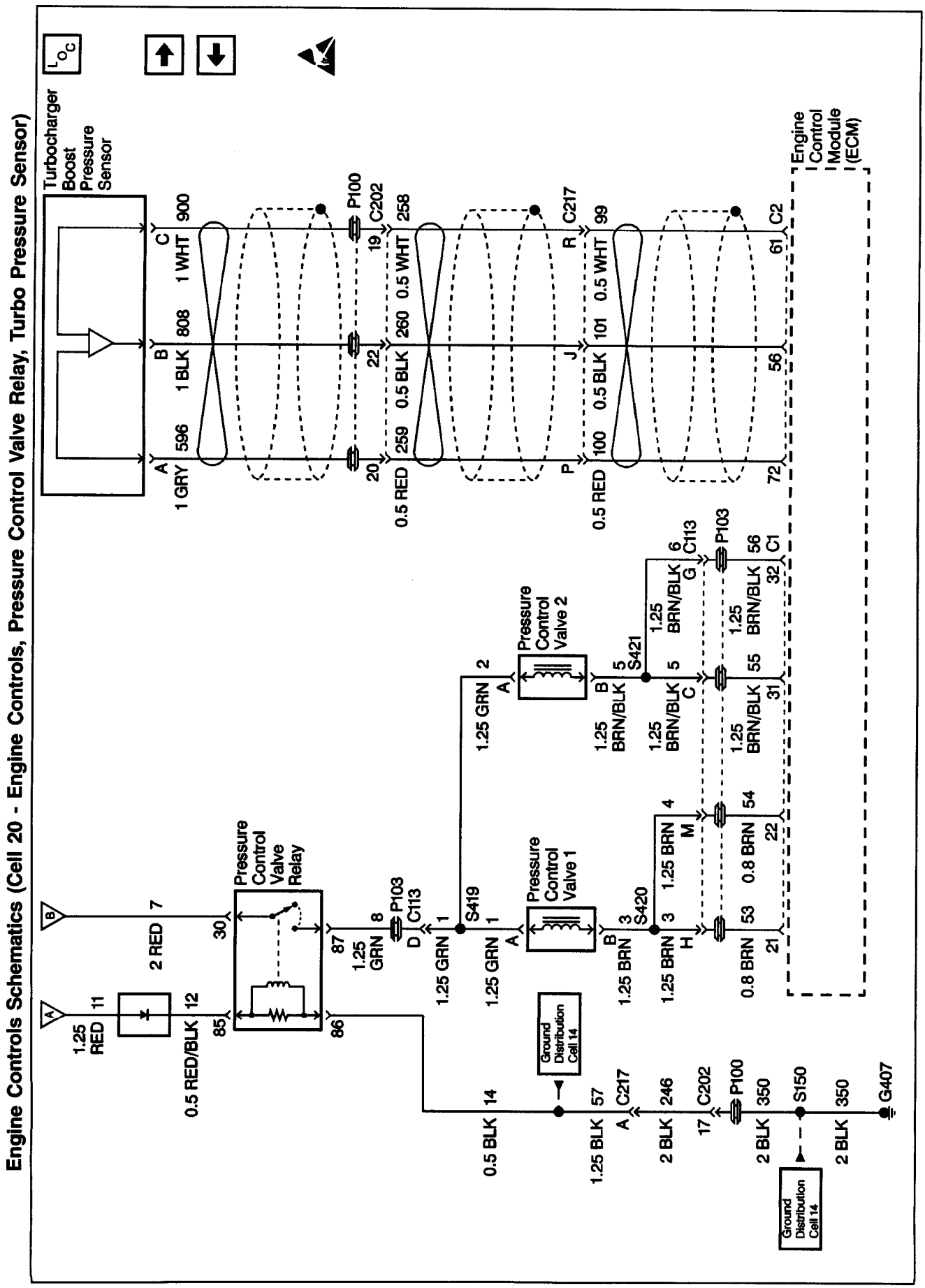

Engine Controls Schematics (Cell 20 - Engine Controls, Power and Ground, DLC, Check Connector)
301648
Hot In RUN And START
Hot At All Times
Circuit Breaker 3 15 A
Circuit Breaker 10 15 A
IP Fuse Block
Ignition Main Relay
Engine Control Module (ECM)
Electronic Brake Control Module, ABS Hydraulic
Electronic Brake Control Module, Air ABS
Data Link Connector (DLC)
Splice Pack 5
Ground Distribution Cell 14
Diagnosis Switch
Memory Clear Switch
Engine Shut Down
Check Connector
1 TAN/WHT 799
2 BLK/WHT 351
0.5 RED 24
1.25 RED 240
2 RED 242
1.25 RED/WHT 101
1.25 RED/WHT 91
0.5 YEL 118
0.5 YEL 109
0.5 BLK 13
1.25 RED/WHT 87
0.5 PNK 30
0.5 WHT 30
0.5 RED/BLK 21
0.5 BLK 23
0.5 BLK 31
0.5 BLK 26
0.5 BLK 33
1.25 BLK 59
1.25 BLK 60
0.5 LT GRN/RED 22
1.25 BLK 57
1.25 BLK 58
1.25 BLK 61
0.5 BLK 13
1.25 BLK 246
2 BLK 245
2 BLK 15
2 BLK 17
2 BLK S150
2 BLK 350
0.8 BLK 350
1.25 LT GRN 409
1.25 LT GRN 280
1.25 BLK 280
1.25 BLK 265
1.25 BLU 264
0.5 WHT/RED 28
0.5 WHT 29
1.25 BLU 410
1.25 BLU 409
0.8 BRN/WHT 396
0.8 BLK/WHT 413
1 LT GRN 1922
1 DK BLU 1921
1.25 LT GRN 409
1.25 LT GRN 280
1.25 BLK 280
1.25 BLK 265
1.25 BLU 410
1.25 BLU 409
0.8 BRN/WHT 396
0.8 BLK/WHT 413
1 LT GRN 1922
1 DK BLU 1921

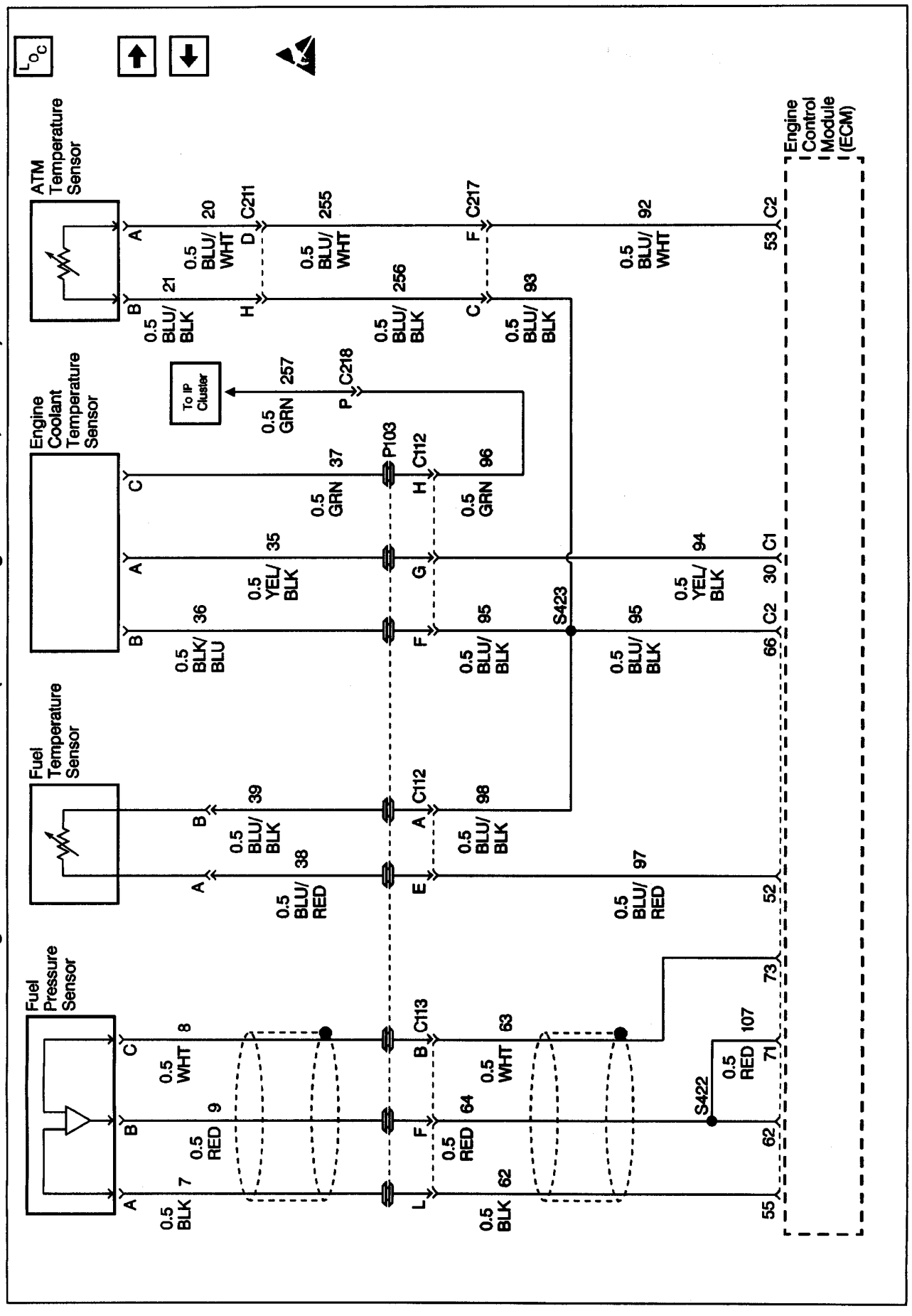

Engine Controls Schematics (Cell 20 - Engine Controls, MIL Lamp, Glow Plugs)
301651
Batteries
62 BLK
Fuse Link
Starter Solenoid
IP Fuse Block
Circuit Breaker 4 15 A
Hot In H (Heat)
Hot In RUN And START
Circuit Breaker 6 15 A
Glow Plug Relay
Control Resister
Glow Plugs
IP Cluster
Service Engine Soon
Ground Distribution Cell 14
Engine Control Module (ECM)
Fuse Block Details Cell 11
8 RED
2 BLK/ RED
0.8 BLK
2 BLK
3 BLK
0.8 BRN/ WHT
0.5 BRN/ WHT
1.25 BRN
0.5 BRN/WHT
2 BRN
RED/ BLK
C417
P100
C205
C207
C118
C200
C212
C217
S227
S279
S280
S243
S260
S269
S324
S325
S326
S327
S328
G105
F2

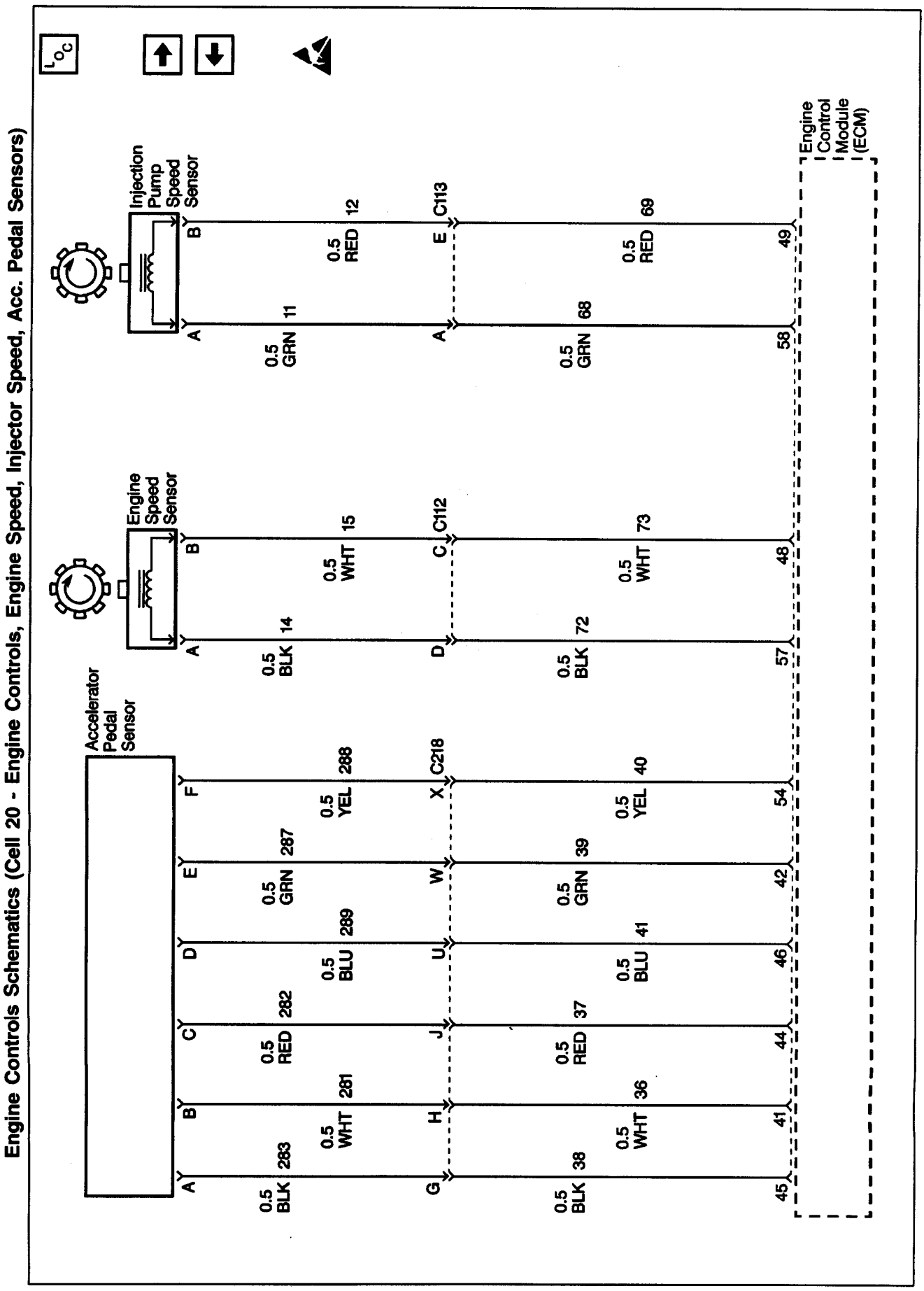

Engine Controls Schematics (Cell 20 - Engine Controls, Fuel Tank Sensor — Diesel Dual Tank)
301653
Hot In Run
IP Fuse Block
CIRCUIT BREAKER #9 20 A
LH Fuel Tank Sender (Primary)
Full 90Ω Empty 0Ω
Fuel Sender And Transfer Pump Control Module
Averaging Circuit
Control Logic
Relay Drive
RH Fuel Tank Sender
Full 90Ω Empty 0Ω
Fuel Meter
Instrument Cluster Cell 81
IP Cluster
Fuel Transfer Pump
Fuel Transfer Pump Relay
Fuse Block Details Cell 11
S286
S287
S295
S417
S415
G408
P100
C200
C212
C402
C404
C410
C3
0.8 BLK 350
1 BLK 350
0.8 DK BLU 1936
0.8 PPL
0.8 LT BLU 1937
0.8 LT GRN 497
1 PNK 139
2 PNK 145
1 GRY 120
1 BLK 350

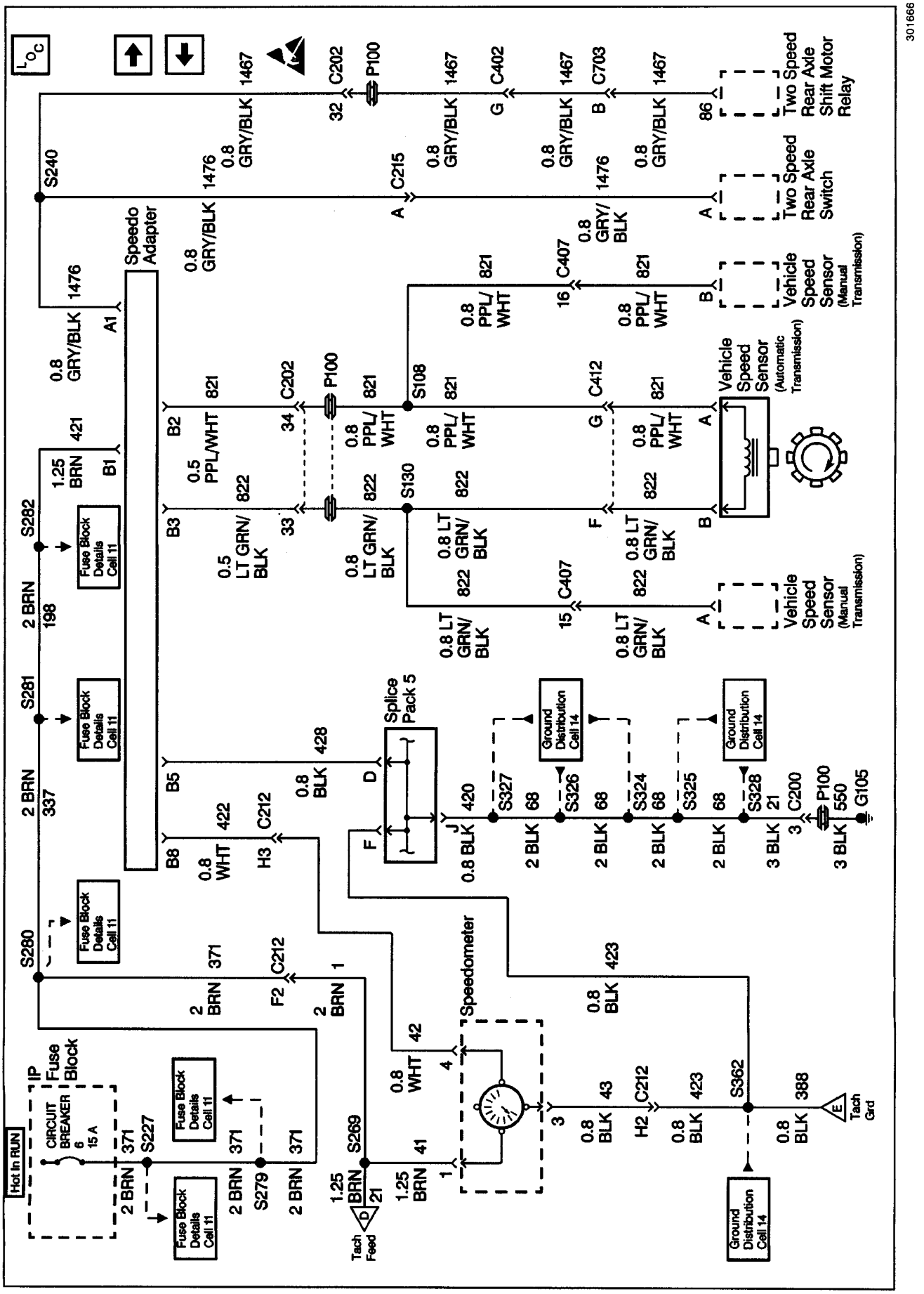

Engine Controls Schematics (Cell 20 - Engine Controls, Cylinder 1,3,5 Fuel Injectors)
301656
Engine Control Module (ECM)
C2
P103
C114
C122
C123
Cylinder 1 Injector
Cylinder 3 Injector
Cylinder 5 Injector
1.25 RED/YEL
1.25 GRN
1.25 GRN/WHT
1.25 GRN/RED


Engine Controls Schematics (Cell 20 - Engine Controls, Cylinder 2,4,6 Fuel Injectors)
301657
Engine Control Module (ECM)
C2
P103
C114
C123
C122
Cylinder 4 Injector
Cylinder 2 Injector
Cylinder 6 Injector
1.25 BLU/RED
1.25 BLU/WHT
1.25 BLU
1.25 RED/YEL

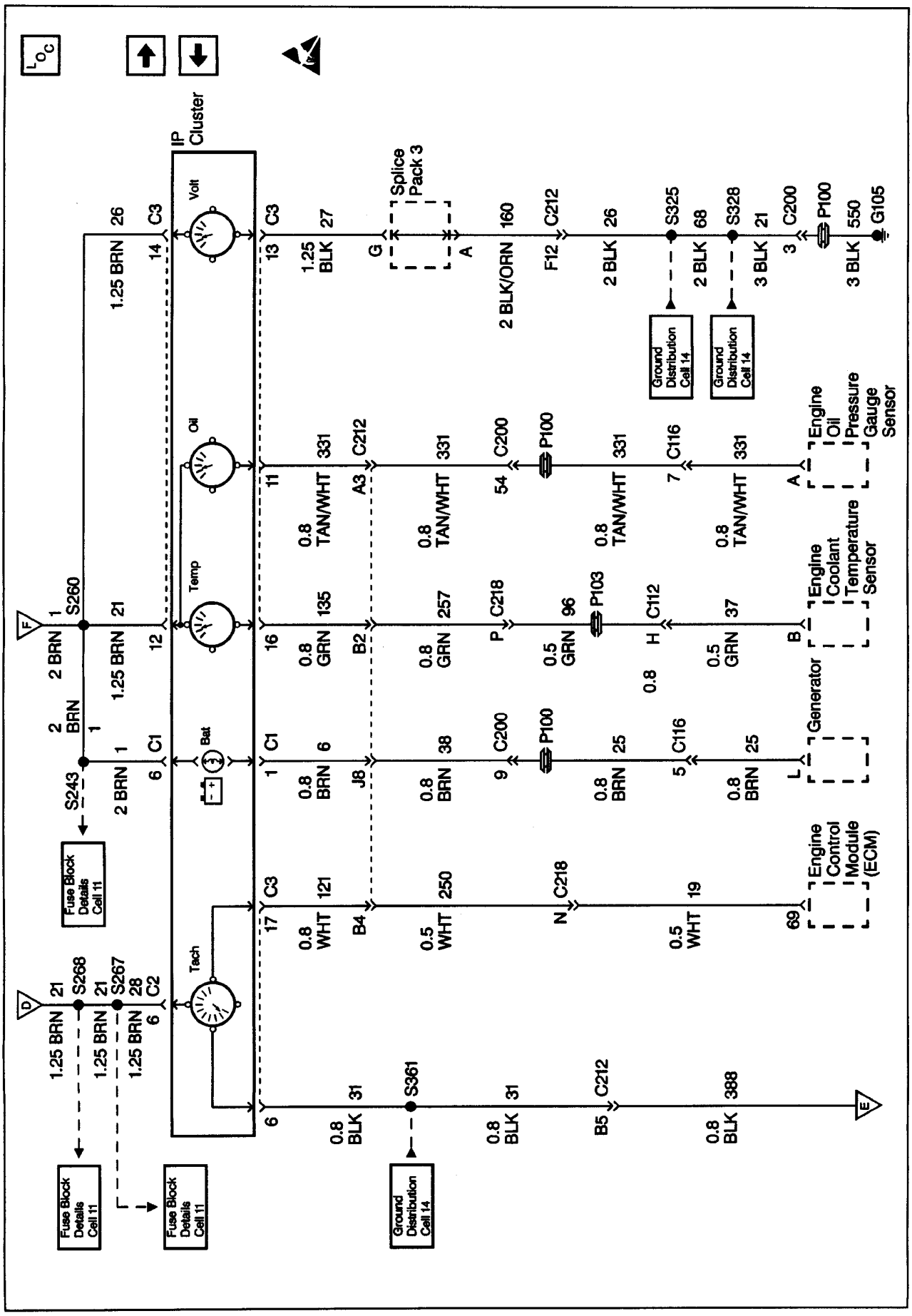

Engine Controls Schematics (Cell 20 - Engine Controls, Pressure Control Valve Relay, Turbo Pressure Sensor)
301660
Turbocharger Boost Pressure Sensor
Engine Control Module (ECM)
Pressure Control Valve Relay
Pressure Control Valve 1
Pressure Control Valve 2
Ground Distribution Cell 14
Ground Distribution Cell 14
1.25 RED
2 RED
0.5 RED/BLK
1 GRY
1 BLK
1 WHT
0.5 RED
0.5 BLK
0.5 WHT
0.5 RED
0.5 BLK
0.5 WHT
1.25 GRN
1.25 GRN
1.25 GRN
1.25 BRN
1.25 BRN
0.8 BRN
0.8 BRN
1.25 BRN/BLK
1.25 BRN/BLK
1.25 BRN/BLK
1.25 BRN/BLK
0.5 BLK
1.25 BLK
2 BLK
2 BLK
2 BLK
P100
P103
P103
S419
S420
S421
S150
G407
C202
C217
C217
C2
C1
C113
C113

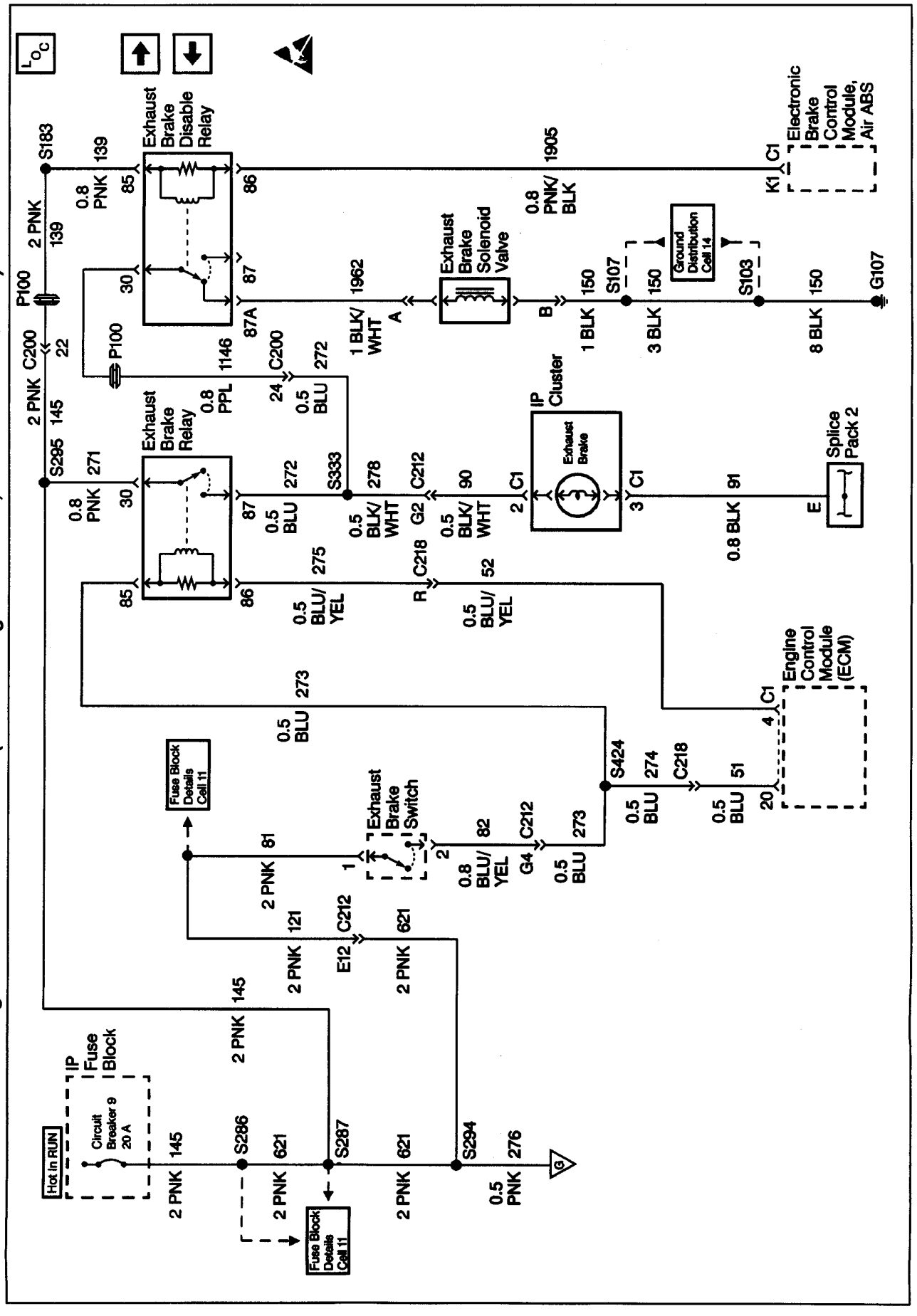

Engine Controls Schematics (Cell 20 - Engine Controls, Sensors)
301663
ATM Temperature Sensor
Engine Coolant Temperature Sensor
Fuel Temperature Sensor
Fuel Pressure Sensor
To IP Cluster
Engine Control Module (ECM)
C211
C217
C218
P103
C112
C113
S423
S422
C1
C2


Engine Controls Schematics (Cell 20 - Engine Controls, Engine Speed, Injector Speed, Acc. Pedal Sensors)
301665
Injection Pump Speed Sensor
Engine Speed Sensor
Accelerator Pedal Sensor
Engine Control Module (ECM)
0.5 GRN 11
0.5 RED 12
0.5 RED 69
0.5 GRN 68
0.5 BLK 14
0.5 WHT 15
0.5 WHT 73
0.5 BLK 72
0.5 BLK 283
0.5 WHT 281
0.5 RED 282
0.5 BLU 289
0.5 GRN 287
0.5 YEL 288
0.5 YEL 40
0.5 GRN 39
0.5 BLU 41
0.5 RED 37
0.5 WHT 36
0.5 BLK 38
C113
C112
C218
49
58
48
57
54
42
46
44
41
45

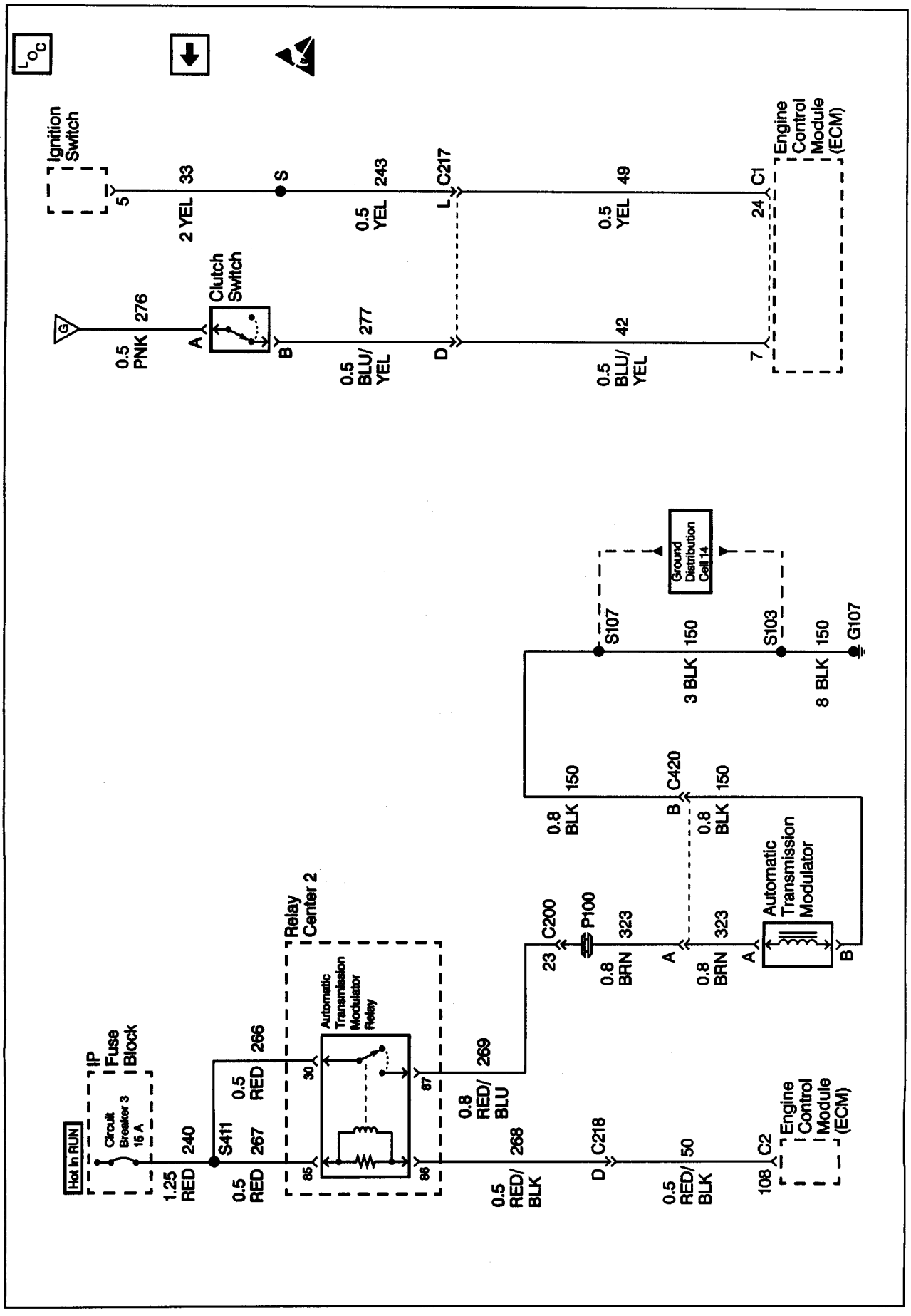

Engine Controls Schematics (Cell 20 - Engine Controls, Speedo Adapter)
301666
Hot In RUN
IP Fuse Block
CIRCUIT BREAKER 6 15 A
Fuse Block Details Cell 11
Speedo Adapter
Speedometer
Splice Pack 5
Ground Distribution Cell 14
Vehicle Speed Sensor (Automatic Transmission)
Vehicle Speed Sensor (Manual Transmission)
Two Speed Rear Axle Switch
Two Speed Rear Axle Shift Motor Relay
Tach Feed
Tach Grd
S240
S280
S281
S282
S227
S279
S269
S130
S108
S326
S324
S325
S327
S328
S362
C202
C212
C215
C402
C407
C412
C703
C200
P100
G105
1998 - MD-Isuzu

Engine Controls Schematics (Cell 20 - Engine Controls, IP Cluster)




Engine Controls Schematics (Cell 20 - Engine Controls, Exhaust Brake Circuit)
301669
Exhaust Brake Disable Relay
Exhaust Brake Relay
Exhaust Brake Solenoid Valve
Exhaust Brake Switch
Electronic Brake Control Module, Air ABS
Engine Control Module (ECM)
IP Cluster
Exhaust Brake
Splice Pack 2
IP Fuse Block
Circuit Breaker 9 20 A
Hot In RUN
Ground Distribution Cell 14
Fuse Block Details Cell 11
Fuse Block Details Cell 11
S183
P100
C200
S295
S333
S424
S286
S287
S294
S107
S103
G107
C212
C218
E12
G4
G2
K1
C1
1905
1962
1146
272
278
273
274
275
276
1 BLK/WHT
0.8 PNK/BLK
0.8 PNK
0.8 PPL
0.5 BLU
0.5 BLK/WHT
0.5 BLU/YEL
0.8 BLU/YEL
0.8 BLK
1 BLK
3 BLK
8 BLK
2 PNK
0.5 PNK
1998 - MD-Isuzu

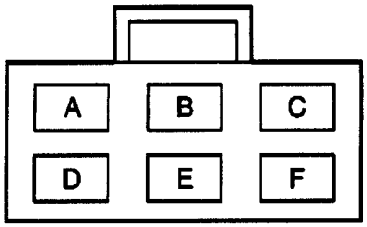
Engine Controls Schematics (Cell 20 - Engine Controls, Automatic Transmission Modulator, Clutch Switch)



Component Locator

Engine Controls Connector End Views

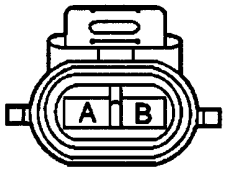
Accel Sensor



237082

Connector Part Information		• 6 Way • Female	
Pin	Wire Color	Circuit No.	Function
A	BLK	283	ECM Pin-45
B	WHT	281	ECM Pin-41
C	RED	282	ECM Pin-44
D	BLU	289	ECM Pin-46
E	GRN	287	ECM Pin-42
F	YEL	288	ECM Pin-54

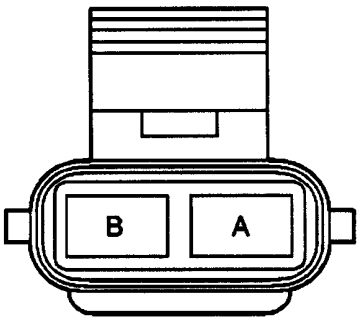
ATM Temp Sensor



236598

Connector Part Information		• 2 Way F • (GRY)	
Pin	Wire Color	Circuit No.	Function
A	BLU/WHT	20	ECM Pin 53
B	BLU/BLK	21	ECM Pin 66

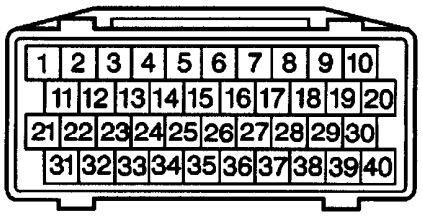
Automatic Transmission Modulator



68721

Connector Part Information		• 15300027 • 2 Way F Metri-Pack 280 Series, Sealed (BLK)	
Pin	Wire Color	Circuit No.	Function
A	BRN	323	Shift Solenoid Feed
B	BLK	150	Ground

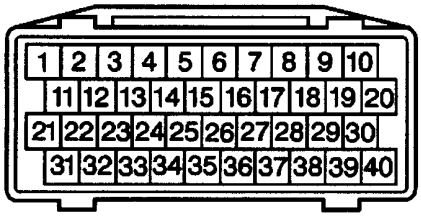
Engine Control Module C1



339162

Connector Part Information		• 40 Way • Female	
Pin	Wire Color	Circuit No.	Function
1–3	—	—	Not Used
4	BLU/YEL	52	Exhaust Brake Relay
5–6	—	—	Not Used
7	BLU/YEL	42	Clutch Switch
8–9	—	—	Not Used
10	PNK/GRN	34	Fast Idle-Up
11–12	—	—	Not Used
13	RED	9	Fuse Output-Ignition
14–18	—	—	Not Used
19	PNK	23	Ground
20	BLU	51	Exhaust Brake Relay
21	BRN	53	Pressure Control Valve 1

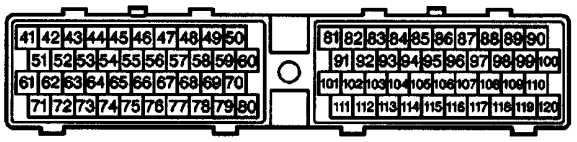
Engine Control Module C1 (cont'd)



339162

Connector Part Information		• 40 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
22	BRN	54	Pressure Control Valve 1
23	RED	10	Fuse Output-Ignition
24	YEL	49	Ignition Switch
25	LT GRN/RED	22	Ground
26	RED	27	Fuse Output-Ignition
27	RED/BLK	21	Ground
28	—	—	Not Used
29	PNK/BLK	35	Fast Idle-Down
30	YEL/BLK	94	Engine Coolant Temperature Sensor
31	BRN/BLK	55	Pressure Control Valve 2
32	BRN/BLK	56	Pressure Control Valve 2
33–38	—	—	Not Used
39	LT BLU	20	Multifunction Alarm Module
40	—	—	Not Used

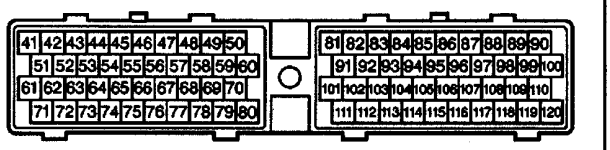
Electronic Control Module C2



339160

Connector Part Information		• 80 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
41	WHT	36	Accelerator Pedal Sensor
42	GRN	39	Accelerator Pedal Sensor
43	—	—	Not Used
44	RED	37	Accelerator Pedal Sensor
45	BLK	38	Accelerator Pedal Sensor
46	BLU	41	Accelerator Pedal Sensor
47	—	—	Not Used
48	WHT	73	Engine Speed Sensor
49	RED	69	Injection Pump Speed Sensor
50–51	—	—	Not Used
52	BLU/RED	97	Fuel Temperature Sensor
53	BLU/WHT	92	ATM Temperature Sensor
54	YEL	40	Accelerator Pedal Sensor
55	BLK	106	Fuel Pressure Sensor
56	BLK	108	Turbocharger Boost Pressure Sensor
57	BLK	72	Engine Speed Sensor
58	GRN	68	Injection Pump Speed Sensor
59	—	—	Not Used
60	WHT	30	Check Connector Pin-D
61	WHT	99	Turbocharger Boost Pressure Sensor
62	RED	65	Fuel Pressure Sensor
63–65	—	—	Not Used
66	BLU/BLK	95	Engine Coolant Temperature Sensor
67–68	—	—	Not Used

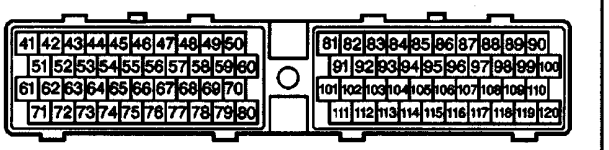
Electronic Control Module C2 (cont'd)



339160

Connector Part Information		• 80 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
69	WHT	19	IP Cluster (Tach.)
70	—	—	Not Used
71	RED	107	Fuel Pressure Sensor
72	RED	100	Turbocharger Boost Pressure Sensor
73	WHT	63	Fuel Pressure Sensor
74–75	—	—	Not Used
76	—	74	Shield
77	—	70	Shield
78–80	—	—	Not Used
81	BLK	57	Ground
82	BLK	58	Ground
83–84	—	—	Not Used
85	BLU/RED	90	Cylinder 4 Injector
86	BLU/WHT	87	Cylinder 2 Injector
87	BLU	85	Cylinder 6 Injector
88	GRN/RED	82	Cylinder 3 Injector
89	GRN/WHT	79	Cylinder 5 Injector
90	GRN	77	Cylinder 1 Injector
91	RED/WHT	2	Ignition Main Relay Contact
92–93	—	—	Not Used
94	BLU/RED	91	Cylinder 4 Injector
95	BLU/WHT	88	Cylinder 2 Injector
96	BLU	86	Cylinder 6 Injector
97	GRN/RED	83	Cylinder 3 Injector
98	GRN/WHT	80	Cylinder 5 Injector

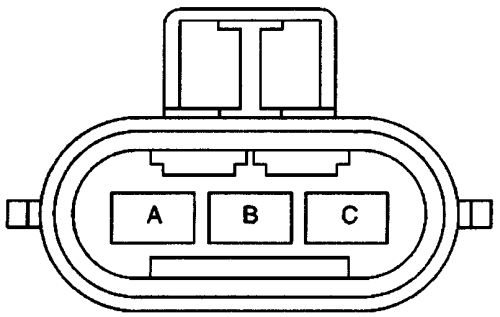
Electronic Control Module C2 (cont'd)



339160

Connector Part Information		• 80 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
99	GRN	78	Cylinder 1 Injector
100	RED/YEL	76	Cylinder 5 Injector and Cylinder 1 Injector
101	RED/WHT	3	Ignition Main Relay Contact
102	BLK	59	Ground
103	RED	4	Fuse Output-Battery
104-105	—	—	Not Used
106	BRN/WHT	16	IP Cluster (Service Engine Soon)
107	—	—	Not Used
108	RED/BLK	50	Automatic Transmission Modulator Relay (Located in Relay Center 2)
109	YEL	6	Ignition Main Relay Coil
110	RED/YEL	81	Cylinder 3 Injector
111	BLK	60	Ground
112	—	—	Not Used
113	WHT/RED	28	Data Link Connector
114	WHT	29	Data Link Connector
115–117	—	—	Not Used
118	YEL	5	Ignition Main Relay Coil
119	REDYEL	84	Cylinder 6 Injector and Cylinder 2 Injector
120	RED/BLU	89	Cylinder 4 Injector

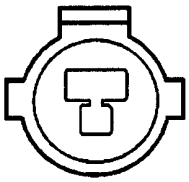
Engine Coolant Temperature Sensor



40389

Connector Part Information		• 3 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	YEL/BLK	35	ECM Pin-30
B	GRN	37	IP Cluster (Temp.)
C	BLU/BLK	36	ECM Pin-66

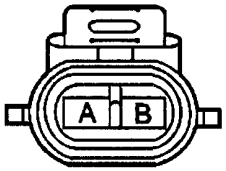
Engine Oil Pressure Gauge Sender (Isuzu)



246685

Connector Part Information		• 1 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BRN/WHT	7	Oil Pressure Switch Signal

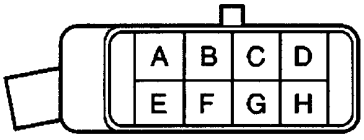
Engine Speed Sensor



236598

Connector Part Information		• 2 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLK	14	ECM Pin-57
B	WHT	15	ECM Pin-48

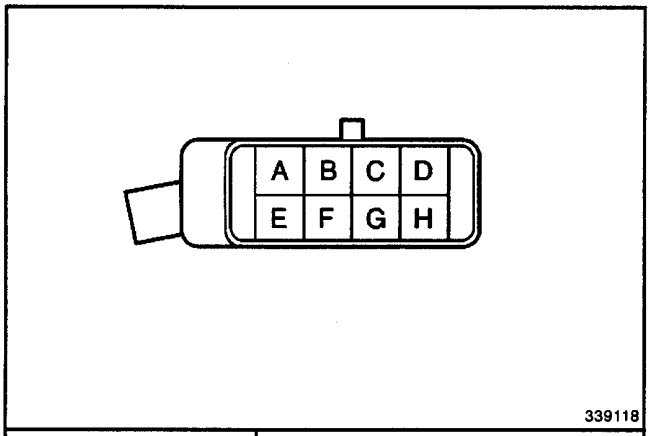
Fuel Injection-to-Engine Assembly (C122)



339118

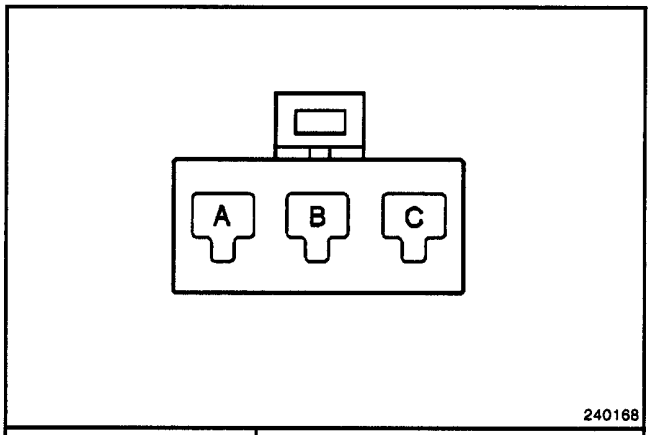
Connector Part Information		8 Way F	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	GRN	19	Cylinder 1 Injector
B	GRN	20	Cylinder 1 Injector
C	RED/YEL	17	Cylinder 1 Injector
D	RED/YEL	23	Cylinder 3 Injector
E	BLU	24	Cylinder 3 Injector
F	BLU	25	Cylinder 3 Injector
G	GRN/WHT	30	Cylinder 2 Injector
H	GRN/WHT	31	Cylinder 2 Injector

Fuel Injection-to-Engine Assembly (C123)



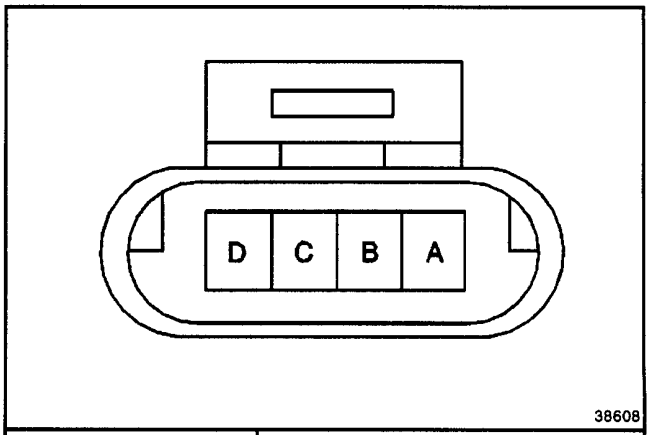
Connector Part Information		8 Way F	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLU/RED	33	Cylinder 4 Injector
B	BLU/RED	34	Cylinder 4 Injector
C	RED/YEL	32	Cylinder 4 Injector
D	RED/YEL	27	Cylinder 6 Injector
E	BLU	28	Cylinder 6 Injector
F	BLU	29	Cylinder 6 Injector
G	GRN/WHT	21	Cylinder 5 Injector
H	GRN/WHT	22	Cylinder 5 Injector

Fuel Pressure Sensor



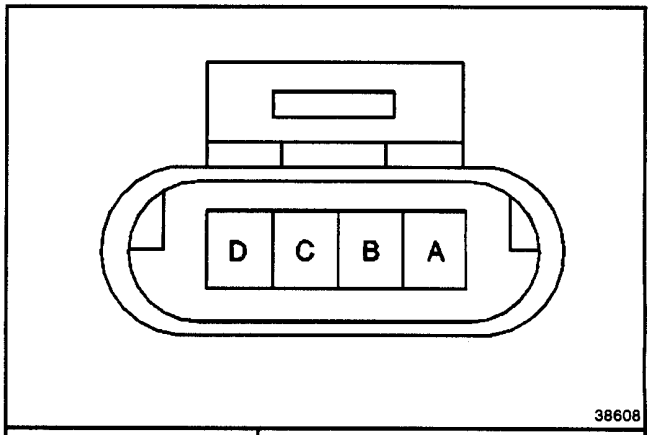
Connector Part Information		• 3 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLK	7	ECM Pin-55
B	RED	9	ECM Pin-62
C	WHT	8	ECM Pin-73

Fuel Sender (Single Fuel Tank)



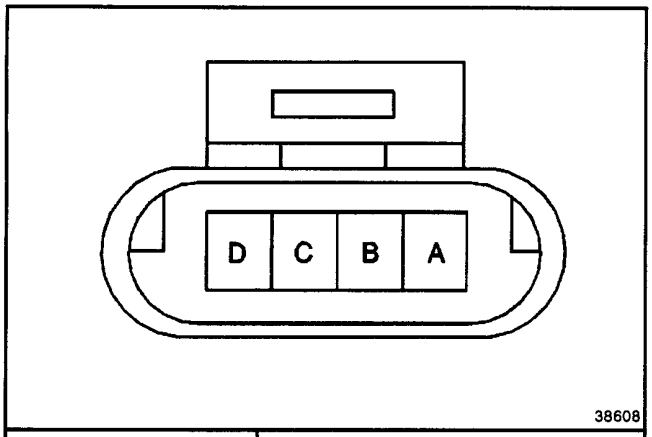
Connector Part Information		• 12162189 • 4 Way F Metri-Pack 150.2 Series Pull To Seat, Sealed (BLK)	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLK	350	Ground
B–C	—	—	Not Used
D	PPL	30	Fuel Gauge Sensor Signal

Fuel Sender (Duel Fuel Tank-Left Hand)



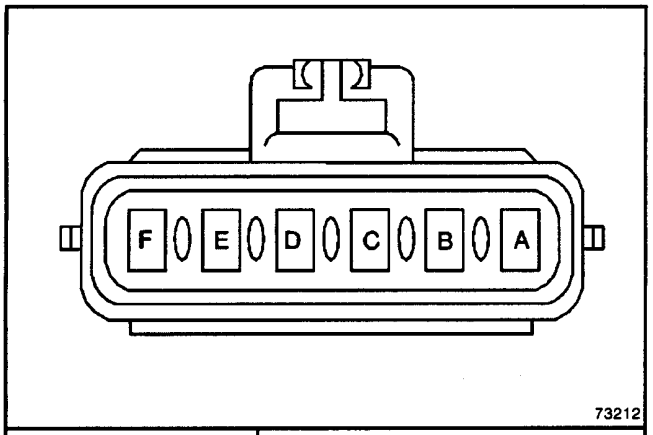
Connector Part Information		• 12162189 • 4 Way F Metri-Pack 150.2 Series Pull To Seat, Sealed (BLK)	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLK	350	Ground
B–C	—	—	Not Used
D	DK BLU	1936	Fuel Gauge Sensor Signal-Left

Fuel Sender (Duel Fuel Tank-Right Hand)



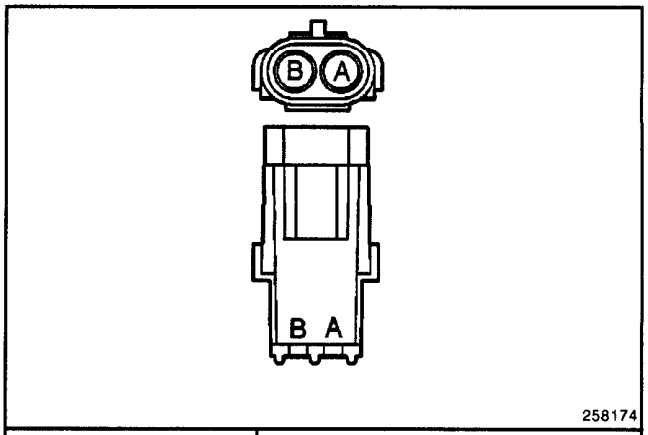
Connector Part Information	• 12162189 • 4 Way F Metri-Pack 150.2 P2S, Sealed (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLK	350	Ground
B–C	—	—	Not Used
D	DK BLU	1937	Fuel Gauge Sensor Signal-Right

Fuel Sender and Transfer Pump Control Module



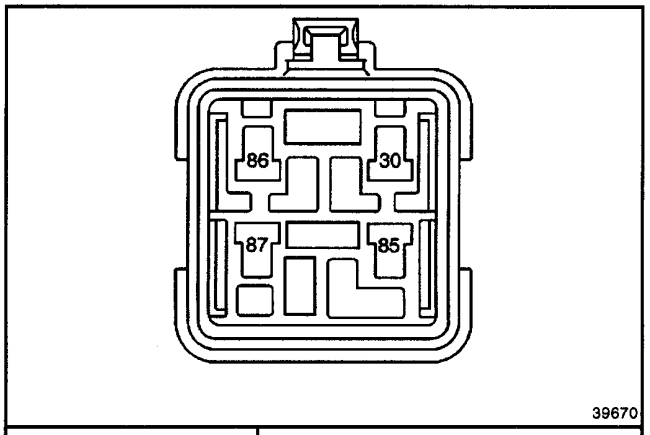
Connector Part Information	• 12059573 • 6 Way F Metri-Pack 280 Series, Sealed (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	PNK	139	Fuse Output-Ignition
B	LT BLU	1937	Fuel Gauge Sensor Signal-Right
C	DK BLU	1936	Fuel Gauge Sensor Signal-Left
D	LT GRN	497	Fuel Pump Relay Output-Coil-Secondary
E	BLK	350	Ground
F	PPL	30	Fuel Gauge Sensor Signal

Fuel Transfer Pump



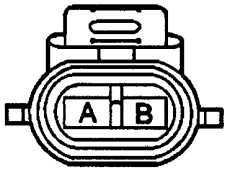
Connector Part Information	• 12010973 • 2 Way M Weather Pack (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLK	350	Ground
B	GRA	120	Fuel Pump,Motor Feed

Fuel Transfer Pump Relay



Connector Part Information	• 12129716 • 4 Way F Metri-Pack 280 Series, Flexlock, Sealed (GRA)		
Pin	**Wire Color**	**Circuit No.**	**Function**
30	PNK	139	Fuse Output-Ignition
85	PNK	139	Fuse Output-Ignition
86	LT GRN	497	Fuel Pump Relay Output-Coil-Secondary
87	GRA	120	Fuel Pump Motor Feed

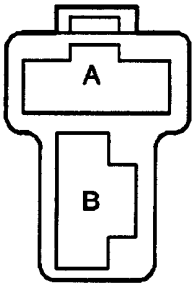
Fuel Temperature Sensor



236598

Connector Part Information		• 2Way • Female	
Pin	Wire Color	Circuit No.	Function
A	BLU/RED	38	ECM Pin-52
B	BLU/BLK	39	ECM Pin-66

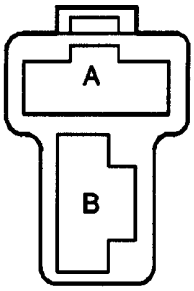
Glow Plug Relay C1



236009

Connector Part Information		• 2 Way • Female	
Pin	Wire Color	Circuit No.	Function
A	RED	50	Fuse Output-Battery
B	RED/BLK	45	Control Resistor

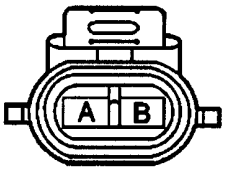
Glow Plug Relay C2



236009

Connector Part Information		• 2 Way • Female	
Pin	Wire Color	Circuit No.	Function
A	BLK	49	Ground
B	BLK/RED	48	Fuse Output-Ignition (Hot in Heat Switch Position)

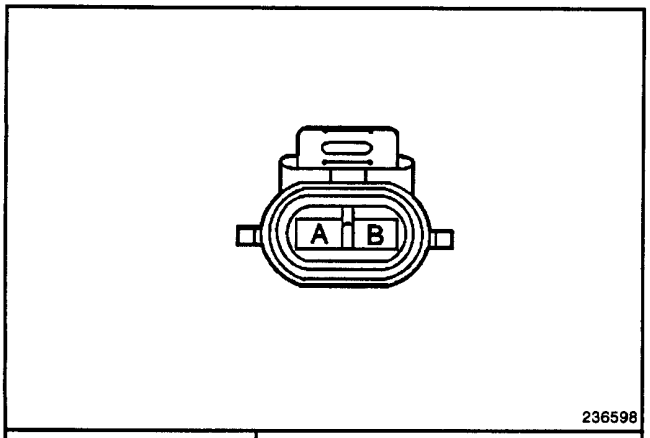
Injection Pump Speed Sensor



236598

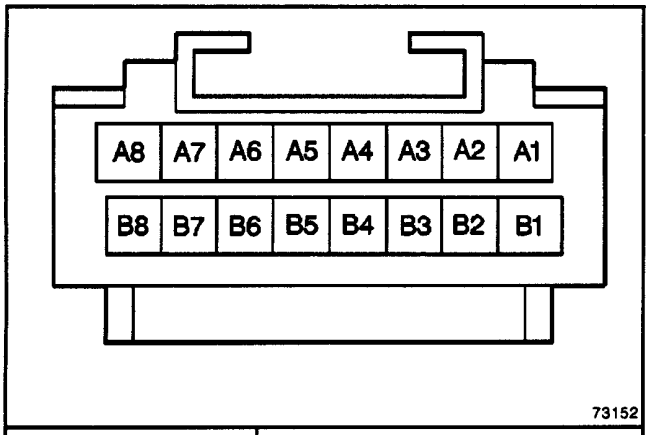
Connector Part Information		• 2 Way • Female	
Pin	Wire Color	Circuit No.	Function
A	GRN	11	ECM Pin-58
B	RED	12	ECM Pin-49

Low Coolant Level Indicator Switch



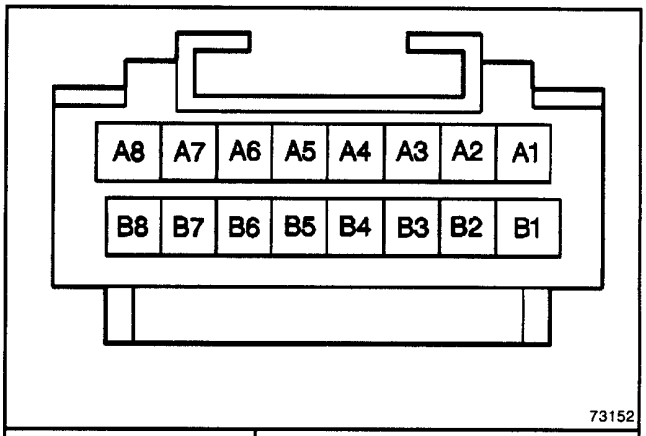
Connector Part Information	• 12052641 • ASM 2F M/P 150 (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	LT GRN	1478	Low Coolant Sensor Signal
B	BLK	150	Ground

Multifunction Alarm Module (MFAM) (Air Brakes)



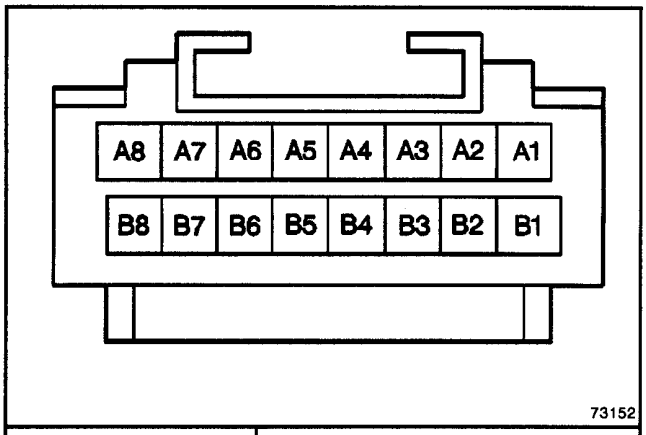
Connector Part Information	• 12084944 • ASM 16F MIC/P 100 (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A1–A4	—	—	Not Used
A5	PNK	611	Fused Output Ignition
A6	—	—	Not Used
A7	BRN/BLK	610	Low Oil Pressure Switch
A8	BLK	605	Ground
B1	LT GRN	601	Low Coolant Probe
B2	YEL/RED	603	Low Coolant Indicator Lamp
B3–B4	—	—	Not used
B5	BRN/WHT	602	Low Air Switch
B6	BLU/YEL	607	Check Gauges Indicator Lamp

Multifunction Alarm Module (MFAM) (Air Brakes) (cont'd)



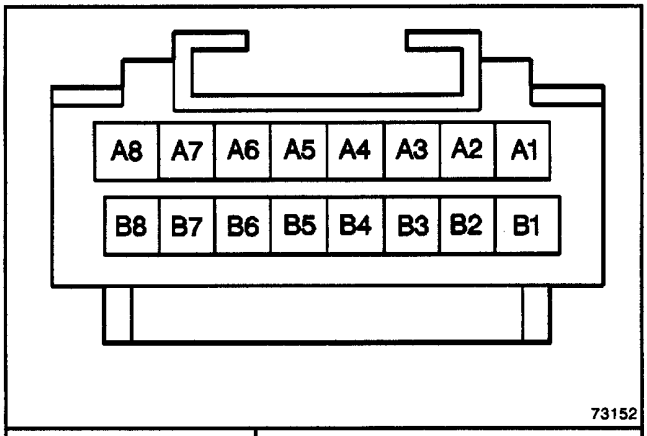
Connector Part Information	• 12084944 • ASM 16F MIC/P 100 (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
B7	BRN	609	Coolant Temperature Switch
B8	—	—	Not Used

Multifunction Alarm Module (MFAM) (Hydraulic)



Connector Part Information	• 12084944 • ASM 16F MIC/P 100 (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A1	LT BLU	475	Brake (Hydraulic)
A2	YEL	468	M.F.A.M. Pin-A2
A3	WHT	478	Stoplamp Switch Input
A4	ORN/BLK	487	Starter Input
A5	PNK	480	Fused Output Ignition
A6	BRN/WHT	482	Primary Brake Indicator Lamp Output
A7	BRN/BLK	466	Low Oil Pressure Switch
A8	BLK	485	Ground Buss
B1	LT GRN	481	Low Coolant Probe

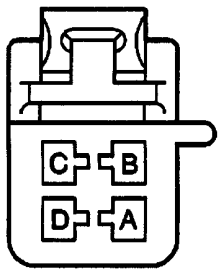
Multifunction Alarm Module (MFAM) (Hydraulic) (cont'd)



73152

Connector Part Information	• 12084944 • ASM 16F MIC/P 100 (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
B2	YEL/RED	483	Low Coolant Indicator Lamp
B3	YEL/BLK	484	Auxiliary Brake Indicator Lamp
B4	WHT	477	Stoplamp Switch Input
B5	—	—	Not Used
B6	BLU/YEL	488	Check Gauges Indicator Lamp
B7	BRN	465	Coolant Temperature Switch
B8	ORN/BLUL	476	Fuse Output Battery

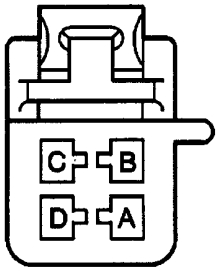
Multifunction Alarm Module (MFAM) C2 w/ Auto Engine Shutdown



280782

Connector Part Information	• 12064760 • 4 Way F Metri-Pack 150 Series (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	LT BLU	252	Engine Stop
B–C	—	—	Not Used

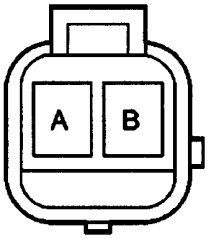
Multifunction Alarm Module (MFAM) C2 w/ Auto Engine Shutdown (cont'd)



280782

Connector Part Information	• 12064760 • 4 Way F Metri-Pack 150 Series (BLK)		
Pin	**Wire Color**	**Circuit No.**	**Function**
D	GRN	65	Engine Coolant Temperature Switch (Engine Shutdown)

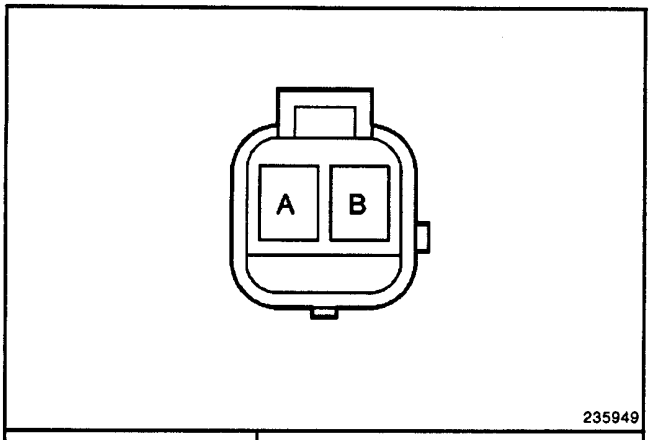
Pressure Control Valve 1



235949

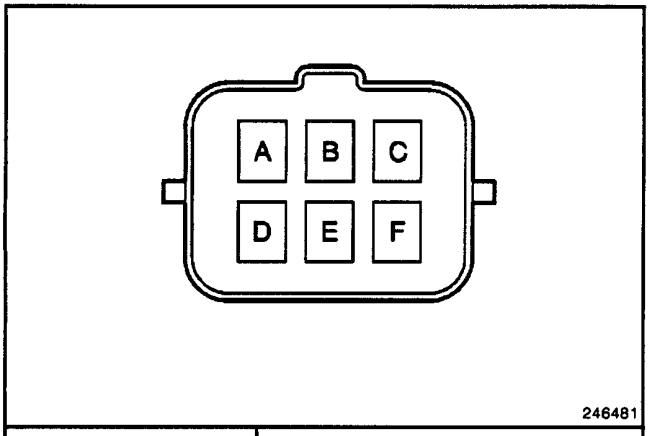
Connector Part Information	• 2 Way • Female		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	GRN	1	Pressure Control Valve Relay
B	BRN	3	ECM Pin-21

Pressure Control Valve 2



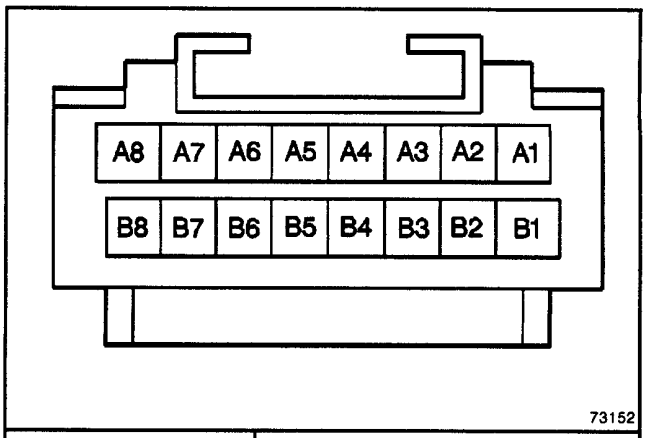
Connector Part Information	• 2 Way • Female		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	GRN	2	Pressure Control Valve Relay
B	BRN/BLK	5	ECM Pin-31

Pre-Stroke Actuator and Pressure Sensor



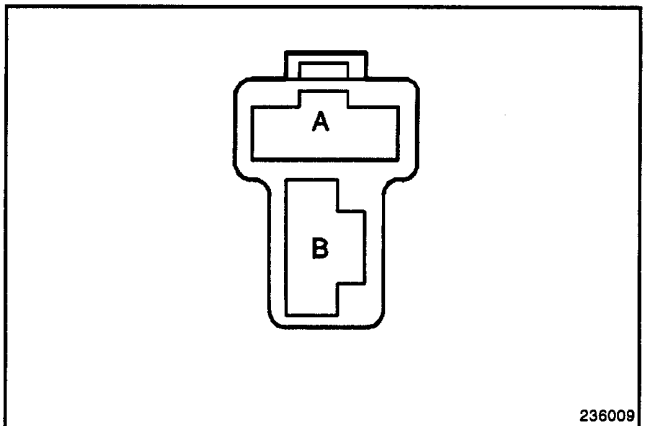
Connector Part Information	6 Way (GRA)		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	BLK	267	Ground
B	BLK	261	TICS Module ( )
C	RED/BLK	260	TICS Module (+)
D	WHT	266	TICs Module (OSC)
E	GRY	292	(Shield)
F	BLK	270	TICS Module (MID)

Speedo Adaptor



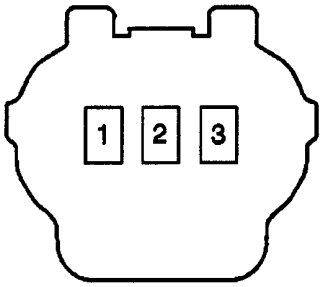
Connector Part Information	• 16 Way • Female		
Pin	**Wire Color**	**Circuit No.**	**Function**
A1	GRA/BLK	418	Two Speed Rear Axle Switch and Two Speed Rear Axle Shift Motor Relay
A2–A8	—	—	Not Used
B1	BRN	421	Fuse Output-Ignition
B2	PPL/WHT	425	Vehicle Speed Sensor
B2	PPL/WHT	432	Vehicle Speed Sensor
B3	LT GRN/BLK	426	Vehicle Speed Sensor
B3	LT GRN/BLK	431	Vehicle Speed Sensor
B4	—	—	Not Used
B5	BLK	428	Splice Pack 5
B6–B7	—	—	Not Used
B8	WHT	422	Speedometer

Stop Lamp Switch (Hydraulic)



Connector Part Information	• 2 Way • Female		
Pin	**Wire Color**	**Circuit No.**	**Function**
A	WHT	471	Stop Lamp Switch
B	GRN/WHT	470	Stop Lamp Switch

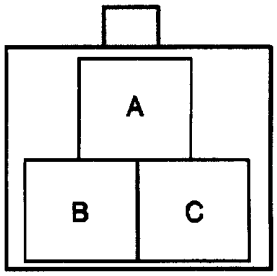
Turbo Boost Pressure Sensor



339127

Connector Part Information		• 12186893 • 3 Way F	
Pin	**Wire Color**	**Circuit No.**	**Function**
1	GRA	596	Reference Voltage Feed-5 volt Reference
2	BLK	808	Sensor Return
3	WHT	900	Turbo Boost Pressure Signal

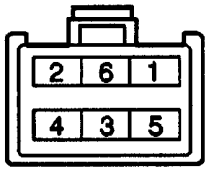
Two Speed Rear Axle Switch (Manual)



339122

Connector Part Information		• 3 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	GRA/BLK	21	Two Speed Rear Axle Input
B	BLK	22	Two Speed Rear Axle Input
C	—	—	Not Used

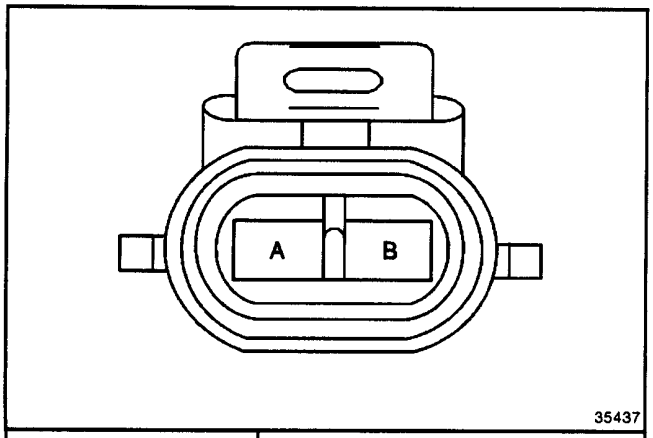
Two Speed Axle Switch (Auto)



237080

Connector Part Information		• 6 Way • Female	
Pin	**Wire Color**	**Circuit No.**	**Function**
1	BLK	152	Two Speed Axle Switch
2	GRA/BLK	151	Two Speed Axle Switch
3	—	—	Not Used
4	BLK/RED	154	Rheostatt
5	BRN	153	Ilumination
6	—	—	Not Used

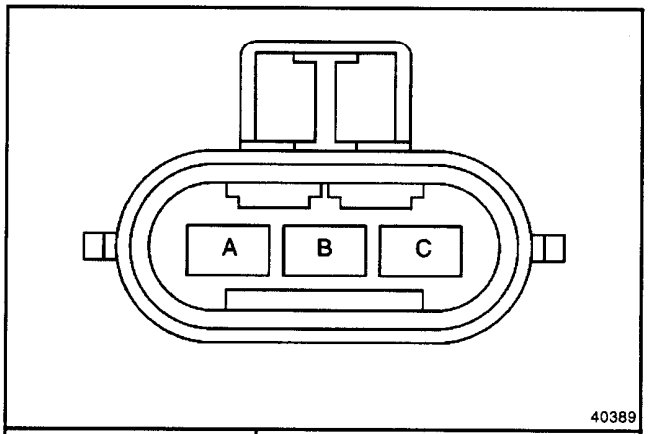
Vehicle Speed Sensor (Automatic)



35437

Connector Part Information		• 12052644 • 2 Way F Metri-Pack 150 Series (GRA)	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	PPL/WHT	821	Vehicle Speed Sensor Signal
B	LT GRN/BLK	822	Vehicle Speed Sensor Return

Vehicle Speed Sensor (Manual)



40389

Connector Part Information		• 3 Way F • (GRN)	
Pin	**Wire Color**	**Circuit No.**	**Function**
A	LT GRN/BLK	24	Vehicle Speed Sensor Signal
B	PPL/WHT	25	Vehicle Speed Sensor Return
C	PNK	26	Fuse Output-Ignition

BLANK

Engine Exhaust

Specifications

Fastener Tightening Specifications

Application	Specification	
	Metric	English
Exhaust Clamp Nut	24 N·m	18 lb ft
Exhaust Hanger Nut	24 N·m	18 lb ft
Front Exhaust Pipe Nut	29 N·m	21 lb ft
Wide Band Clamp	10 N·m	89 lb in

Diagnostic Information and Procedures

Vibration or Rattling

Problem	Action
The components are loose.	1. Tighten the connections. 2. Inspect the following components for damage: • The hangers • The mounting brackets • The clamps
The components are misaligned.	1. Align the components. 2. Inspect the following components for damage: • The hangers • The mounting brackets • The clamps

Restricted Exhaust

Problem	Action
The exhaust tubing is kinked.	Repair or replace the damaged tubing.
The muffler is restricted.	1. Remove the muffler. 2. Inspect the muffler for a restriction. 3. Replace the muffler if the condition of the muffler is doubtful. Refer to *Muffler Replacement.*
The tail pipe is obstructed.	1. Remove the obstruction. 2. If the end of the tail pipe is crimped, straighten the outlet. Refer to *Tail Pipe Replacement.*
The inner layer of the double layer pipe is separating.	Replace the pipe. Refer to *Exhaust Pipe Replacement (Front)* and *Exhaust Pipe Replacement (Rear).*

Exhaust Noise

Problem	Action
The exhaust components leak.	Tighten the clamps or the couplings.
The components are improperly installed or misaligned.	• Align the components. • Tighten the connections.
The following conditions are present in the tubing or the muffler: • Ruptures • Burn-outs	Replace the damaged components. Refer to *Muffler Replacement.*
Flaws are present in the following components: • The clamps • The pipes • The muffler	Replace the components. Refer to *Exhaust Pipe Replacement (Front), Exhaust Pipe Replacement (Rear)* or *Muffler Replacement.*
Some of the exhaust system components are missing.	Install the missing components.

Exhaust Brake (Continuously On)

Problem	Action
The clutch pedal or the accelerator pedal switches are maladjusted.	Adjust the switches. Refer to Accelerator Pedal Switch and Clutch Pedal Switch.
The switches are improperly wired.	• Inspect the wiring. • Repair the wiring as needed.
A short is present in the wiring harness.	Repair the wiring.

Exhaust Brake (Engine Overheats/Loses Power)

Problem	Action
The exhaust manifold valve is stuck partially closed.	Loosen and lubricate the exhaust manifold valve or replace the exhaust manifold valve.
The exhaust manifold valve is adjusted so that it is partially closed.	Adjust the exhaust manifold valve.

Exhaust Brake (Does Not Operate)

Problem	Action
A fuse is blown.	Replace the fuse.
The accelerator pedal or the clutch pedal switches are improperly adjusted or faulty.	Adjust or replace the clutch pedal switch or the accelerator pedal switch. Refer to Clutch Pedal Switch or Accelerator Pedal Switch.
The following conditions exist at the switches or the control valves: • Poor connections • Corroded terminals	Clean or replace the switches or the control valves. Refer to Control Valves.
The air lines exhibit any of the following conditions: • Kinks • Restrictions • Ice	Repair the lines. In freezing weather, ensure that the air tanks are drained.
The relay crank is seized.	Repair the relay crank.

Exhaust Brake (Does Not Operate) (cont'd)

Problem	Action
The relay rod is broken or missing.	Repair or replace the relay rod.
The air cylinder or the control valve is jammed with ice.	Melt the ice. In freezing weather, ensure that the air tanks are drained.
The control valve is faulty. (The valve should open when 12 volts is applied.)	Replace the control valve. Refer to Control Valve.
The air cylinder is faulty.	Replace the air cylinder.
A broken wire is present in the harness.	Repair the wire.

Exhaust Brake (Slow To Operate)

Problem	Action
The exhaust manifold valve or the relay crank is tight.	1. Loosen the exhaust manifold valve or the relay crank. 2. Lubricate the exhaust manifold valve or the relay crank.
The accelerator pedal or clutch pedal switches are improperly adjusted.	Adjust the accelerator pedal switch or the clutch pedal switch.

Exhaust Brake (Weak Braking Action)

Problem	Action
The exhaust manifold valve is improperly adjusted or tight.	1. Loosen and/or adjust the exhaust manifold valve. 2. Lubricate the exhaust manifold valve, as necessary.
The relay crank is tight.	1. Loosen the relay crank. 2. Lubricate the relay crank.
The air lines are kinked or partially plugged with ice.	Repair the air lines. In freezing weather, ensure that the air tanks are drained.
The fittings at the air lines leak.	Tighten the fittings.
Leaking air cylinder	Replace the air cylinder.

Exhaust Brake (Will Not Turn Off)

Problem	Action
The relay crank or exhaust manifold valve is seized.	1. Loosen the relay crank or the exhaust manifold valve. 2. Lubricate the relay crank or the exhaust manifold valve.
The control valve or the air cylinder is jammed with ice.	1. Melt the ice. 2. Drain the lines. In freezing weather, ensure that the air tanks are drained.
A short is present in the wiring harness. (The wiring harness has 12 volts at the control solenoid in every control switch position.)	Repair the wiring.
The control switch is faulty.	Replace the control switch.

Repair Instructions

Exhaust System Replacement

Inspection Procedure

Inspect the exhaust pipes, the catalytic converter (if equipped), the muffler, and the tailpipe for the following conditions:

- Cracked joints
- Broken welds
- Corrosion damage

  These conditions may result in a leaking exhaust system.

Inspect the clamps, the brackets, and the insulators for the following conditions:

- Cracks
- Stripped bolt threads
- Corroded bolt threads

Verify that the exhaust system (including the heat shield) does not exhibit the following conditions:

- Leaks
- Binding
- Grounding
- Excessive vibration

The above conditions may occur if any of the following components are loose or damaged:

- The flange bolts
- The heat shields
- The brackets
- The pipes

Inspect the exhaust system components and the alignment if any of these conditions exist. Align and replace the components as necessary.

Exhaust Components Removal

Caution: Always wear protective goggles and gloves when removing exhaust parts as falling rust and sharp edges from worn exhaust components could result in serious personal injury.

An accumulation of dirt and corrosion can make the removal of the exhaust components difficult. Use a penetrating oil on the threads in order to assist in removing the exhaust components.

Exhaust Components Installation

Important: Replace the exhaust system parts with original equipment manufacturer (OEM) standard components. This action ensures that the vehicle operates as designed.

Important:

- Replace the tailpipe when the muffler is replaced.
- Use new packings and nuts when installing the exhaust pipe to the engine manifold.

  Clean the engine manifold stud threads with a wire brush before installing the new nuts.

Ensure that the components are correctly aligned when installing a new exhaust pipe or a new muffler or tailpipe. Incorrectly aligned components may cause rattles and noise vibrations in the exhaust.

Use the following steps when aligning the exhaust system:

1. Leave all of the bolts and the nuts loose.
2. Properly align all of the components.
3. Tighten the bolts and the nut, working from the front to the rear.

Replace the following components, if the components are damaged, in order to maintain the exhaust system alignment:

- The exhaust system hangers
- The hanger brackets
- The clamps

Exhaust Clamps Replacement (Wide Band Clamp)

1. Inspect all of the components for the following damage. Replace the damaged components as necessary:
   - Cracks
   - Bends
   - Stripped threads
   - Corrosion damage
   - Leaks
2. Insert a small pipe into the small end of the sleeve. Slide the sleeve back onto the pipe.
3. Install the pipes. Insert the small pipe into the large pipe.
4. Slide the sleeve over the pipe joint.
5. Install the block and the spacer bars.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
6. Install the bolts.

   Tighten

   Tighten the bolts until the spacer bars and the sleeve are clamped to the block. Do not exceed 80 N.m (59 lb ft).

Exhaust Clamps Replacement (U-Bolt Clamp)

1. Inspect all of the components for the following damage. Replace the damaged components as necessary:
   - Cracks
   - Bends
   - Stripped threads
   - Corrosion
2. Insert the exhaust clamp through the muffler hanger assembly.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
3. Install the nut on the exhaust clamp.

   Tighten

   Tighten the nuts to 60 N.m (44 lb ft).

Exhaust Clamps Replacement (Slip Joint)

Inspect all of the components for the following damage. Replace the damaged components as necessary:

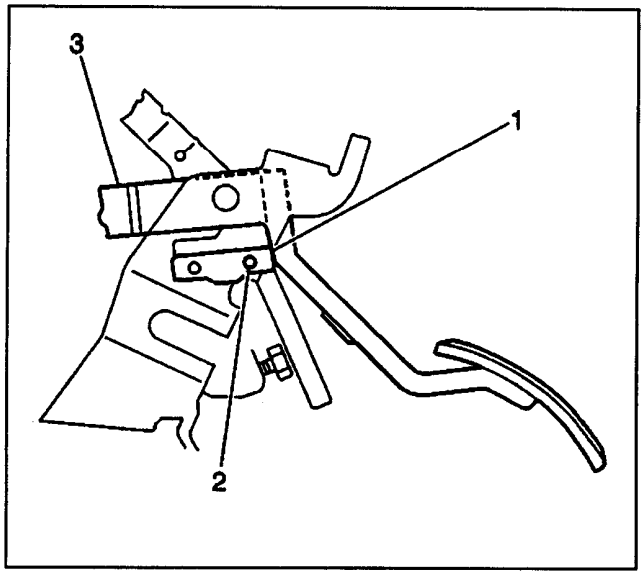
- Cracks
- Bends
- Stripped threads
- Corrosion damage
- Leaks

Accelerator Pedal Switch Replacement

Removal Procedure

Caution: Refer to Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the negative battery cable.
2. Remove the pedal switch connector.
3. Remove the bolts (2).
4. Remove the accelerator pedal switch (1).



236567

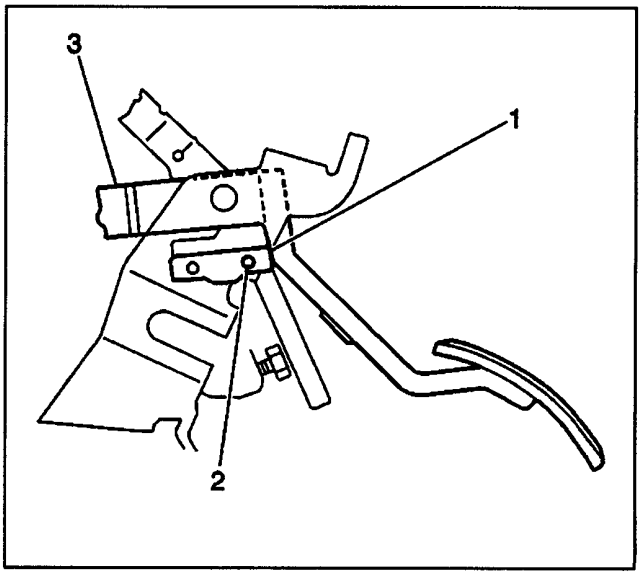
Installation Procedure

1. Install the accelerator pedal switch (1) to the bracket.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the bolts.

   Tighten

   Tighten the bolts finger tight.
3. Ensure that the fast idle control is fully backed off.
4. Ensure that the accelerator linkage is properly adjusted.
5. Move the accelerator pedal switch (1) toward the actuating lever (3) until you hear a click.
6. Check the adjustment. The adjustment is correct when you hear the switch click immediately after you push in the accelerator pedal from the idle position.
7. Tighten the bolts.
8. Install the pedal switch connector.
9. Connect the negative battery cable.



236567

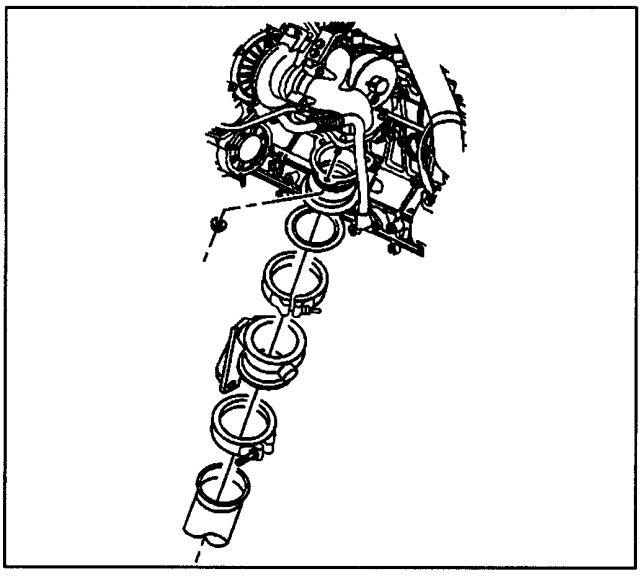
Clutch Pedal Switch Replacement

Removal Procedure

1. Release all of the compressed air from the air tanks.
2. Remove the control valve connector.
3. Remove the air lines.
4. Remove the bolts.
5. Remove the nuts.
6. Remove the washer.
7. Remove the control valve.

Installation Procedure

1. Connect the control valve to the frame.
2. Install the bolts.
3. Install the washers.
4. Install the nuts.
5. Install the air lines.
6. Install the control valve connector.



236570

Exhaust Brake Actuator Control Valve Replacement (Valve)

Removal Procedure

Caution: Make sure actuator is not pressurized before performing any service procedures. The actuator assembly, when pressurized, exerts sufficient force to cause personal injury. Refer to Air Brakes to depressurize the system before performing any service procedures.

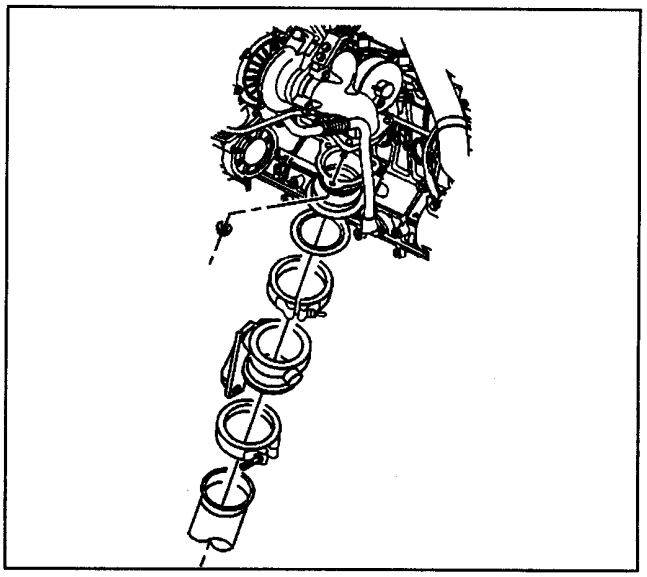
1. Inspect the exhaust brake for foreign objects that are trapped between the following components:
   - The lever and the stop peg
   - The actuator and the bracket
2. Inspect the following components for tightness:
   - The two mounting bracket bolts
   - The stop peg
   - The clamp rings
3. Inspect the following components for dirt:
   - The actuator push rod end
   - The lip seal
   - The breather
   - The pivot
4. Perform the following actions simultaneously:
   - Hold the actuator rod across the flats.
   - Slacken the locknut.
5. Remove the inlet hose elbow.

6. Remove the following components:
   - The circlip
   - The washer
7. Remove the actuator from the fixed pivot.
8. Unthread the actuator rod from the ball joint in order to remove the actuator rod.
9. Inspect the condition of the actuator sleeve.
   Replace the actuator sleeve, if necessary.

Installation Procedure

Notice: Refer to *Fastener Notice* in Cautions and Notices.

1. Thread the locknut onto the actuator rod.
   Tighten
   Tighten the actuator rod locknut to 14 N.m (10 lb ft).
2. Install the end of the actuator rod into the ball joint.
3. Slide the actuator over the pivot pin.
4. Install the washer and the circlip.
   Ensure that the circlip is properly seated.
5. Install the inlet hose elbow.
   Tighten
   Tighten the inlet hose elbow to 20 N.m (14 lb ft).
6. Verify that the following conditions exist:
   - The actuator rod is properly adjusted.
   - The butterfly valve lever contacts the stop peg when the butterfly valve lever is in the fully open position.
   - The butterfly valve lever contacts the stop peg when the butterfly valve lever is in the fully closed position.



236570

Exhaust Brake Actuator Control Valve Replacement (Actuator Sleeve)

Removal Procedure

1. Remove the circlip and the washer.
2. Slide the actuator off of the following components:
   - The actuator sleeve
   - The pivot pin
3. Remove the actuator sleeve.
4. Remove the washer.

Installation Procedure

1. Install the washer over the pivot pin.
2. Install a new actuator sleeve into the actuator.
3. Slide the actuator and the sleeve onto the pivot pin.
4. Install the washer and the circlip. Ensure that the washer is properly seated.

Exhaust Brake Actuator Stop Peg Replacement

Removal Procedure

1. Close the butterfly valve.
2. Remove the stop peg.
3. Remove the washer.

Installation Procedure

1. Install a new washer.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install a new stop peg.

   Tighten

   Tighten the stop peg to 24 N·m (18 lb ft).
3. Verify that the following conditions exist:
   - The actuator rod is properly adjusted.
   - The butterfly valve lever contacts the stop peg when the butterfly valve lever is in the fully open position.
   - The butterfly valve lever contacts the stop peg when the butterfly valve lever is in the fully closed position.

Exhaust Brake Ball Joint Replacement

Removal Procedure

1. Remove the exhaust brake actuator.

   Refer to *Exhaust Brake Actuator Control Valve Replacement (Valve).*
2. Remove the wire retaining clip from the ball joint.
3. Detach the ball joint from the assembly.

Installation Procedure

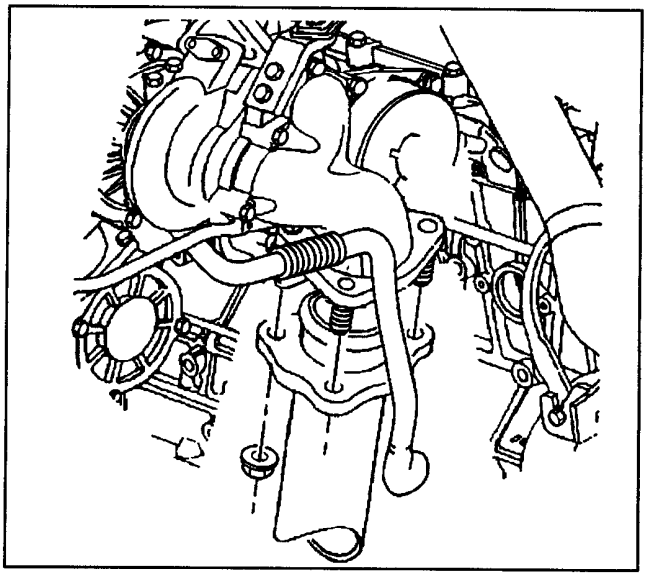
1. Install a new ball joint cap.
2. Install a new wire retaining clip.
3. Install the exhaust brake actuator.

   Refer to *Exhaust Brake Actuator Control Valve Replacement (Valve).*

Exhaust Pipe Replacement (Front)

Removal Procedure

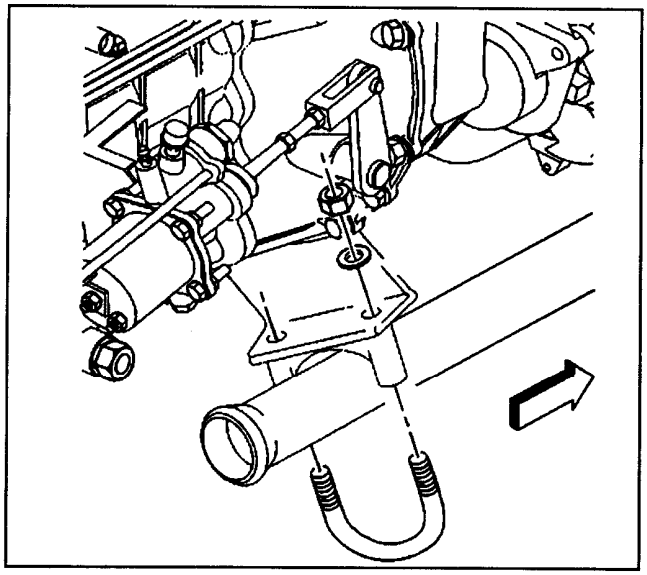
1. Remove the nuts from the turbocharger.
2. Remove the clamp from the flexible pipe.



236579

3. Remove the clamp from the transmission bracket.
4. Remove the front exhaust pipe.
5. Inspect all of the components for the following conditions:
   - Cracks
   - Bends
   - Stripped threads
   - Corrosion
   - Leaks

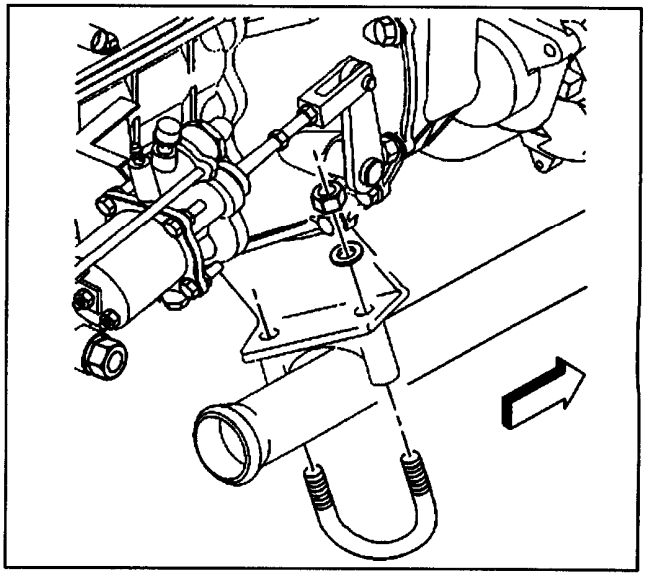
   Replace the components as necessary.



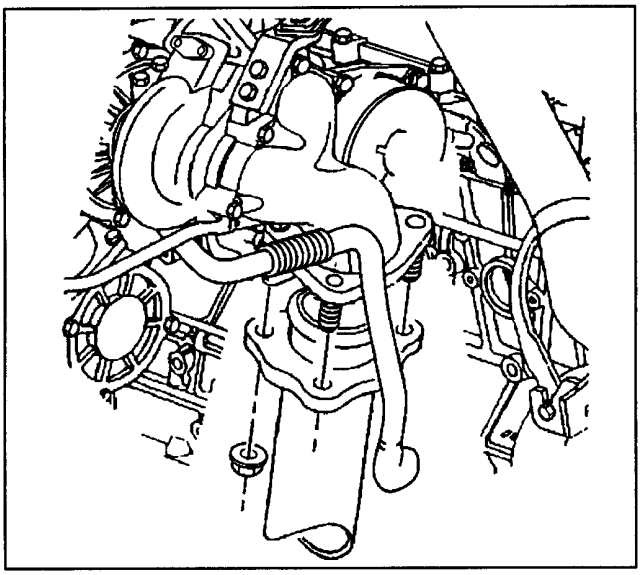
236578

Installation Procedure

1. Place the front exhaust pipe into position.
2. Install the clamp to the transmission bracket.



236578



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3. Install the clamp at the flexible pipe.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.

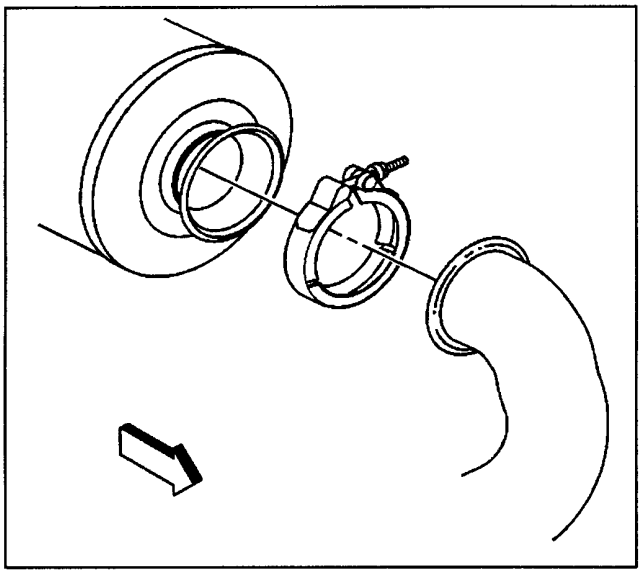
4. Install the nuts to the turbocharger.

   Tighten

   4.1. Tighten the front exhaust pipe nuts to 29 N·m (21 lb ft).

   4.2. Tighten the bolts on the wide band clamp to 10 N·m (89 lb in).

   4.3. Tighten the nuts on the exhaust clamps to 24 N·m (18 lb ft).

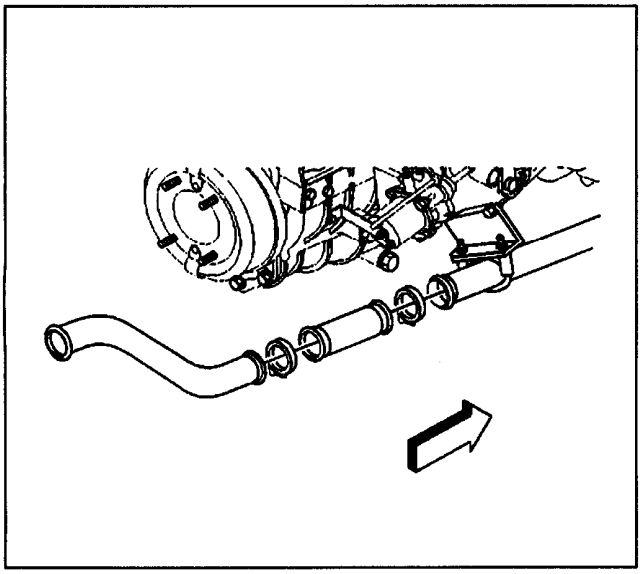


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Exhaust Pipe Replacement (Rear)

Removal Procedure

1. Loosen the clamps on the flexible pipe.
2. Remove the clamps at the muffler.



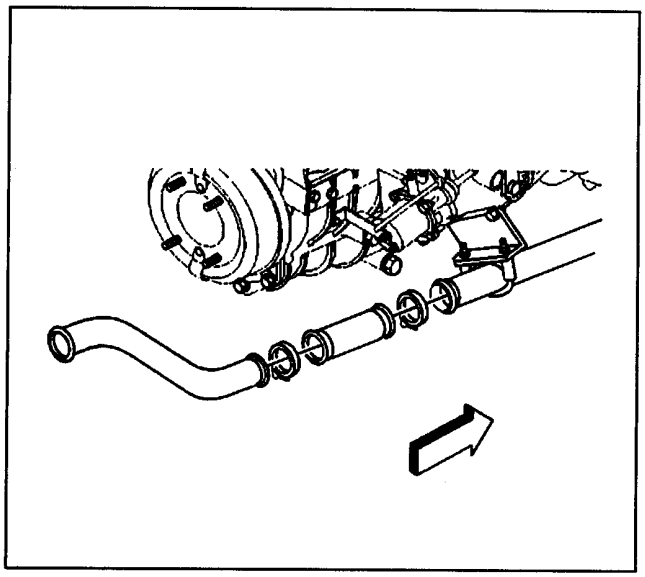
236576

3. Remove the rear exhaust pipe.
4. Inspect all of the components for the following conditions:
   - Cracks
   - Bends
   - Stripped threads
   - Corrosion
   - Leaks

   Replace the components as necessary.

Installation Procedure

1. Put the rear exhaust pipe into position.



236576

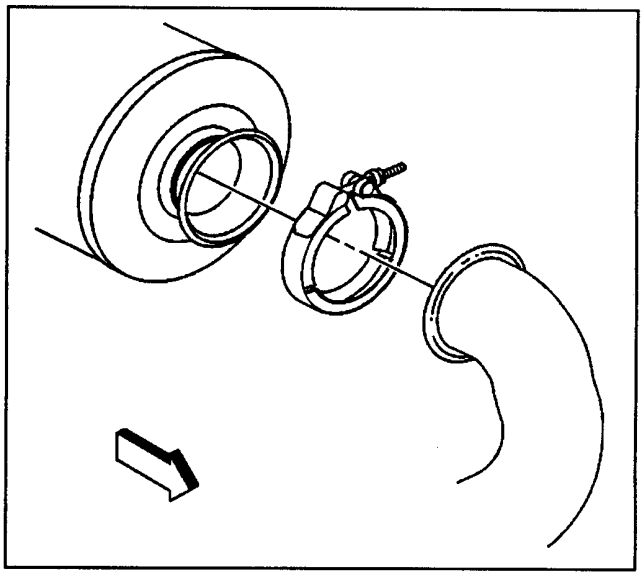
2. Install the clamp at the muffler.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.

3. Install the clamp at the flexible pipe.

   Tighten

   Tighten the clamp to 10 N.m (89 lb in).

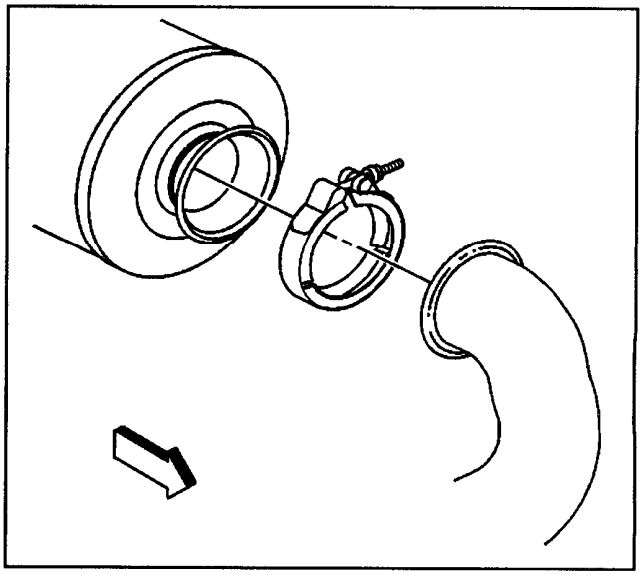


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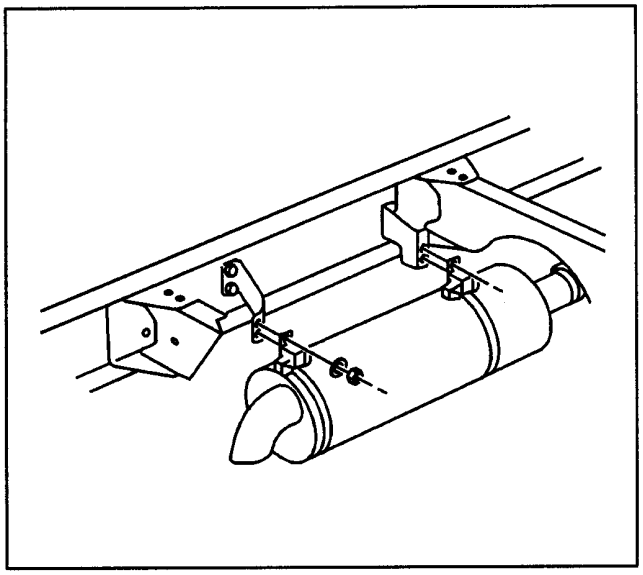
Muffler Replacement

Removal Procedure

1. Remove the clamp from the rear exhaust pipe to the muffler.



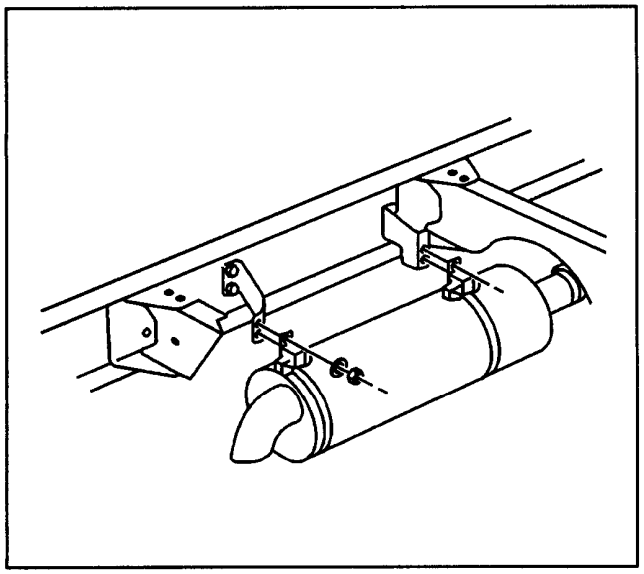
236575



206335

2. Remove the nuts from the muffler hanger.
3. Remove the muffler.
4. Inspect all of the components for the following conditions:
   - Cracks
   - Bends
   - Stripped threads
   - Corrosion
   - Leaks

   Repair or replace the components as necessary.

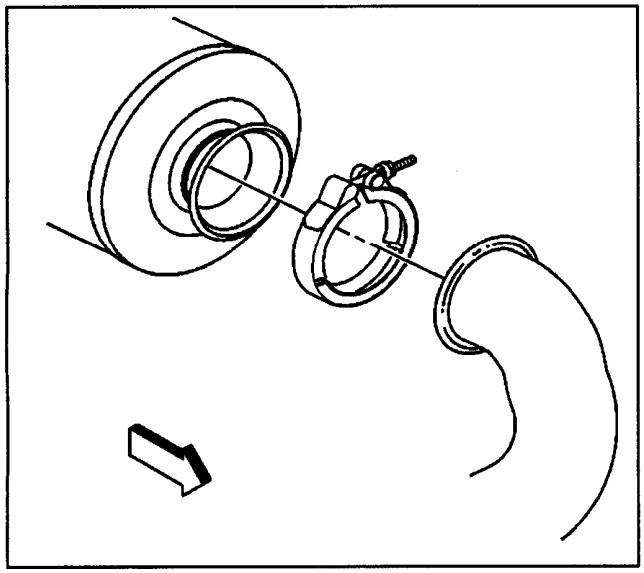


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Installation Procedure

Notice: Refer to *Fastener Notice* in Cautions and Notices.

1. Install the muffler hanger to the muffler.
   Tighten
   Tighten the muffler clamp nuts to 29 N·m (21 lb ft).
2. Install the nuts to the muffler hanger.
   Tighten
   Tighten the exhaust hanger nuts to 24 N·m (18 lb ft).



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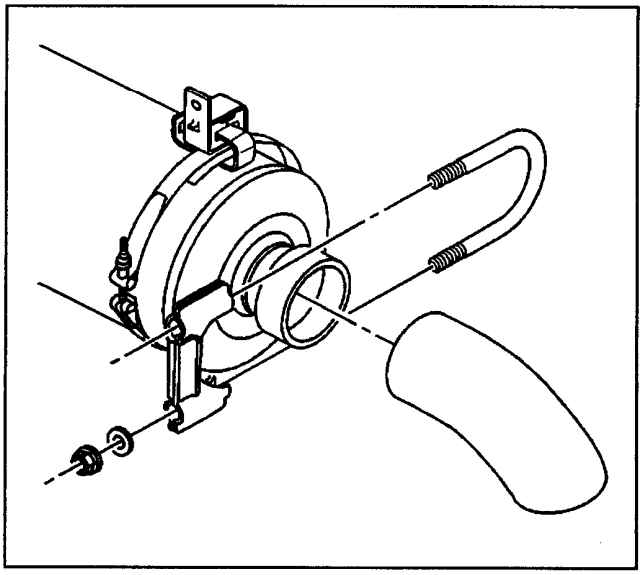
3. Install the clamp to the rear exhaust pipe.
   Important: Install a new tail pipe when the muffler is replaced.
4. Install a new tailpipe to the muffler.
   Tighten
   Tighten the tailpipe clamp nuts to 24 N·m (18 lb ft).

Tail Pipe Replacement

Removal Procedure

1. Remove the clamp.
2. Remove the tailpipe.
3. Inspect all of the components for the following conditions:
   - Cracks
   - Bends
   - Stripped threads
   - Corrosion
   - Leaks

   Repair or replace the components, as necessary.



236572

Installation Procedure

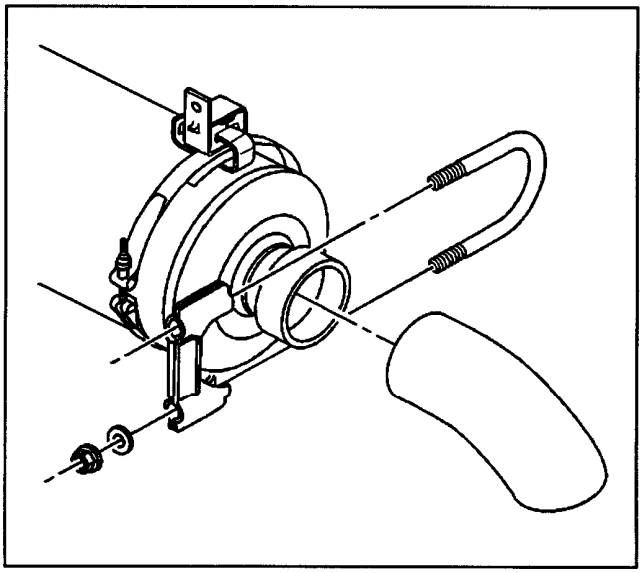
Important: Install a new tail pipe when you replace the muffler.

1. Install the tailpipe into the muffler.

   Notice: Refer to *Fastener Notice* in Cautions and Notices.
2. Install the clamp.

   Tighten

   Tighten the nuts alternately and uniformly to 24 N·m (18 lb ft).



236572

Description and Operation

Exhaust System Description

Exhaust system designs vary according to the following items:

- The model destination
- The intended use of the vehicle

The exhaust system is suspended by hangers. The hangers are attached to the frame members. The hangers allow some movement of the exhaust system. The hangers prevent the transfer of noise and vibration into the vehicle.

Heat shields protect the vehicle and the environment from high temperatures. The high temperatures may develop from the exhaust system.

Inspect the following components:

- The exhaust pipes
- The muffler
- The tailpipe

Inspect the above components for the following conditions:

- Cracked joints
- Broken welds
- Corrosion

  The above conditions could result in a leaky exhaust system.

Inspect the following components for cracks or stripped or corroded thread bolts:

- The clamps
- The brackets
- The insulators

Inspect the exhaust system (including the heat shields) for the following conditions:

- Leaks
- Binding
- Grounding
- Excessive vibration

The conditions that are mentioned above are usually caused when the following components are damaged or loose:

- The flange bolts
- The heat shields
- The brackets
- The pipes

If any of the mentioned conditions exist, inspect the components and the alignment of the exhaust system. Align or replace the components as necessary.

Installing Exhaust Components

Important:

- Ensure that any exhaust system parts that you replace meet the original equipment manufacturer (OEM) standard. This action will ensure that the vehicle operates as designed.
- When you replace the muffler, you should also replace the tail pipe.
- When you install the exhaust pipe to the engine manifold, use new packings and new nuts. Clean the engine manifold stud threads with a wire brush before installing the new nuts.

Inspect for correct alignment whenever the following new components are installed onto any model:

- A new exhaust pipe
- A muffler
- A tail pipe

Misaligned parts may cause rattles and noise vibration in the exhaust.

When aligning the system, leave all of the bolts and the nuts loose until all of the components are properly aligned. Then tighten the bolts and the nuts, working from the front to the rear.

If any of the following components are damaged, replace the components. This action will maintain the correct exhaust system alignment.

- The exhaust system hangers
- The hanger brackets
- The clamps

Exhaust Brake Operation

The exhaust brake system increases the amount of power that is absorbed by the engine when the following conditions exist:

1. The exhaust brake system is turned on.
2. The vehicle is coasting.
3. The clutch is engaged.

The exhaust brake system consists of the following components:

- The exhaust manifold valve
- The air cylinder
- The control valve
- The control switches

Current flows through the fuse to the clutch pedal switch when the ignition switch is in the ON position. The clutch pedal switch and the accelerator switch are normally closed.

Current flows to the control switch when the clutch and the accelerator pedals are in the released position. When the clutch and the accelerator pedals are in the released position, the engine is at idle and the clutch is fully engaged.

Current flows to the control valve and to the indicator lamp when the control switch is turned ON.

The following actions occur when the control valve is energized:

1. The control valve opens.
2. The open control valve allows air to flow from the brake system air line to the air cylinder.
3. When the air cylinder is supplied with compressed air, the air cylinder pushes the exhaust manifold valve shut.
4. The exhaust pressure allows the engine to become a more effective brake.

The following actions occur when the clutch or the accelerator pedal is pushed in:

1. The accelerator pedal switch or the clutch pedal opens.
2. The power supply to the control valve is interrupted.
3. The control valve closes. This action removes air pressure from the air cylinder.
4. The air cylinder pulls the exhaust manifold open.
5. Normal engine operation resumes.

BLANK

SECTION 6A6

DIESEL ENGINE ON-VEHICLE SERVICE

NOTICE: *Always use the correct fastener in the correct location. When you replace a fastener, use ONLY the exact part number for that application. ISUZU will call out those fasteners that require a replacement after removal. ISUZU will also call out the fasteners that require thread lockers or thread sealant. UNLESS OTHERWISE SPECIFIED, do not use supplemental coatings (paints, greases, or other corrosion inhibitors) on threaded fasteners or fastener joint interfaces. Generally, such coatings adversely affect the fastener torque and the joint clamping force, and may damage the fastener. When you install fasteners, use the correct tightening sequence and specifications. Following these instructions can help you avoid damage to parts and systems.*

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GENERAL DESCRIPTION

The ISUZU model 6HK1-TC engine is used in the vehicle covered in this manual. The engine is an in-line six cylinder, four stroke, water cooled, direct fuel injection, turbocharged diesel. The charge air cooler is the air to air heat exchange system using a corrugated-fin heat exchanger installed in front of the radiator.

The forged crankshaft is supported by seven precision insert main bearings. The crankshaft thrust washer is located at the number seven crankshaft main bearing.

The connecting rods have precision insert type crankshaft (big end) bearings. The piston pins are retained by snap rings. The pistons have three compression rings and one oil

control ring. The pistons are cooled by oil jets. Dry liners are used. The liners have been phosphated (P-Mn method), both inside and outside for long life.

The camshaft is supported by four plain bearings, and is gear driven. Motion is transferred to the overhead valves by shaft type roller valve rocker arms.

The cylinder head may be rebuilt with new valve guides and seats. Refer to "Engine Overhaul" in SECTION 6A6B.

For further information on engine overhaul of the 7.8L, refer to SECTION 6A6B.

For information about the turbocharger, refer to SECTION 6J.

ENGINE IDENTIFICATION

The engine used in this vehicle is the 7.8L (475 CID).

The engine identification number is on the front right hand side (passenger) of the cylinder block. For further information, refer to SECTION 0A.

ENGINE LUBRICATION

A gear type oil pump is used. The engine is equipped with both full flow and bypass filters. An oil cooler is provided to help control oil temperatures. Major moving parts are supplied with oil from a large oil gallery in the cylinder block.

ON-VEHICLE SERVICE

VALVE ROCKER ARM COVER

Remover or Disconnect (Figure 1)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Air inlet pipes. Refer to SECTION 6J.
4. Valve rocker arm cover with gasket.

NOTICE: Do not pry on the valve rocker arm cover. Damage to the sealing surfaces may result.

Clean

- Oil and grease from the sealing surfaces on the cylinder head and the valve rocker arm cover.

Install or Connect (Figure 1)

1. Valve rocker arm cover and the gasket to the cylinder head.
2. Valve rocker arm bolts.

Tighten

- Valve rocker arm cover bolts to 13.N·m (113 lb. in.).

3. Air inlet pipes.
4. Negative battery cables.
5. Lower the cab.

VALVE ROCKER ARM AND CAMSHAFT

Remove or Disconnect (Figure 2)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Air inlet pipes. Refer to SECTION 6J.
4. Valve rocker arm cover. Refer to "Valve Rocker Arm Cover" in this section.
5. Connector both on the top of injectors and from engine harness.
6. Harness assembly.
7. Loosen all the valve adjusters, but do not remove.
8. Loosen the valve rocker arm shaft bracket bolts evenly, starting from the outer bolts moving to the inner bolts.

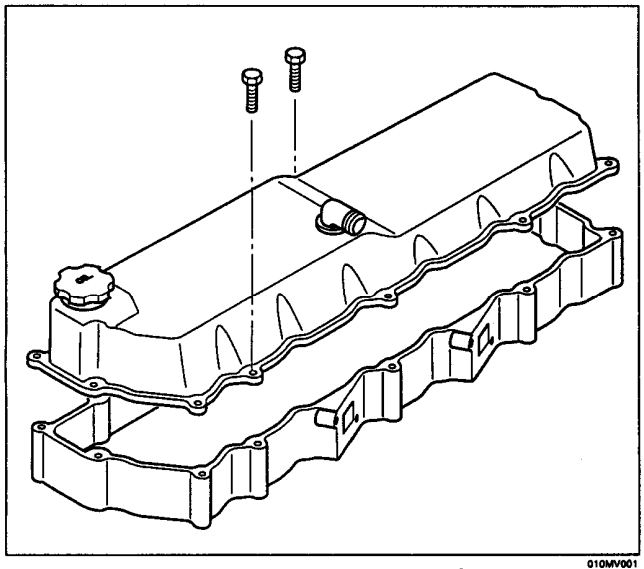


Figure 1 – Valve Rocker Arm Cover

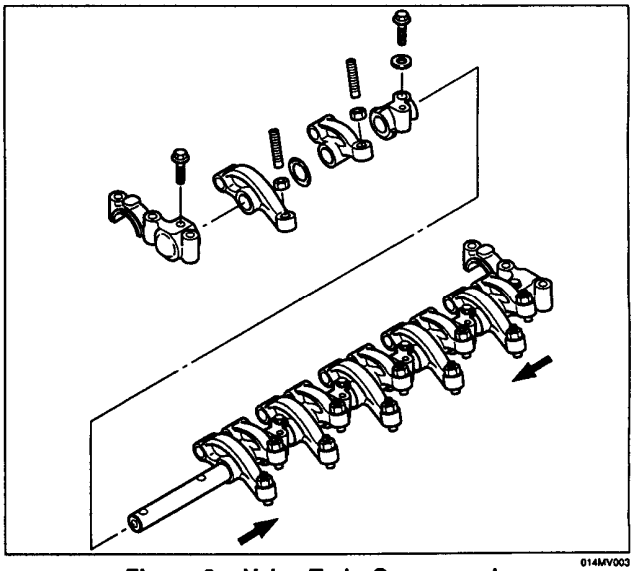


Figure 2 – Valve Train Components

Important

- Do not remove the rocker arm shaft bracket bolts from the valve rocker arm shaft assembly until the assembly is removed from the vehicle. Place on a work bench before disassembling.

9. Valve rocker arm shaft assembly.
10. Loosen camshaft bearing cap nuts evenly, starting from the outer nut moving to the inner nut.
11. Camshaft assembly.

Important

- Store used components in order so they can be reassembled in the same location.

Disassemble

- Rocker arm shaft bracket bolts, front camshaft bracket, valve rocker arm, valve rocker arm spring, valve rocker arm shaft bracket, and the rear camshaft bracket from the valve rocker arm shaft.

Clean

- Oil and dirt from the valve rocker arm assembly with approved cleaners.

Inspect

- All the valve rocker arm components for excessive scoring and wear. Replace if necessary.

Measure

- Valve rocker arm. Refer to SECTION 6A6B for valve rocker arm specifications.

Install or Connect (Figures 3 and 6)

1. Camshaft to the cylinder head.
2. Camshaft bearing caps to the cylinder head.

Important

- Camshaft bearing caps must be installed in facing front mark to engine front.

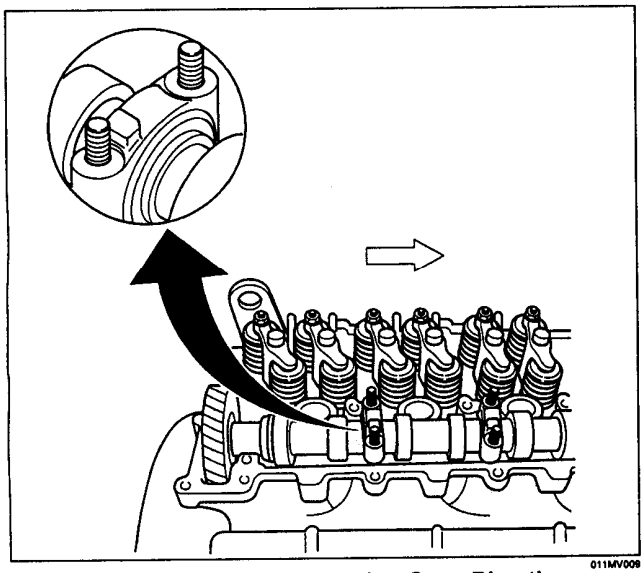


Figure 3 – Camshaft Bearing Caps Direction

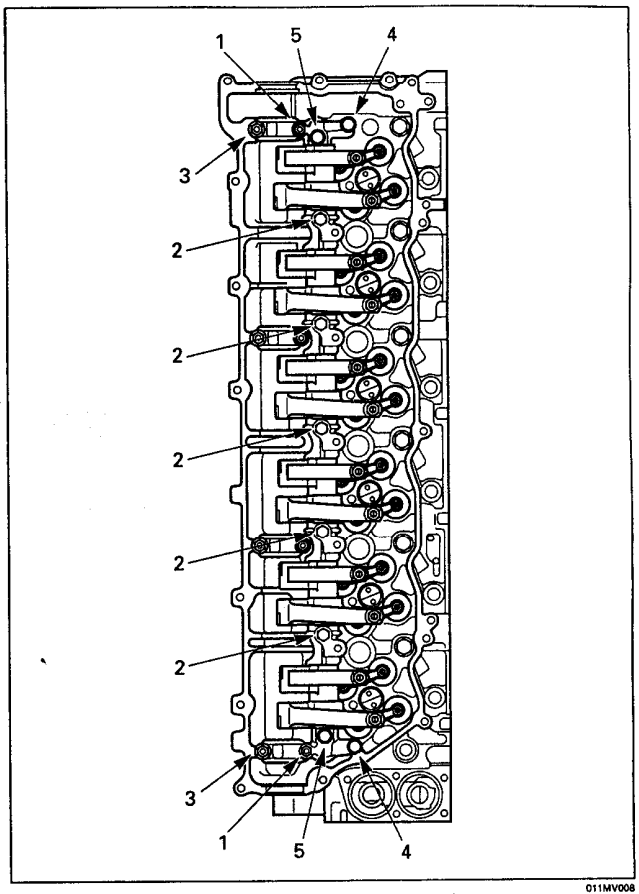


Figure 4 – Camshaft Tightening Sequence

3. Camshaft bearing cap nuts

Tighten

- Bolts to 27.5 N·m (20 lb. ft.).

4. Valve rocker arm assembly to the cylinder head.

Tighten

- Valve rocker arm shaft bracket bolts. Refer to Figure 5 for tightening sequence.
  — M8 Bolts to 27.5 N·m (20 lb. ft.).
  — M10 Bolts to 56 N·m (41 lb. ft.).

Adjust

- Refer to SECTION 6A6B for the "Valve Rocker Arm Adjustment" procedure.

5. Apply the sealant to lower surface of lower case and put on the cylinder head.

Tighten

- Bolts 19 N·m (14 lb·ft)

6. Harness assembly.

Tighten

- Bolt 21 N·m (16 lb.ft)

7. Tighten connector nuts to injector
   - Nut 1.4 N·m (12 lb.in)
8. Connect harness connector.
9. Valve rocker arm cover and the gasket to the cylinder head.
10. Valve rocker arm cover bolts.

Tighten

- Valve rocker arm cover bolts to 13 N·m (113 lb.in.).

11. Air inlet pipes.
12. Negative battery cables.
13. Lower the cab.

VALVE STEM SEAL AND VALVE SPRING

Tools Required:
J36022 Air Adapter
J43267 Valve Stem Seal Installer
J43263 Valve Spring Compressor.

Remove or Disconnect (Figures 5 through 7)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Air inlet pipes. Refer to SECTION 6J.
4. Valve rocker arm cover. Refer to "Valve Rocker Arm Cover" in this section.
5. Valve rocker arm shaft assembly. Refer to "Valve Rocker Arm" in this section.
6. Valve bridge.
7. Glow plugs.
8. Valve keys.
   A. Install J36022 adapter into the cylinder head.
   B. Apply compressed air to hold the valves in place.
   C. Install J43263 to the cylinder head and compress the valve spring.
   D. Remove the valve keys.
   E. Carefully release the valve spring tension.
9. Valve spring retainers.
10. Inner and outer valve springs.
11. Valve spring seats.
12. Valve stem seals.

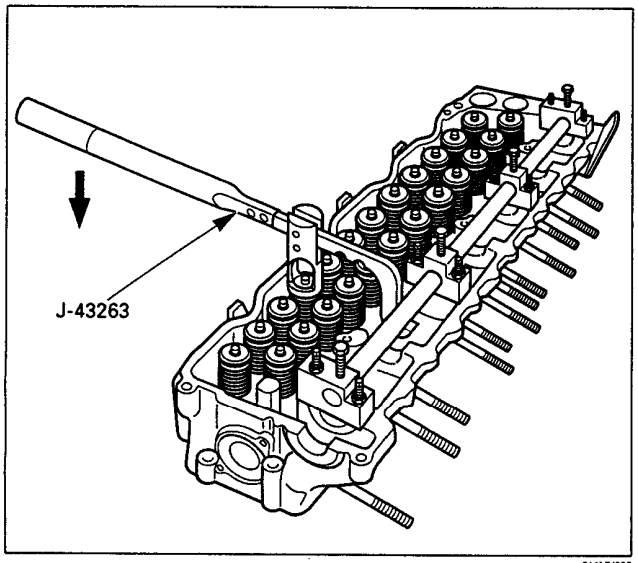


Figure 5 – Compressing the Valve Spring

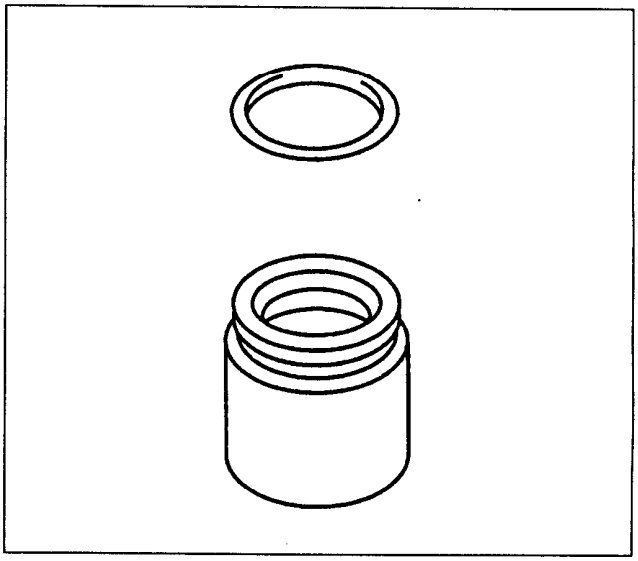


Figure 6 – Valve Seal

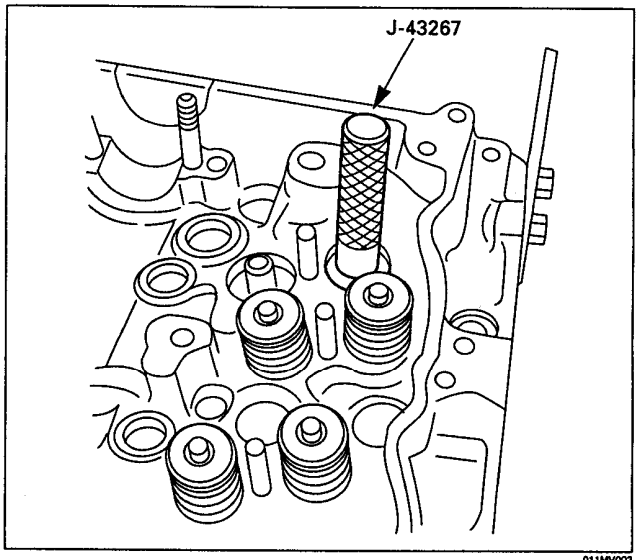


Figure 7 – Installing the Valve Seal

Install or Connect (Figures 5 through 7)

- Lubricate the new valve stem seals with clean engine oil.
- Valve stem seals using J43267.

1. Valve stem seals.
2. Valve spring seats.
3. Inner and outer valve springs.
4. Valve spring retainers.
   A. With compressed air applied to the cylinder, compress the valve spring using J43263.
   B. Install the valve keys.
   C. Carefully release the valve spring tension. Make sure the valve keys stay in place.
   D. Remove J43263.
   E. Remove J36022.
5. Valve bridge.
6. Glow plugs.
7. Valve rocker arm assembly. Refer to "Valve Rocker Arm" in this section.
8. Valve rocker arm cover.

9. Air inlet pipes.
10. Negative battery cables.
11. Lower the cab.

INTAKE MANIFOLD

Remove or Disconnect (Figures 8 and 9)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Air inlet pipes and brackets. Refer to SECTION 6J.
4. Coolant over flow hose bracket from the intake manifold. Refer to SECTION 6B.

Important

- Do not bend the fuel injector lines in any shape or form to ease the removal of the intake manifold.

5. Fuel lines from the fuel common rail to the fuel injector. Refer to SECTION 6C2.
6. Fuel lines from injection pump to fuel common rail.

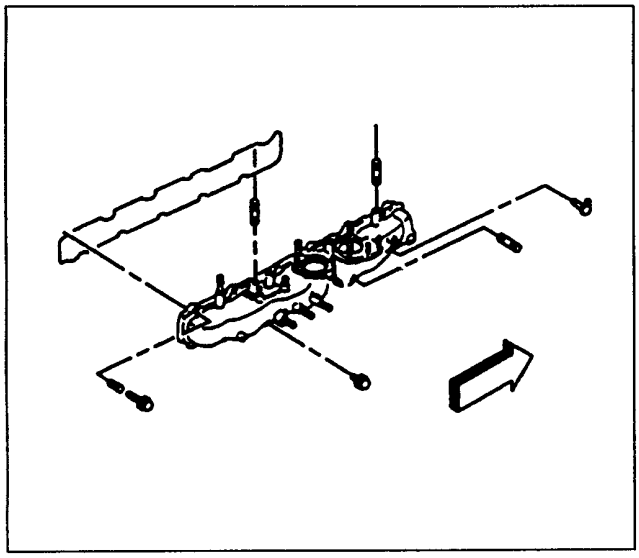


Figure 8 – Intake Manifold and Gasket

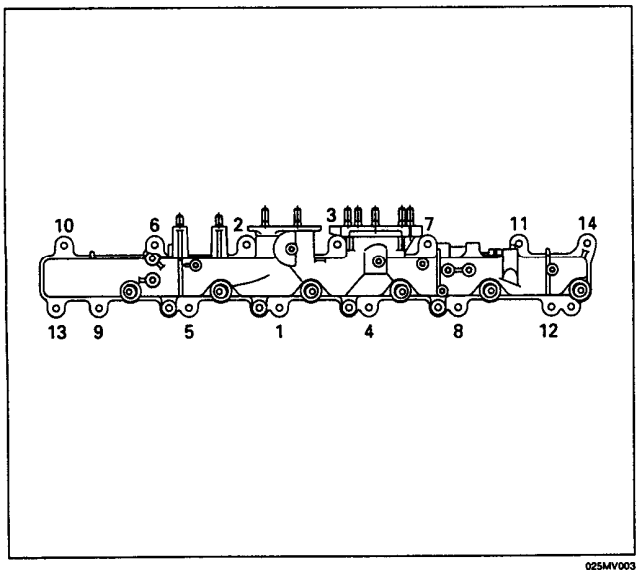


Figure 9 – Intake Manifold Tightening Sequence

7. Fuel injector return line from the fuel injector, fuel common rail and the fuel supply pump. Refer to SECTION 6C2.
8. Fuel filter and the bracket from the intake manifold. Refer to SECTION 6C2.
9. Intake manifold bolts.
10. Intake manifold and the gasket.

Inspect

- Intake manifold for cracks or damage to the gasket mating surfaces.

Install or Connect (Figures 8 and 9)

1. Intake manifold and gasket to the cylinder head.
2. Intake manifold bolts and nuts.
3. Fuel common rail.

Tighten

- Intake manifold bolts to 15 N·m (130 lb. in.).

4. Fuel lines from the supply pump to the fuel common rail.
5. Fuel lines from the common rail the fuel injector.
6. Fuel injector return line from fuel injector, fuel common rail and the fuel supply pump.
7. Fuel filter and the bracket to the intake manifold.
8. Fuel lines to the fuel filter and to the fuel supply pump.
9. Negative battery cables.
10. Lower the cab.

EXHAUST MANIFOLD

Remove or Disconnect (Figure 10)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Turbocharger assembly. Refer to SECTION 6J.
4. Exhaust heat shield.
5. Exhaust manifold nuts, bolts, washers, and the spacers.
6. Exhaust manifold and the gasket.

Inspect

- Exhaust manifold for cracks or damage.

Measure

- Use a straight edge to check the flatness of the exhaust manifold. If a gap of 0.4 mm (0.015 in.) or more exists, replace the exhaust manifold.

Install or Connect (Figure)

1. Exhaust gasket and the exhaust manifold.
2. Exhaust manifold bolts, washers, spacers and the nuts.

Tighten

- Exhaust manifold bolts and nuts to 34 N·m (25 lb. ft).

3. Exhaust manifold heat shield.
4. Turbocharger assembly.
5. Negative battery cables.
6. Lower the cab.

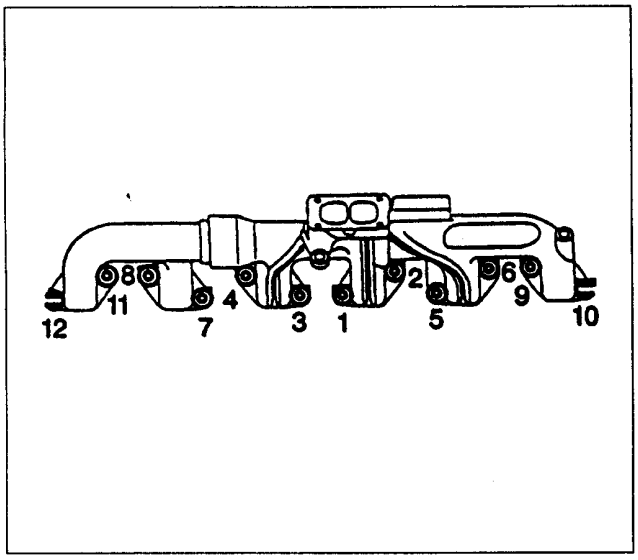


Figure 10 – Exhaust Manifold

CYLINDER HEAD

Remove or Disconnect (Figures 11 through 14)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Drain the cooling system. Refer to SECTION 6B.
4. Air inlet pipes. Refer to SECTION 6J.
5. Turbocharger assembly. Refer to SECTION 6J.
6. Intake manifold assembly. Refer to "Intake Manifold" in this section.
7. Exhaust manifold assembly. Refer to "Exhaust Manifold" in this section.
8. Heat shield and bracket.
9. Valve rocker arm cover. Refer to "Valve Rocker Arm Cover" in this section.
10. Valve rocker arm and camshaft from the cylinder head. Refer to "Valve rocker arm and camshaft" in this section.
11. Fuel injector nozzles. Refer to SECTION 6C2.
12. Coolant line from the air compressor to the cylinder head.
13. Glow plugs. Refer to SECTION 6D6.
14. Air compressor line bracket from the rear of the cylinder head. Refer to SECTION 5J.
15. Cylinder head bolts from the cylinder head.
16. Cylinder head and the gasket from the engine.

Clean

- Carbon deposits from the combustion chambers.
- All traces of the old cylinder head gasket from the cylinder head and the engine block.
- Cylinder head bolt threads using a wire brush
- Metal chips and dirt from the threads in the cylinder block.

Inspect

- Cylinder head for cracks or damaged parts.
- Threaded parts for wear or damage.

Measure

- Use a straight edge to check the flatness of the cylinder head. If the cylinder head has more than 0.2 mm (0.0078 in.) gap between the straight edge and the surface of the cylinder head, replace the cylinder head. Refer to SECTION 6A6B.

Install or Connect (Figures 10 through 14)

1. Cylinder head and the gasket to the engine block.
   - Apply sealant to the rear corners of the cylinder block.
   - Install the cylinder head gasket with the part number facing up.
2. Cylinder head bolts to the cylinder head.

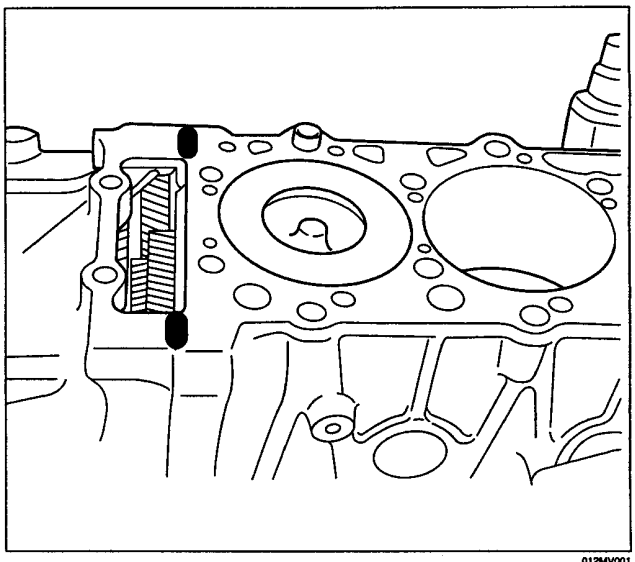


Figure 11 – Apply the Sealant

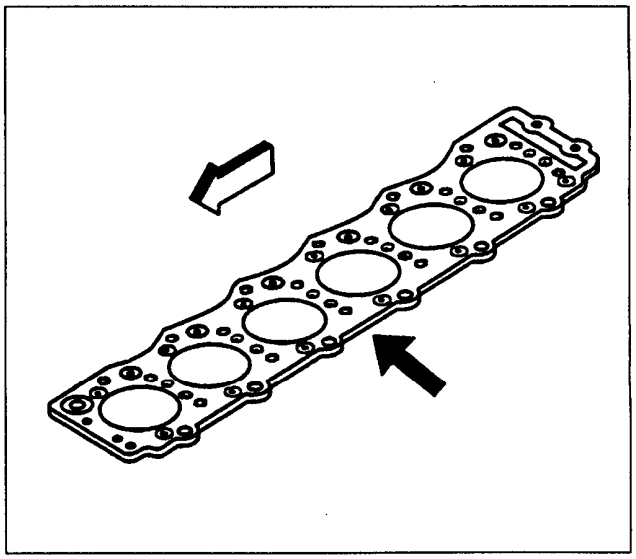


Figure 12 – Installing the Cylinder Head Gasket

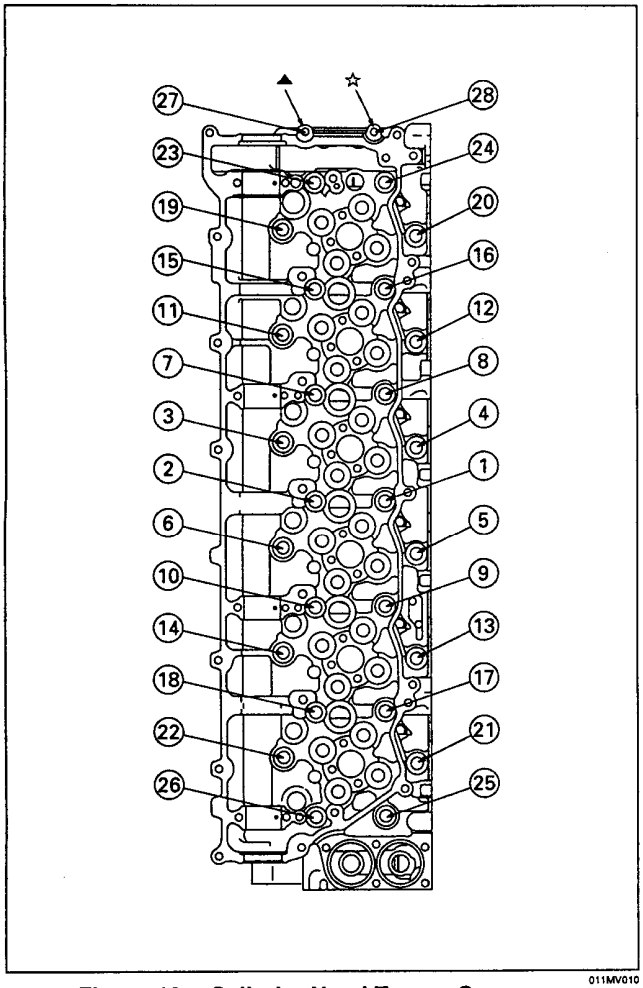


Figure 13 – Cylinder Head Torque Sequence

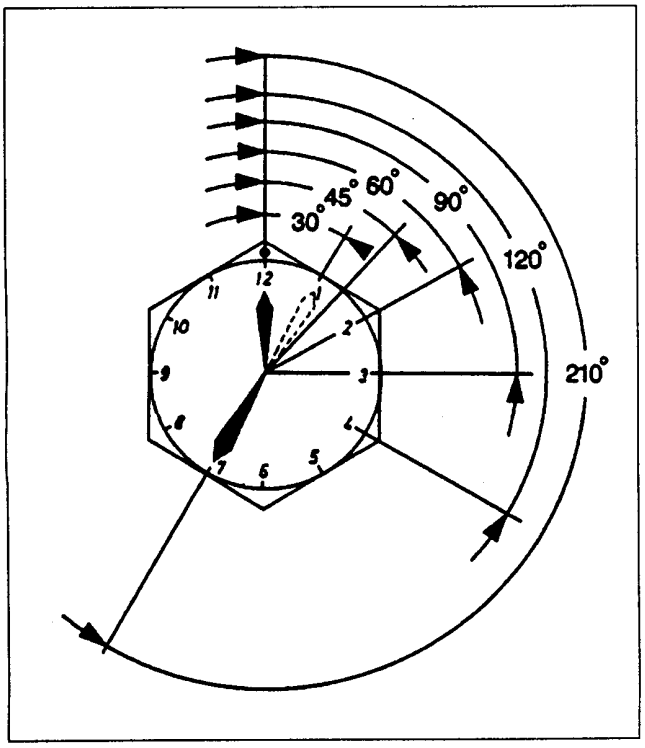


Figure 14 – Final Torque Step

Tighten

- Cylinder head bolts in the following steps.

For M14 Bolts

- Apply molybdenum disulfide grease to thread and contact surface of washer.
- Tighten cylinder head bolt and follow the tightening order 1 to 26.
  - — 98 N·m (72 lb. ft.).
  - — 147 N·m (108 lb. ft.).
  - — Turn all the cylinder head bolts an additional 30 to 60 degree.

For M10 Bolts

- Apply engine oil to threads and follow the tightening order number 27 to 28.
  - — 39 N·m (28 lb. ft.)

3. Camshaft and valve rocker arm to the cylinder head. Refer to "Valve rocker arm and Camshaft" in this section.
4. Valve rocker arm cover.
5. Coolant line from the air compressor to the cylinder head.
6. Air compressor lines and the bracket to the rear of the cylinder head.
7. Glow plugs.
8. Fuel injector nozzles.
9. Valve rocker arm cover.
10. Exhaust manifold. Refer to "Exhaust Manifold" in this section.
11. Intake manifold. Refer to "Intake Manifold'" in this section.
12. Turbocharger assembly. Refer to SECTION 6J.
13. Air inlet pipes.
14. Negative battery cables.
15. Lower the cab.

CYLINDER HEAD REPAIR

- Refer to SECTION 6A6B for cylinder head repair.

CRANKSHAFT BALANCER (EXTERNAL) FRONT COVER AND FRONT COVER OIL SEAL

Tools Required:
J.39046 Crankshaft Balancer (External) Remover and Installer
J41220 Oil Slinger Remover
J41221 Oil Seal Installer

Remove or Disconnect (Figures 15 through 16)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Drive belts. Refer to SECTION 6B.
4. Crankshaft balancer bolts and washers from the crankshaft balancer.
5. Crankshaft balancer bolt and the washer.
6. Crankshaft balancer from the crankshaft.
7. Front cover seal.
   - Carefully pry out the seal with a screw driver. Do not damage the front cover.
8. Front cover bolts.
9. Front cover.

Important

- Oil slinger must be replaced if the front cover oil seal has been removed.
- Install J41220 and remove the oil slinger.

Install or Connect (Figures 17 through 20)

1. Oil slinger.
   - Install J41221.
     A. Apply clean engine oil to the oil slinger.
     B. Insert the oil slinger into the adapter.
     C. Install the oil slinger sleeve to the adapter, and tighten the center bolt until the sleeve comes in contact with the adapter and stops.
     D. After pressing in the oil slinger, make sure that the distance between the crankshaft end surface and the oil slinger is, 11.5 ± 0.15 mm (0.453 ± 0.006 in.).
        - Check the measurement at several different points.
2. Apply the sealant on the cylinder block then install the front cover.
3. Front cover bolts.

Tighjten

- Bolts to 19 N·m (14 lb. ft.).

4. Front cover seal.
   - Install J41221.
     A. Apply clean engine oil to the oil seal.
     B. Insert the oil seal into the adapter.
     C. Install the oil seal to the adapter, and tighten the center bolt until the sleeve comes in contact with the adapter and stops.
     D. After pressing in the oil seal, make sure that the distance between the crankshaft end surface and the oil seal is 8.5 ± 0.15 mm (0.335 ± 0.005 in.).
        - Check the measurement at several different points.

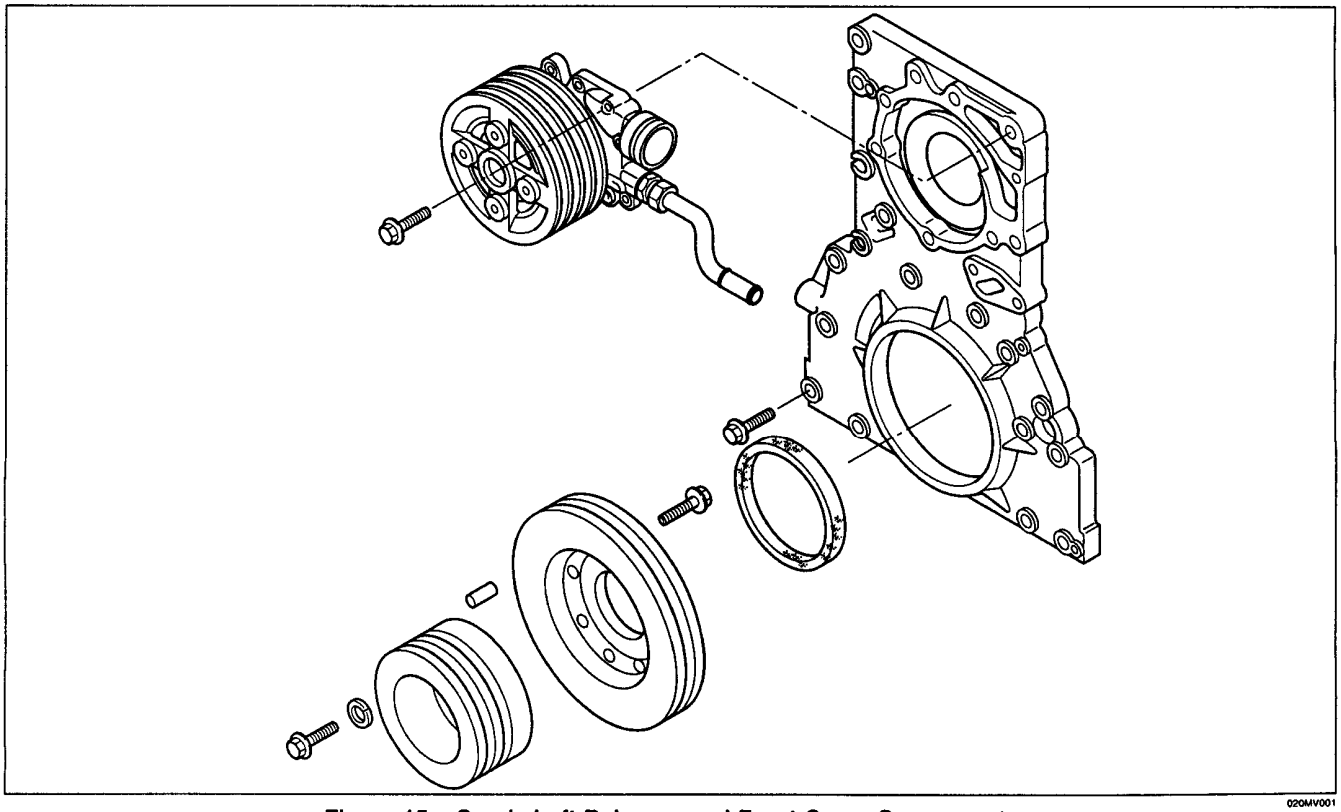


Figure 15 – Crankshaft Balancer and Front Cover Components

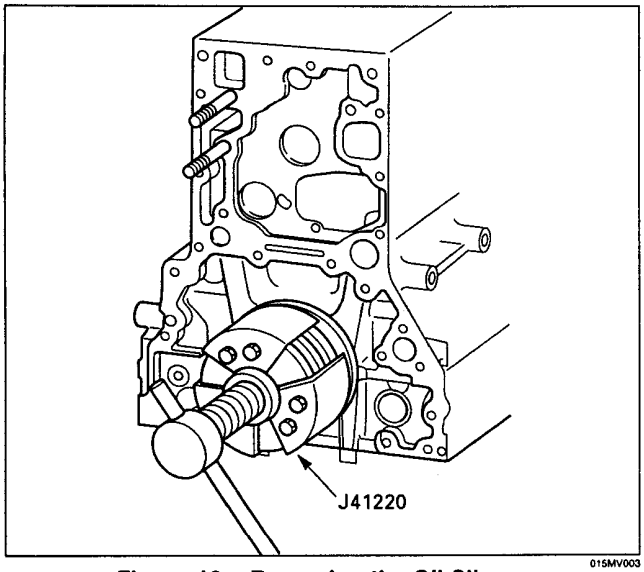


Figure 16 – Removing the Oil Slinger

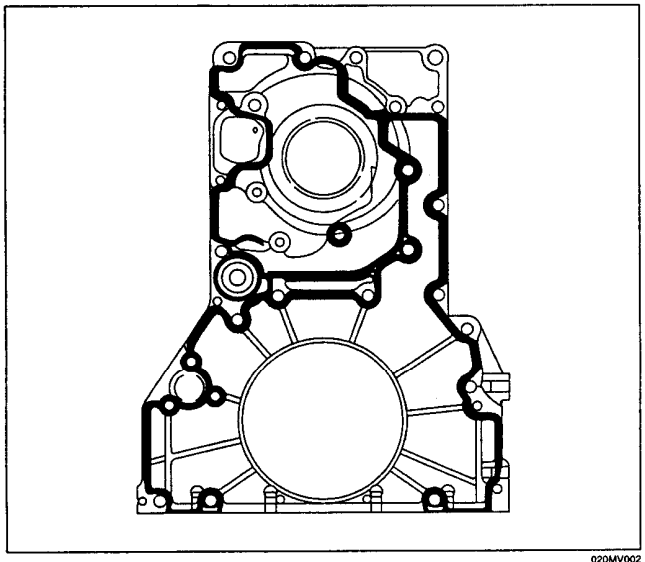


Figure 17 – Apply the Sealant

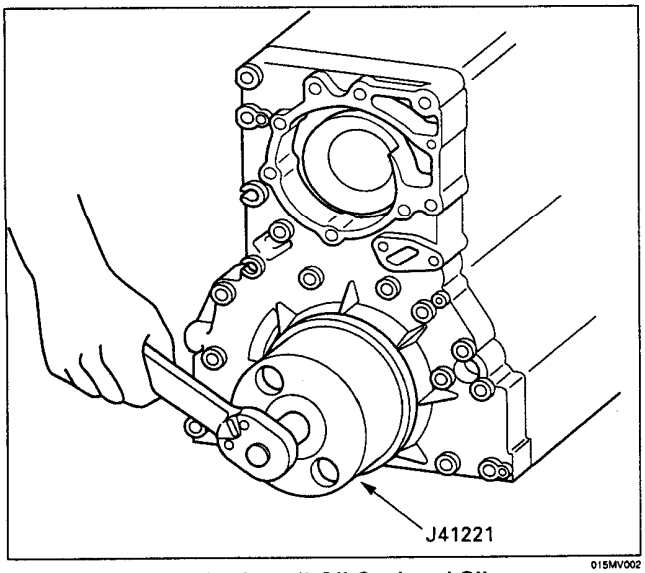


Figure 18 – Install Oil Seal and Slinger

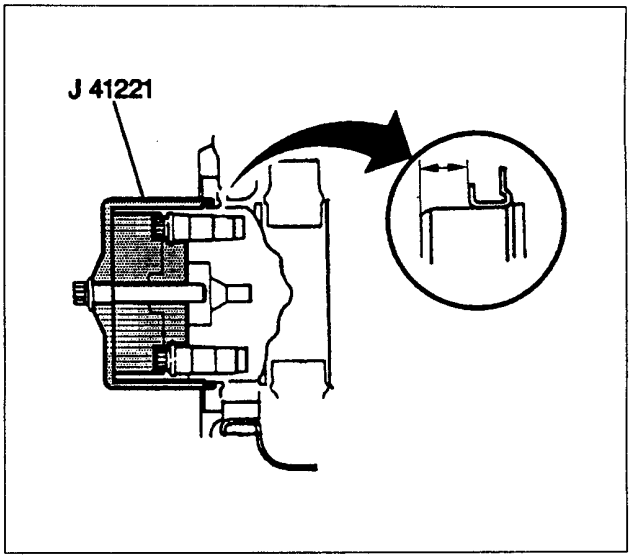


Figure 19 – Checking the Slinger Clearance

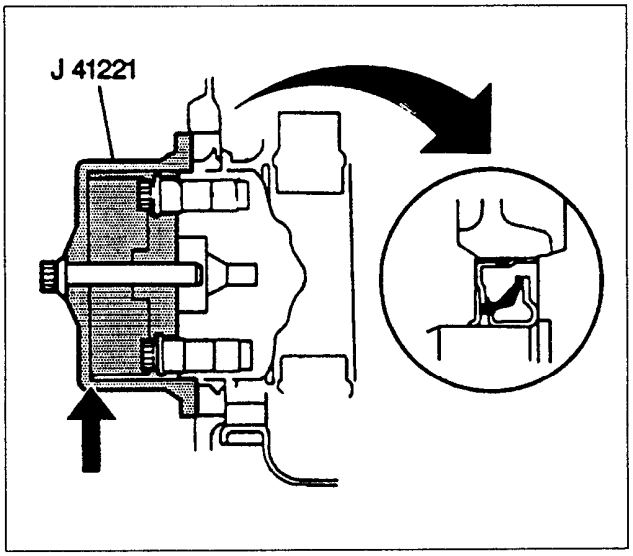


Figure 20 – Checking the Seal Clearance

Inspect

- Crankshaft balancer for excessive wear or damage.
- Crankshaft balancer for silicone leakage. If leakage appears, replace the crankshaft balancer.

5. Crankshaft balancer, bolts and washers.

Tighten

- Crankshaft balancer bolts and nuts to 48 N·m (35 lb. ft.).

6. Crankshaft balancer to the crankshaft.
7. Crankshaft balancer bolt and washer to the crankshaft.

Tighten

- Crankshaft balancer bolt and washer to 200 N·m (148 lb. ft.).

8. Drive belts.
9. Negative battery cables.
10. Lower the cab.

OIL PAN

Remove or Disconnect

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
   - Drain the crankcase.
3. Engine oil level indicator.
4. Bolts from the oil pan.
5. Oil pan.

Clean

- Sealant from the oil pan and the engine block.
- Sludge and dirt from the inside of the oil pan.
- All mating surfaces must be free of oil and dirt.

Install or Connect (Figures 21 through 23)

1. Apply sealant to the oil pan.
2. Apply sealant to the four corners of the cylinder block.
   - Apply a bead of silicone sealant approx. 2 mm (0.08 in.) thick and approx. 3 mm (0.12 in.) wide.
3. Bolts to the oil pan.

Tighten

- Oil pan bolts to 24 N·m (17 lb. ft.).

4. Engine oil level indicator.
5. Negative battery cables.
6. Lower the cab.
   - Fill the crankcase with the proper grade and quantity of engine oil. Refer to SECTION 0B.

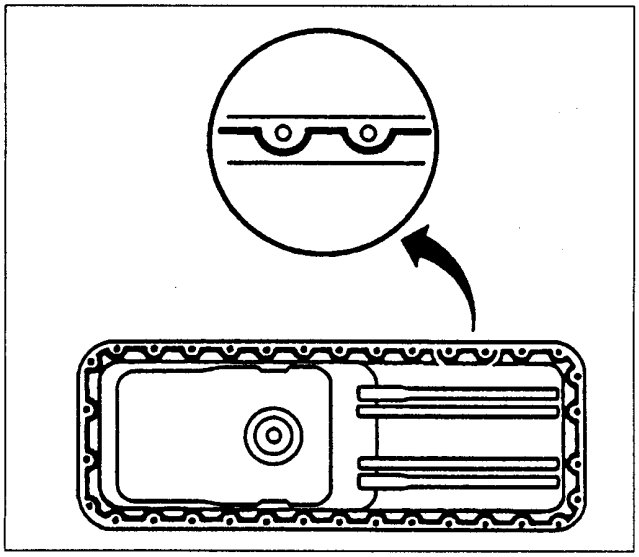
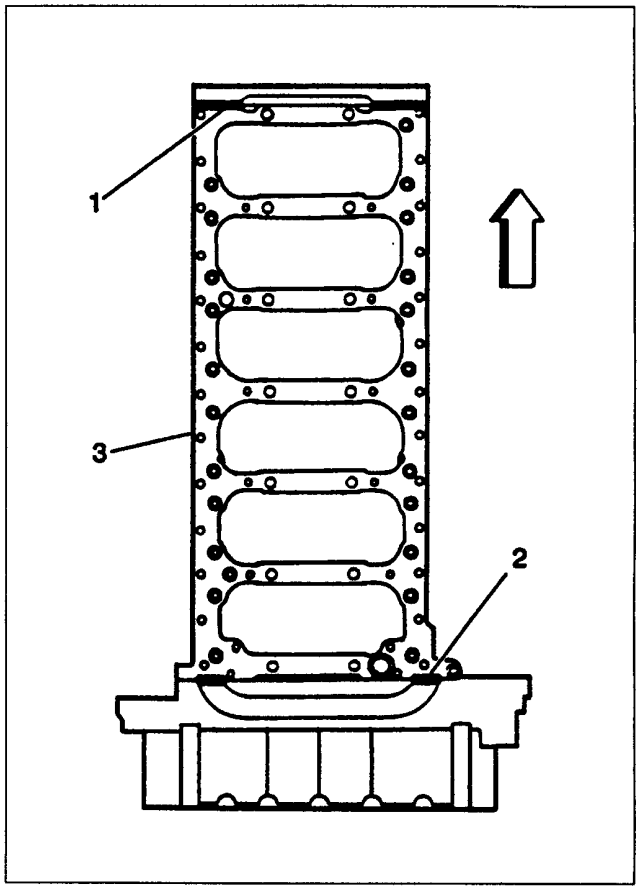


Figure 21 – Apply the Sealant



Legend
(1) Applying the Sealant at the Front Corners
(2) Applying the Sealant at the Rear Corners
(3) Cylinder Block

Figure 22 – Applying the Sealant

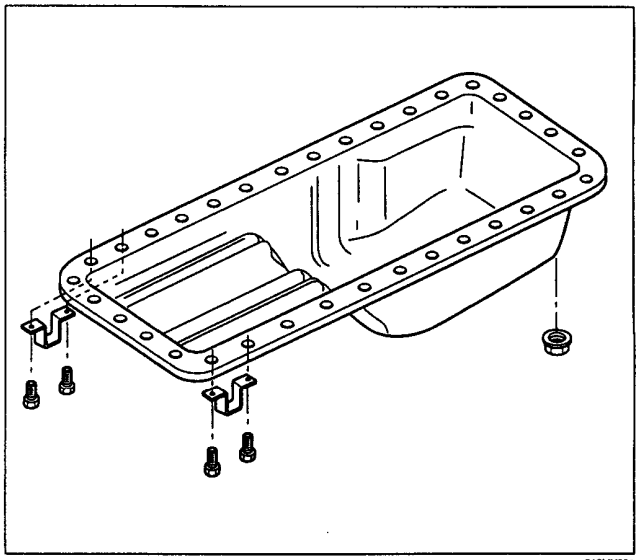


Figure 23 – Oil Pan

OIL PUMP

- For further information, refer to SECTION 6A6B.

OIL PUMP REPAIR

- For further information, refer to SECTION 6A6B.

CRANKSHAFT REAR OIL SEAL

Tools Required:
J41220 Oil Slinger Remover
J41221 Oil Seal Installer

Remove or Disconnect (Figure 24)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Raise the vehicle.
   - Support the engine with a suitable stand.
4. Transmission assembly. Refer to SECTION 7A6 for automatic transmission, or SECTION 7B for manual transmission.
5. Flywheel or clutch. Refer to SECTION 7C.
6. Oil slinger and the rear crankshaft oil seal.
   - Install J41220 and remove the oil slinger and oil seal.

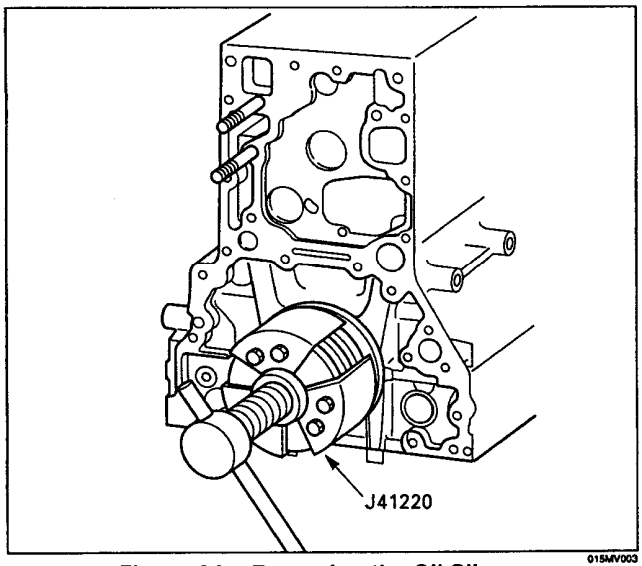


Figure 24 – Removing the Oil Slinger

Important

- Crankshaft rear oil slinger is gray. Front cover oil slinger is black.

Install or Connect (Figure 25 through 28)

1. Oil slinger.
   - Install J41221.
     A. Do not apply engine oil to the oil slinger inside surface.
     B. Insert the oil slinger into the adapter.
     C. Install the oil slinger sleeve to the adapter, and tighten the center bolt until the sleeve comes in contact with the adapter and stops.
     D. After pressing in the oil slinger, make sure that the distance between the crankshaft end surface and the oil slinger is (1) 10.5 ± 0.15 mm (0.413 ± 0.006 in.).
   - Check the measurement at several different points.

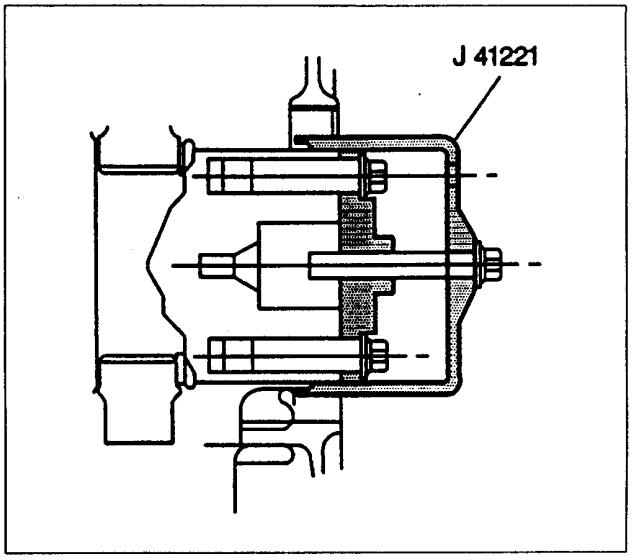
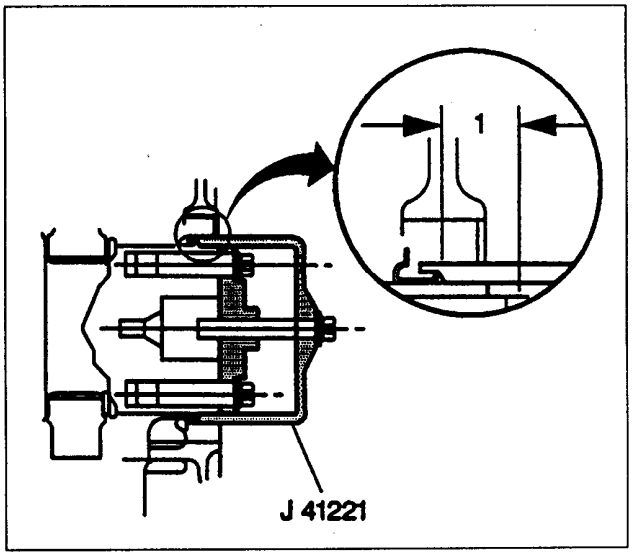


Figure 25 – Installing the Oil Slinger



Legend
(1) Measuring the Depth

Figure 26 – Measuring the Installed Depth

2. Crankshaft rear seal.
   - Install J41221.
     A. Apply clean engine oil to the oil seal lip. Do not apply engine oil to outside surface.
     B. Insert the oil seal adapter.
     C. Install the oil seal to the adapter, and tighten the center bolt until the sleeve comes in contact with the adapter and stops.

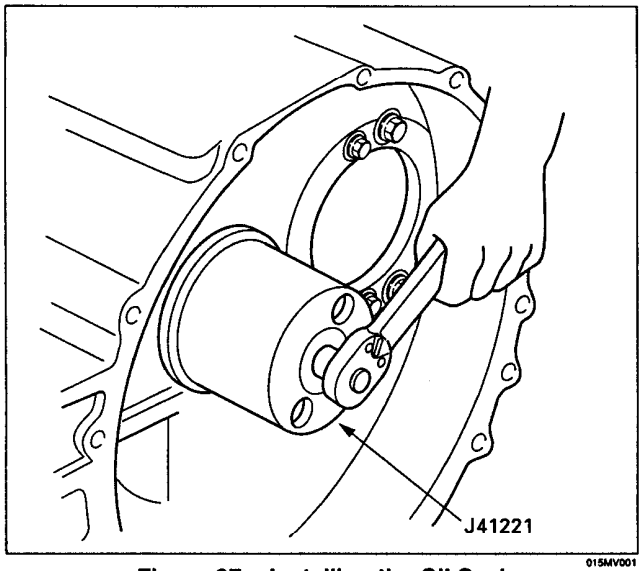


Figure 27 – Installing the Oil Seal

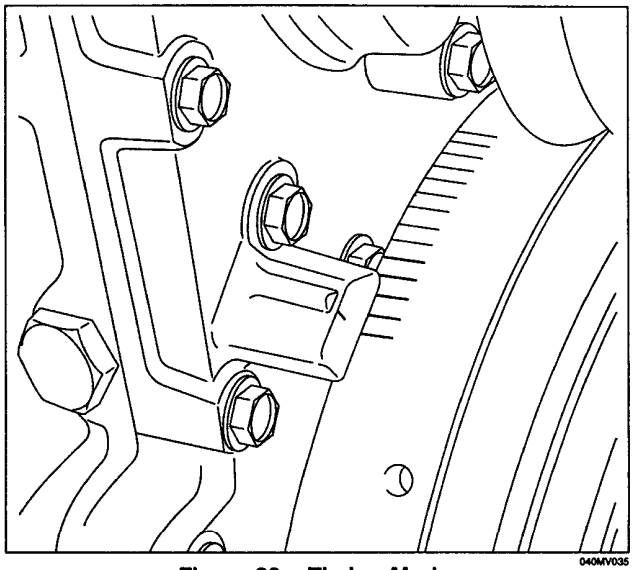
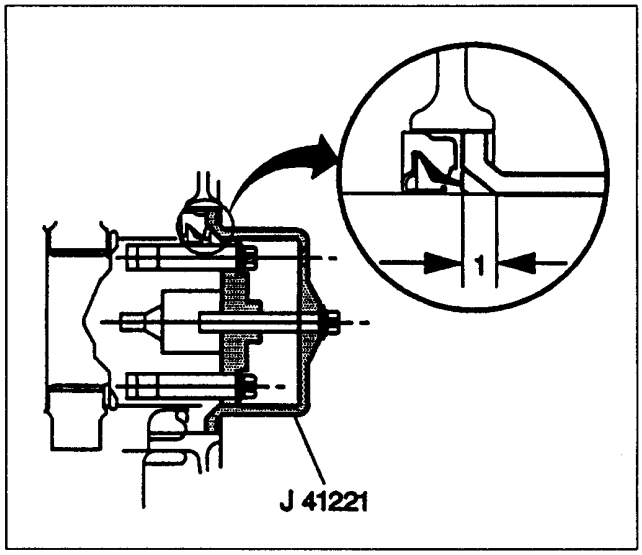


Figure 29 – Timing Marks



Legend
(1) Measuring the Depth

Figure 28 – Measuring the Installed Depth

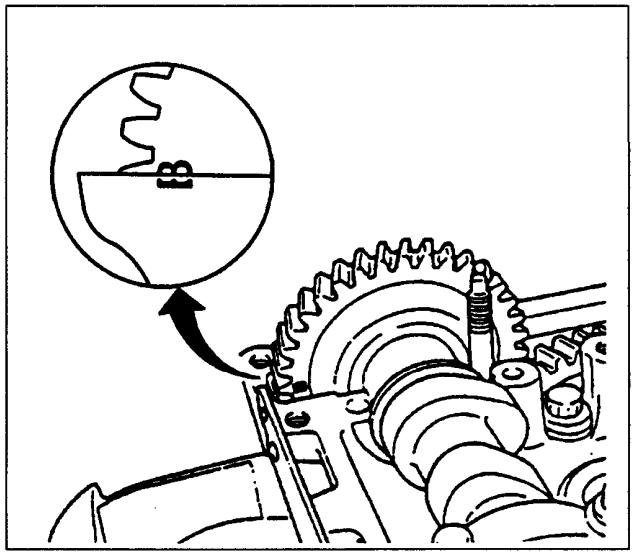


Figure 30 – Camshaft Timing Marks

D. After pressing in the oil seal, make sure that the distance between the crankshaft end surface and the oil seal is (1) 7.5 ± 0.15 mm (0.295 ± 0.006 in.).
   - Check the measurement at several different points.

3. Flywheel or clutch. Refer to SECTION 7C.
4. Transmission assembly.
   - Remove engine support.
5. Lower the vehicle.
6. Negative battery cables.
7. Lower the cab.

CAMSHAFT

Tools Required:
J 22888-D Crankshaft Sprocket Puller

Remove or Disconnect (Figures 29 through 34)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Glow plugs. Refer to SECTION 6D6.
4. Valve rocker arm cover. Refer to "Valve Rocker Arm Cover" in this section.
5. Rotate the engine to top dead center and align the timing marks on the camshaft (B).
6. Both connector on the injector and from engine harness.
7. Harness assembly.
8. Loosen the valve rocker arm adjusters, but do not remove them.
9. Loosen the valve rocker arm shaft bracket bolts evenly, starting from the outside bolts moving to the inner bolts.
10. Valve rocker arm assembly.
11. Loosen camshaft bearing cap nuts evenly starting from the outer nut moving to the inner nut.
12. Camshaft assembly with gear.

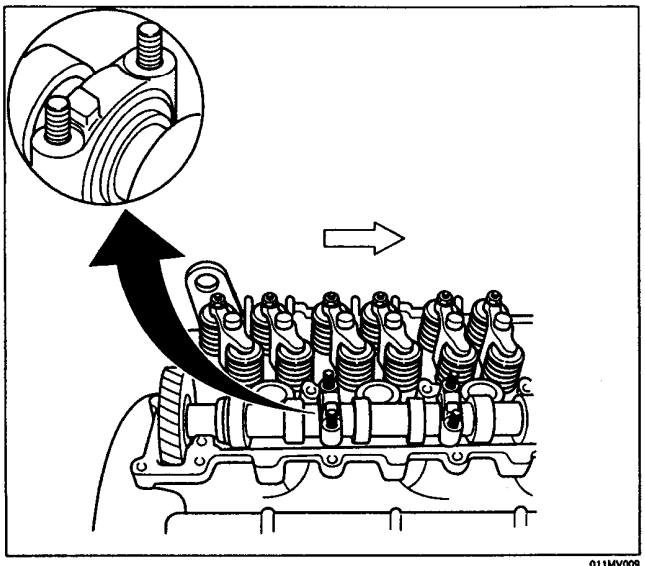


Figure 31 – Camshaft Bearing Caps Direction

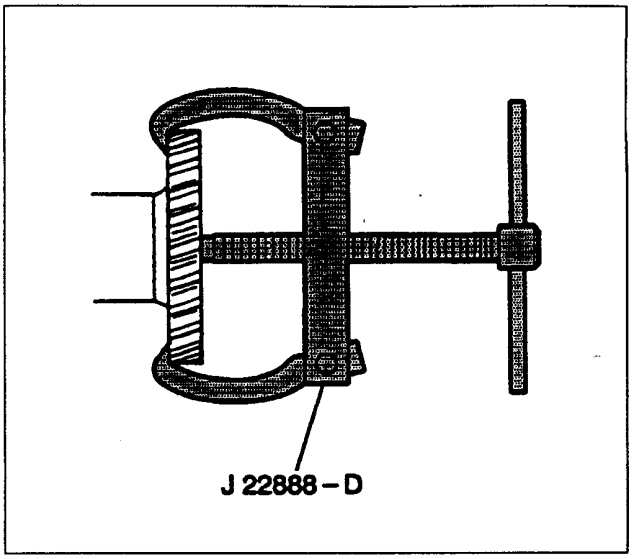


Figure 33 – Removing the Camshaft Gear

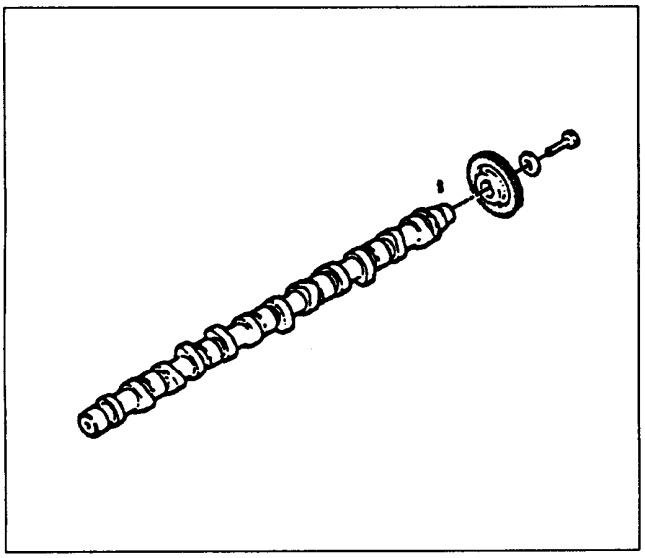


Figure 32 – Camshaft and Components

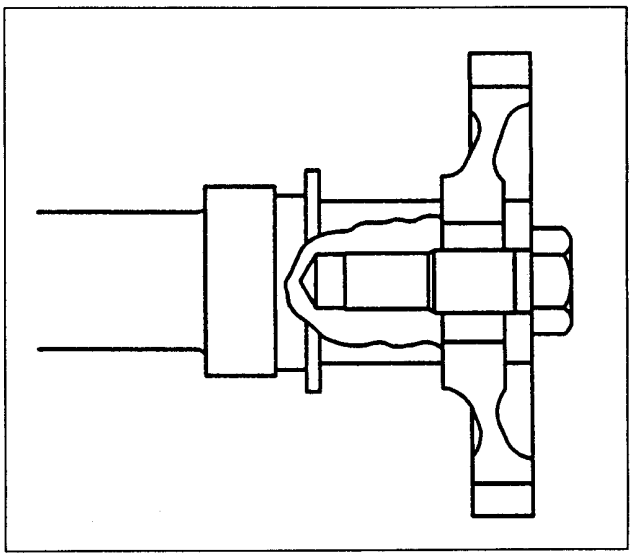


Figure 34 – Installing the Camshaft Gear

Important

- Do not remove the rocker arm shaft bracket bolts from the valve rocker arm shaft assembly.

13. Gear from the camshaft.
    - Install J22888-D on gear.
    - Remove the gear.

Clean

- Camshaft gear bore and keyway.

Inspect

- Camshaft for excessive wear on the lobes and the bearing surfaces.
- Camshaft gear for chips or broken teeth.

Measure

- Camshaft
- Refer to SECTION 6A6B in this manual for the camshaft specifications.

Install or Connect (Figures 31 and 34)

1. Gear to the camshaft.
2. Bolt to the camshaft.

Tighten

- Camshaft gear bolt to 142 N·m (105 lb. ft.).

3. Camshaft and bearing cap to the cylinder head. Refer to "Valve Rocker Arm and Camshaft" in this section.
4. Valve rocker arm assembly to the cylinder head. Refer to "Valve Rocker Arm and Camshaft" in this section.

Adjust

- Valve Rocker Arms.
- Refer to SECTION 6A6B, for the valve rocker arm adjustment procedure.

5. Valve rocker arm cover and gasket to the cylinder head.
6. Valve rocker arm cover bolts.

Tighten

- Valve rocker arm cover bolts to 13 N·m (113 lb. in.).

7. Glow plugs.
8. Negative battery cables.
9. Lower the cab.

CONNECTING ROD AND PISTON

1. Remove the engine assembly. Refer to "Engine" in this section.
2. Refer to "Engine Overhaul" in SECTION 6A6B.

CRANKSHAFT MAIN BEARING

1. Remove the engine. Refer to "Engine" in this section.
2. Refer to "Engine Overhaul" in SECTION 6A6B.

CRANKSHAFT

1. Remove the engine. Refer to "Engine" in this section.
2. Refer to "Engine Overhaul" in SECTION 6A6B.

FLYWHEEL

Remove or Disconnect (Figure 35)

1. Negative battery cables. Refer to SECTION 6D1.
2. Raise the vehicle.
3. Transmission assembly. Refer to SECTION 7A6 for automatic transmission, or SECTION 7B for manual transmission.
4. Clutch assembly, (if equipped). Refer to SECTION 7C.
5. Bolts and spacer.
6. Flywheel assembly. Refer to SECTION 7A.

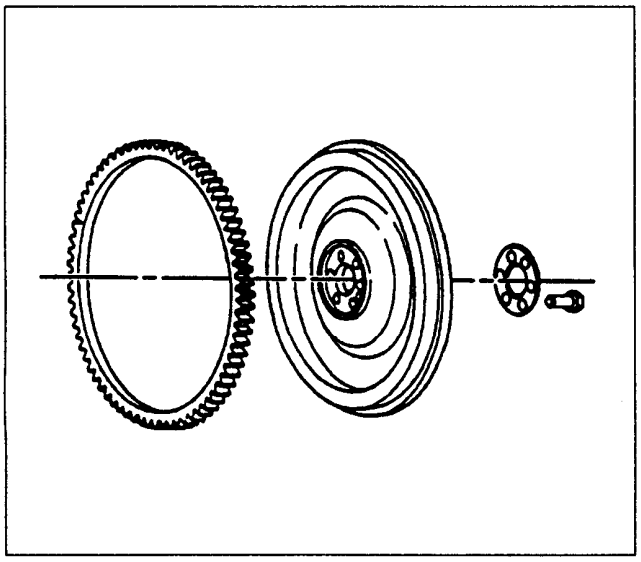


Figure 35 – Flywheel and components

Inspect

- Flywheel for burning, scoring, warping or excessive wear.
- Flywheel ring gear for worn or broken teeth.

FLYWHEEL RING GEAR

Remove or Disconnect (Figure 35)

1. Use a torch to heat the flywheel ring gear evenly.

NOTICE: ***Never heat the flywheel ring gear to red hot. This will change its metal structure and could cause damage to the ring gear or flywheel***

2. Drive the flywheel ring gear off with a hammer and a drift.
3. Heat the flywheel ring gear evenly to allow the ring gear fit on the flywheel. Do not allow the temperature exceed 120 deg C (250 deg F).
4. Ring gear to the flywheel, as soon as it is heated (Figure 36).

Install or Connect (Figure 35)

1. Flywheel to the crankshaft.
2. Bolts and spacer to the flywheel, (apply a small amount of molybdenum to the bolts). Refer to SECTION 7A, for the proper bolt tightening sequence.
3. Clutch to the flywheel.
4. Transmission assembly to the engine.
5. Lower the vehicle.
6. Negative battery cables.

ENGINE MOUNTS

Cushion-type mountings are used at both the front and the rear of the engine.

INSPECTING ENGINE MOUNTS

NOTICE: ***Broken or deteriorated mounts can cause misalignment and eventually destroy certain drive train components. Also, when a single mount breaks, the remaining mountings are subjected to abnormally high stresses, which may lead to early wear and breakage.***

Engine mounts should be inspected periodically and replaced if any damaged or deteriorated mounts are found.

Check the engine mounting brackets for cracks or elongated bolt holes. Replace the brackets if necessary. Check the mounting fasteners for the correct torque. Refer to "Specifications" at the end of this section. Inspect the rubber parts for deterioration and replace if needed.

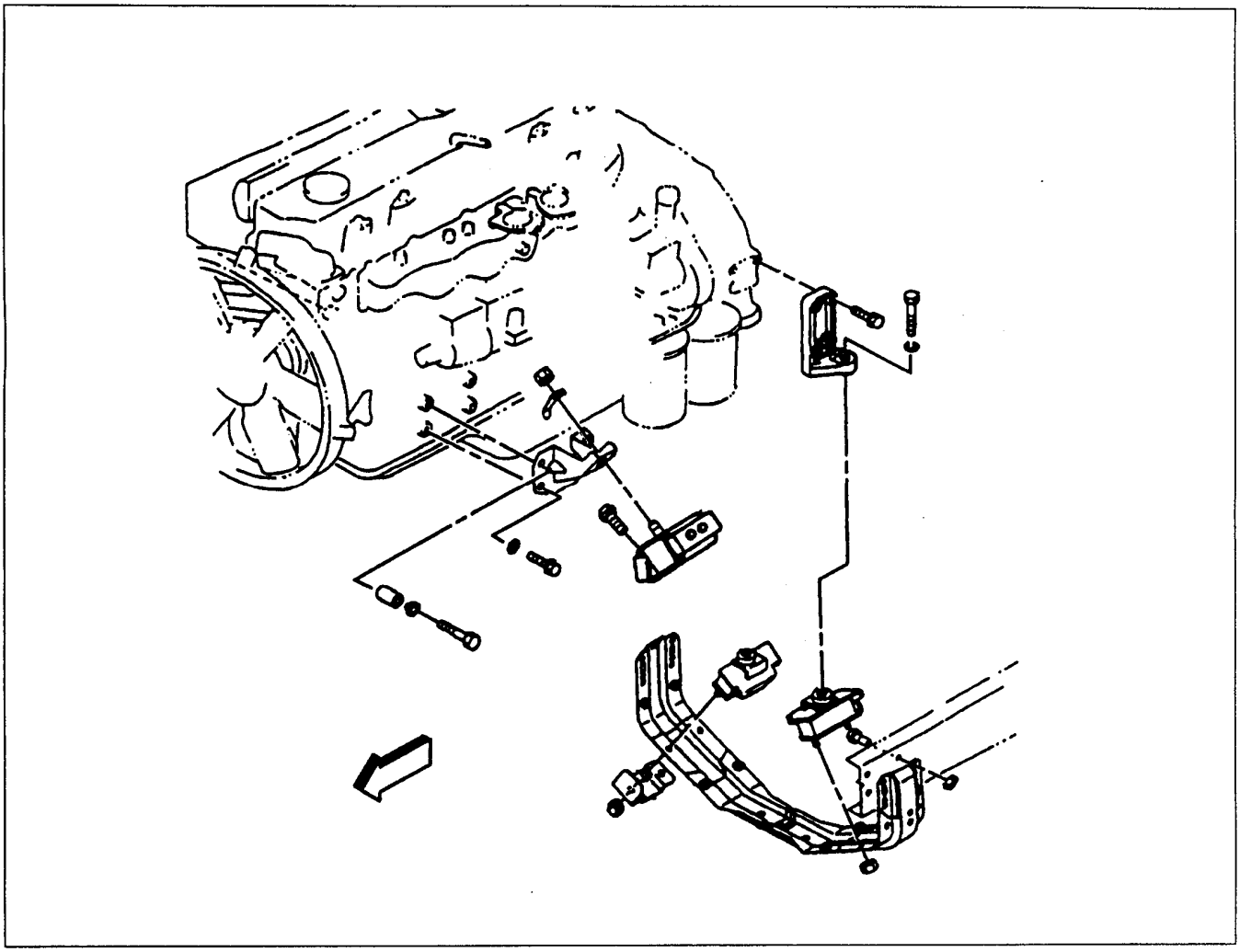


Figure 36 – Engine Mounts

FRONT ENGINE MOUNT

Remove or Disconnect (Figure 36)

NOTICE: ***When the raising or supporting the engine, do not use a jack under the oil pan, any sheet metal, or crankshaft pulley. Jacking against these parts may cause damage.***

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Engine mounting nuts and washers from the mounting bracket to the front mount.

NOTICE: ***When supporting the engine to replace a mount, raise the engine only to the height required to provide clearance for the mount removal. It may be necessary to drain the cooling system and disconnect hoses to avoid damage when the engine is raised. Be careful that control linkage and wiring are not damaged from raising the engine. When replacing a single front mount, both mounts should be detached before attempting to raise the engine. Failure to do this will place excessive stress on the attached mounts when the engine is raised.***

4. Bolts and nuts from the frame to the front mounts.
5. Raise the front of the engine.
   - Provide lifting equipment to safely support and raise the front of engine as required.
   - Raise the engine enough to permit removal of the mounting cushions.
6. Remove the front mounting cushion, spacers, washers as required.
7. Mounting bracket bolts and washers (if used).
8. Mount the front bracket to the engine, (if necessary).

Important

- Any vehicle components held in place by the engine mounting fasteners must be supported before the fasteners are removed.

Install or Connect

1. Mounting bracket to the engine, (if necessary).

Tighten

- Mount bracket bolt to 78.5 N·m (58 lb. ft.).

2. Mounting bracket bolts and washers.

Tighten

- Mounting bolts and nuts to 64 N·m (47 lb. ft.).

3. Front engine mounts to the bracket, (install nuts and washers to hold them in place).
4. Lower the engine.
5. Mounting bolts to the frame.

Tighten

- Mounting nuts to 83 N·m (61 lb. ft.).
- Mounting bolts to 36 N·m (26 lb. ft.).

6. Negative battery cables.
7. Lower the cab.

REAR ENGINE MOUNT

Remove or Disconnect (Figure 36)

1. Through bolts and the washers from both of the rear engine mount brackets.

NOTICE: ***When supporting the engine to replace a mount, raise the engine only to the height required to provide clearance for the mount removal. It may be necessary to drain the cooling system and disconnect hoses to avoid damage when the engine is raised. Be careful that control linkage and wiring are not damaged from raising the engine. When replacing a single front mount, both mounts should be detached before attempting to raise the engine. Failure to do this will place excessive stress on the attached mounts when the engine is raised.***

2. Raise the engine.
3. Rear mounting bolts and nuts.
4. Rear engine mounts from the mounting brackets.
5. Nuts and washers from the rear mounts.
6. Rear mounts from the frame rail.

Install or Connect

1. Rear mounts to the frame rail.
2. Nuts, bolts, and washers to the rear mounts and tighten.

Tighten

- Bolts and nuts to 108 N·m (80 lb. ft.).

3. Rear mounting brackets to the engine.

Tighten

- Rear mount bracket bolt to 75.5 N·m (56 lb. ft.).

4. Lower the engine.
5. Through bolts to the rear mounts.
6. Tighten through bolts.

Tighten

- Bolts to 294 N·m (217 lb. ft.).

ENGINE

NOTICE: ***If the engine is damaged internally and a new engine assembly is installed in the vehicle, make sure all foreign material is completely flushed out of the cooling system. The oil cooler system should also be flushed out (if equipped). Failure to rid the oil or cooler system of debris can result in engine damage to the replacement engine.***

The procedure required to replace an engine varies according to the optional equipment, and available shop facilities. The following procedure is intended only as a guide for performing the work. The technician must determine what additional work is needed.

It is important to note "CAUTIONS" and "NOTICES" against the use of some specific service methods that can harm personnel, damage the vehicle or make it unsafe. A technician who uses a service procedure or tools which are not recommended must be thoroughly satisfied that neither the safety of personnel, nor safety of the vehicle will be jeopardized by the service method selected.

NOTICE: ***On some vehicles it may be necessary to support the transmission as the engine is removed to prevent the transmission from falling, causing damage to the unit.***

Remove or Disconnect (Figure 36)

1. Tilt the cab. Refer to SECTION 0A.
2. Negative battery cables. Refer to SECTION 6D1.
3. Drain the cooling system. Refer to SECTION 6B.

CAUTION: If the vehicle is equipped with air conditioning, removal of refrigerant line must be done by trained personnel. Injuries can result from improper procedures.

4. Air conditioning compressor. Refer to SECTION 1B.
5. Air inlet pipes. Refer to SECTION 6J.
6. Air intake housing from the cab bridge.
7. Coolant reservoir, hose and bracket. Refer to SECTION 6B.
8. Cab bridge support. Refer to SECTION 10B.
9. Engine oil level indicator tube.
10. Power steering pump from the engine, (lay to the side). Refer to SECTION 3B.
11. Air compressor and lines, (if equipped). Refer to SECTION 5J.
12. Radiator and charge air cooler assemblies. Refer to SECTION 6B.
13. Radiator and heater hoses. Refer to SECTION 6B.
14. Engine electrical harness from the retainers and the brackets.
15. Engine electrical harness from all the electrical connectors.
16. All ground straps from the engine to the frame.
17. Engine stop and throttle cables. Refer to SECTION 6C2.
18. Fuel line and connectors from the fuel injection pump. Refer to SECTION 6C2.

Important

- Cap the fuel line and the fittings to prevent the fuel from leaking and dirt from entering the fuel system.

19. Engine tachometer drive cable.
20. Engine brake rod, (if equipped).
21. Raise the vehicle.
22. Exhaust pipe from the turbocharger. Refer to SECTION 6J.
23. Exhaust pipe from the muffler. Refer to SECTION 6F.
24. Starter assembly. Refer to SECTION 6D2C.
25. Torque converter bolts from the torque converter, (if equipped). Refer to SECTION 7A.
26. Lower the vehicle.
27. Support the transmission.
    - Use a suitable support.
28. Attach suitable overhead hoist.
29. Front engine mounting bolts.
30. Bolts from the transmission to the engine.
31. Engine from the transmission assembly. Refer to SECTION 7A6 for automatic transmission, or SECTION 7B for manual transmission.
32. Engine from the vehicle.

Install or Connect (Figure 36)

1. Engine to the transmission assembly.
2. Engine to the engine mounts.
3. Bolts from the transmission to the engine.
4. Engine mount through bolts.

Tighten

- Through bolts to 245 N·m (180 lb. ft.).

5. Front engine mount bolts.

Tighten

- Mount bolts to 36 N·m (26 lb. ft.).

6. Remove the overhead hoist.
7. Raise the vehicle.
8. Torque converter bolts to the torque converter.
9. Starter assembly.
10. Exhaust from the muffler to the turbocharger.
11. Turbocharger to the exhaust.
12. Lower the vehicle.
13. Engine stop and throttle cables.
14. Engine brake rod.
15. Engine tachometer drive cable.
16. Fuels line and connectors to the fuel injection pump.
17. Ground straps to the frame and the engine.
18. Engine electrical harness to all the connectors.
19. Engine electrical harness to the retainers and the brackets.
20. Radiator, charge air cooler and the air conditioning condenser assembly.
21. Radiator and heater hoses to the engine.
22. Air compressor and the lines.
23. Power steering pump.
24. Air conditioning compressor to the mounting bracket.
25. Engine oil level indicator tube.
26. Cab bridge.
27. Coolant reservoir, hose and the bracket.
28. Air intake housing to the cab bridge.
29. Air inlet pipes.
30. Negative battery cables.
31. Lower the cab.
32. Fill the engine cooling system with the proper type and quantity of coolant. Refer to SECTION 6B and 0B.
33. Fill the engine crankcase with the proper grade and quantity of engine oil. Refer to SECTION 0B.
34. Charge the A/C system, refer to SECTION 1B.

Important

- **Check all fluid levels before starting engine.**

THREAD REPAIR

General purpose thread repair kits are available commercially. Damaged threads may be reconditioned by drilling out, rethreading, and installing a suitable thread insert. Refer to "Engine Overhaul" in SECTION 6A6B for further information.

SPECIFICATIONS

GENERAL ENGINE SPECIFICATIONS

MODEL	6HK1-TC
Type	Inline 6, 4 stroke
Induction	Turbocharged Combustion
Combustion	Direct Injection
Bore	115 mm (4.5276 in.)
Stroke	125 mm (4.9213 in.)
Displacement	7.8L (475.1 Cu. In.)
Compression Ratio	16.8:1
Firing Order	1-5-3-6-2-4
Valve Clearance, Cold (Intake and Exhaust)	0.4 mm (0.16 in.)
Full Flow Oil Filter	Cartridge Type
Oil Capacity	14.0L (14.79 Qts) *
Oil Pressure (Minimum at an Idle)	100 kPa (14 psi)
Compression at 200 RPM (Production)	3240 kPa (469 psi)
Compression at 200 RPM (Service Limit)	2157 kPa (313 psi)
Difference between each cylinder	Less than 196 kPa (28 psi)
* Includes full flow filter, which should be changed at each oil change.	

FASTENER TIGHTENING SPECIFICATIONS

Application	N·m	Lb Ft	Lb In.
Camshaft Bearing Cap Nut	27.5	20	—
Camshaft Gear Bolt	142	105	—
Camshaft Thrust Bracket Bolt (No. 1, and No. 7)	27.5	20	—
Charge Air Pipe Bolt	37	7	—
Connecting Rod Bolt (Apply Molybdenum disulfide grease)			
First Stage	39	29	—
Second Stage	plus 60 deg	plus 45 deg	—
Third Stage	plus 30 deg	plus 30 deg	—
Crankshaft Balancer Bolt and Washer	200	148	—
Crankshaft Pulley Bolt and Washer	48	35	—
Cylinder Body Lower Crankcase (M10)	37	27	—
Cylinder Body Lower Crankcase (M14) (Apply Molybdenum disulfide grease)			
First Stage	98	72	—
Second Stage	132	98	—
Third Stage	plus 45 deg	plus 45 deg	—
Cylinder Head Bolt (M14) (Apply Molybdenum disulfide grease)			
First Stage	98	72	—
Second Stage	147	108	—
Third Stage	plus 30 deg	plus 30 deg	—
Cylinder Head Bolt (M10)	39	29	—
Engine Mounting Bolt to the Frame	36	26	—
Engine Mounting Nut to the Frame	83	61	—
Engine Mount Through Bolt	294	217	—
Exhaust Manifold Nut and Bolt	34	25	—
Exhaust Pipe Adapter to the Exhaust Manifold	52	38	—

Application	N·m	Lb Ft	Lb In.
Flywheel Bolt			
First Stage	78	58	—
Second Stage	plus 60 deg	plus 60 deg	—
Third Stage	plus 75 deg	plus 75 deg	—
Front Cover Bolt	19	14	—
Front Engine Mount Bolt	64	47	—
Glow Plug	25	18	—
Idle Gear A Bolt (Apply Molybdenum disulfide grease)	29 + 75 deg	21 + 75 deg	—
Idle Gear A Shaft Bolt	26.5	20	—
Idle Gear B Bolt	95	70	—
Idle Gear B Shaft Bolt	31.4	23	—
Idle Gear C Bolt	95	70	—
Intake Manifold Bolt	15	—	130
Oil Cooler Bolt	19	14	—
Oil Jet Bolt	21	15	—
Oil Pan Bolt	24	17	—
Oil Pump Body Bolt	24	17	—
Oil Strainer Tube Bolt (M8)	24	17	—
Oil Strainer Tube Bolt (M10)	48	5	—
Rear Engine Mounting Nut and Bolt to the Frame	108	80	—
Thermostat Housing Bolt to the Cylinder Head	19	14	—
Turbocharger Drain Line Bolt (to Block)	8	13	—
Turbocharger Drain Line Bolt (to Turbocharger)	27	20	—
Turbocharger Feed Line Bolt (to Block)	18	13	—
Turbocharger Feed Line Bolt (to Turbocharger)	18	13	—
Turbocharger to Exhaust Manifold Nut	52	38	—
Valve Rocker Arm Cover Bolt	13	—	113
Valve Rocker Arm Shaft Support Bolt (M8)	27	20	—
Valve Rocker Arm Shaft Support Bolt (M10)	56	41	—
Water Outlet Bolt (M8)	19	14	—
Water Pump Bolt and Nut	19	14	—
Water by Pass Duct Bolt (M16)	103	76	—

SPECIAL TOOLS

J22888-D Gear Puller
J36022 Air Line Adapter
J41220 Slinger Replacer
J41221 Oil Seal Remover and Installer
J41222 Crankshaft Gear Installer
J43267 Valve Stem Seal Installer
J43263 Valve Spring Compressor

BLANK

SECTION 6A6B

DIESEL ENGINE OVERHAUL

NOTICE: *Always use the correct fastener in the correct location. When you replace a fastener, use ONLY the exact part number for that application. ISUZU will call out those fasteners that require a replacement after removal. ISUZU will also call out the fasteners that require thread lockers or thread sealant. UNLESS OTHERWISE SPECIFIED, do not use supplemental coatings (paints, greases, or other corrosion inhibitors) on threaded fasteners or fastener joint interfaces. Generally, such coatings adversely affect the fastener torque and the joint clamping force, and may damage the fastener. When you install fasteners, use the correct tightening sequence and specifications. Following these instructions can help you avoid damage to parts and systems.*

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GENERAL DESCRIPTION

The ISUZU model 6HK1-TC engine is used in vehicles covered by this manual. The engine is an in line six cylinder, four stroke, water cooled, direct fuel injection, turbocharged diesel. The charge air cooler is the air to air heat exchange system using a corrugated-fin heat exchanger installed in front of the radiator.

The forged crankshaft is supported by seven precision insert main bearings. The crankshaft thrust washer is located at the number seven crankshaft main bearing.

The connecting rods have precision insert type crankshaft (big end) bearings. The piston pins are retained by snap rings. The pistons have three compression rings and one oil control ring. The pistons are cooled by oil jets. The 6HK1-TC diesel uses dry cylinder liners. The liners have been phosphated (P- Mn method), both inside and outside for long life.

The camshaft is supported by seven plain bearings. The camshaft is gear driven. Motion is transferred to the overhead valves by shaft type roller valve rocker arms.

The cylinder head may be rebuilt, with new valve guides and seats.

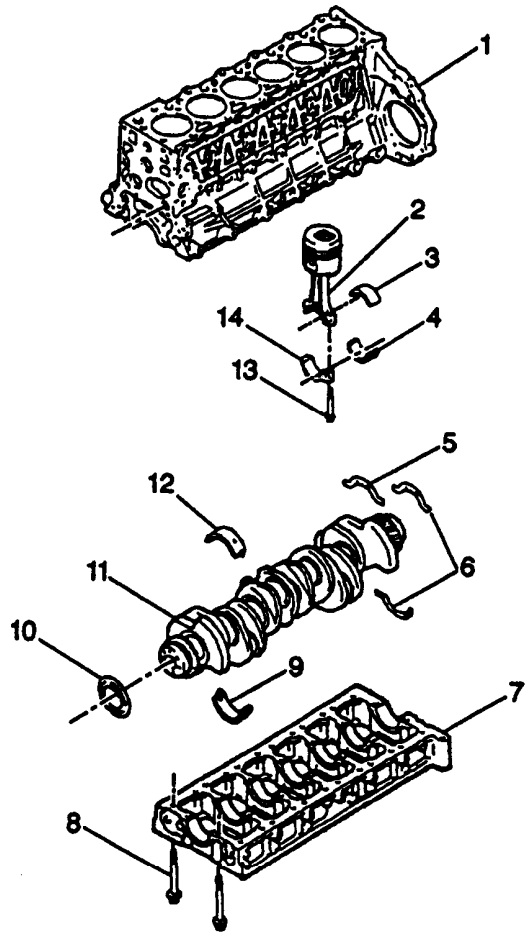
ENGINE IDENTIFICATION

The engine used in this vehicle is a 7.8L (475 CID).

The engine identification number is on the front right hand side (passenger) of the cylinder block. For further information, refer to "GENERAL INFORMATION" in SECTION 0A.

ENGINE LUBRICATION

A gear type oil pump is used. The engine is equipped with both full flow filter. An oil cooler is provided to help control oil temperatures. Major moving parts are supplied with oil from a larger oil gallery in the cylinder block.



(1) Cylinder Block
(2) Piston and Connecting Rod
(3) Upper Connecting Rod Bearing
(4) Lower Connecting Rod Bearing
(5) Thrust Washer
(6) Thrust Washer
(7) Lower Crankcase
(8) Crankshaft Bolt
(9) Lower Crankshaft Main Bearing
(10) Oil Slinger
(11) Crankshaft
(12) Upper Crankshaft Main Bearing
(13) Connecting Rod Bolt
(14) Connecting Rod Cap

Figure 1 — Cylinder Block and Components

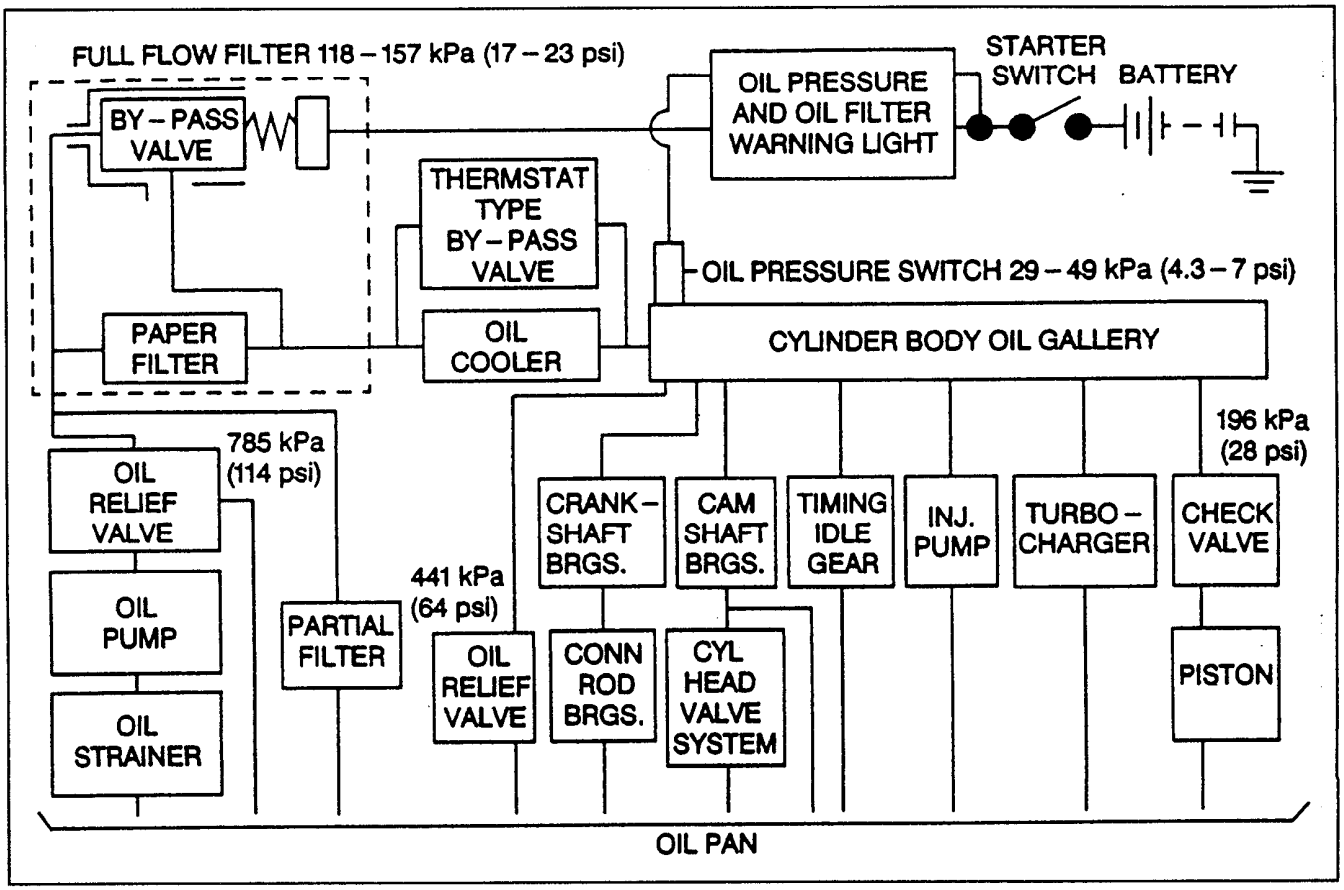


Figure 2 — Lubrication System

DISASSEMBLY OF THE ENGINE

TOOLS AND SHOP EQUIPMENT

A clean well-lit work area should be available. Other necessary equipment includes: a suitable parts cleaning tank, compressed air supply, trays to keep parts and fasteners organized, and an adequate set of hand tools.

An approved engine repair stand will aid the technician and help to prevent personal injury or damage to the engine components.

Special tools are listed and illustrated throughout this section. A complete listing is at the end of this section. These tools (or their equivalents) are specially designed to quickly and safely accomplish the operations for which they are intended. The use of these tools will also minimize possible damage to engine components.

Some precision measuring tools are required for inspection of certain critical components. Torque wrenches are necessary for the correct assembly of various parts.

ACCESSORY REMOVAL

This manual takes into consideration that the engine accessories have been removed. These accessories may include one or more of the following:

- Power Steering Pump
- Air Conditioning Compressor
- Generator
- Air Compressor (for air brakes)
- Starter Motor
- Hydraulic Pump (for hydraulic brakes)
- Drive Belts
- Engine Cooling Fans and Clutch

Diagrams of emissions and vacuum hose routings, wiring harness routing, accessory drive belts layout, etc., should be made before removing accessories.

CLEANING

NOTICE: ***Clean the engine only when it is cold, and never when the engine is running. Spraying or pouring water or other fluids on the engine when it is warm or hot, or when it is running, can cause serious damage to the engine and its components.***

Remove the engine accessories before cleaning to provide better access to the engine exterior surfaces. Cover all openings to the engine, after any engine control units such as, air inlet pipes, glow plugs, turbocharger etc., have been removed. Methods used to clean the engine will depend on what is available. Steam cleaning, pressure washing, or solvent cleaning are some of the acceptable methods. Allow the engine to dry before beginning any of the repair work. It is important that the engine be as clean as possible to prevent dirt from entering critical areas during disassembly.

DRAINING THE ENGINE

Remove or Disconnect

1. Oil pan drain plug.
2. Oil filter.
   - Allow the oil to drain into the proper container.
3. Coolant drain plugs from the engine block.
   - Allow the coolant to drain into the proper container.

Install or Connect

1. Oil drain plug to the oil pan.
2. Coolant drain plugs to the engine block.

FLYWHEEL REMOVAL

For service of the flywheel, refer to SECTION 7A6.

INTAKE MANIFOLD REMOVAL

Remove or Disconnect

1. Fuel injection lines from the fuel injectors.
2. Fuel lines from the fuel filter to the fuel injection pump.
3. Fuel injector return lines from fuel injectors.
4. Coolant pipe and bracket.
5. Fuel line from fuel injection pump to fuel common rail.
6. Fuel common rail.
7. Intake manifold bolts
8. Intake manifold with the gasket.

EXHAUST MANIFOLD REMOVAL

Remove or Disconnect

1. Turbocharger drain pipe with gasket.
2. Oil feed pipe.
3. Turbocharger assembly. Refer to SECTION 6J.
4. Front exhaust pipe.
5. Exhaust manifold nuts, bolts, washers and the spacers.
6. Exhaust manifold with the gasket.

GLOW PLUG REMOVAL

Remove or Disconnect

1. Glow plugs from the cylinder head. Refer to SECTION 6D6.

FUEL INJECTION PUMP REMOVAL

Remove or Disconnect

1. Fuel injection pump from the engine. Refer to SECTION 6C2.

THERMOSTAT HOUSING/THERMOSTAT REMOVAL

Remove or Disconnect

1. Bolts from the thermostat housing.
2. Thermostat housing from the cylinder head.
3. Both thermostats and the gasket from the cylinder head.

VALVE ROCKER ARM COVER REMOVAL

Remove or Disconnect

1. Bolts from the valve rocker arm cover.
2. Valve cover and gasket from the cylinder head.

NOTICE: Do not pry on the valve rocker arm cover. Damage to the sealing surfaces may result.

VALVE ROCKER ARM ASSEMBLY AND CAMSHAFT ASSEMBLY REMOVAL

Remove or Disconnect

1. Both connector on the top of injectors and from engine harness.
2. Harness assembly.
3. Lower case.
4. Loosen all the valve adjusters, but do not remove.
5. Loosen the valve rocker arm shaft bracket bolts evenly, starting from the outer bolts moving to the inner bolts.

Important

- Do not remove the rocker arm shaft bracket bolts from the valve rocker arm shaft assembly until the assembly has been removed from the engine.

6. Valve rocker arm assembly.
7. Loosen camshaft bearing cap nuts evenly, starting from the outer nut moving to the inner nut.
8. Camshaft assembly.

CYLINDER HEAD ASSEMBLY REMOVAL

Remove or Disconnect

1. Cylinder head from the cylinder block.

WATER PUMP REMOVAL

Remove or Disconnect

1. Bolts from the water duct.
2. Water duct and O-ring from the water pump.
3. Bolts from the water pump.
4. Water pump assembly with the gaskets.

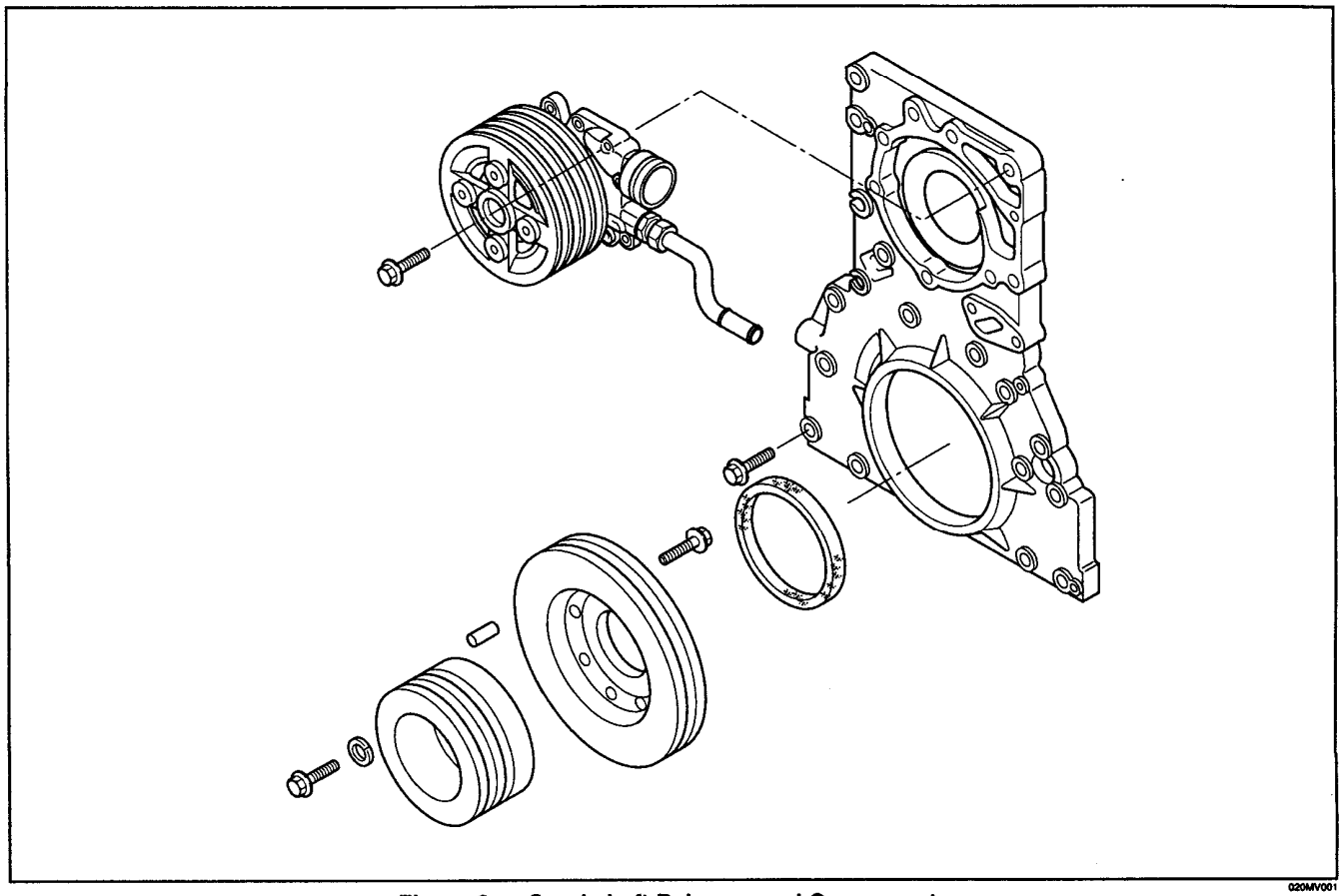


Figure 3 — Crankshaft Balancer and Components

CRANKSHAFT BALANCER REMOVAL

Remove or Disconnect (Figure 3)

1. Bolts and washers from the crankshaft pulley.
2. Crankshaft pulley from the crankshaft.
3. Bolt and washer from the crankshaft.
4. Crankshaft balancer from the crankshaft.

FRONT COVER REMOVAL

Remove or Disconnect (Figure 3)

1. Bolts and washers from the front cover.
2. Front cover from the engine.
3. Seal and gasket from the front cover.

OIL PAN REMOVAL

Remove or Disconnect (Figure 4)

1. Engine oil level indicator.
2. Bolts, nuts and the washers from the oil pan.
3. Oil pan and the gasket from the engine block.

FLYWHEEL HOUSING REMOVAL

Remove or Disconnect

1. NE sensor.
2. Flywheel
3. Cover drive gear power steering pump.
4. Drive gear power steering pump.
5. Bolts from the flywheel housing.
6. Flywheel housing from the engine.

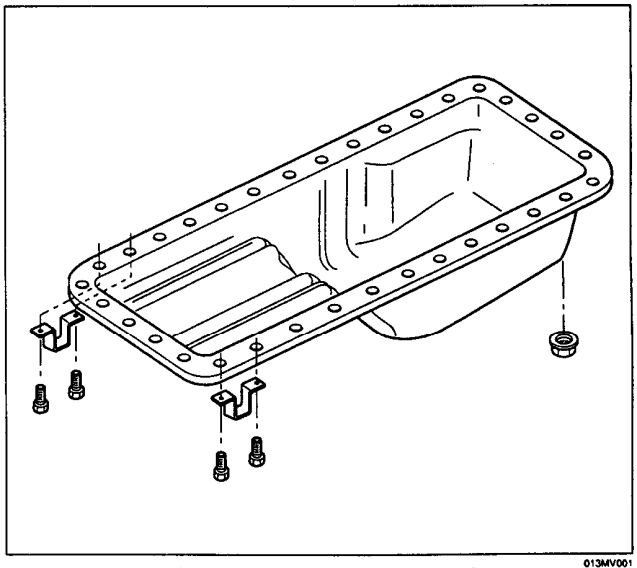


Figure 4 — Oil Pan Removal

OIL PUMP REMOVAL

Remove or Disconnect

1. Oil pick up tube and the O-ring.
2. Oil slinger from the crankshaft. Refer to "CRANKSHAFT REAR SEAL" in SECTION 6A6.

Important

- Do not damage the crankshaft when removing the oil slinger.

3. Idler gears with the shafts from the cylinder block.
4. Oil pump with the drive gear from the cylinder block.

PISTON AND CONNECTING ROD REMOVAL

Remove or Disconnect (Figure 5)

1. Bolts from the connecting rod.
2. Piston and connecting rod from the cylinder.

Important

- The connecting rods and caps are marked from the factory so they can be returned to the proper cylinder. Replacement connecting rods and caps are not marked. They must be marked after installation.

CYLINDER LINER REMOVAL

Remove or Disconnect (Figure 6)

1. Rotate the crankshaft so the journal is just below TDC.
2. Cylinder liner from the block, using wooden or plastic hammer.

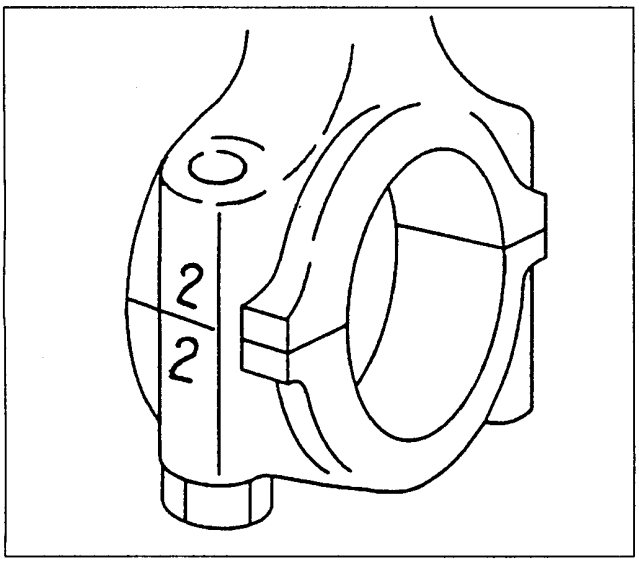


Figure 5 — Connecting Rod Markings

CRANKSHAFT REMOVAL

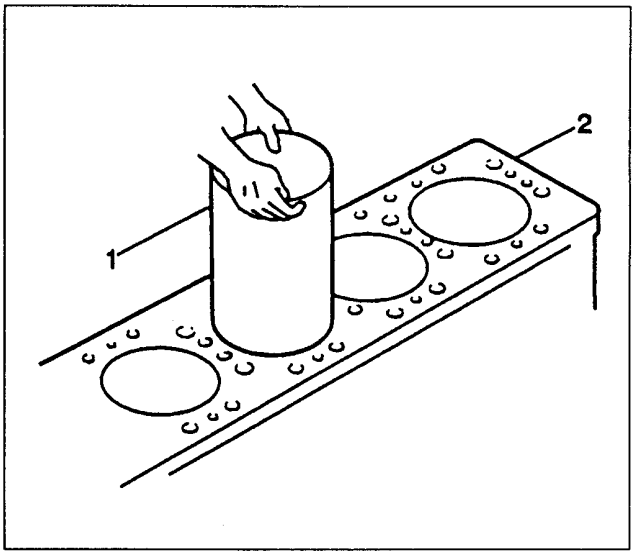
Remove or Disconnect (Figure 1)

1. Loosen the lower crankcase body bolts (marked M14) evenly.
2. Loosen the lower crankcase bolts (marked M10) evenly from the outer bolts to the inner.
3. Crankshaft from the lower crankcase cylinder block.
4. Crankshaft main bearings and thrust washers from the lower crankcase.

OIL JET REMOVAL

Remove or Disconnect (Figure 7)

1. Bolt from the cylinder block.
2. Oil jet and washers from the cylinder block.



Legend
(1) Cylinder Liner
(2) Cylinder Block

Figure 6 — Cylinder Liner Removal

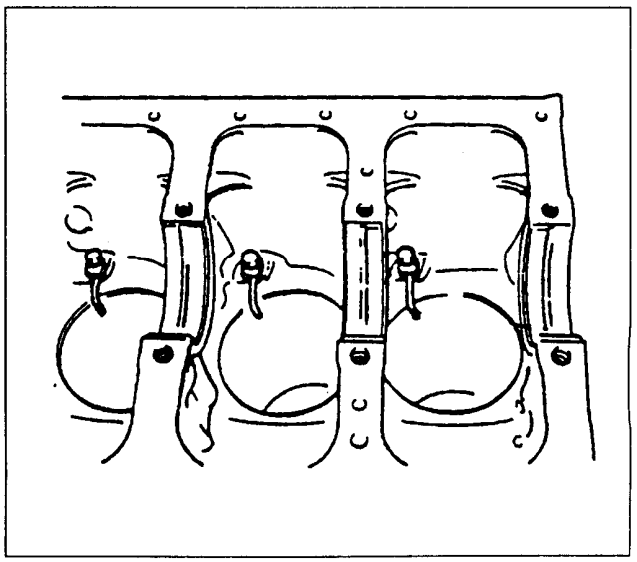


Figure 7 – Oil Jet Removal

CLEANING, INSPECTION, AND REPAIR

You will need a solvent tank large enough to hold the larger engine parts, along with various bristle brushes and a gasket scraper. A source of compressed air will be helpful in the cleaning operations.

Precision measuring tools will be required for the inspection procedure. These include: micrometers, cylinder bore gauge, feeler gauge, dial indicators sets, etc. It is very important that the inspection work be performed with the proper method and tools. The rebuilt engine cannot be expected to perform properly, if any of the parts are worn beyond their serviceable limits.

ENGINE BLOCK

The cylinder block needs to be inspected thoroughly to determine if it is reusable. Before the cylinder block inspection can be performed, it should be stripped of all coolant plugs and oil gallery plugs. To prevent dirt from being stuck into the oil bypass valves, they must be removed before the cylinder block can be cleaned.

OIL FILTER AND CYLINDER BLOCK PLUG REMOVAL

Remove or Disconnect (Figure 8)

1. Oil pipe.
2. Oil filter assembly.
3. Cup plugs and the block heater (if equipped).
4. Oil gallery plugs (if equipped).

CYLINDER BLOCK CLEANING

Clean

1. Block into the solvent.
2. Gasket from the sealing surfaces.
   - Use only the proper cleaning solvent when removing old gasket material.
3. Blow compressed air through all oil passages. Wear protective safety glasses and gloves.
4. Scale deposits from the coolant passages.
5. Crankshaft.

CYLINDER BLOCK INSPECTION

Inspect

1. Cylinder block for cracks and wear.
   - Coolant jackets
   - Crankshaft bearing webs
   - Engine mounting bosses
   - Thrust washer mating surfaces on cylinder block and lower crankcase.

Measure (Figure 9 through 11)

2. Cylinder block for warpage.
   - Use a straight edge and a feeler gauge to measure the four sides and the two diagonals of the cylinder block. If the measured values exceed the 0.2 mm (0.008 in.)., the cylinder block must be replaced.
3. Crankshaft bearing bores (cylinder block and lower crankcase).
4. Use an inside micrometer and measure the crankshaft bearing inside diameter.
   - Subtract the crankshaft main bearing journal diameter from the crankshaft main bearing inside diameter to obtain the proper clearances.
   - No. 4 crankshaft main bearing journal: 81.875 to 81.895 mm.(3.2234 to 3.2242 in.).
     — Production: 0.093 to 0.124 mm (0.0037 to 0.0049 in.).
     — Service Limit: 0.14 mm (0.0055 in.).
   - All other crankshaft main bearing journals:
     — Production: 0.063 to 0.094 mm (0.0025 to 0.0037 in.).
     — Service Limit: 0.14 mm (0.0055 in.).

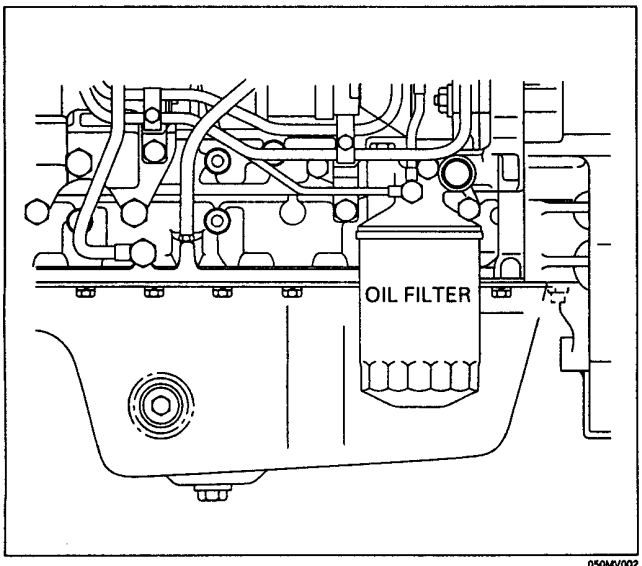


Figure 8 – Oil Filter

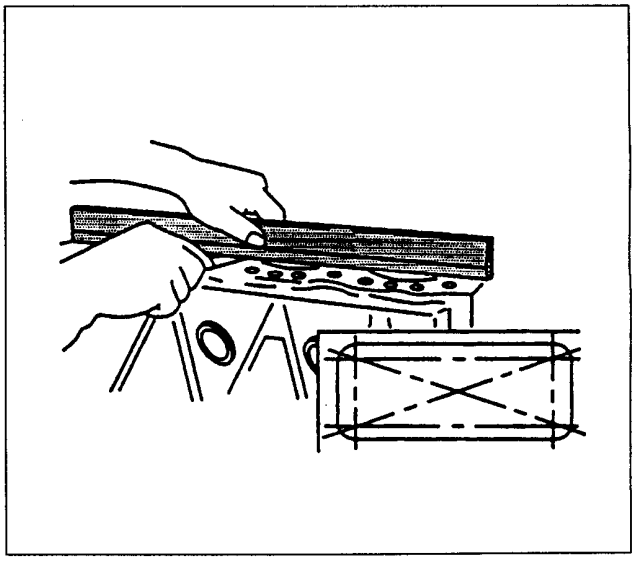


Figure 9 – Checking Cylinder Block for Warpage

CRANKSHAFT INSPECTION

Tools Required:
J22888-D Gear Puller
J41222 Timing Gear Installer

Inspect

1. Crankshaft.
   - Crankshaft for cracks
   - Crankshaft main bearing surfaces
   - Crankshaft thrust washer surfaces for excessive wear
   - Crankshaft timing gear for chipped or broken teeth

Measure (Figures 11 through 14)

1. Crankshaft main bearing journals.
   - No. 4 crankshaft main bearing journal: 81.875 to 81.895 mm.(3.2234 to 3.2242 in.).
   - All other crankshaft main bearing journals: 81.905 to 81.925 mm.(3.2246 to 3.2254 in.).
2. Crankshaft for run out.
   - Mount the crankshaft between centers or on V blocks and check.
   - Run out should not exceed 0.45 mm (0.0177 in.).
3. Crankshaft connecting rod journals at two different points on the journal.
   - Connecting rod bearings journals should be: 72.902 to 72.922 mm (2.8702 to 2.8709 in.).
   - If the crankshaft does not meet specifications, it should be replaced.

Important

- Replace the crankshaft or the main bearing inserts or both, to obtain the proper clearances.

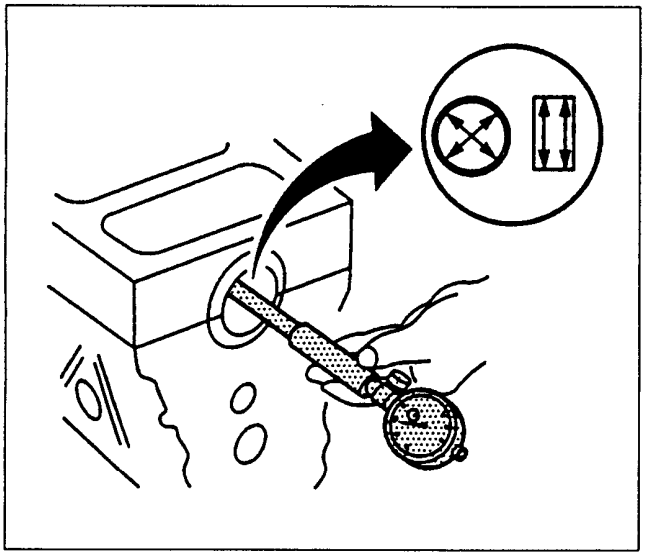


Figure 10 – Measuring Crankshaft Journal Inside Diameter

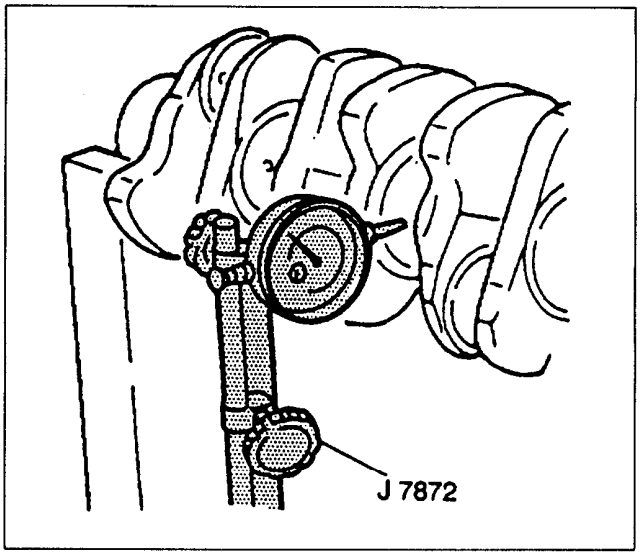


Figure 12 Measuring Crankshaft Run Out

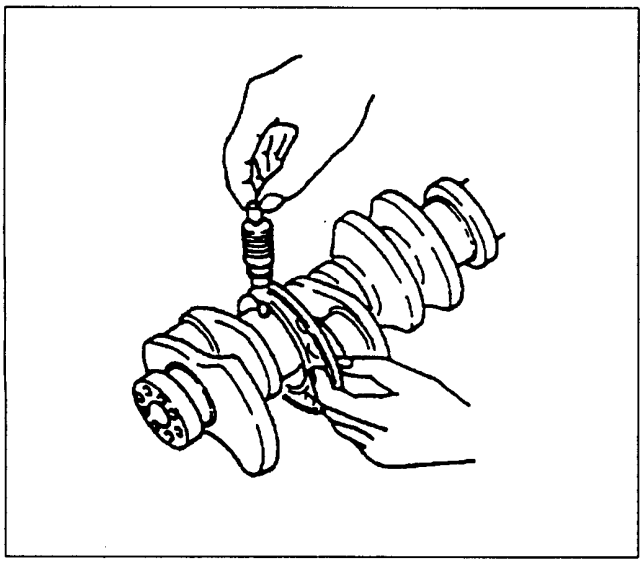


Figure 11 – Measuring Crankshaft Main Journal

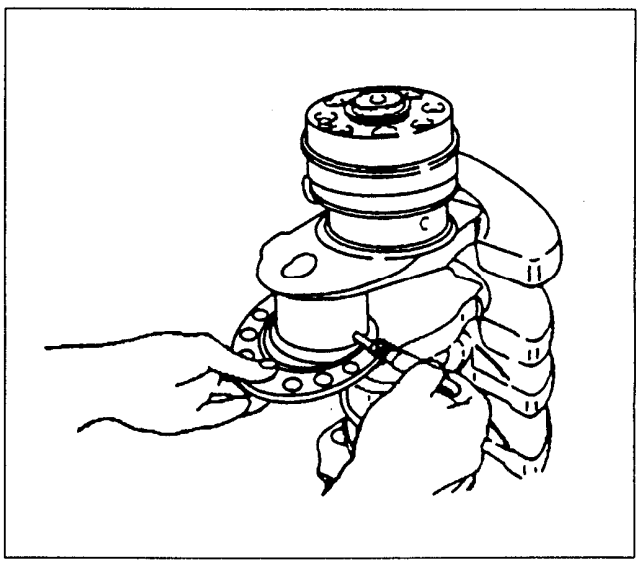


Figure 13 – Measuring Connecting Rod Journal

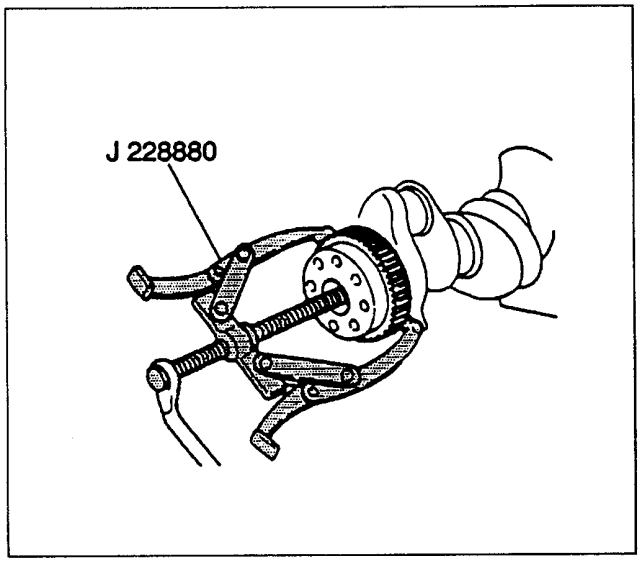


Figure 14 – Crankshaft Timing Gear Removal

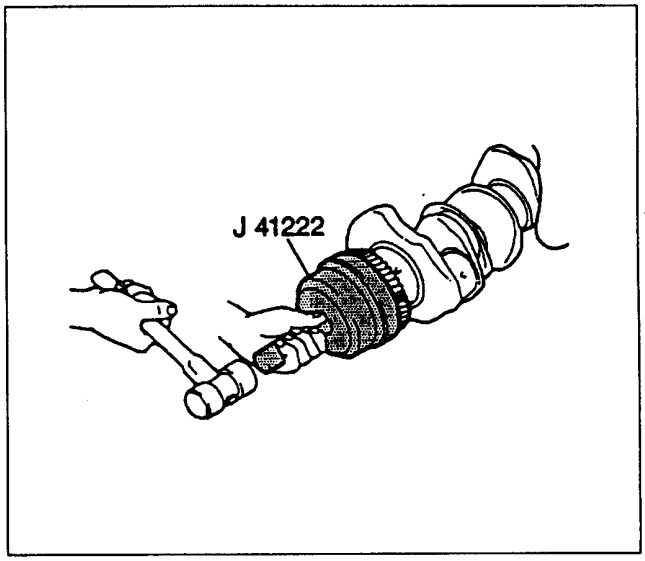


Figure 15 – Crankshaft Timing Gear Installation

CRANKSHAFT TIMING GEAR INSPECTION AND REPLACEMENT

Tools Required:
J22880 Gear Puller
J41222 Gear Installer

Remove or Disconnect (Figure 14)

1. Install tool J22880 on the crankshaft timing gear.
2. Crankshaft timing gear from the crankshaft.

Install or Connect (Figure 15)

1. Crankshaft timing gear to the crankshaft.
2. With tool J41222, install crankshaft timing gear on the crankshaft.

Important

- When installing crankshaft timing gear, make sure that the timing mark is facing away from the cylinder block.

OIL PUMP INSPECTION AND REPAIR

Disassembly and Inspection (Figure 16 through 20)

1. Driven gear and shaft (6) from the oil pump body (2).
2. Cotter pin (4) from the oil pump (4).
3. Oil relief valve (3) from the oil pump (3).
4. Oil pump drive gear (1).
   - Use a gear puller to remove the oil pump drive gear.
5. Drive gear (5).

Clean

- Clean all parts in solvent.
- Blow the parts dry with compressed air. Wear protective safety glasses and gloves.

Inspect

- Oil pump body (2) for cracks or damage.
- Gears (5 and 6) for pitting and wear.

Measure

- Gear tooth to wall clearance.
- Clearance must not exceed 0.3 mm (0.012 in.).
- Gear end clearance.
- Clearance must not exceed 0.2 mm (0.08 in.).

Important

- If the clearances are excessive, replace the oil pump as an assembly.

Measure

- For drive gear shaft (1) and oil pump body clearance.
- Use a micrometer to measure the drive gear shafts.
- The measurement should be: 15.9 mm (0.626 in.).
- Use an inside micrometer to measure the oil pump body inside diameter (2).
- Use an inside micrometer to measure the cylinder block body bushing (1) for the oil pump.
- If the clearance between the gear shaft and the oil pump body or the cylinder block bushing exceeds. 0.2 mm (0.008 in.)., both the oil pump and or the cylinder block bushing may have to be replaced.

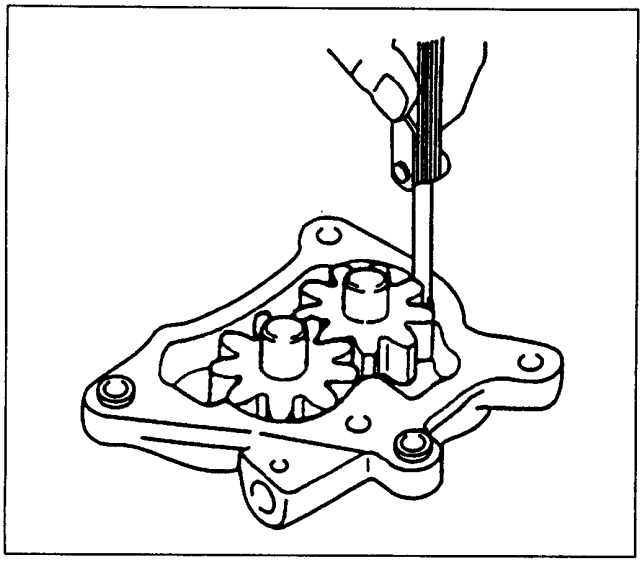


Figure 16 – Measuring Gear to Wall Clearance

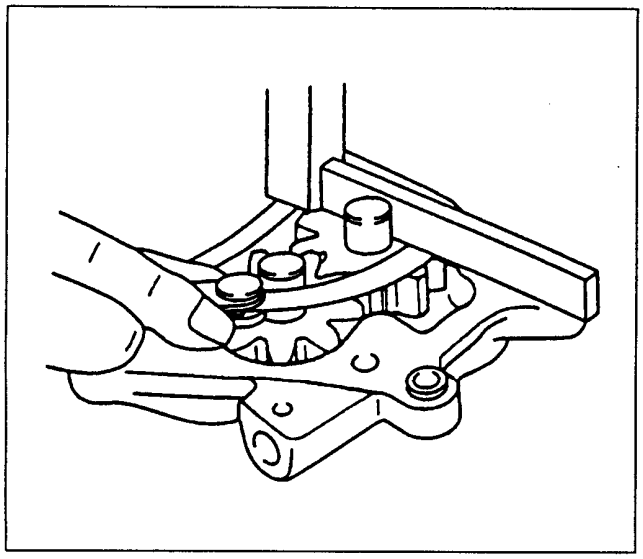
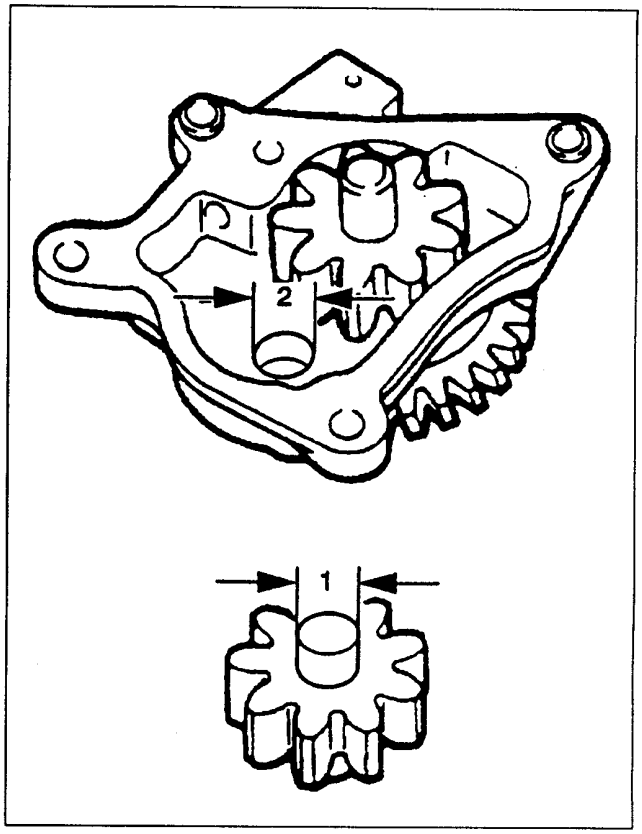
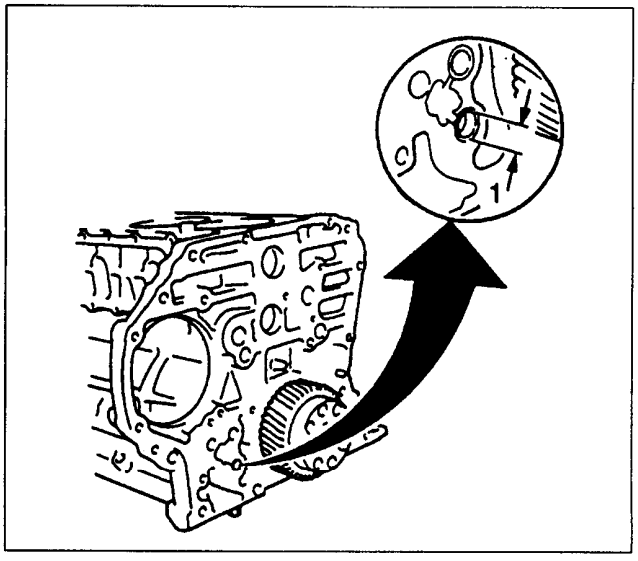


Figure 17 – Measuring Gear End Clearance



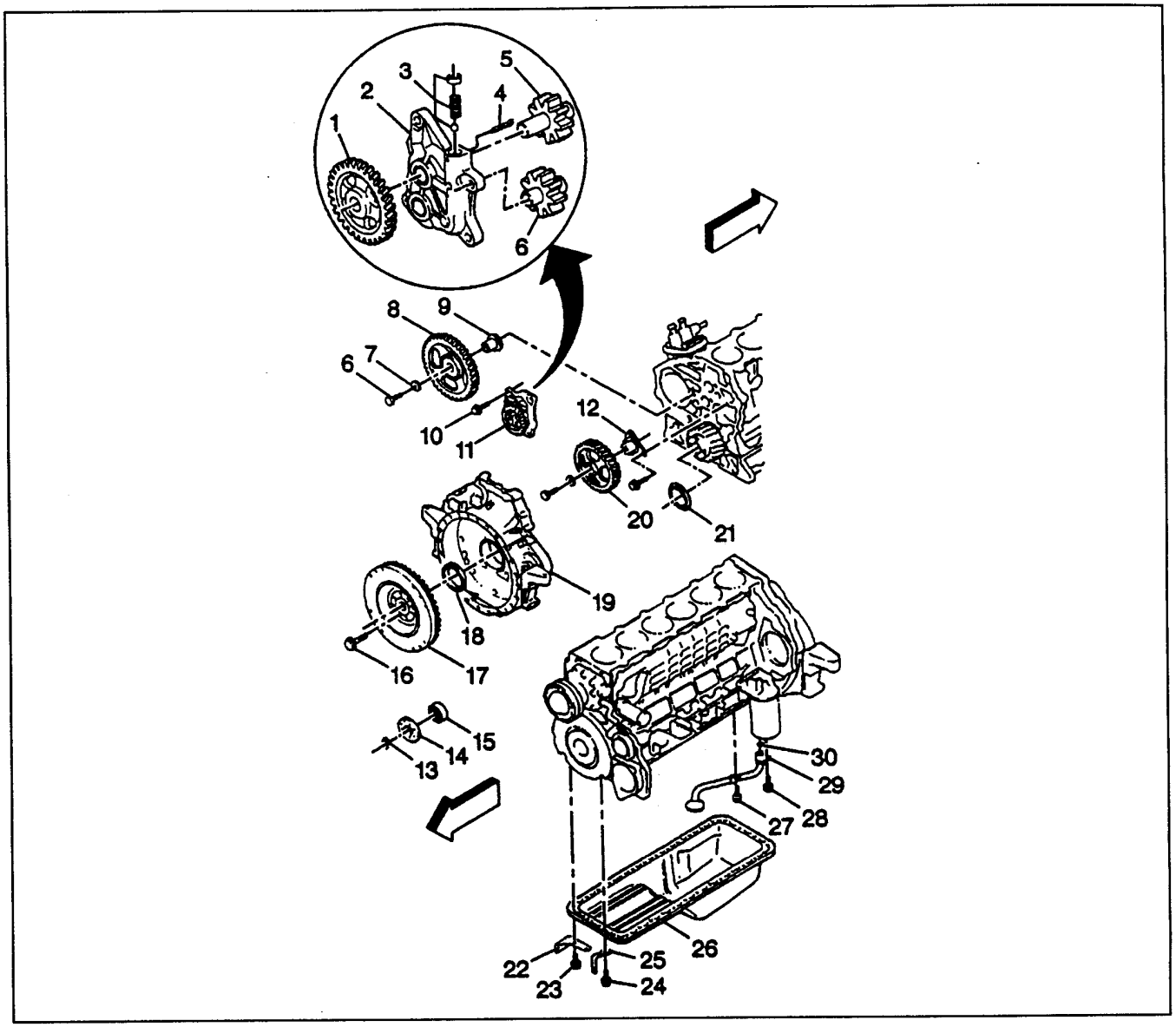
Legend
(1) Drive Gear Shaft
(2) Driven Gear Bushing

Figure 18 — Oil Pump Body Clearance



Legend
(1) Oil Pump Cylinder Block Bushing

Figure 19 — Cylinder Block Oil Pump Bushing Clearance



Legend

(1) Oil Pump Drive Gear
(2) Oil Pump Body
(3) Oil Pump Relief Valve Assembly
(4) Cotter Pin
(5) Drive Gear
(6) Driven Gear and Shaft
(7) Washer
(8) Idler Gear A
(9) Idler Gear Shaft
(10) Oil Pump Mounting Bolt
(11) Oil Pump Assembly
(12) Idler Gear B Shaft
(13) Snap Ring for Pilot Bearing
(14) Spacer
(15) Pilot Bearing
(16) Crankshaft Bolt
(17) Flywheel
(18) Crankshaft Rear Oil Seal
(19) Flywheel Housing
(20) Idler Gear B
(21) Oil Slinger
(22) Bracket
(23) Bolt
(24) Bolt
(25) Bracket
(26) Oil Pan
(27) Bolt for Oil Pick Up Tube
(28) Bolt for Oil Pick Up Tube
(29) Oil Pick Up Tube
(30) O-ring for Oil Pick Up Tube

Figure 20 — Oil Pump and Components

Reassemble (Figure 20)

1. Apply clean engine oil to the drive gear (5).
2. Install the oil pump drive gear to the drive gear (5).
   - When installing the drive gear (1), make sure that the large hub side of the gear is facing away from the oil pump body (2).
   - Use a bench press to press the drive gear on to the drive gear shaft.
3. Oil relief valve assembly (3) into the oil pump body (2).
4. Cotter pin (4) to the oil pump body (2).
5. Apply clean engine oil to the drive gear and drive gear shaft.
6. Driven gear and shaft (6) to the oil pump body (2).

IDLER GEAR INSPECTION AND REPLACEMENT

Tools Required:
J7872 Dial Indicator With Magnetic Base
J26900 Micrometer

Measure (Figures 21 and 22)

1. Idler gear end play.
   - If the measurement is greater than 0.2 mm (0.008 in.)., the idler gear and or hub should be replaced.
2. Idler gear backlash.
   - With dial indicator J7872, rest the plunger on the teeth of the idler gear. Zero the gauge and rock the idler gear back and forth to read the gear backlash. If the reading is more than 0.3 mm (0.012 in.)., replace the worn gear or gears.

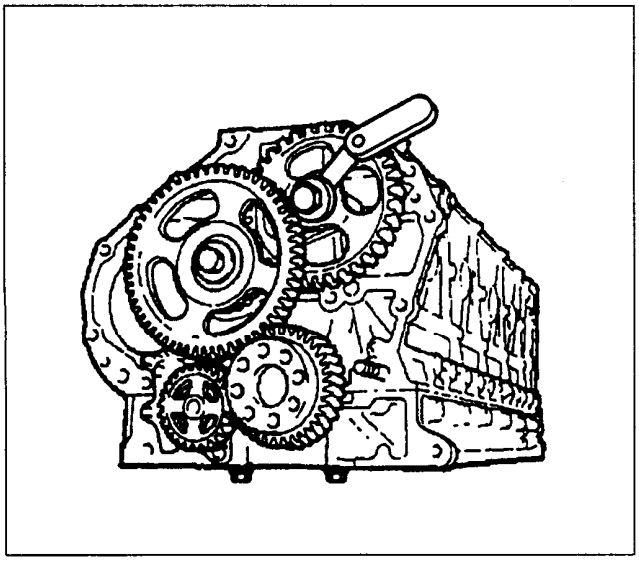


Figure 21 – Measuring the Idler Gear End Play

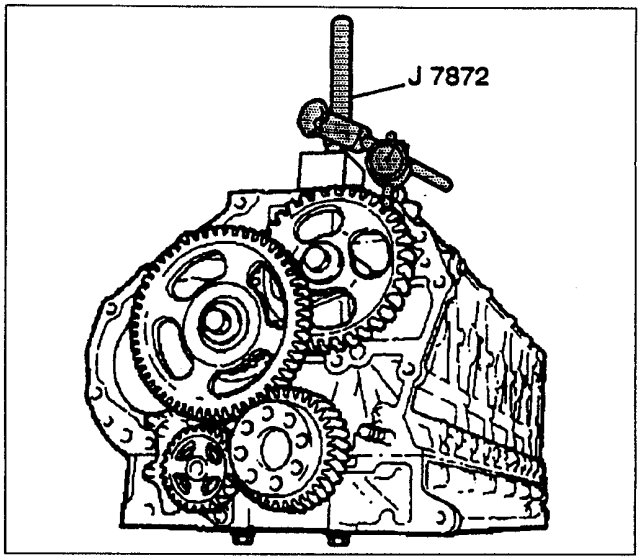


Figure 22 – Measuring the Idler Gear Backlash

Disassemble (Figures 23 and 24)

1. Rotate the crankshaft until the timing marks are aligned.
2. Bolt and washer from the idler gear.
3. Idler gear from the hub.
4. Mounting bolts from the hub.
5. Hub from the cylinder block.

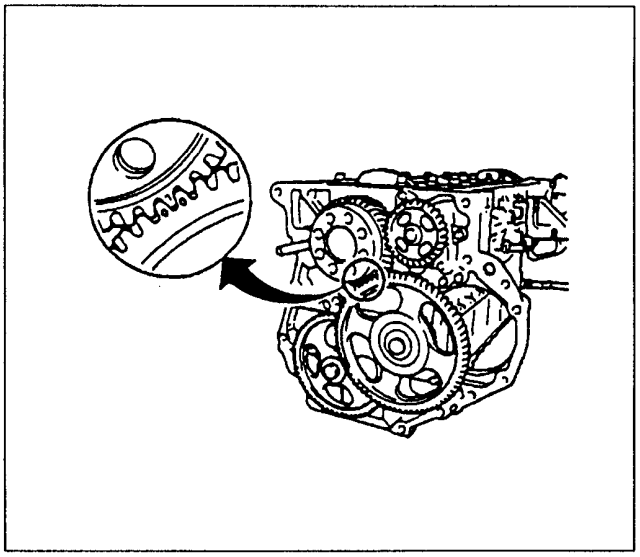


Figure 23 – Alignment of Timing Marks

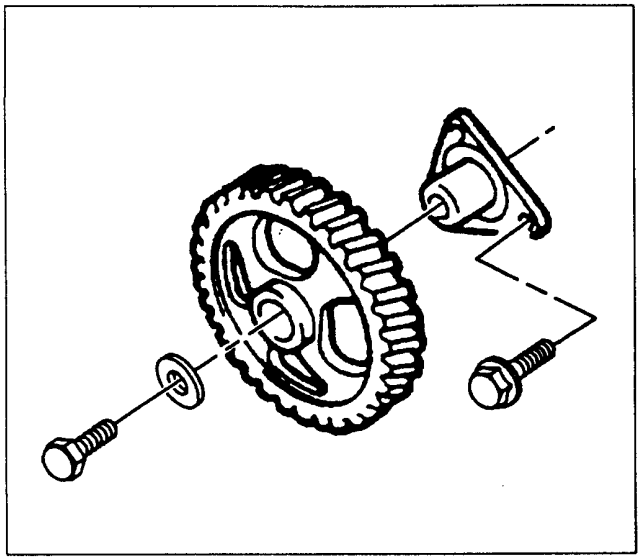


Figure 24 – Idler Gear and Hub

Inspect

- Gear teeth for chips or excessive wear.
- Gear bushing for scoring or damage.
- Hub for scoring or damage.

Measure (Figures 25 and 26)

- Measure the idler gear hub with tool J26900 .
- Measure the idler gear bushing inside diameter, using an inside diameter micrometer.
- Subtract the hub outside diameter from the idler gear bushing inside diameter to obtain the hub to idler gear bushing clearance.
  - — Production clearance is: 0.02 to 0.062 mm (0.00078 to 0.0024 in.).
  - — Service limit: 0.2 mm (0.0079 in.).
- If the clearance is excessive, replace the hub or gear as required. The bushing is not available separately.

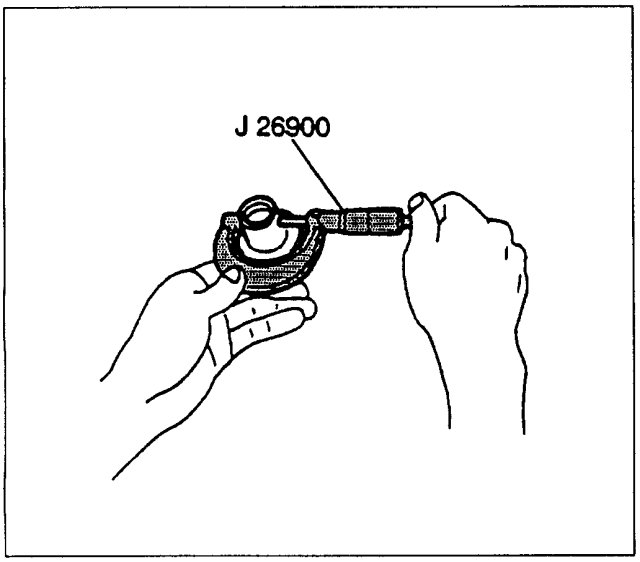


Figure 25 – Measuring the Hub Outside Diameter

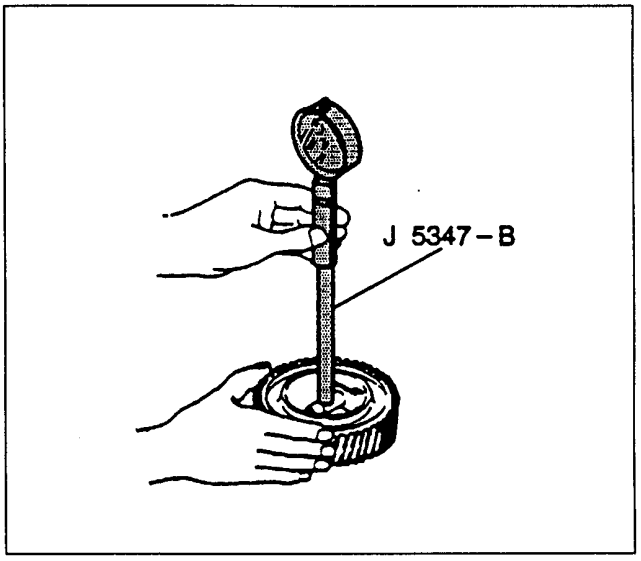


Figure 26 – Measuring Idler Gear Inside Diameter

PISTON, CONNECTING ROD AND CYLINDER LINER ASSEMBLIES

Remove or Disconnect (Figures 27 through 32)

1. Piston rings from the piston.
2. Snap rings from the piston pin.
3. Piston pin from the piston.
   - Heat the piston if necessary to aid in the piston pin removal. Do not drive the piston pin out.

Clean

- Piston and rings in cleaning solvent. Do not use a wire brush on the piston, damage may occur.
- Piston ring grooves with a ring groove cleaning tool.

Inspect

- Pistons for cracks and scoring.
- Liner for scratches, cracks, and scoring.

Measure

- Piston ring groove clearance.
  - — First groove: 0.080 to 0.115 mm (0.0031 to 0.0045 in.).
  - — Service limit: 0.2 mm (0.0787 in.).
  - — Second and third grooves: 0.05 mm to 0.08 mm (0.0019 to 0.0031 in.).
  - — Service limit: 0.15 mm (0.0059 in.).
  - — Oil control ring: 0.030 to 0.07 mm (0.0012 to 0.0028 in.).
  - — Service limit: 0.15 mm (0.0059 in.).
- Piston ring end gap (Figure 29).
- Insert piston assembly into the cylinder liner, 195 mm (7.67 in.). below the top of the cylinder liner.
- Piston ring gap:
  - — First compression ring 0.18 to 0.28 mm (0.0071 to 0.0110 in.).
  - — Service limit 1.2 mm (0.0472 in.).

— Second and third compression rings 0.35 to 0.5 mm (0.01378 to 0.01958 in.).
— Service limit 1.2 mm (0.0472 in.).
— Oil control ring 0.15 to 0.35 mm (0.0059 to 0.0138 in.).
— Service limit 1.2 mm (0.0472 in.).

- Piston pin bore inside diameter measurement.
  — 40.004 to 40.012 mm (1.5750 to 1.5752 in.).
- Piston pin to the piston clearance. Measure the piston pin at three different points.
  — 39.995 to 40.000 mm (1.5746 to 1.5748 in.).
- Replace piston pin, if it is less than the specification.
- Subtract the piston pin diameter from the piston pin bore reading.
- Proper clearance 0.004 to 0.017 mm (0.0002 to 0.0007 in.).

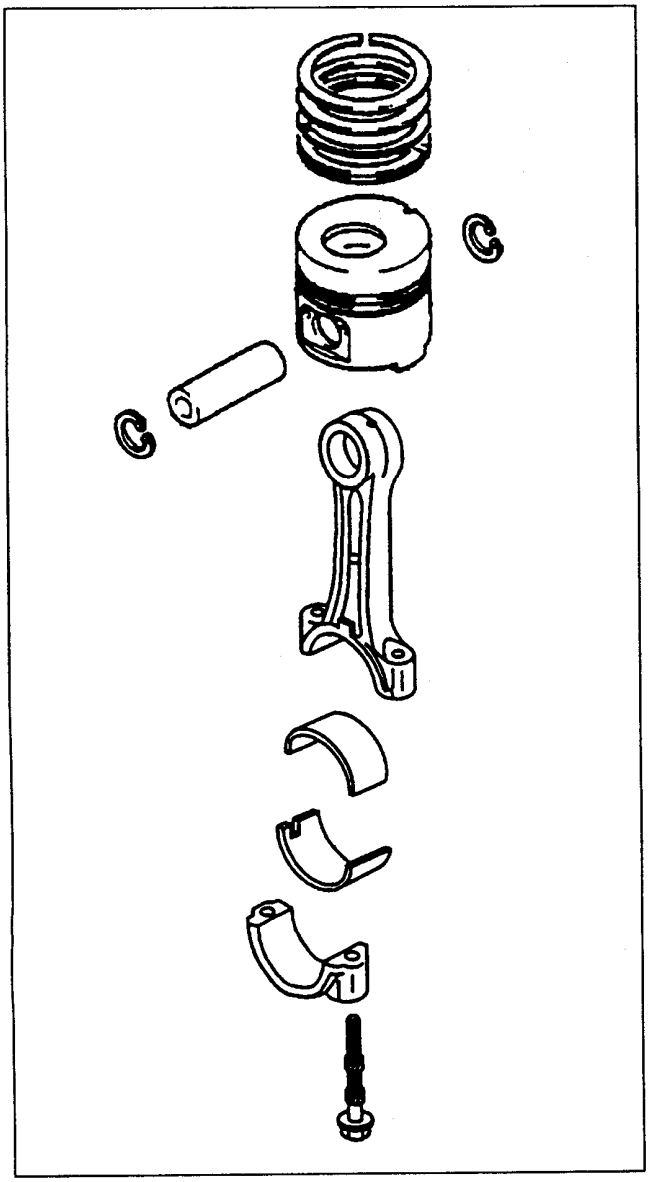


Figure 27 – Piston and Connecting Rod Components

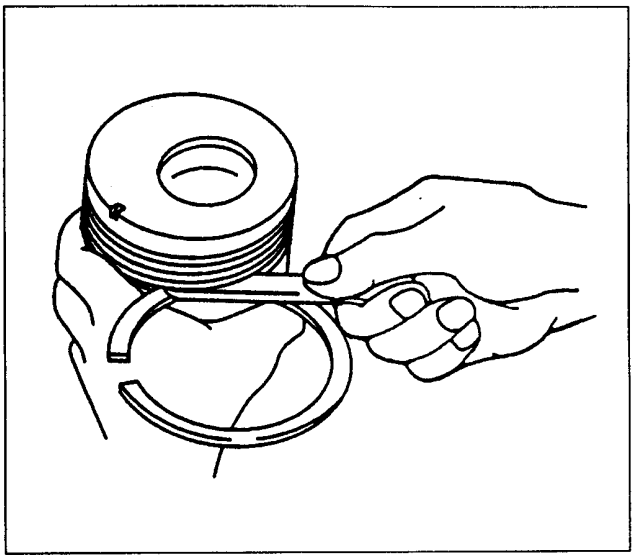


Figure 28 – Measuring Piston Ring Groove Clearance

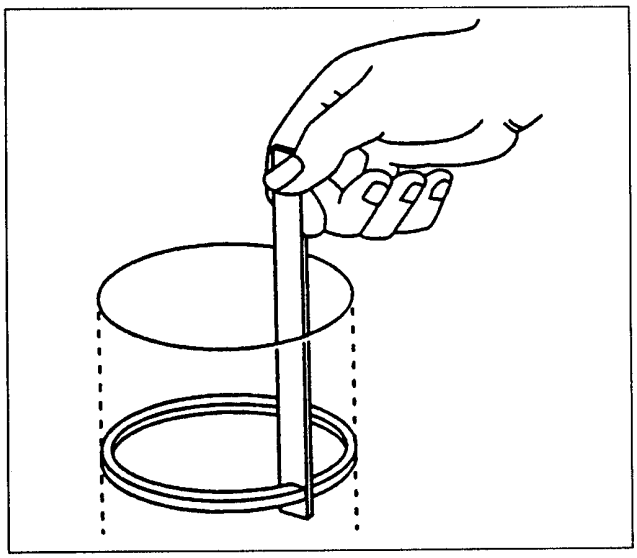


Figure 29 – Measuring Piston Ring End Gap

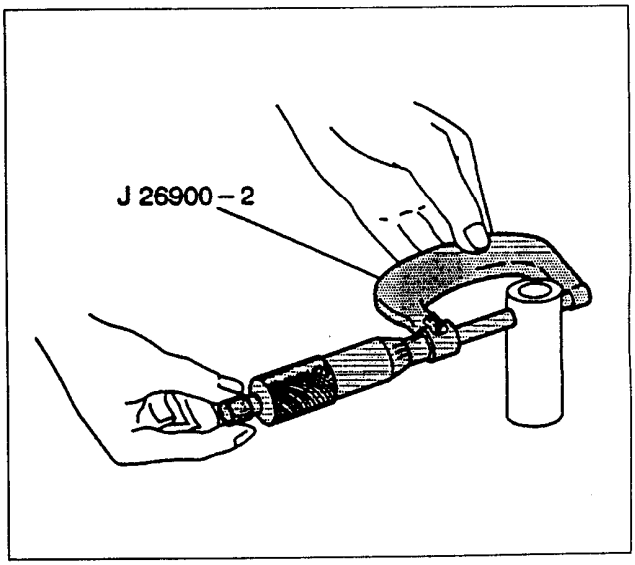
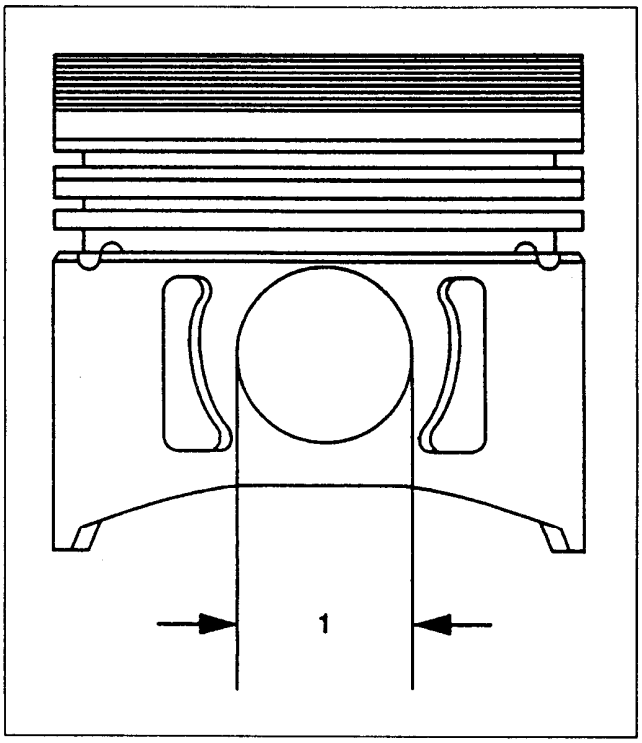


Figure 30 – Piston Pin Measurement



Legend
(1) Piston Pin Bore Measurement
Figure 31 — Measuring the Piston Pin Bore

PISTON SELECTION

Measure (Figures 32 and 33)

1. Cylinder liner outside diamete.
   - Place the bore gauge 20 mm (0.79 in.)., below the gasket surface.
   - Replace the cylinder liner if not with in specifications.
     — Grade 1: 117.981 to 117.990 mm (4.6449 to 4.6453 in.).
     — Grade 2: 117.991 to 118.000 mm (4.6453 to 4.6457 in.).
     — Grade 3: 118.001 to 118.010 mm (4.6457 to 4.64619 in.).
   - When replace the cylinder liner from service part liner, select liner grade 1X for factory liner grade 1 and 2, liner grade 3X for factory liner grade 3.
     The cylinder liner bore diameter grade have not grade for service part liner.
2. Piston diameter.
   - Place the micrometer 82 mm (3.23 in.). below the piston crown, at a right angle to the piston pin bore.
     — Grade A: 114.970 to 114.979 mm (4.5264 to 4.5267 in.).
     — Grade B: 114.980 to 114.989 mm (4.5268 to 4.5271 in.).
     — Grade C: 114.990 to 115.000 mm (4.5272 to 4.5276 in.).
   - There are three different sizes of pistons to be installed from factory. The size grades are referred to as: "A", "B" and "C".
   - The size grade letter is stamped on the piston crown. The engine may come with any combination of piston sizes.
   - Replace the piston, the piston grade have not stamped for service part piston.
   - Pistons are supplied either as part of the cylinder liner set, or separately.
   - When replacing the cylinder liner, also replace the piston. When replacing a piston separately, be sure that the piston to cylinder liner clearance is within factory specifications.
   - Separately supplied pistons have a not stamp grade mark.
   - For cylinder liners inside grade have not grade, mark it mean any service part pistons are installed to replaced service part liners.
3. Piston to cylinder liner clearance.
   - Subtract the piston diameter from the cylinder liner bore diameter.
   - Correct clearance is 0.122 to 0.159 mm (0.0048 to 0.0063 in.).
   - If the clearance is correct, the piston and the cylinder liner are acceptable for further use.
   - If the clearance is incorrect, try a new piston.

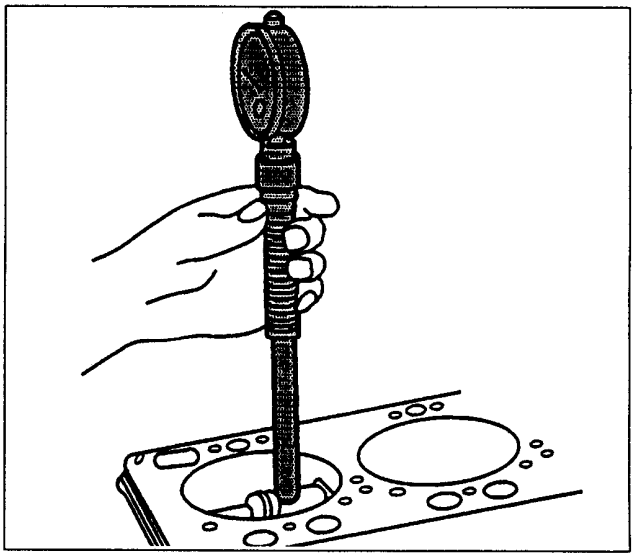


Figure 32 – Measuring the Cylinder Liner Bore

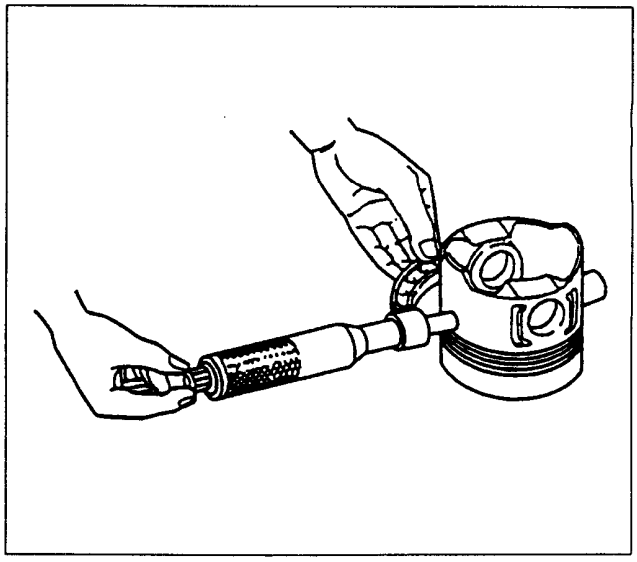


Figure 33 – Measuring the Piston

- If the clearance cannot be brought within factory specifications by the use of new piston, the cylinder liner must be replaced. There are no "oversize" pistons available.

Important

- Never attempt to hone the cylinder liner. Honing may damage the chrome finish on the liners surface.

INSPECTING THE CONNECTING ROD

Clean

- Clean all parts in solvent.
- Blow the parts dry with compressed air. Wear protective safety glasses and gloves.

Inspect (Figure 34)

- Connecting rods and connecting rod caps for cracks, damage, etc.
- Piston pin bushing for scoring.
- Connecting rod bearing insert for scoring.
- Connecting rod bearing insert tension. Moderate finger pressure should be needed to push the bearing insert into place.
- Connecting rod journal on the crankshaft for scoring or other damage.

Measure (Figures 31, 34 and 36)

- Piston pin to the piston clearance. Measure the piston pin at three different points.
- Replace the piston pin if the piston pin is less than 39.95 mm (1.5728 in.).
- Piston pin bushing inside diamete.
- The correct diameter is: 40.012 to 40.022 mm (1.5753 to 1.5767 in.).

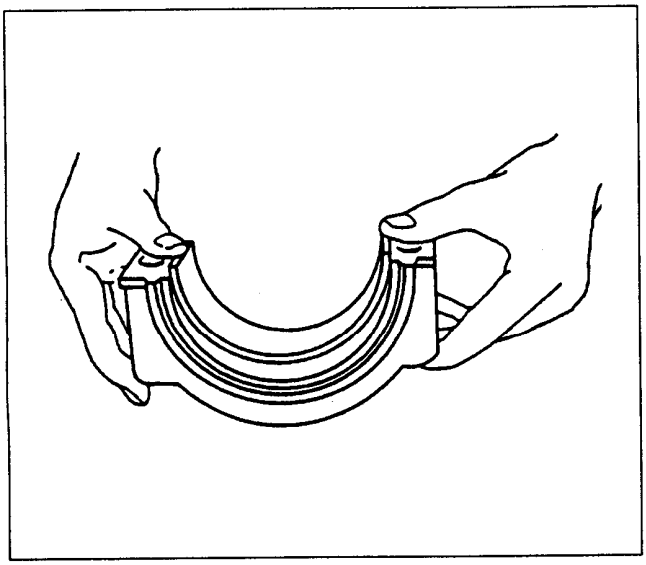


Figure 34 – Connecting Rod Bearing Tension

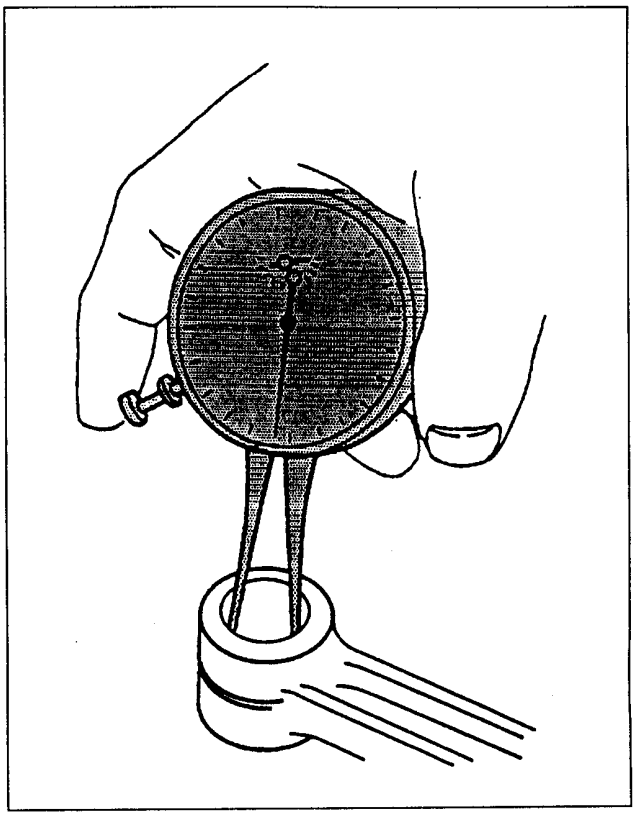


Figure 35 – Measuring Piston Pin Bushing Inside Diameter

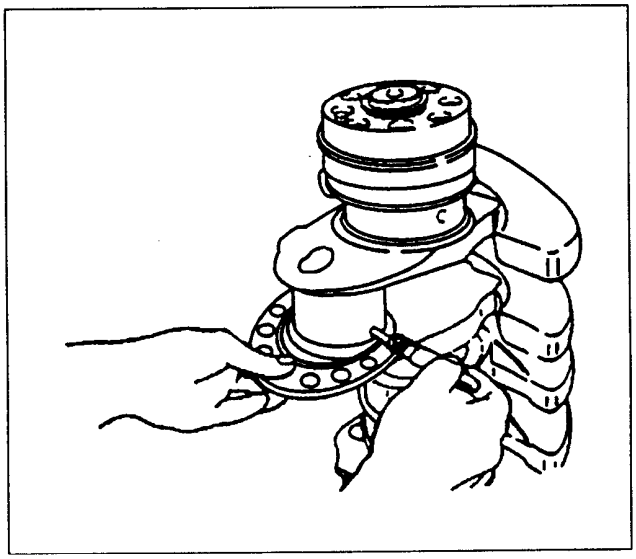


Figure 36 – Measuring the Connecting Rod Journal

- Piston pin to piston pin bushing clearance is as follows.
  - — Clearance: 0.012 to 0.027 mm (0.0005 to 0.0011 in.).
  - — Service limit: 0.05 mm (0.002 in.).
- Subtract the piston pin diameter from the piston pin bushing inside diameter.
- Connecting rod journal diameter, measure at two different points.
  - — Measurements should be: 72.902 to 72.922 mm (2.8701 to 2.8709 in.).

Important

- Undersize bearing are not available. If the crankshaft is worn, replaced it.

Measure

- Connecting rod bearing clearances can be measured by using the plastic gauge method.

Install or Connect (Figures 37 and 38)

1. Apply a piece of plastic gauge the width of the connecting rod bearing journal.
2. Connecting rod bearing inserts to the connecting rod and the connecting rod cap.
   - Apply a small amount of molybdenum grease to the bolts.

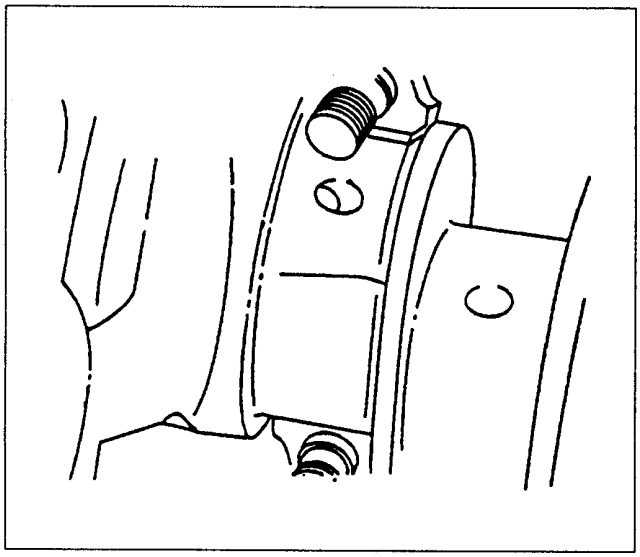


Figure 37 – Installing the Plastic Gauge

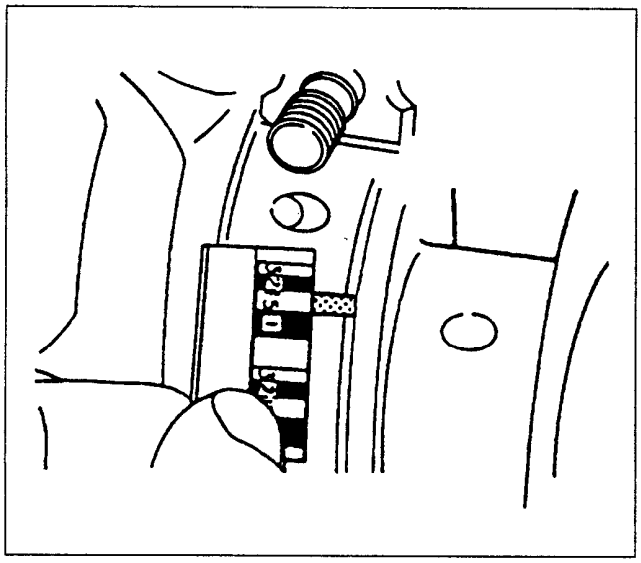


Figure 38 – Measuring the Plastic Gauge

3. Tighten the connecting rod bolts.

Tighten

- Bolts to 39 N·m (29 lb. ft.). Then tighten an additional 60 degrees and then 30 degrees.

Remove or Disconnect (Figure 38)

1. Remove the connecting rod cap from the crankshaft.
2. Measure the plastic gauge.

Important

- **Do not remove the plastic gauge from the crankshaft journal until the clearance measurement is finished.**

Measure

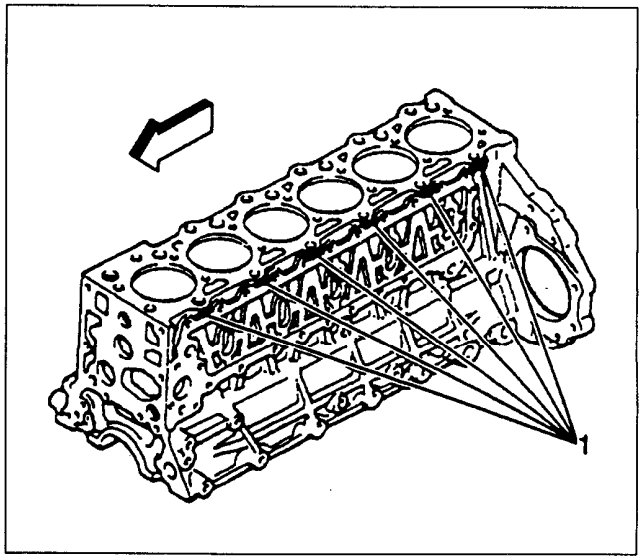
- Check the connecting rod bearing clearances.
- If the clearances are within factory specifications, the connecting rod bearings are satisfaction.
- Remove the plastic gauge.
- If the clearances are not within factory specifications, replace the connecting rod bearing inserts as a set (upper and lower inserts).
- Repeat the procedure.
- If connecting rod bearings still are not within factory specifications, replace the crankshaft.

CYLINDER LINER SELECTION

The cylinder liner body upper left side has been stamped during production to indicate the correct cylinder liner. The cylinder liner grade (1, 2, or 3) is indicated by this stamp.

Replacement cylinder liners have their grade (1X or 3X) stamped on the outside of the cylinder liner.

Select the 1X grade of replacement cylinder liners as marked 1 and 2 on the upper left side of the cylinder body, or 3X grade of replacement cylinder liners as marked 3 on the upper left side of the cylinder body.



Legend

(1) Cylinder Liner Grades

Figure 39 — Cylinder Liner Grademark

Measure

- Cylinder body bore to cylinder liner outside diameter clearance.
- Standard clearance: 0.011 to 0.029 mm (0.0004 to 0.0011 in.).

Important

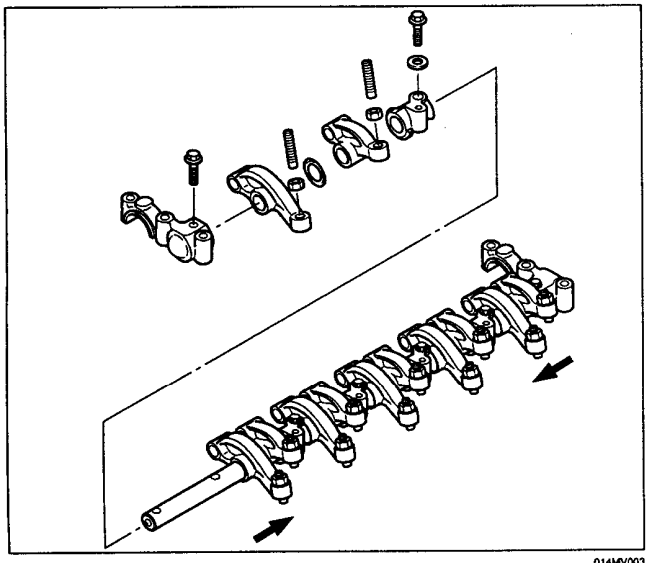
- Clearance refers to the gap between the larger cylinder body bore and the smaller cylinder liner outside diameter.

CYLINDER HEAD AND VALVE TRAIN COMPONENTS

VALVE TRAIN COMPONENTS

Remove or Disconnect (Figure 40)

1. Valve rocker arm shaft assembly from the cylinder head.



014MV003

Figure 40 – Rocker Arm Shaft Assembly

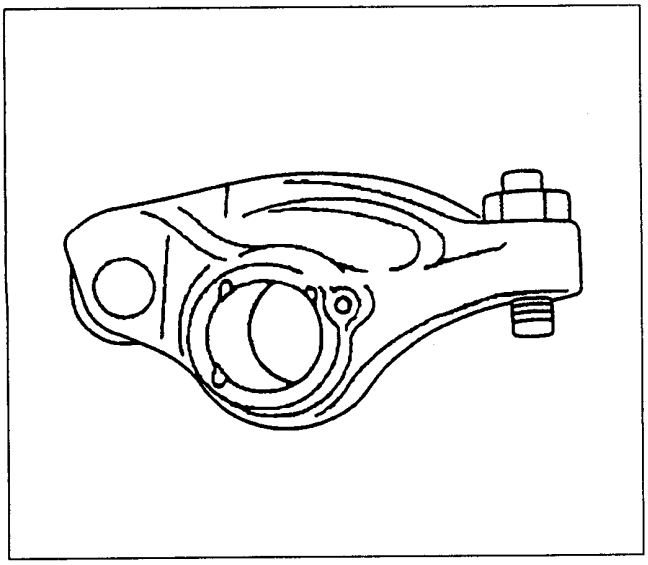
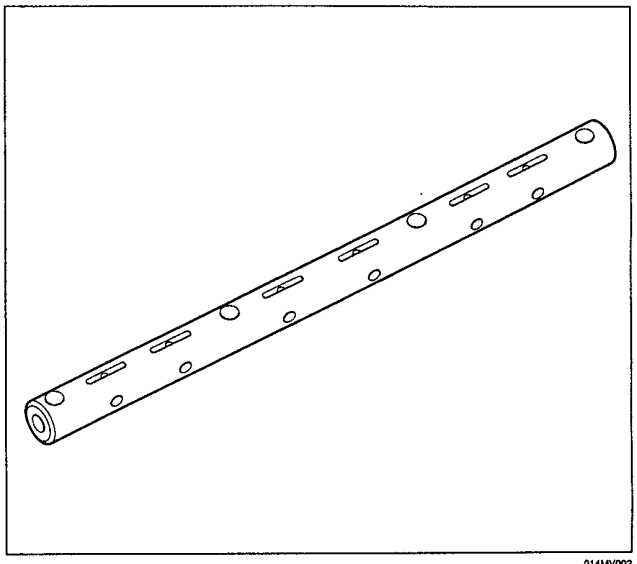


Figure 41 – Valve Rocker Arm



014MV002

Figure 42 – Valve Rocker Arm Shaft

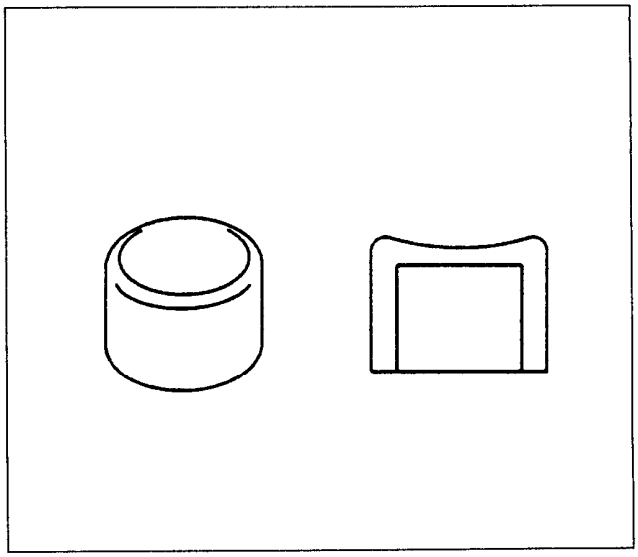


Figure 43 – Valve Bridge Cap

Disassemble

- Valve rocker arm shaft assembly.

Clean

- Clean all parts with cleaning solvent.
- Use compressed air to blow dry the parts. Wear safety eye glasses and gloves.

Inspect (Figures 41 through 43)

- Camshaft retaining brackets for cracks or damage.
- Valve rocker arm shaft for scoring or wear.
- Valve rocker arm inside diameter for scoring or wear.
- Valve rocker arm and the valve bridge cap contact area for pitting and excessive wear.

Measure

- Valve rocker arm inside diameter.
  - Production diameter is: 22.010 to 22.035 mm (0.8665 to 0.8675 in.).
  - Service limit: 22.15 mm (0.872 in.). Replace the part if the measurement is greater than the specification.
- Valve rocker arm shaft.
  - Production diameter: 21.979 to 22.0 mm (0.8653 to 0.8661 in.).
  - Service limit: 21.85 mm (0.8602 in.). Replace the part if the measurement is less than the specifications.
- Subtract the valve rocker arm shaft diameter from the valve rocker arm diameter to obtain the valve rocker arm clearance.
  - Production clearance: 0.010 to 0.056 mm (0.0004 to 0.0022 in.).
  - Service limit: 0.2 mm (0.0079 in.). Replace the part if the measurement is greater than the specification.
- With a pocket scale (ruler) across the top of the valve cap, measure the distance from the bottom of the scale (ruler) to the bottom of the valve cap. If the measurement is greater than 0.1 mm (0.004 in.)., replace the valve cap.

CAMSHAFT INSPECTION

Inspect

- Camshaft lobes and bearing journals for pitting, abnormal or excessive wear.
- Camshaft gear for chipped or broken teeth.

Measure (Figures 44 through 46)

- Camshaft journals at two different points.
  - Production diameter: 39.950 to 39.975 mm (1.5728 to 1.5738 in.).
  - Service limit: 39.85 mm (1.569 in.).

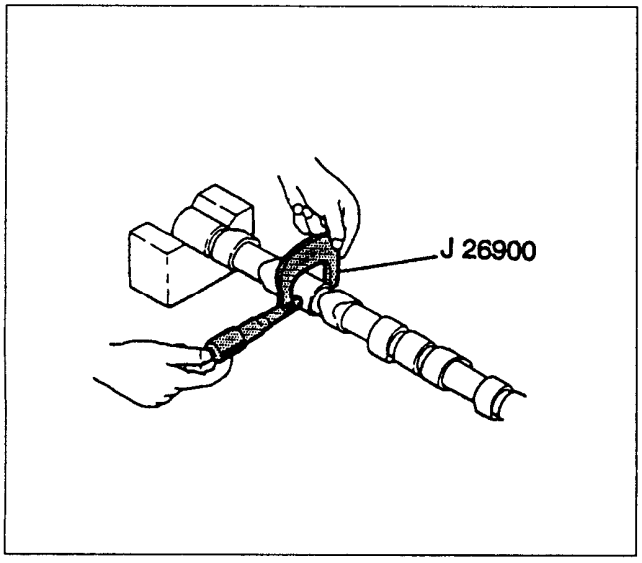


Figure 44 – Measuring the Camshaft Journals

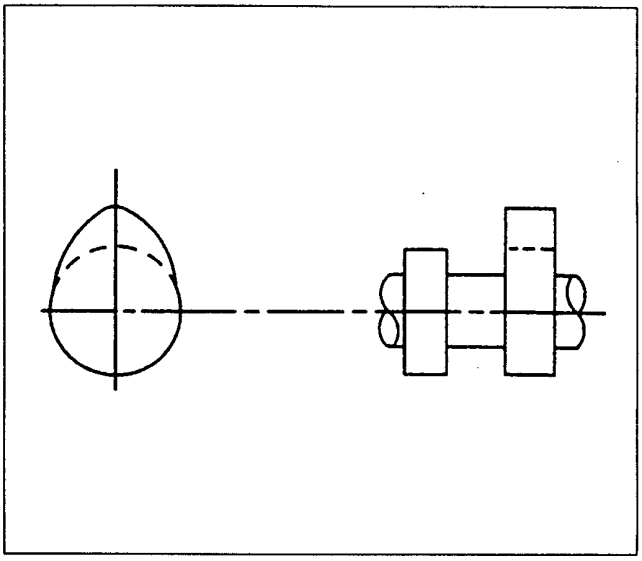


Figure 45 – Measuring the Camshaft Lobes

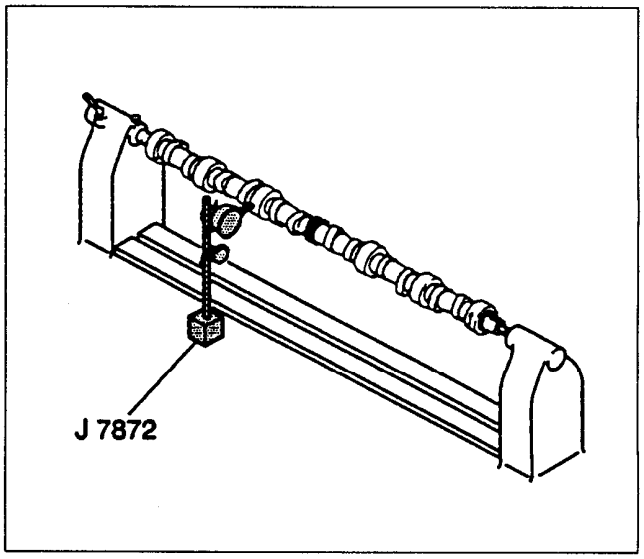


Figure 46 – Measuring Camshaft Runout

- Camshaft bearing inside diameter. The correct measurement is 40.0 to 40.04 mm (1.575 to 1.576 in.).
- Camshaft journal to camshaft bearing clearance.
  - Subtract the camshaft bearing journal diameter, from the camshaft inside diameter.
  - Production clearance: 0.025 to 0.09 mm (0.001 to 0.004 in.).
  - Service limit: 0.15 mm (0.006 in.).
- Camshaft lobe height.
  - Camshaft lobe height should be: 52.851 mm (2.0807 in.) for intake and 54.541 mm (2.1473 in.) for exhaust. Replace the camshaft if the measurement height is below 52.017 mm (2.0500 in.) for intake, 53.761 mm (2.1166 in.) for exhaust.
- Camshaft for runout.
- If the measurement is greater than 0.05 mm (0.0020 in.)., replace the camshaft.

CYLINDER HEAD CLEANING, INSPECTION AND REPAIR

Remove or Disconnect (Figure 47)

1. Remove the valve springs.

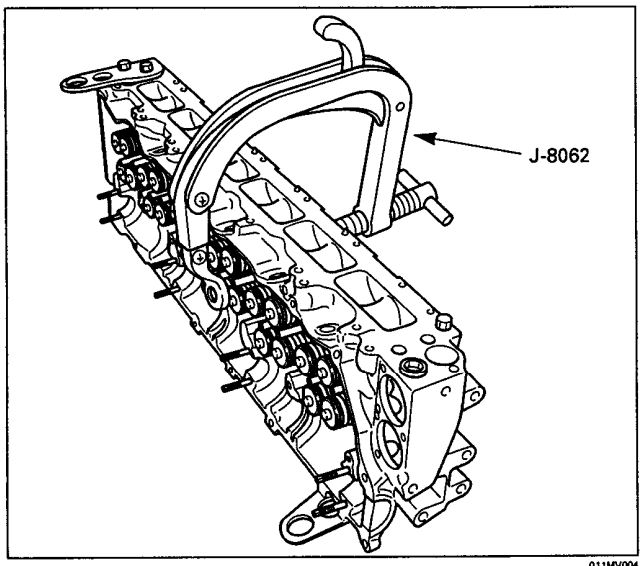


Figure 47 – Compressing the Valve Springs

Inspect

- Carbon from all of the valve ports and combustion chambers.
- Valve guide and bore of dirt and carbon.
- Valve stems and heads.

Important

- Do not use a wire wheel.
- Remove traces of the old gaskets from the cylinder head.

Inspect

- Cylinder head for cracks or damaged threaded holes.
- Cylinder head gasket mating surfaces for damage.
- Valves for damage.
- Valve seats for damage.

Measure (Figures 48 through 53)

- Cylinder head for flatness.
- Check in six different directions. If the cylinder head is distorted more than 0.2 mm (0.0078 in.)., replace the cylinder head.

Important

- **Do not resurface the cylinder head.***

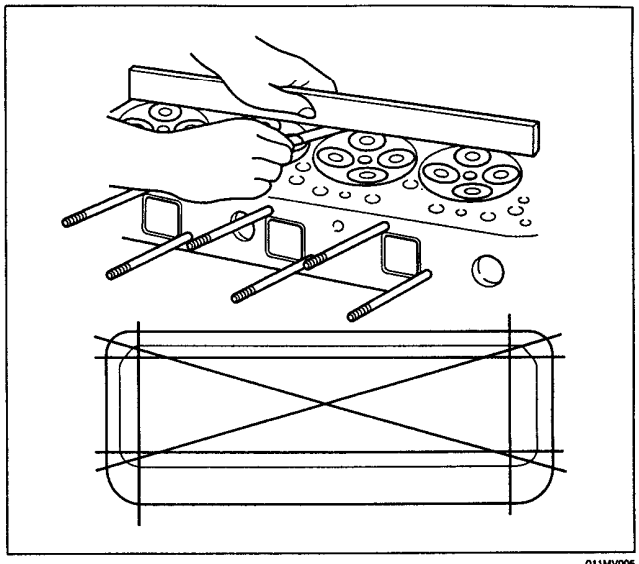


Figure 48 – Checking Cylinder Head for Flatness

2. Valve installed depth.
   - If the measurement is more than 2.5 mm (0.098 in.). for the intake valve and 2.8 mm (0.110 in.). for the exhaust valve, replace the valve or the valve seat as required.

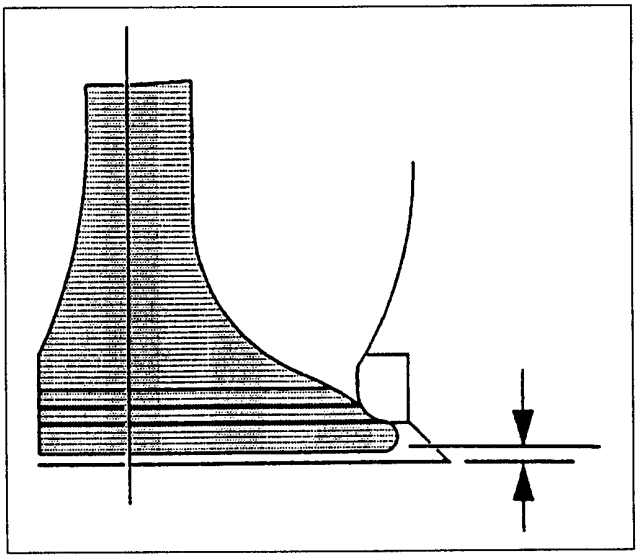


Figure 49 – Measuring the Valve Installed Depth

3. Valve stem diameter.
   - Production specification for the intake valve: 7.946 to 7.961 mm (0.3128 to 0.3134 in.).
   - Service limit: 7.88 mm (0.3102 in.).
   - Production specification for the exhaust valve: 7.921 to 7.936 mm (0.3118 to 0.3124 in.).
   - Service limit: 7.88 mm (0.3102 in.).

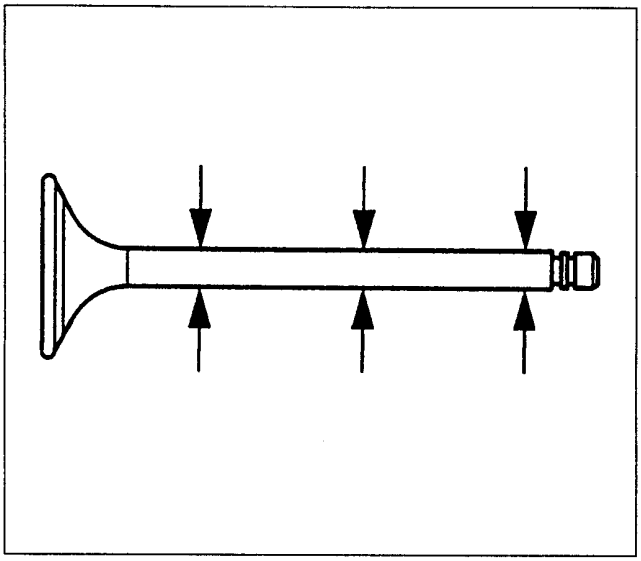


Figure 50 – Measuring the Valve Stem Diameter

4. Valve guide inside diameter.
5. Valve guide to valve stem clearance.
6. Locate the dial indicator so that the plunger is 10 mm (0.39370 in.). above the valve guide.

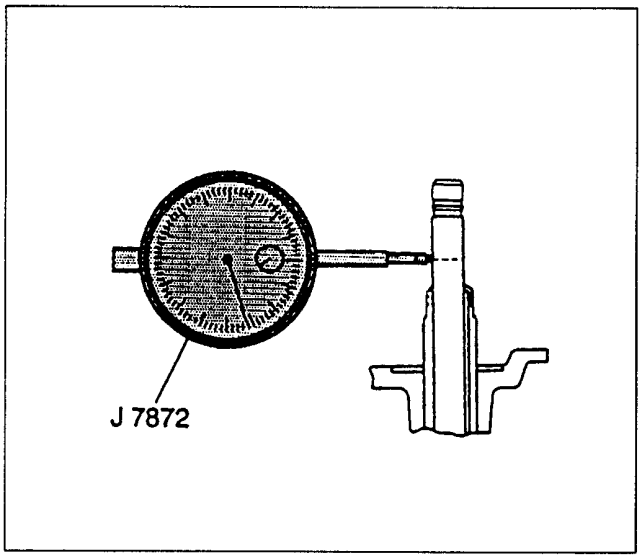


Figure 51 – Measuring the Valve Stem Clearance

7. Hold the valve on its seat.
8. Move the valve stem from side to side to obtain the clearance reading.
   - Production specification for the intake valve guide: 0.04 to 0.07 mm (0.0016 to 0.0028 in.).
   - Service limit: 0.2 mm (0.0079 in.).
   - Production specification for the exhaust valve guide: 0.06 to 0.1 mm (0.0024 to 0.0039 in.).
   - Service limit: 0.25 mm (0.0098 in.).
9. Valve spring length.
   - Production specification for intake valve spring: 65.9 mm (2.5945 in.).
   - Service limit: 64.8 mm (2.5512 in.).
   - Production specification for exhaust spring: 68.1 mm (2.6811 in.).
   - Service limit: 66.9 mm (2.6339 in.).

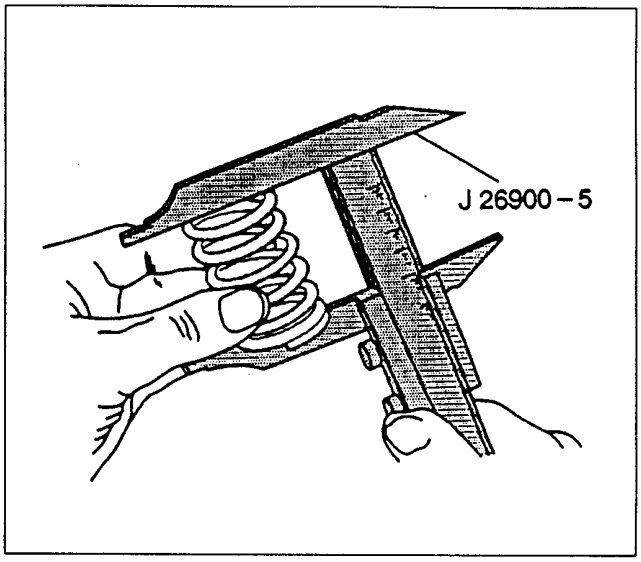


Figure 52 – Measuring the Valve Spring Length

10. Valve spring tension.
    - Compress the valve springs to the specified height.
      — Specified height 46 mm (1.8110 in.). length.
      — Intake Production: 348.1 N (78.3 lb.).
      — Service Limit: 296 N (67 lb.).
      — Exhaust Production: 382.5 N (86 lb.).
      — Service Limit: 325 N (73 lb.).
    - If valve springs are not within factory specifications, replace the valve springs.

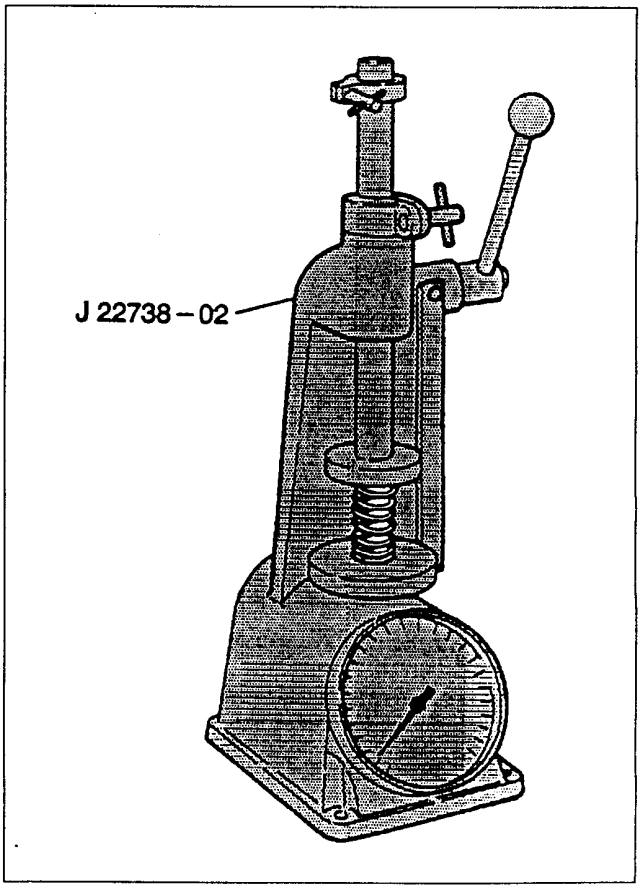


Figure 53 – Measuring the Valve Spring Tension

VALVE SEAT

Reconditioning of the valve seats is very important because the seating of the valves must be precise in order for the engine to deliver the power and the performance it was designed to produce.

Another important factor is the cooling of the valve head. Good contact between each valve and its seat in the cylinder head is a must to insure that the heat in the valve head will be properly dispersed.

Several different types of equipment are available for grinding of the valve seats. The recommendations of the equipment manufacturer should be carefully followed to attain the proper results.

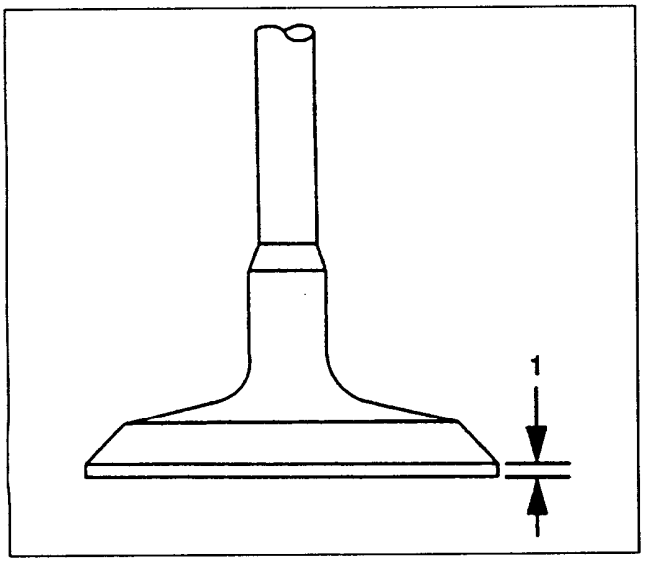
Regardless of what type of equipment is being used, it is necessary that the valve guide bores are clear of carbon or dirt to ensure the proper centering of the pilot in the valve guide. The correct seat angle is 89 degrees and 45 minutes for exhaust, 119 degrees and 45 minutes for intake.

If too much material is removed from the valve seat, the valve install depth may become too excessive. If this is the case, the valve seat must be replaced.

Valves that are pitted, should be replaced to the new part. Valve stems which show excessive wear, or valves that are warped, should be replaced.

Measure

1. Valve margin thickness.
   - Measurement for intake valves: 1.71 mm (0.0673 in.).
   - Measurement for exhaust valves: 1.75 mm (0.0689 in.).
2. Valve face angle.
   - Face angle for the intake valve: 60 degrees.
   - Face angle for the exhaust valve: 45 degrees.



Legend
(1) Valve Margin

Figure 54 — Valve Margin Thickness

VALVE GUIDE REPLACEMENT

Tools Required:
J43272 Valve Guide Remover and Installer

Remove or Disconnect (Figure 55)

1. Place the cylinder head on wooden blocks with combustion chamber facing up.
2. Drive valve guide out with tool J43272.

Clean

- Clean the valve guide bore in the cylinder head.

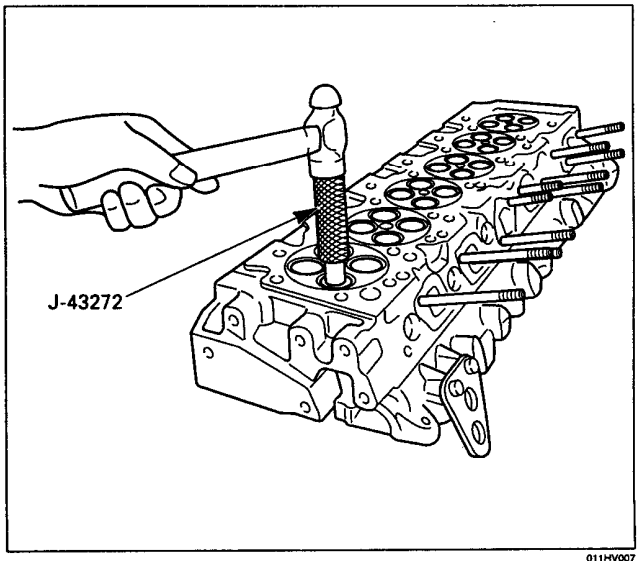


Figure 55 – Removing the Valve Guide

Install or Connect (Figure 56)

1. Install new valve guide with tool J43272, Valve Guide Installer.
   - Measure the distance from the top of the valve guide to the cylinder head surface.
     — 19 mm (0.7480 in.).
   - Tool J43272 is supplied with a installer designed to install the valve guide to the proper depth.

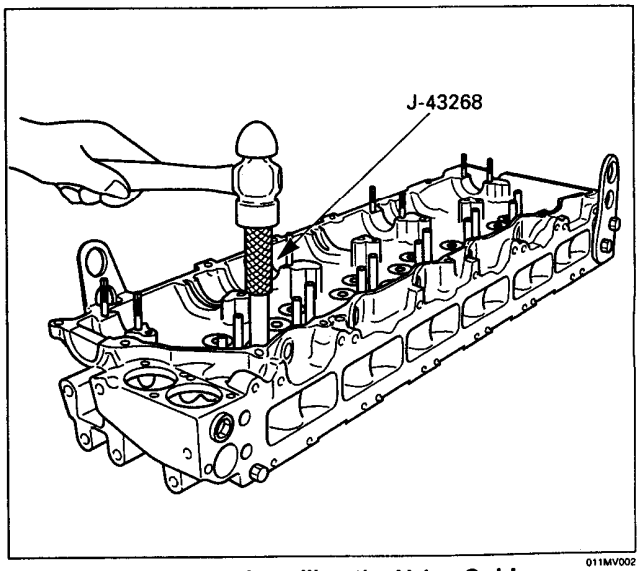


Figure 56 – Installing the Valve Guide

VALVE SEAT REPLACEMENT

Remove or Disconnect (Figure 55)

1. Grind the valve seat (intake and exhaust) until the seat measures (1) 0.5 to 1 mm (0.0196 to 0.04 in.). thick.
2. Remove the valve seat with a pry tool.

Clean

- Thoroughly clean the valve seat counter bore in the cylinder head before installing new seat.

Install or Connect (Figure 49)

1. Press the new valve seat into the cylinder head.
2. Grind valve seat.

Important

- When a new valve seat and new valve are used together, the installed depth should be 0.65 to 1.1 mm (0.0255 to 0.0433 in.). The installed depth should not be any greater than 2.5 mm (0.098 in.). for the intake valve, and 2.8 mm (0.110 in.). for the exhaust valve.

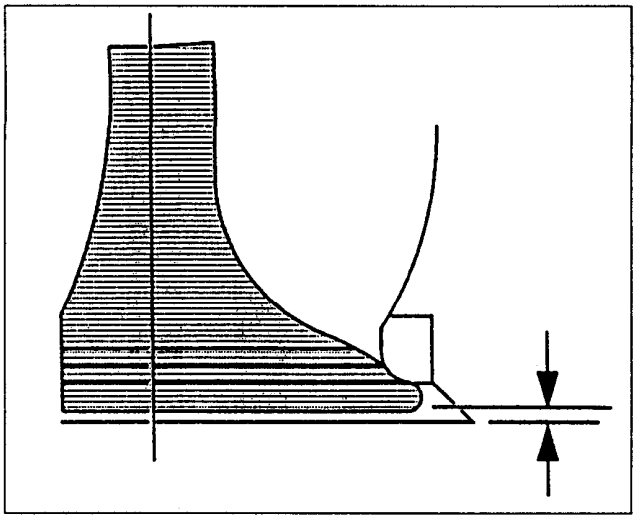


Figure 57 — Valve Installed Depth

VALVE LAPPING

The valves should be lapped just before the final assembly to assure a good valve seal.

1. Apply Prussian blue dye or equivalent to the valve seat.
2. Insert the valve into the proper port.
3. Rotate the valve lightly, then remove.
4. Inspect the valve face.

Measure

- The valve seat width will be indicated by the mark on the valve face.

5. Measure the valve seat width.
   - Intake valve should be: 3.2 mm (0.1260 in.).
   - Exhaust valve should be: 2.8 mm (0.1102 in.).

Important

- Contact area should be centered on the valve face. If not, check the condition of the valve seat and repair as needed.

6. Repeat steps 1 through 5 on the remaining valves.

Clean

- Clean all the Prussian blue dye from the valves and the valve seats.

7. Apply a medium valve lapping compound to the valve.
8. Lap the valve until a light gray ring appears all the way around the valve face.
9. Thoroughly clean all the valve lapping compound from the valve and valve seat.
10. Repeat this procedure on the remaining valve and valve seats.

INSTALLING THE VALVE SEALS

Tools Required:
J43267 Valve Seal Installer

Install or Connect (Figures 58 and 59)

1. Lubricate the valve stem seal with clean engine oil.
2. Install valve stem seal using tool J43267.

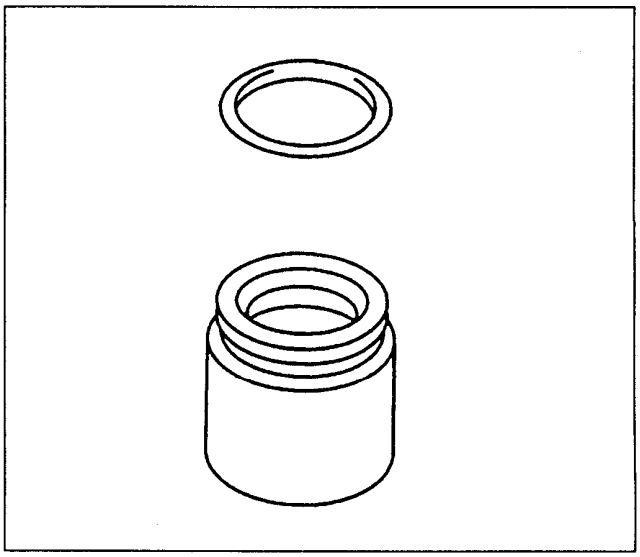


Figure 58 – Valve Seal and Garter Spring

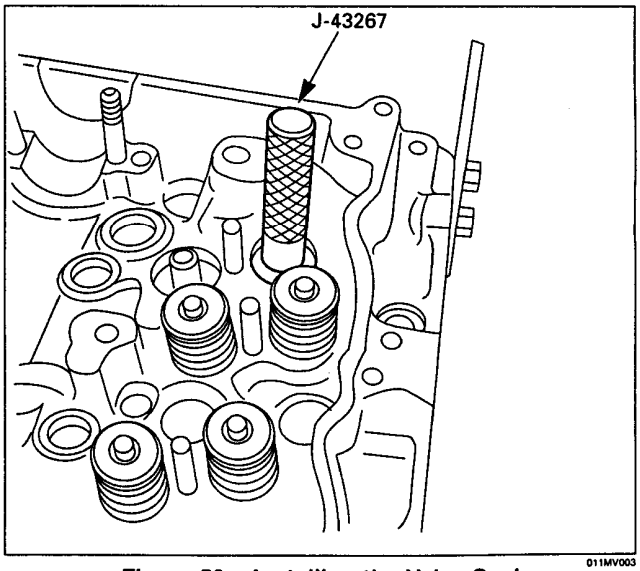


Figure 59 – Installing the Valve Seal

INJECTION NOZZLE SLEEVE REPLACEMENT

Tools Required:
J43265 Remover: Nozzle Sleeve
J43266 Installer: Nozzle Sleeve

Remove or Disconnect (Figure 60)

1. Place the cylinder head on wooden block with combustion chamber facing up.
2. Remove the injection nozzle sleeve with tool J43265.

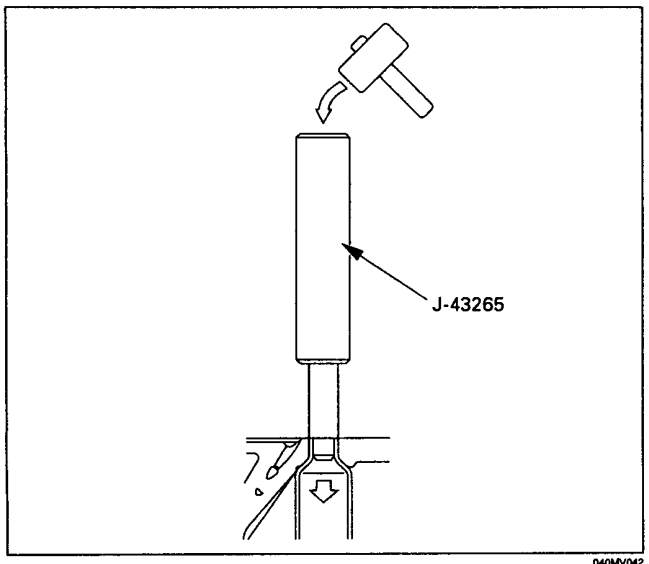


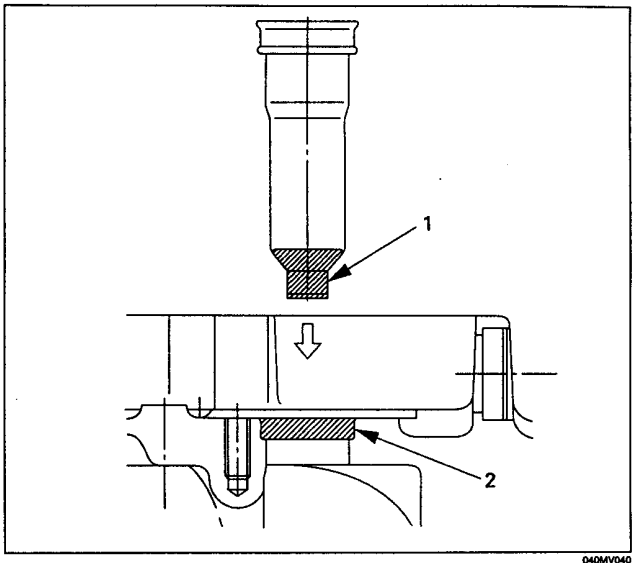
Figure 60 – Nozzle Sleeve Removal

Clean

- Clean the injection nozzle sleeve bore in the cylinder head.

Install or Connect (Figures 61 and 62)

1. Apply sealant to new injection nozzle sleeve (1) and cylinder head nozzle sleeve bore (2) as shown in the illustration.
2. Insert the injection nozzle sleeve to cylinder head.
3. Use injection nozzle clamp bolt to clamp the injection nozzle sleeve with tool J43266.
4. Put ball bearing (Outside diameter 9.525 mm (3.8 in.) into the injection nozzle sleeve and set too J43266.
5. Strike out the ball bearing by tool J43266.



Legend
(1) Sealant on Injection Nozzle Sleeve.
(2) Sealant on Cylinder Head Nozzle Sleeve Bore.

Figure 61 – Apply Sealant to Nozzle Sleeve

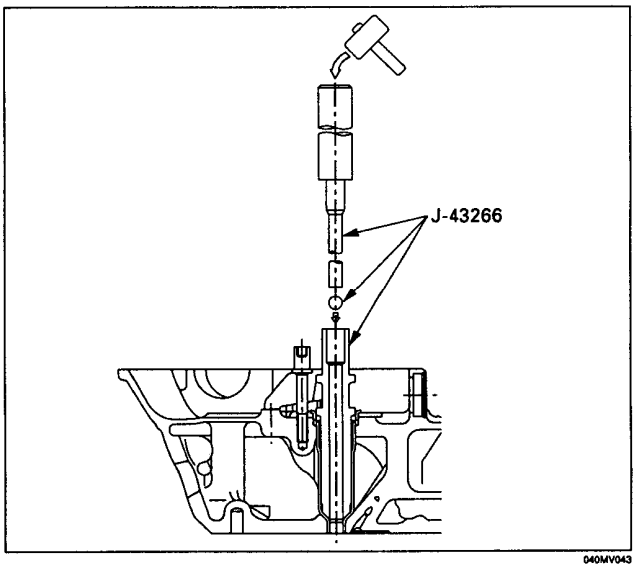


Figure 62 – Nozzle Sleeve Installation

ASSEMBLING THE CYLINDER HEAD

Tools Required:
J8062 Valve Spring Compressor

Install or Connect (Figure 63)

1. Apply clean engine oil to the valve stem.
2. Insert the valve into the proper port.
3. Valve spring seats to the cylinder head.
4. Valve spring with retainer.

Important

- Painted part of the valve springs (close spaced) coils must be toward the cylinder head.

5. Compress the valve springs, using J8062.
6. Apply a small amount of grease on the end of the valve stem.
   - Apply a small amount of grease to the end of the valve stem. This will help retain the valves keys in position while releasing tool J8062.
7. Valve keys to the valve stem.
8. Slowly release valve spring compressing tool J8062.

Important

- Make sure that the valve keys are installed properly before proceeding to the next set of valves.

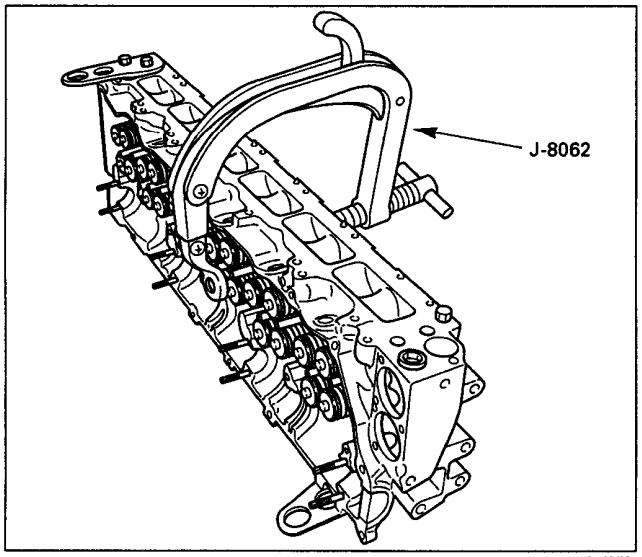


Figure 63 – Compressing the valve spring

ASSEMBLY OF THE ENGINE

OIL JET INSTALLATION

Install or Connect (Figure 64)

1. Bolt and washers to the oil jet.
2. Oil jet to the cylinder block.
3. Tighten the oil jet.

Tighten

- Bolts to 21 N·m (15 lb. ft.).

Important

- Failure to install the oil jets to the cylinder block will cause loss of oil pressure and possible engine damage.

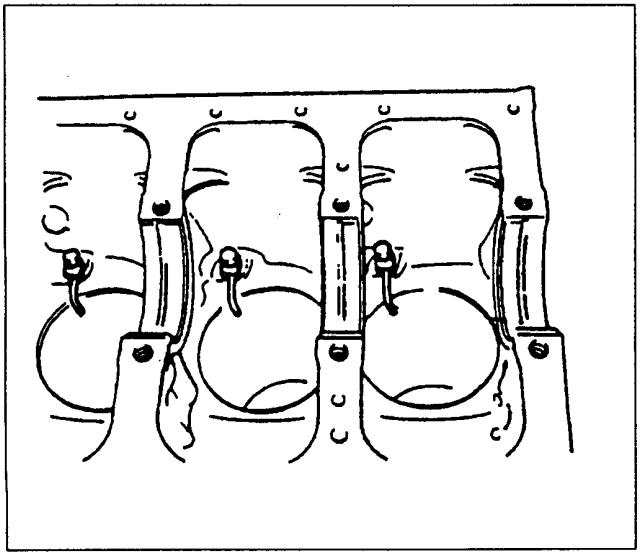


Figure 64 – Installation of the Oil Jets

OIL FILTER INSTALLATION

Install or Connect (Figure 8)

1. Oil filter bracket and gasket to the cylinder block .
2. Bolts to the oil filter bracket.
3. Tighten oil filter bracket bolts.

Tighten

- Bolts to 38 N·m (28 lb. ft.).

4. Install the oil filter.
   - Fill filter with oil before installing it to the bracket.

CRANKSHAFT INSTALLATION

Crankshaft main bearings are of the precision insert type and do not utilize shims for adjustment. If the clearances are found to be excessive, a new bearing, both upper and lower inserts will be required. If the clearances are still excessive with the new crankshaft main bearings, the crankshaft must be replaced. No undersize bearings are available for this engine.

The simplest and most accurate way to measure the crankshaft main bearing clearance is the use of plastic gauge. This wax-like material compresses evenly between the bearing and the crankshaft journal surfaces without damaging them.

Install or Connect (Figures 65 through 68)

1. Upper crankshaft main bearing inserts into the cylinder block.
   - Upper crankshaft main bearing inserts have the oil holes and grooves in them.
   - Make sure that the bearing inserts fit correctly into the cylinder block.
2. Crankshaft into the cylinder block.
3. Upper thrust washer into the cylinder block.
   - Upper thrust washer does not have a locating tab. It must be rolled into the cylinder block.
   - New thrust washers must be used if the crankshaft end play measurement at disassembly was excessive.
4. Lower crankshaft bearing inserts into the lower crankcase housing.
   - Lower crankshaft bearing inserts are plain and have no grooves in them.
   - Make sure that the bearing inserts fit correctly into the cylinder block.

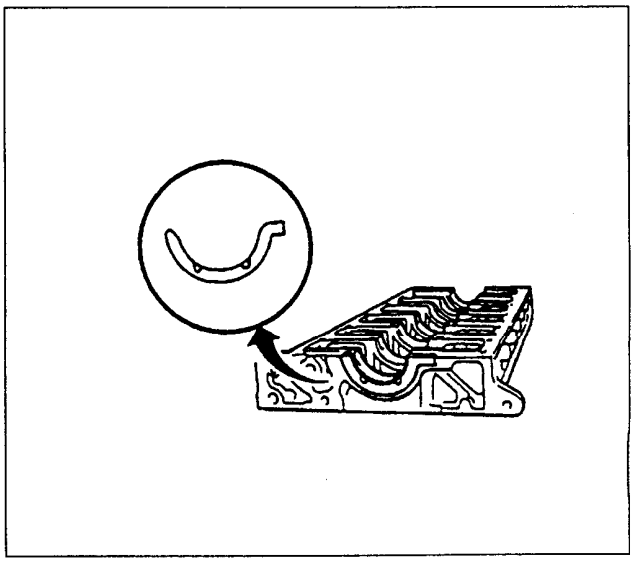


Figure 65 – Lower Thrust Washer Installation

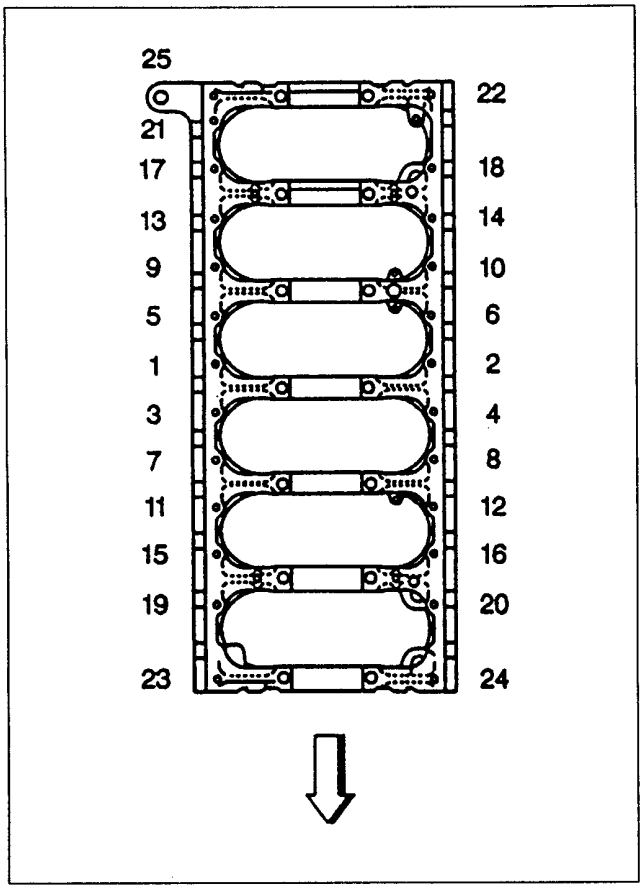


Figure 66 – Cylinder Block to Lower Crankcase Bolt Tightenng Sequence

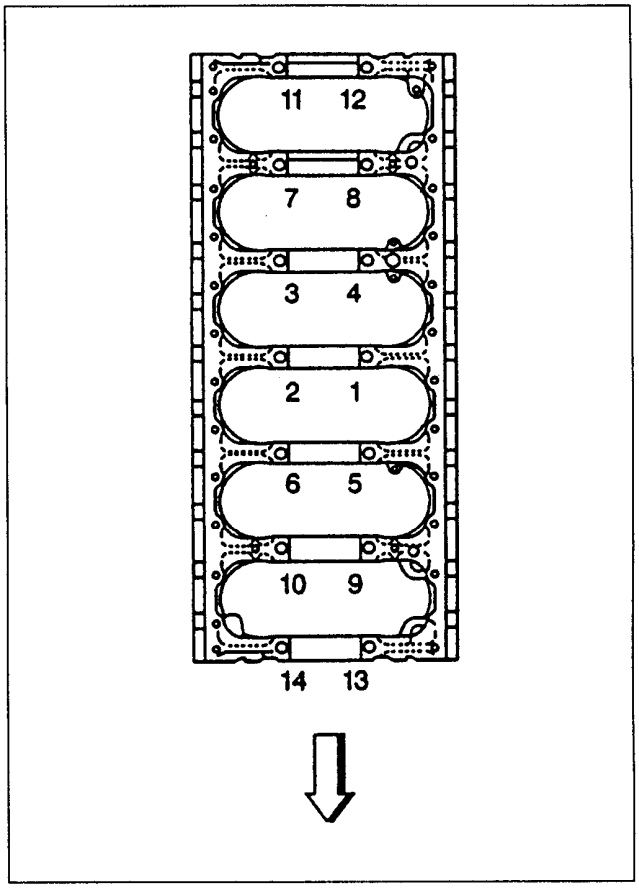


Figure 67 – Lower Crankcase Bolt Tightening Sequence

Install or Connect

1. Apply clean engine oil to the crankshaft main bearing and inserts.
2. Crankshaft into the cylinder block.
3. Apply sealant to sealing surface of lower crankcase.
4. Lower thrust washer half to the lower crankcase housing, with the grooves facing inward.
5. Apply a small amount of molybdenum grease to the bolts. (M14 Bolts only)
6. Bolts to the lower crankcase housing.
7. Tighten the bolts.
   - The head of the bolt will be marked 14.

Tighten

   - Tighten bolts in steps:
     — 98 N·m (73 lb. ft.).
     — 132 N·m (98 lb. ft.).
     — turn an additional 30 to 60 degrees.
8. Bolts (marked M10) to the crankcase.
   - Bolts evenly in sequence to 37 N·m (27 lb. ft.).
9. Rotate the crankshaft.
   - The crankshaft should rotate freely.
   - If the crankshaft does not rotate freely, loosen the lower crankcase housing bolts (marked M10), until the tight crankshaft main bearing is located.

Tighten

- Burrs on the crankshaft bores.
- Foreign matter between the cylinder block and lower crankcase housing.
- Faulty crankshaft main bearing insert.
- Repair as necessary.

Measure (Figure 68)

- Crankshaft for end play.
- Tap the crankshaft on the flywheel end with a brass hammer to force it forward.
- Insert a feeler gauge between the lower thrust washer half and the crankshaft.
- Production end play is 0.15 to 0.33 mm. (0.005 to 0.012 in.). The service limit is 0.4 mm. (0.0157 in.).

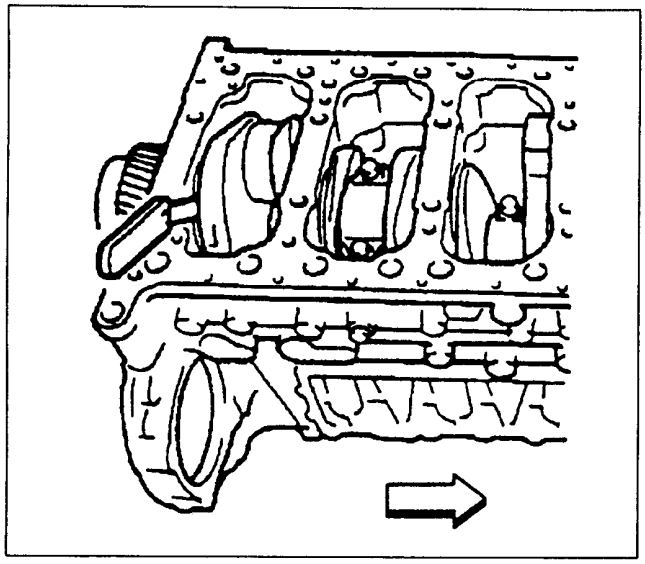


Figure 68 – Measuring Crankshaft End Play

FRONT COVER INSTALLATION

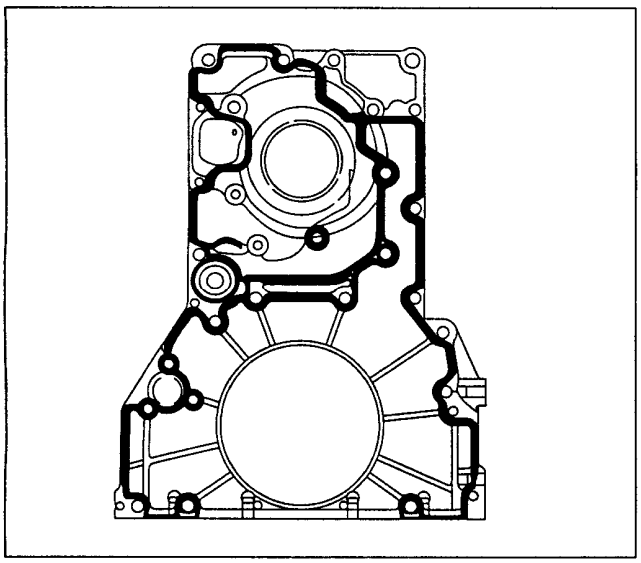
Tools Required:
J39046 Crankshaft Balancer (External) Remover and Installer
J41220 Oil Slinger Remover
J41221 Oil Seal Installer

Install or Connect (Figures 69 through 72)

1. Apply RTV sealant (Three Bond 1207C or equivalent) to the front cover.
2. Front cover to the cylinder block.
3. Bolts to the front cover.
4. Tighten the front cover bolts.

Tighten

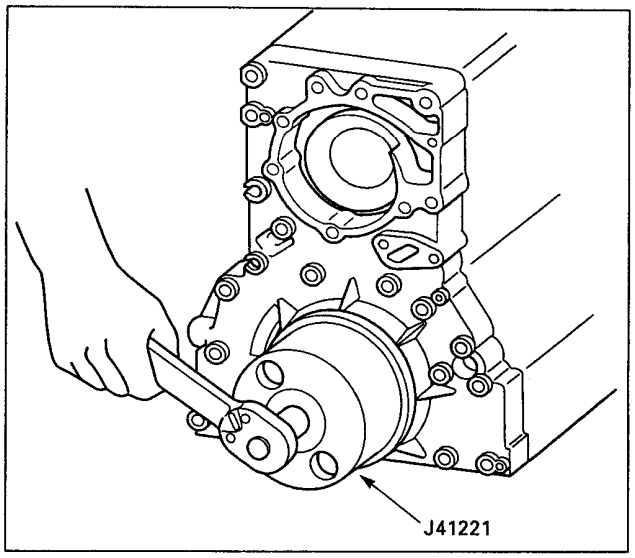
- Bolts to 19 N·m (14 lb. ft.).



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Figure 69 – Apply the Sealant

5. Oil slinger.
   - Install J41221.
     A. Apply clean engine oil to the oil slinger.
     B. Insert the oil slinger into the adapter.
     C. Install the oil slinger sleeve to the adapter, and tighten the center bolt until the sleeve comes in contact with the adapter and stops.
     D. After pressing in the oil slinger, make sure that the distance between the crankshaft end surface and the oil slinger is 11.5 ± 0.15 mm (0.453 ± 0.006 in.).
        - Check the measurement at several different points.



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Figure 70 – Install the Oil Slinger and Oil Seal

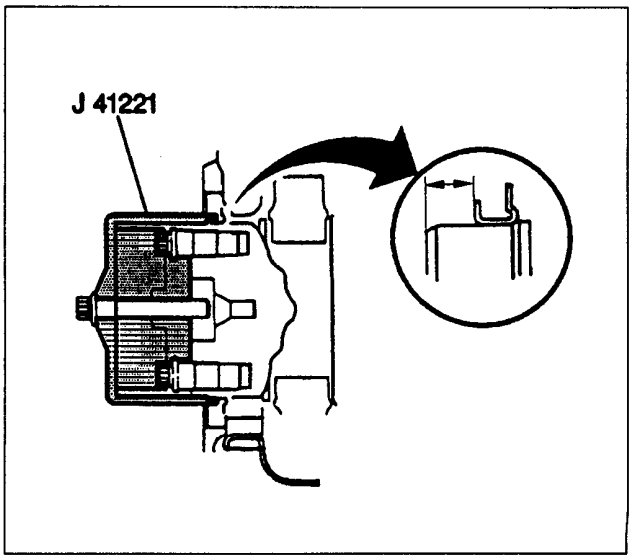


Figure 71 – Checking the Clearance

- Install J41221.
  A. Apply clean engine oil to the oil seal.
  B. Insert the oil seal into the adapter.
  C. *Install the* oil seal to the adapter, and tighten the center bolt until the sleeve comes in contact with the adapter and stops.
  D. After pressing in the oil seal, make sure that the distance between the crankshaft end surface and the oil slinger is 8.5 ± 0.15 mm (0.335 ± 0.006 in.).
     - Check the measurement at several different points.

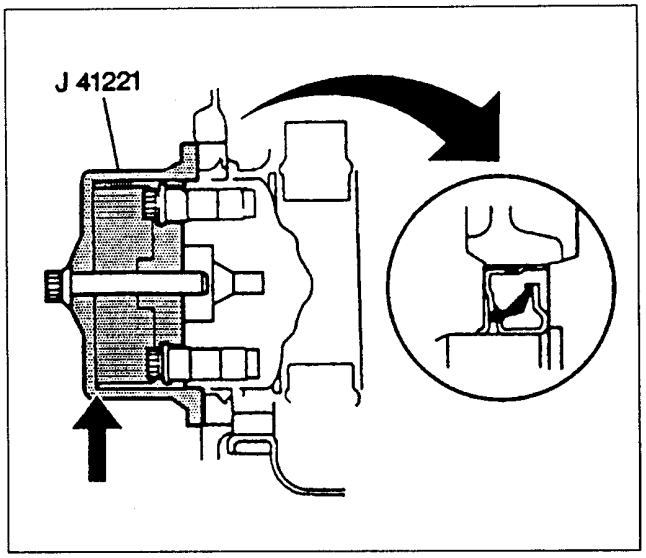


Figure 72 – Checking the Seal Clearance

Inspect

- Crankshaft balancer for excessive wear or damage.
- Crankshaft balancer for silicone leakage. If leakage appears, replace the crankshaft balancer.

6. Crankshaft balancer bolts, washers and the crankshaft balancer.

Tighten

- Bolts and nuts to 48 N·m (35 lb. ft.).

7. Crankshaft balancer to the crankshaft.
8. Crankshaft balancer bolt and washer to the crankshaft.

Tighten

- Crankshaft balancer bolt and washer to 200 N·m (148 lb. ft.).

WATER PUMP INSTALLATION

Install or Connect

1. Water pump and gasket to the cylinder block.
2. Water pump bolts to the cylinder block.
3. Tighten the water pump bolts.

Tighten

- Bolts (M10) to 36 N·m (28 lb. ft.).
- Bolts and nuts (M8) to 19 N·m (14 lb. ft.).

4. Water duct and the O-ring to the cylinder head and the water pump.
   - Apply a small amount of liquid soap on the O-ring for easier installation.
5. Bolts to the water duct.

Tighten

- Water duct bolts to:
  — Bolts marked M8 to 19 N·m (14 lb. ft.).
  — Bolts marked M16 to 103 N·m (76 lb. ft.).

CYLINDER LINER INSTALLATION

Install or Connect

1. Clean cylinder liners and bores with solvent.
2. Blow dry the cylinder liners with compressed air. Wear protective safety glasses and gloves.

Important

- All foreign material must be carefully removed from the cylinder liner and from the cylinder bore, before the cylinder liner installation.

3. Apply clean engine oil to outside cylinder liner.
4. Cylinder liner into the cylinder block.

Important

- The installation of the cylinder liner retaining bolt and washer will prevent the cylinder liners from moving or falling free, if the engine is being moved or rotated on the engine stand.

5. Cylinder liner retaining bolts and washers.
   - Cylinder liner retaining bolt.
     — Size and pitch: M14-2 mm.
     — Length: 30 mm (1.181 in.).
   - Cylinder liner retainer washer.
     — Thickness: 3 to 5 mm (0.118 to 0.197 in.).
     — Outside diameter: 40 mm (1.575 in.).

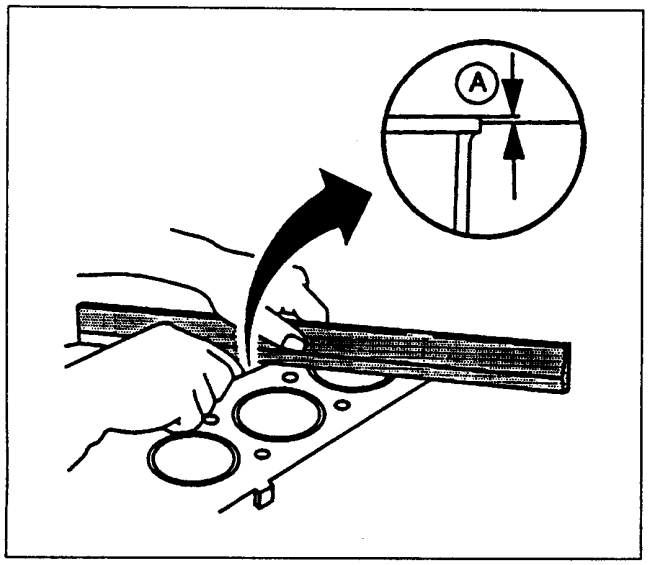
Important

- Remove the cylinder liner retaining bolt and washer when installing the piston assembly. Reinstall the retaining bolt and the washer, after the piston assembly has been installed.
- Leave the retaining bolt and the washer in place and do not remove until the installation of the cylinder head assembly.

6. Measure the amount of the cylinder liner projection (A).

Measure

- Use a straight edge and feeler gauge, as shown in (Figure 73). If properly installed, the cylinder liner should project 0.06 to 0.1 mm (0.0024 to 0.0039 in.). above the gasket mating surface of the cylinder head.
- The difference in the cylinder liner projection height between any two adjacent cylinders, must not exceed 0.03 mm (0.0012 in.).



Legend
(A) Measured Projection
Figure 73 — Measuring the Cylinder Liner Projection

7. Recheck the piston to cylinder liner clearance.

PISTON AND CONNECTING ROD INSTALLATION

Tools Required:
J8037 Piston Ring Compressor

Install or Connect (Figures 74 through 77)

1. Piston to the connecting rod.
   - Position the piston assembly, so the mark on the crown of the piston and the mark on connecting rod are facing opposite.
2. Separate the connecting rod and the connecting rod bearing cap.
3. Piston rings to the piston assembly.
   - Install the piston rings with marks facing up .

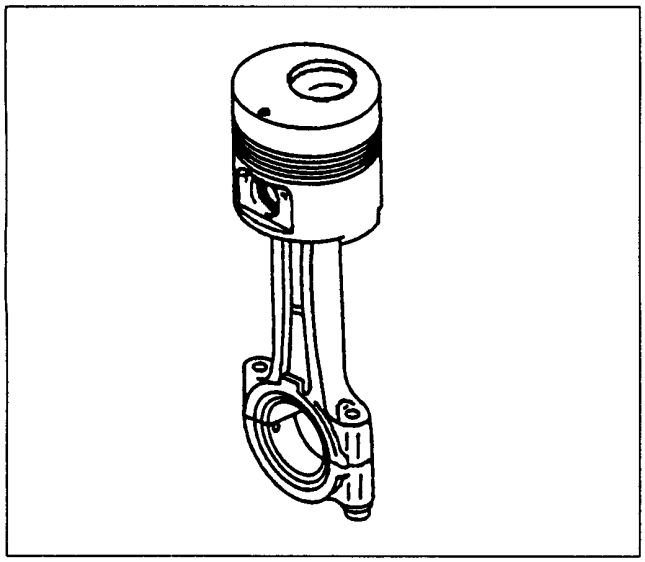


Figure 74 – Piston and Connecting Rod Alignment

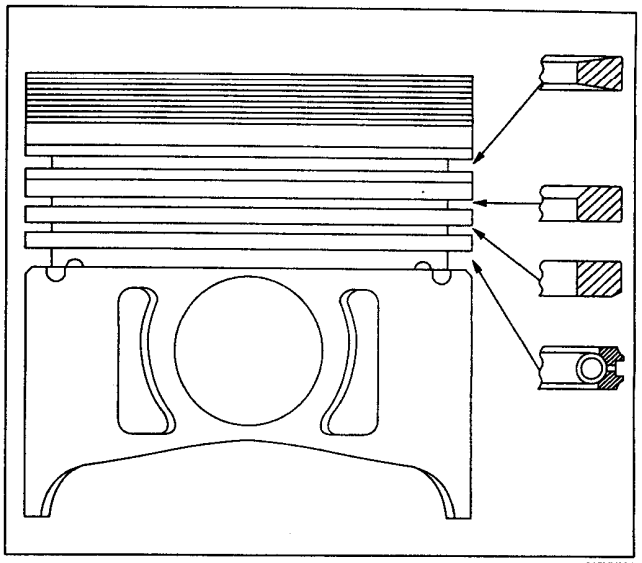


Figure 75 – Piston Ring Installation

   - Stagger the piston rings, so the piston ring gaps are 45 degrees apart.
4. Rotate the crankshaft so that the connecting rod journal being worked on is at the bottom of the compression stroke.
5. Apply clean engine oil to the piston assembly.
6. Install tool J8037 piston ring compressor to the piston assembly

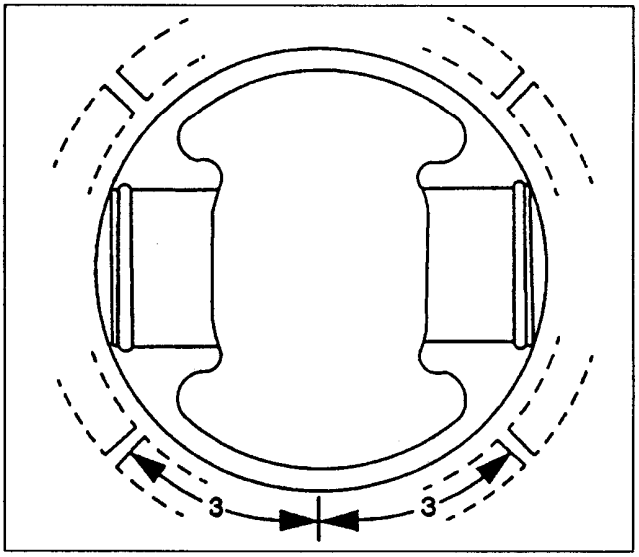


Figure 76 – Piston Ring Gap

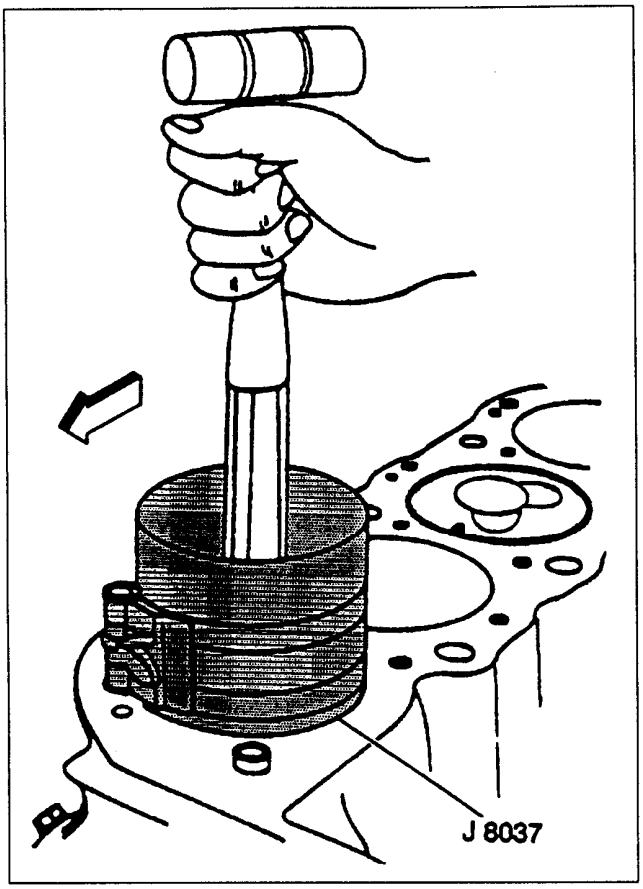


Figure 77 – Installing the Piston and Connecting Rod

7. With a hammer handle, use light blows to tap the piston down into its bore.
   - Hold the ring compressor against the cylinder block until all the piston rings have entered the cylinder bore.
   - From underneath the cylinder block, guide the connecting rod so that it does not come in contact with the connecting rod journal, and damage it.
8. Install the connecting rod bearing insert into the connecting rod and the connecting rod bearing cap.
9. Connecting rod cap to the connecting rod.
10. Bolts to the connecting rod.
11. Tighten the bolts.

Tighten

- Apply a small amount of molybdenum grease to connecting rod bolt.
- Tighten in three steps.
  - — First Step: 39 N·m (29 lb. ft.).
  - — Second Step: Turn both bolts 60 degrees.
  - — Third Step: Then turn both bolts an additional 30 degrees.

12. Rotate the engine.
    - A slight, but even effort will be needed to rotate the engine.
    - If the effort to rotate the engine is uneven or extremely hard, slightly loosen the connecting rod bolts one at a time and rotate the engine to locate the cause and repair as needed.

OIL PUMP INSTALLATION

Tools Required:
J41220 Oil Slinger Remover
J41221 Oil Seal installer

Install or Connect (Figures 78 through 85)

1. Idler gear shaft to the cylinder block.
2. Apply clean engine oil to the bushing inside the cylinder block.
3. Apply RTV sealant (Three Bond 1141E or equivalent) to the edge of the oil pump.

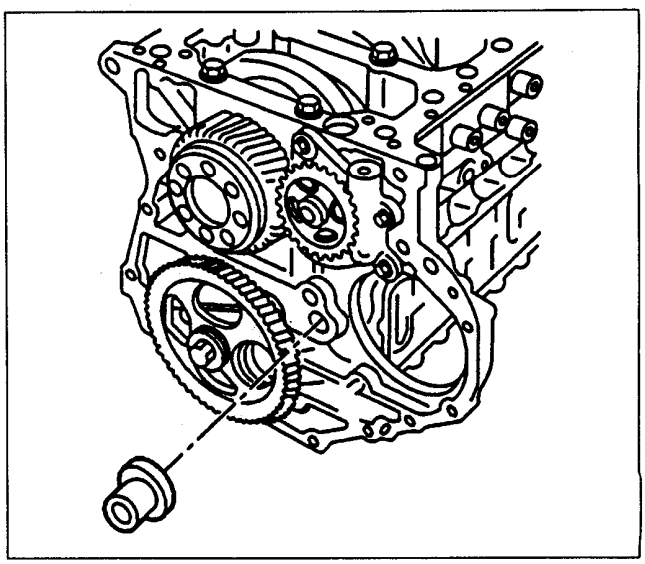


Figure 78 – Idler Gear Shaft

Important

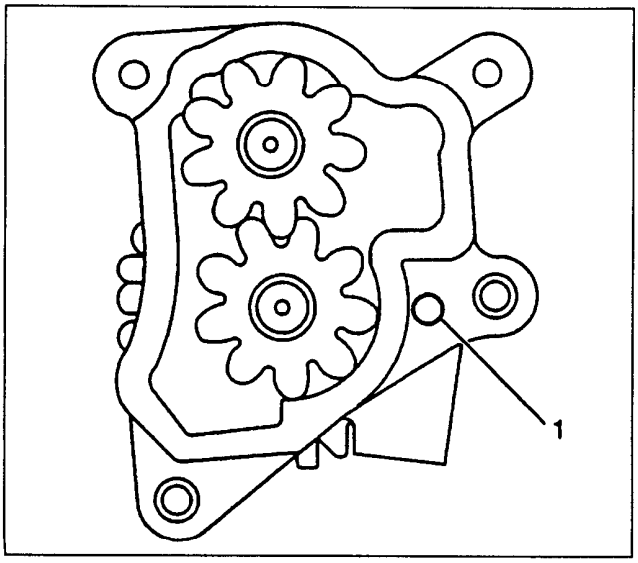
- Do not apply sealant over hole (1), refer to. This will restrict the flow of oil into the cylinder block.

4. Oil pump to the cylinder block.
5. Bolts to the oil pump.
6. Tighten the oil pump bolts.

Tighten

- Bolts to 24 N·m (17 lb. ft.).

7. Idler gear to the idler gear shaft.



Legend
(1) Oil Hole

Figure 79 — Applying Sealant to the Oil Pump

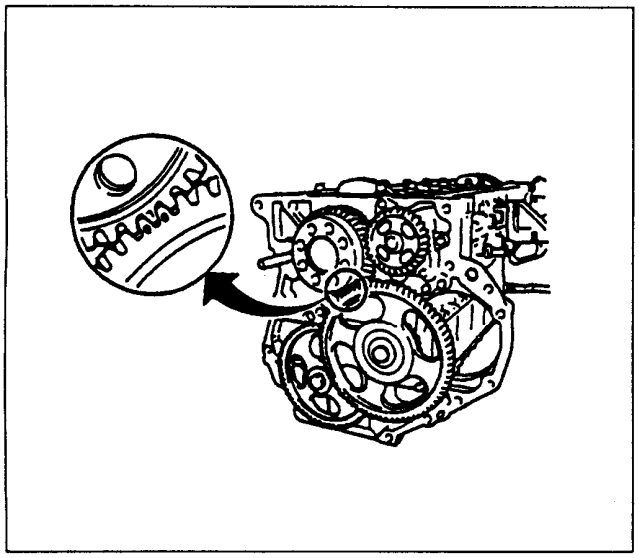
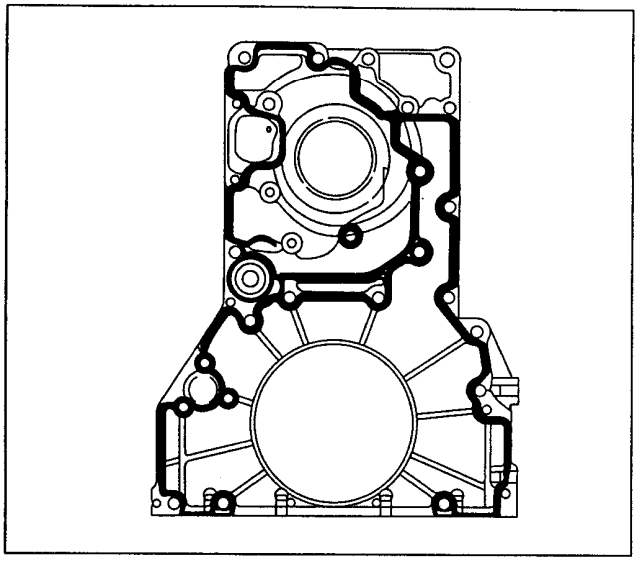


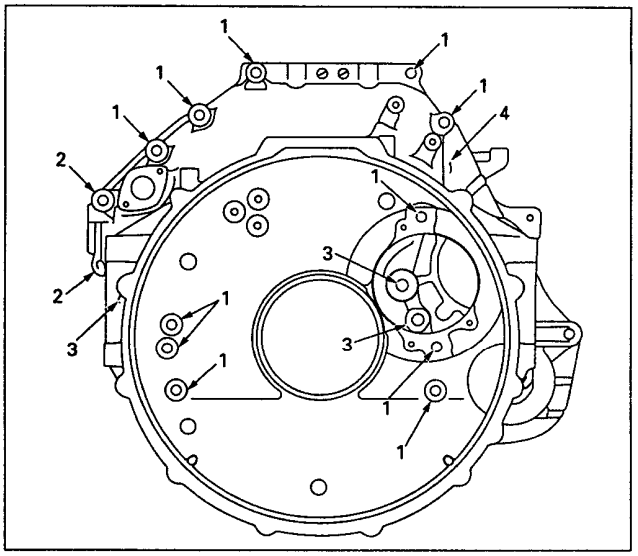
Figure 80 – Aligning the Timing Marks

8. Rotate crankshaft so that number 1 piston is on top dead center.
9. Align the crankshaft gear mark L and the idler gear (A) mark 0.
10. Tighten the idler gear (A) bolt.
    - Idler gear shaft oil port must be facing the cylinder block.



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Figure 81 – Applying Sealant to the Flywheel Housing



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Figure 82 – Flywheel Housing Bolt Tightening Sequence

Tighten

- Apply molybdenum grease to bolts
- Tighten in two-steps
  - — First stage 29 N·m (21 lb. ft.)
  - — Second stage 75 degrees

11. Apply RTV sealant (Three Bond 1141E or equivalent) to the flywheel housing fitting surfaces.
12. Flywheel housing to the cylinder block.
13. Bolts to the cylinder block.
14. Tighten the bolts.

Tighten

- Bolt marked 1, to 92 N·m (71 lb. ft.).
- Bolt marked 2, to 73 N·m (54 lb. ft.).
- Bolt marked 3, to 118 N·m (87 lb. ft.).
- Bolt marked 4, to 86 N·m (64 lb. ft.).

15. Oil slinger to crankshaft.
    A. Apply clean engine oil to the oil slinger.
    B. Insert the oil slinger into the adapter.
    C. Install the oil slinger sleeve to the adapter.
16. After pressing in the oil slinger, make sure that the distance between the crankshaft end surface and the oil slinger is (1) 10.5 ± 0.15 mm (0.413 ± 0.006 in.).
    A. Check the measurement at several different points.

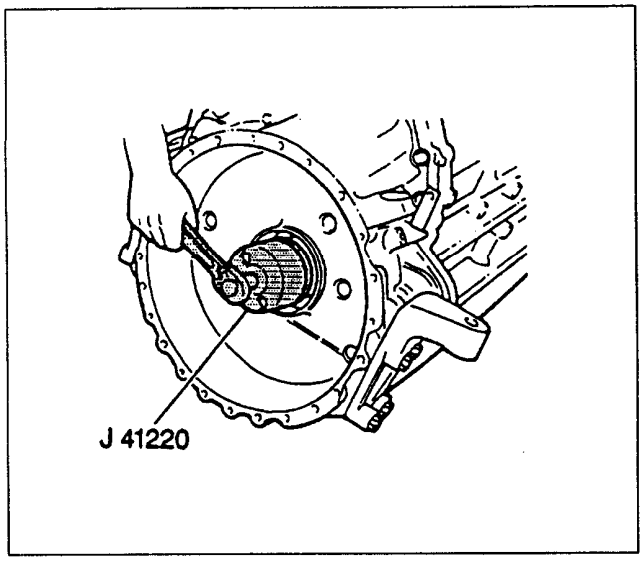
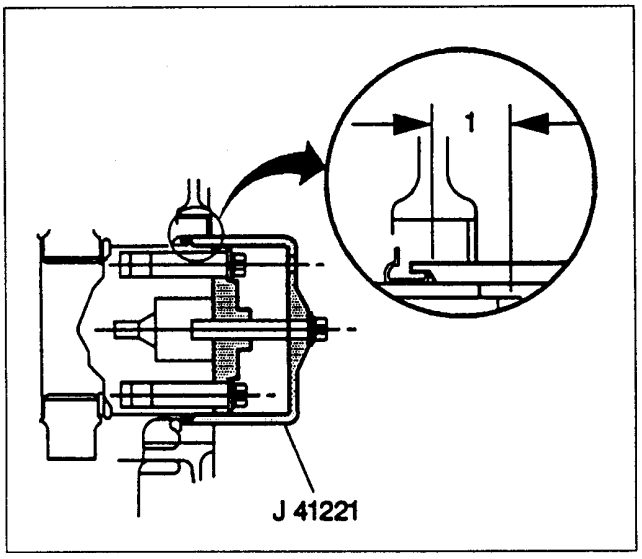


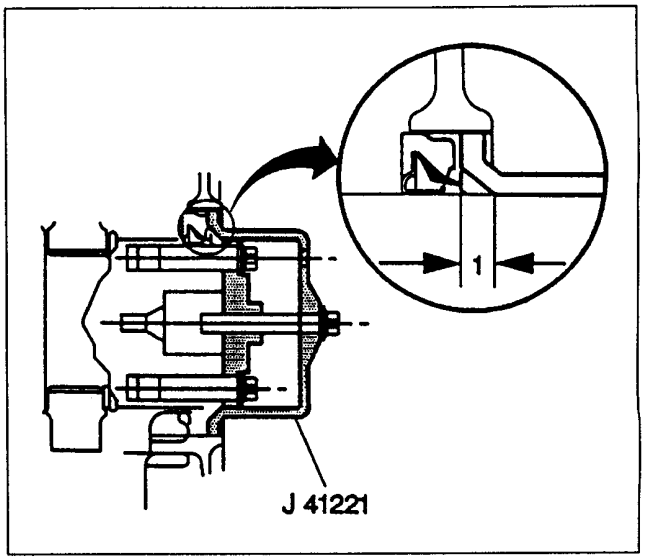
Figure 83 – Oil Slinger to the Crankshaft



Legend
(1) Measurement of the Oil Slinger

Figure 84 — Oil Slinger Installation

17. Crankshaft rear seal.
    • Install J41221.
    A. Apply clean engine oil to the oil seal.
    B. Insert the oil seal adapter.
    C. Install the oil seal to the adapter, and tighten the center bolt until the sleeve comes in contact with the adapter and stops.
    D. After pressing in the oil seal, make sure that the distance between the crankshaft end surface and the oil slinger is (1) 7.5 ± 0.15 mm (0.295 ± 0.006 in.).
    • Check the measurement at several different points.



Legend
(1) Measure Depth

Figure 85 — Oil Seal Installation

18. Flywheel to the crankshaft. Refer to SECTION 7A6.
19. Oil pump pick up tube and O-ring.
20. Bolts to the oil pump pick up tube.
21. Bolts.

Tighten

- Bolt marked M8, to 24 N·m (17 lb.ft.).
- Bolt marked M10, to 48 N·m (35 lb. ft.).

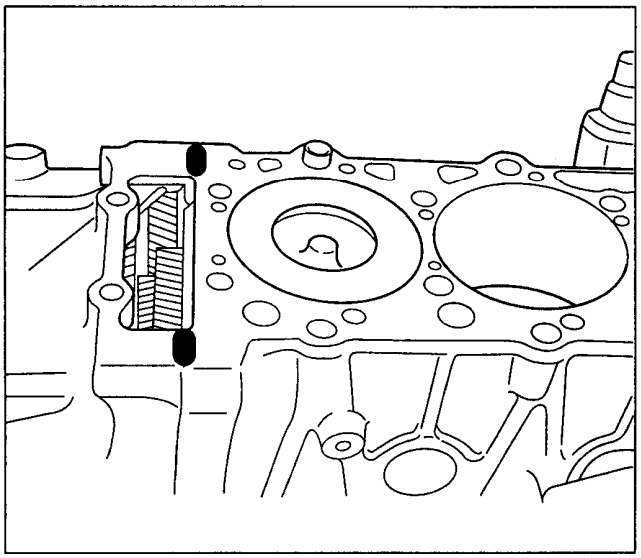
OIL PAN INSTALLATION

1. Refer to SECTION 6A6, for the installation of the oil pan.

CYLINDER HEAD INSTALLATION

Install or Connect (Figure 86 through 89)

1. Remove the cylinder liner retaining bolts and washers.
2. Apply RTV sealant (Three Bond 1207C or equivalent) to the rear corners of the cylinder block.
3. Install the cylinder head gasket with part number facing up.
4. Cylinder head bolts to the cylinder head.



012MV001

Figure 86 – Applying the Sealant

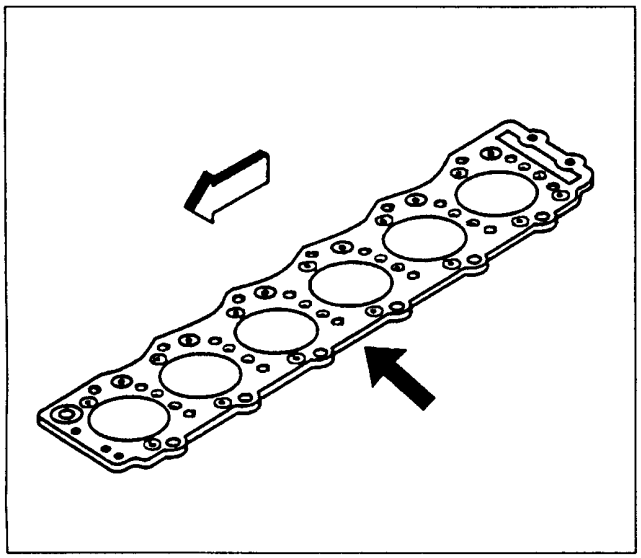


Figure 87 – Installation of the Cylinder Head Gasket

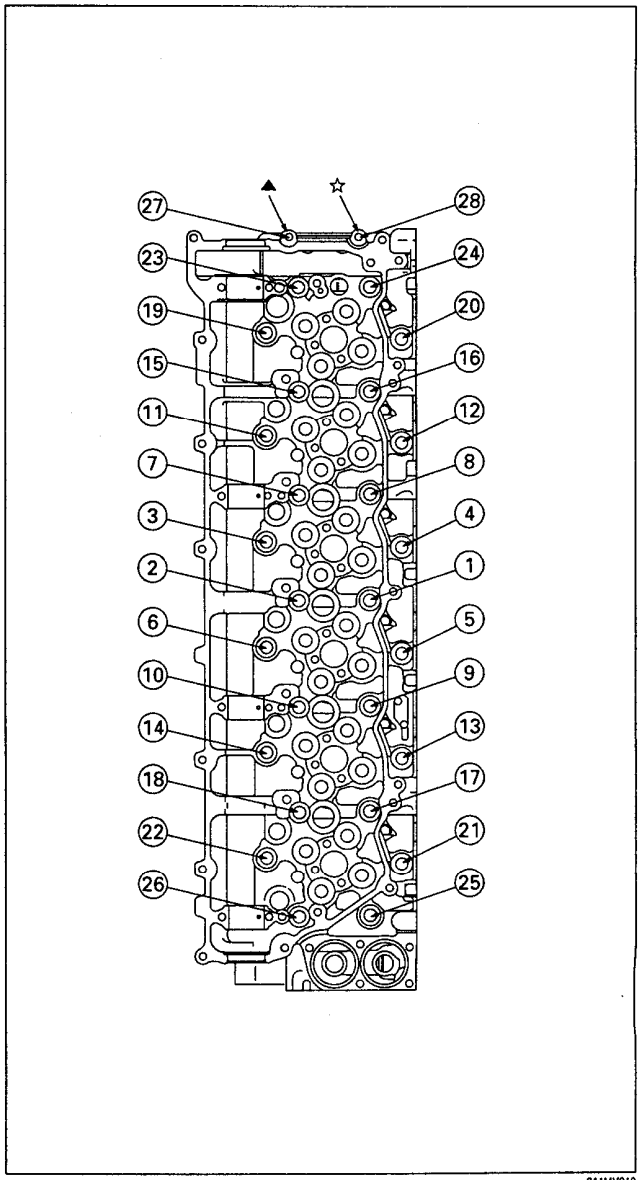
Tighten

- Apply a small amount of molybdenum grease to the M14 bolts.
- Cylinder head bolts in the following steps .
  - — 98 N·m (72 lb. ft.).
  - — 147 N·m (108 lb. ft.).
  - — Turn all the cylinder head bolts an additional 45 degrees.
- Apply clean engine oil to M10 bolts
  Tighten them to order number 27 to 28.
  - — 38 N·m (28 lb. ft.)

5. Install both of the thermostats.
6. Thermostat housing with gasket.
7. Thermostat housing bolts to the cylinder block.
8. Tighten thermostat housing bolts.

Tighten

- Bolts to 19 N·m (14 lb. ft.).



011MV010

Figure 88 – Cylinder Head Torque Sequence

CAMSHAFT INSTALLATION

Install or Connect (Figures 90 and 91)

1. Apply clean engine oil to the camshaft bearing surfaces.
2. Camshaft and the drive gear to the cylinder head.

Important

- When installing the camshaft, make sure that the timing marks are in the proper alignment.

3. Bearing caps to the cylinder head.
   - When installing camshaft bearing caps, make sure that the bearing caps are in numerical sequence.
4. Camshaft bearing cap bolts to the cylinder head.
5. Camshaft bearing cap bolts.

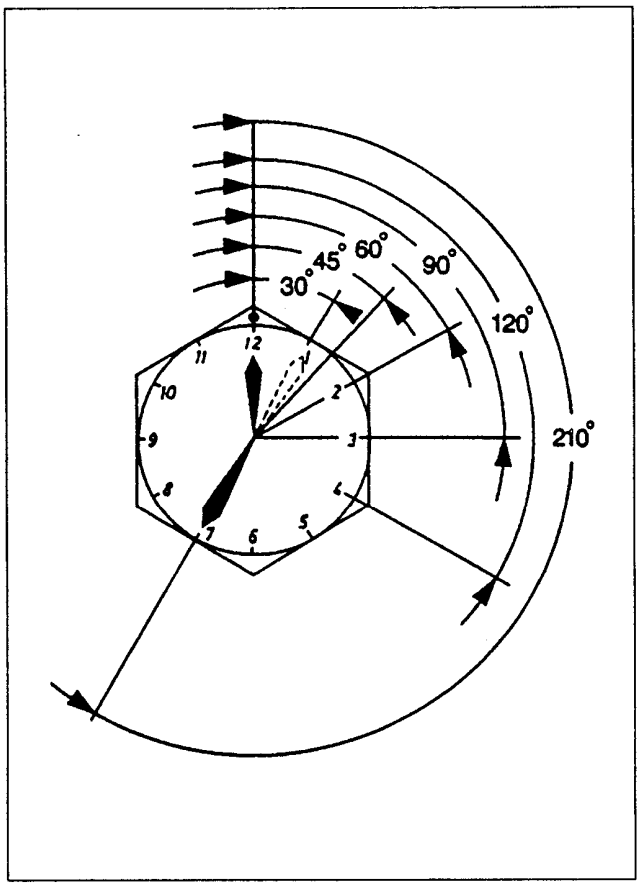


Figure 89 – Final Torque Step

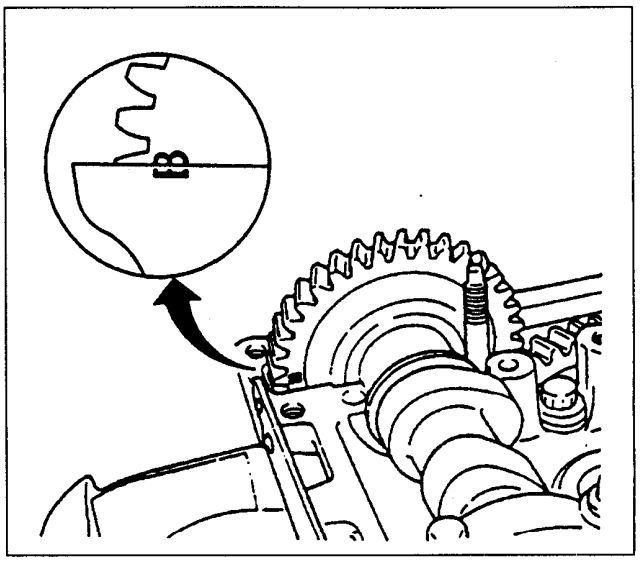


Figure 90 – Camshaft Timing Marks

Tighten

- Bolts to 27 N·m (20 lb. ft.).

VALVE TRAIN INSTALLATION

Install or Connect

1. Valve rocker arm shaft to the cylinder head.
2. Valve rocker arm bolts to the cylinder head.

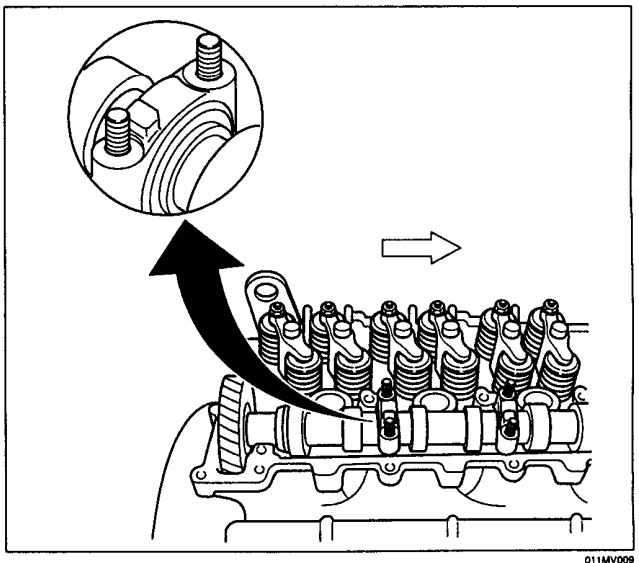


Figure 91 – Camshaft Bearing Caps

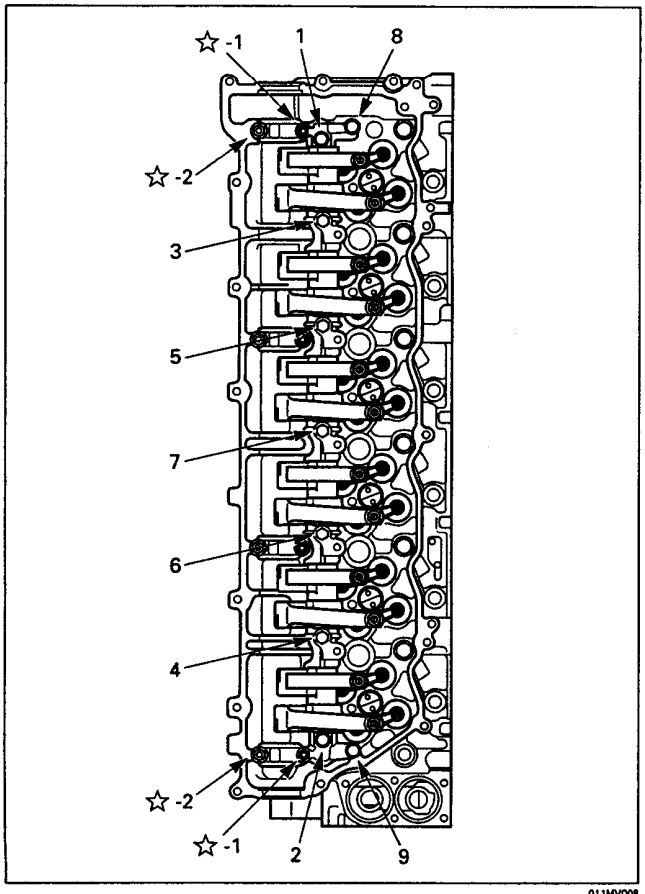


Figure 92 – Valve Rocker Arm Shaft Tightening Sequence

3. Tighten the valve rocker arm bolts.

Tighten

- First of all tighten star mark 1 nut then tighten star mark 2 nut.
- After tighten star mark 1 and 2, tighten rocker arm shaft braket bolts in sequence.
  - — Star mark nut 1 and 2 to 27 N·m (20 lb.ft.)
  - — Bolts 1 through 7 to 56 N·m (41 lb. ft.)
  - — Bolts 8 and 9 to 27 N·m (20 lb. ft.)

VALVE ADJUSTMENT

Adjust (Figures 93 through 96)

1. Rotate the engine so that the timing marks on the front cover and the crankshaft balancer are aligned. Number 1 cylinder should be at TDC.
2. Before adjust the valve clearance, loose adjustment screw both on the rocker arm and the valve bridge.
3. Adjust all the valves clearances to 0.4 mm (0.016 in.).
   - Insert a feeler gauge between the rocker arm and the cap of valve bridge and adjust by turning the adjusitng screw on the rocker arm until there is a slight drag on the feeler gauge. Tighten the lock nut securely.
   - With a feeler gauge inserted, screw in the adjusting screw on the bridge gradually until it touches to the end of the valve stem, and make sure that the movement of the feeler gauge becomes hard.

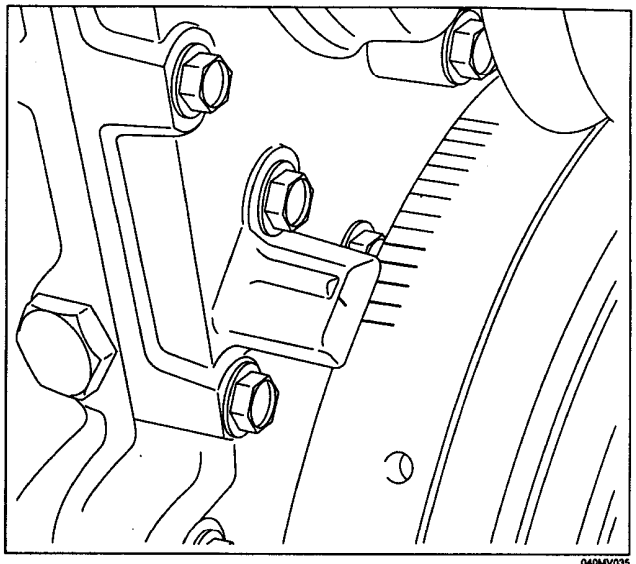


Figure 93 – Timing Marks

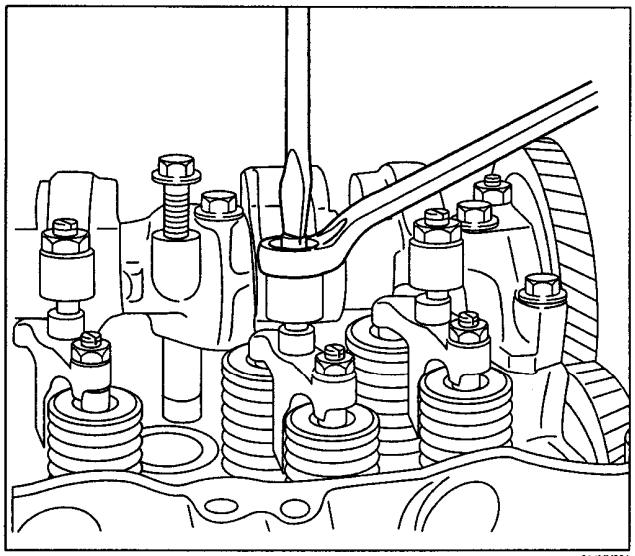


Figure 94 – Valve Adjustment

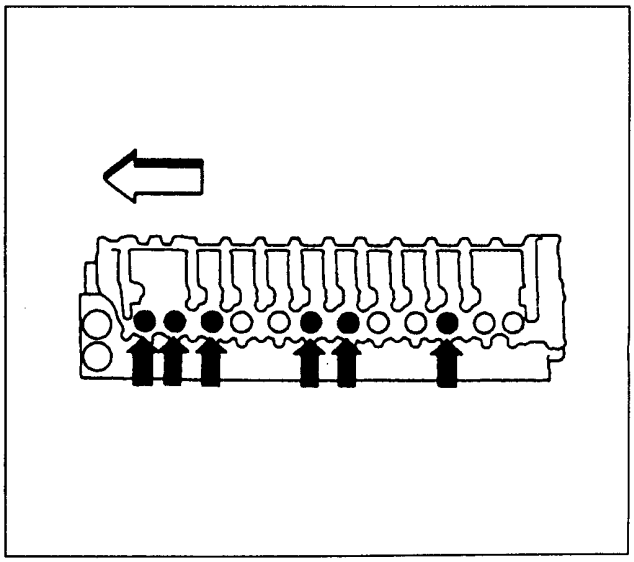


Figure 95 – Valve Adjustment Sequence One

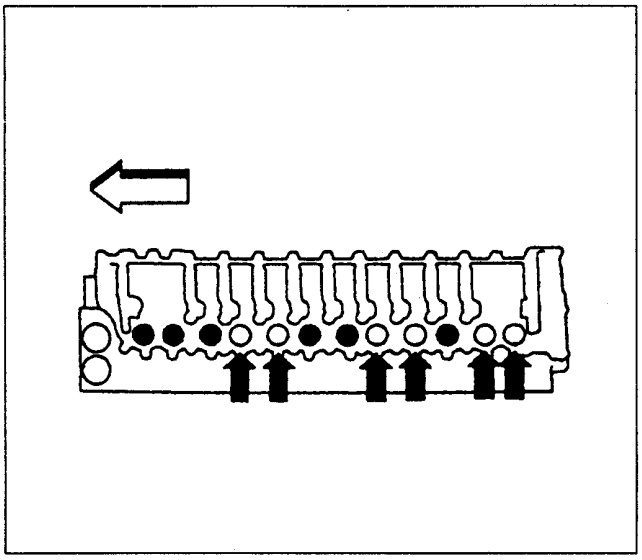


Figure 96 – Valve Adjustment Sequence Two

- In this condition, the opposite end of the bridge is raised. Readjust by loosening the adjusting screw on the bridge until there is a slight drag on the feeler gauge and tighten the lock nut securely.
- Adjust the intake valves on cylinders 1, 2, 4.
- Adjust the exhaust valves on cylinders 1, 3, 5.

3. Tighten adjusting lock nut.

Tighten

- Adjusting lock nut to 22 N·m (16 lb. ft.).

4. Rotate the engine one full turn so that the timing marks on the crankshaft balancer and the front cover are in alignment again.
5. Adjust all the valve clearances to 0.4 mm (0.016 in.).

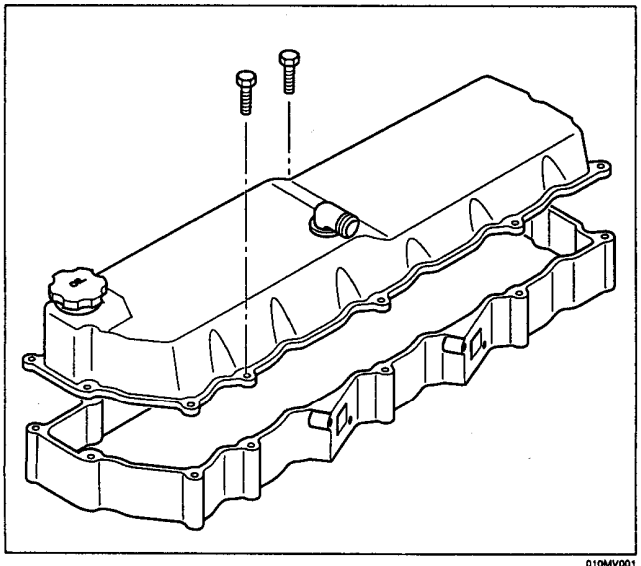


Figure 97 – Valve Rocker Arm Cover

- Insert a feeler gauge between the rocker arm and the cap of valve bridge and adjust by turning the adjusitng screw on the rocker arm until there is a slight drag on the feeler gauge. Tighten the lock nut securely.
- With a feeler gauge inserted, screw in the adjusting screw on the bridge gradually until it touches to the end of the valve stem, and make sure that the movement of the feeler gauge becomes hard.
- In this condition, the opposite end of the bridge is raised. Readjust by loosening the adjusting screw on the bridge until there is a slight drag on the feeler gauge and tighten the lock nut securely.
- Adjust the intake valves on cylinders 3, 5, 6 .
- Adjust the exhaust valves on cylinders 2, 4, 6.

6. Tighten adjusting lock nut.

Tighten

- Adjusting lock nut to 22 N·m (16 lb. ft.).

7. Recheck all the valve clearances and readjust if necessary.
8. Valve rocker arm cover and gasket to the cylinder head.
9. Valve rocker cover bolts to the cylinder head.
10. Tighten valve rocker arm cover bolts.

Tighten

- Valve rocker arm cover bolts to 13 N·m (113 lb. in.).
- Tighten center bolts first, then the outer bolts.

INTAKE MANIFOLD INSTALLATION

Install or Connect (Figures 98 and 99)

1. Intake manifold and gasket to the cylinder head.
2. Nuts and bolts to the intake manifold.
3. Tighten the nuts and bolts in sequence.

Tighten

- Nuts and bolts to 13 N·m (113 lb. in.).

EXHAUST MANIFOLD INSTALLATION

Install or Connect (Figure 100)

1. Exhaust manifold and gasket to the cylinder head.
2. Exhaust manifold nuts, bolts, washers and the spacers (Figure 100).

Tighten

- Nuts and bolts to 34 N·m (25 lb. ft.).

3. Turbocharger to the exhaust manifold. Refer to SECTION 6J.

GLOW PLUG INSTALLATION

For service of the glow plugs, refer to SECTION 6D6.

FUEL INJECTORS AND FUEL INJECTION PUMP INSTALLATION

For service of the fuel injectors and the fuel injection pump, refer to SECTION 6C2.

FLYWHEEL INSTALLATION

For service of the flywheel, refer to SECTION 7A6.

ENGINE ACCESSORY INSTALLATION

- Refer to the proper SECTION, for the following accessories:
  - Power Steering Pump.
  - Air Conditioning Compressor.
  - Generator.
  - Air compressor (for air brakes).
  - Starter Motor.
  - Hydraulic Pump (for normal brakes).
  - Drive Belts
  - Engine Cooling Fans and Clutch.

INSTALL THE ENGINE

For service of the engine, refer to SECTION 6A6.

THREAD REPAIR

General purpose thread repair kits are available commercially. Damaged threads may be reconditioned by drilling out, rethreading, and installing a suitable thread insert.

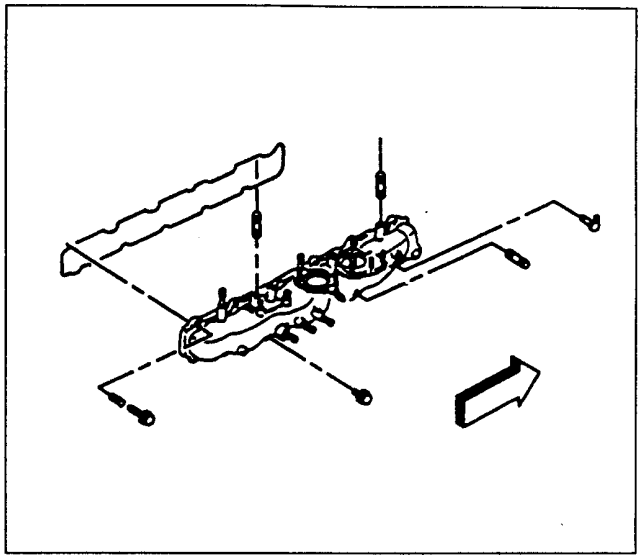


Figure 98 – Intake mamifold and Gasket

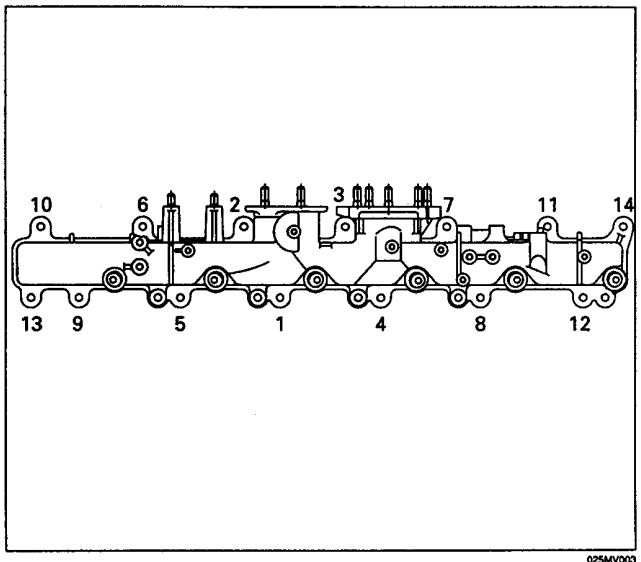


Figure 99 – Intake Manifold Tightening Sequence

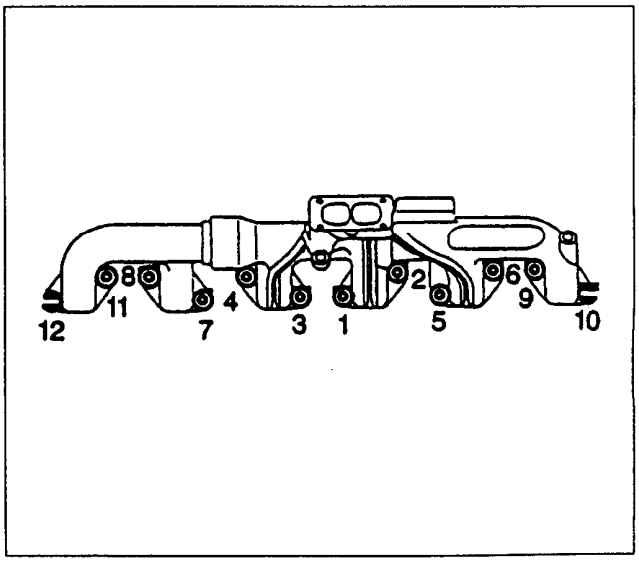


Figure 100 – Exhaust Manifold Nut Tightening Sequence

SPECIFICATIONS

GENERAL ENGINE SPECIFICATIONS

MODEL	6HK1-TC
Type	Inline 6, 4 stroke
Induction	Turbocharged
Combustion Chamber Type	Direct Injection
Bore	115 mm (4.5276")
Stroke	125 mm (4.9213")
Displacement	7.786 L (475 Cu.")
Compression Ratio	16.8:1
Firing Order	1-5-3-6-2-4
Valve Clearance, Cold	0.4 mm (0.16")
Full Flow Oil Filter	Cartridge Type
Oil Capacity	14.0L (14.79 Qts) *
Oil Pressure (Minimum at Idle)	Approximately 100 kPa (14 psi).
Compression Pressure at 200 RPM	
Production	3240 kPa (469 psi)
Service Limit	2157 kPa (313 psi)
Difference between each cylinder	Less than 196 kPa (28 psi)
* Includes full flow filter, which should be changed at each oil change.	

ENGINE SPECIFICATIONS

Item		Production	Service Limit
CAMSHAFT			
Camshaft Bearing Inside Diameter		40.0 to 40.04 mm (1.5748 to 1.5764")	40.19 mm (1.58228")
Camshaft Lobe Height	IN	52.851 mm (2.0807")	52.071 mm (2.0500")
	EXH	54.541 mm (2.1473")	53.761 mm (2.1166")
Camshaft Run-Out		–	0.05 mm (0.0020")
Journal Diameter		39.950 to 39.975 mm (1.57283 to 1.57382")	39.85 mm (1.5689")
Journal to Bearing Clearance		0.025 to 0.09 mm (0.0010 to 0.0035")	0.15 to (0.00590")
CONNECTING ROD.*			
Distortion (per 100 mm).		0.05 mm (0.0020") or less	0.2 mm (0.0079")
Piston Pin Bushing Inside Diameter		40.012 to 40 022 mm (1.5753 to 1.5757")	—
Piston Pin to Connecting Rod Bushing Clearance		0.012 to 0.027 mm (0.0005 to 0.0011")	0.05 mm (0.0020")
CRANKSHAFT AND CONNECTING ROD BEARINGS			
Available Undersize Connecting Rod Bearings		none	none
Connecting Rod Bearing Clearance		0.037 to 0.076 mm (0.00146 to 0.00299")	0.100 mm (0.00394")
Connecting Rod Journal Diameter		72.902 to 72.922 mm (2.8702 to 2.8709")	—
Available Crankshaft Undersize Main Bearings		none	none
CRANKSHAFT			
Crankshaft Main Bearing No. 4 (center) Crearance		0.093 to 0.124 mm (0.0037 to 0.0049")	0.14 mm (0.0055")

Item	Production	Service Limit
Crankshaft Main Bearings (except No. 4) Crearance	0.063 to 0.094 mm (0.0025 to 0.0037")	0.14 mm (0.0055")
Crankshaft End Play	0.15 to 0.33 mm (0.0059 to 0.0130")	0.4 mm (0.0157")
Crankshaft Run-out	0.06 mm (0.0024") or less	0.4 mm (0.0157")
CYLINDER HEAD		
Head Gasket Surface Distortion	0.05 mm (0.002") or less	0.2 mm (0.0079")
CYLINDER LINER		
Cylinder Liner Grade 1X for Service Part (Outside Diameter)	117.990 to 118.000 mm (4.6453 to 4.6457")	—
Cylinder Liner Grade 3X for Service Part (Outside Diameter)	118.001 to 118.010 mm (4.6457 to 4.6461")	—
Cylinder Liner Service Part Inside Diameter (Grade not available)	115.031 to 115.050 mm (4.5288 to 4.5295")	—
Cylinder Block Bore and Cylinder Liner Outside Diameter Clearance	0.011 to 0.029 mm (0.0004 to 0.0011")	—
Projection Above Cylinder Block Gasket Surface	0.06 to 0.1 mm (0.0236 to 0.0039")	—
OIL PUMP		
Drive Gear and Drive Gear Shaft Interference	0.015 to 0.044 mm (0.0006 to 0.0017")	—
Gear and Body Clearance	0.064 to 0.109 mm (0.0025 to 0.0043")	0.2 mm (0.0079")
Gear Shaft and Pump Body or Bushing Clearance	0.04 to 0.07 mm (0.0016 to 0.0028")	0.2 mm (0.0079")
Gear Shaft Outside Diameter	15.989 to 16.0 mm (0.6249 to 0.6299")	15.9 mm (0.6260")
Gear Tooth and Cover Inner Wall Clearance	0.125 to 0.221 mm (0.0049 to 0.0087")	0.3 mm (0.0118")
PISTON DIAMETER		
Service Part Size Grade is not available	114.970 to 115.000 mm (4.5264 to 4.5276")	—
Clearance between Piston and Liner	0.031 to 0.061 mm (0.0012 to 0.0024")	—
PISTON RING END GAP		
First Compression Ring	0.18 to 0.28 mm (0.0071 to 0.0110")	1.5 mm (0.0590")
Second and Third Compression Ring	0.35 to 0.5 mm (0.01378 to 0.01958")	1.5 mm (0.0590")
Oil Control Ring	0.15 to 0.35 mm (0.0059 to 0.0138")	1.5 mm (0.0590")
PISTON RING TO GROOVE CLEARANCE		
1st Compression Ring	0.09 to 0.13 mm (0.0035 to 0.0051")	0.2 mm (0.0079")
2nd and 3rd Compression Ring	0.03 to 0.07 mm (0.0012 to 0.0028")	0.15 mm (0.0059")
Oil Control Ring	0.030 to 0.07 mm (0.0012 to 0.0028")	0.15 mm (0.0059")
Piston Pin Diameter	39.995 mm (1.5746")	—
Piston Pin Hole Diameter in the Piston	40.004 to 40.012 mm (1.5750 to 1.5752")	—
Piston Pin to Piston Clearance	0.009 to 0.017 mm (0.0004 to 0.0007")	0.05 mm (0.002")

Item	Production	Service Limit
TIMING GEARS.*		
Idler Gear *Backlash*	0.1 to 0.17 mm (0.0039 to 0.0067")	0.3 mm (0.0118")
Idler Gear end Play Gear "A" and "B"	0.08 to 0.155 mm (0.0031 to 0.00610")	0.2 mm (0.0079")
Gear "C"	0.09 to 0.154 mm (0.0035 to 0.0061")	0.2 mm (0.0079")
VALVE GUIDES AND SEATS		
Minimum Valve Margin Thickness	—	—
Intake	1.71 mm (0.0673")	1.3 mm (0.0512")
Exhaust	1.75 mm (0.0689")	1.25 mm (0.0492")
Valve Face Angle : Intake	60 degrees	—
Valve Face Angle : Exhaust	45 degrees	—
VALVE GUIDE TO VALVE STEM CLEARANCE		
Intake	0.039 to 0.071 mm (0.0015 to 0.0028")	0.2 mm (0.0079")
Exhaust	0.064 to 0.096 mm (0.0025 to 0.0038")	0.25 mm (0.0098")
VALVE INSTALLED DEPTH		
Intake	1 mm (0.0394")	2.5 mm (0.0984")
Exhaust	1.3 mm (0.0512")	2.8 mm (0.1102")
VALVE STEM DIAMETER		
Intake	7.946 to 7.961 mm (0.3128 to 0.3134")	7.80 mm (0.3071")
Exhaust	7.921 to 7.936 mm (0.3118 to 0.3124")	7.77 mm (0.3059")
VALVE SEAT WIDTH		
Intake	3.2 mm (0.1260")	—
Exhaust	2.8 mm (0.1102")	—
VALVE SPRINGS		
FREE LENGTH		
Intake	65.9 mm (2.5945")	64.8 mm (2.5512")
Exhaust	68.1 mm (2.6811")	66.9 mm (2.6339")
INCLINATION		
Intake	2.5 mm (0.0984") or less	2.9 mm (0.1142")
Exhaustr	2.5 mm (0.0984") or less	3.0 mm (0.1181")
TENSION (At 46.0 mm [1.8110"] length)		
Intake	348.1 N (78.3 lb.).	296 N (69 lb.).
Exhaust	382.5 N (86 lb.).	325 N (73 lb.).
VALVE TRAIN		
Valve Rocker Arm Inside Diameter	22.01 to 22.035 mm (0.8665 to 0.8675")	22.15 mm (0.8720")
Valve Rocker Arm to Shaft Clearance	0.01 to 0.056 mm (0.0004 to 0.0022")	0.2 mm (0.0079")
Valve Rocker Arm to Shaft Diameter	21.979 to 22.0 mm (0.8653 to 0.8661")	21.85 mm (0.8602")

FASTENER TIGHTENING SPECIFICATIONS

Application	N·m	Lb Ft	Lb In.
Camshaft Bearing Cap	27	20	—
Camshaft Gear Bolt	142	105	—
Rocker Arm Shaft Bracket Nuts (Star mark 1 to 2)	27	20	—
Rocker Arm Shaft Bracket Bolts (8 to 9)	27	20	—
Rocket Arm Shaft Bracket Bolts (1 through 7)	56	41	—
Charge Air Pipe Bolt	37	27	—
Connecting Rod Bolt			
First Stage	39	29	—
Second Stage	plus 60 degrees	plus 60 degrees	—
Third Stage	plus 30 degrees	plus 30 degrees	—
Crankshaft Balancer Bolt and Washer	200	148	—
Crankshaft Pulley Bolt and Washer	48	35	—
Cylinder Body Lower Crankcase (M10)	37	27	—
Cylinder Lower Crankcase (M14) Apply molybdenum grease			
First Stage	98	72	—
Second Stage	132	98	—
Third Stage	plus 30 to 60 degrees	plus 30 to 60 degrees	—
Cylinder Head Bolt (M14) Apply molybdenum grease			
First Stage	98	72	—
Second Stage	147	108	—
Third Stage	plus 30 to 60 degrees	plus 30 to 60 degrees	—
Cylinder Head Bolt (M10) Apply engine oil	38	28	—
Engine Mounting Bolt to the Frame	36	26	—
Engine Mounting Nut to the Frame	83	61	—
Engine Mount Through Bolt	294	217	—
Exhaust Manifold Nut	34	25	—
Exhaust Pipe Adapter to the Exhaust Manifold	52	38	—
Flywheel Bolt Apply molybdenum grease			
First Stage	78	58	—
Second Stage	plus 60 degrees	plus 60 degrees	—
Third Stage	plus 60 degrees	plus 60 degrees	—
Front Cover Bolt	19	4	—
Front Engine Mount Bolt	79	57	—
Idler Gear Bolt (Idler A) Apply molybdenum grease			
First stage	29	21	—
Second stage	plus 75 degrees	plus 75 degrees	—
Idler Gear Bolt (Idler B)	95	70	—
Idler Gear Shaft Bolt (Idler B)	31	23	—
Intake Manifold Bolt	13	—	113
Oil Cooler Bolt	19	14	—
Oil Filter Bracket Bolt	38	28	—
Oil Jet Bolt	21	15	—
Oil Pan Bolt	24	17	—
Oil Pump Body Bolt	24	17	—
Oil Strainer Tube Bolt (M8)	24	17	—
Oil Strainer Tube Bolt (M10)	48	35	—
Rear Engine Mounting Nut and bolt to the Frame	108	80	—
Thermostat Housing Bolt to the Cylinder Head	19	14	—
Turbocharger Drain Line Bolt (to Block)	18	13	—
Turbocharger Drain Line Bolt (to Turbocharger)	27	20	—

Application	N·m	Lb Ft	Lb In.
Turbocharger Feed Line Bolt (to Block)	18	13	—
Turbocharger Feed Line Bolt (to Turbocharger)	18	13	—
Turbocharger to Exhaust Manifold Nut	52	38	—
Valve Rocker Arm Cover Bolt	13	—	113
Water Outlet Bolt (M8)	19	14	—
Water Pump Bolt (M16)	103	76	—

SPECIAL TOOLS

J26999-12 Compression Gauge
J29109 Engine Stand
J34915 Engine Stand Adapter
J43264 Compression Gauge Adapter
J43272 Valve Guide Remover and Installer
J43267 Valve Stem Seal Installer
J36660 Torque Angle Meter
J41220 Slinger Remover
J41221 Oil Seal Remover and Installer
J41222 Crankshaft Gear Installer
J43263 Valve Spring Compressor
J43269 Injection Pipe Seal Installer
J43266 Nozzle Sleeve Installer
J43265 Nozzle Sleeve Remover
J43268 Guide Bridge Installer

SECTION 6B1B

WATER PUMP OVERHAUL

NOTICE: *Always use the correct fastener in the correct location. When you replace a fastener, use ONLY the exact part number for that application. ISUZU will call out those fasteners that require a replacement after removal. ISUZU will also call out the fasteners that require thread lockers or thread sealant. UNLESS OTHERWISE SPECIFIED, do not use supplemental coatings (paints, greases, or other corrosion inhibitors) on threaded fasteners or fastener joint interfaces. Generally, such coatings adversely affect the fastener torque and the joint clamping force, and may damage the fastener. When you install fasteners, use the correct tightening sequence and specifications. Following these instructions can help you avoid damage to parts and systems.*

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Seal Installation Height	6B1B- 5
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DISASSEMBLY

Disassemble (Figures 1 through 5)

1. Impeller using a suitable puller.
2. Pulley using a suitable puller.
3. Dust thrower.
4. Snap ring using snap ring pliers.
5. Spindle, bearing and spacer using a plastic hammer to lightly tap the spindle free.
6. Front seal.
7. Seal unit using a arbor press and a suitable remover.
8. Bearings and spacer from the spindle using an arbor press.

INSPECTION AND REPAIR

Replace or repair any component that has wear, damage or any other abnormal condition found through inspection.

Inspect (Figures 1 and 6)

- For proper fit of the shaft to pulley center to pulley.
- Housing for cracks or burrs.
- Shaft for cracks, burrs or pitting. Replace as necessary.

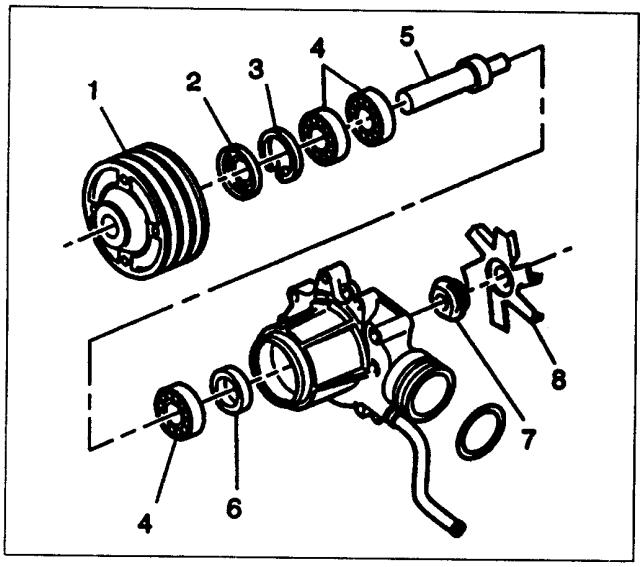
PUMP SPINDLE INTERFERENCES

Interference	mm	in.
Shaft to Pulley Center	0.048 – 0.078	0.0019 – 0.0031
Shaft to Impeller	0.027 – 0.120	0.0011 – 0.0047

ASSEMBLY

Assemble (Figures 7 through 12)

1. Bearings and spacer onto the spindle.
2. Spindle, bearings and spacer to housing using an arbor press and a suitable installer.
3. Prior to installing the front seal, perform the following:
   A. Apply multipurpose type grease to the lip seal.
   B. Apply engine oil to the lip seals outer circumference.
   C. Position the seal so that the lip of the seal is facing forward.
4. Front seal.
5. Snap ring using snap ring pliers.
6. Dust thrower.



Legend
(1) Pulley
(2) Dust Thrower
(3) Snap ring
(4) Bearings and Spacer
(5) Spindle
(6) Front Seal
(7) Seal Unit
(8) Impeller

Figure 1 – Water Pump Component

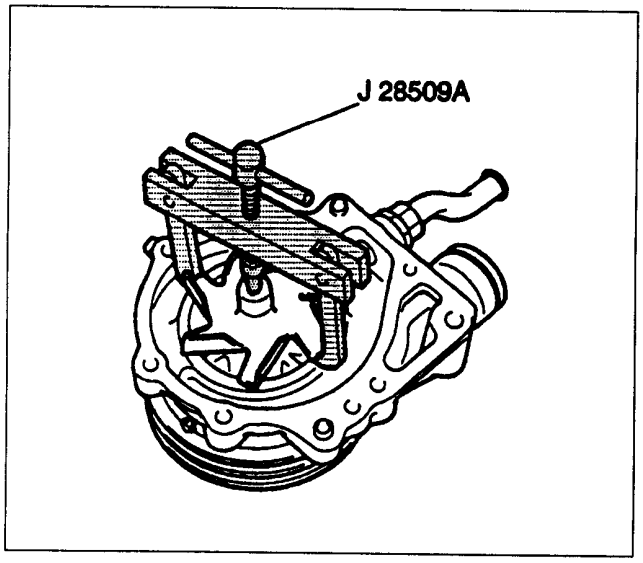


Figure 2 – Impeller Removal

7. Pulley using a bench press.

CAUTION: To protect the bearings and housing during this procedure, the press must contact the impeller side of the pump shaft and the pulley.

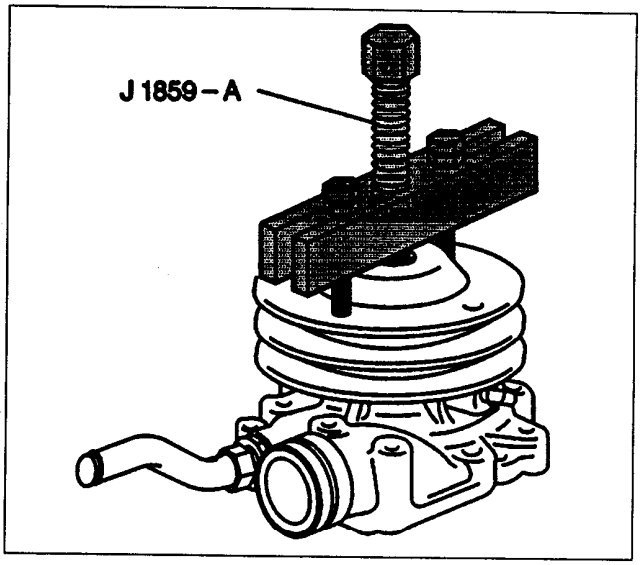


Figure 3 – Pulley Removal

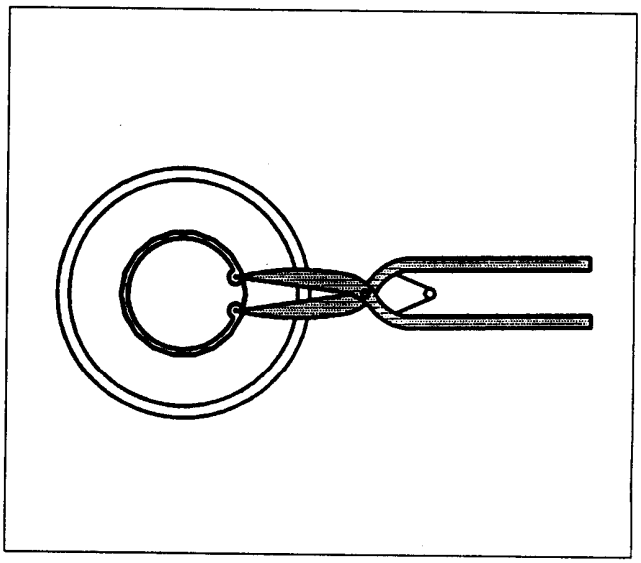


Figure 4 – Snap Ring Removal

8. Apply a thin coat of liquid gasket (Three Bond 1207C or equivalent) to the seal unit before installing.
9. Seal unit to the housing.

Measure

- Install seal unit to specified height using a bench press and installer.
- Seal height 11.0 – 11.6 mm (0.433 – 0.457 in.)

CAUTION: To protect the bearings and housing during this procedure, the press must contact the impeller and the pulley.

10. Impeller to the shaft using bench press, until the impeller bottoms out against the shaft.

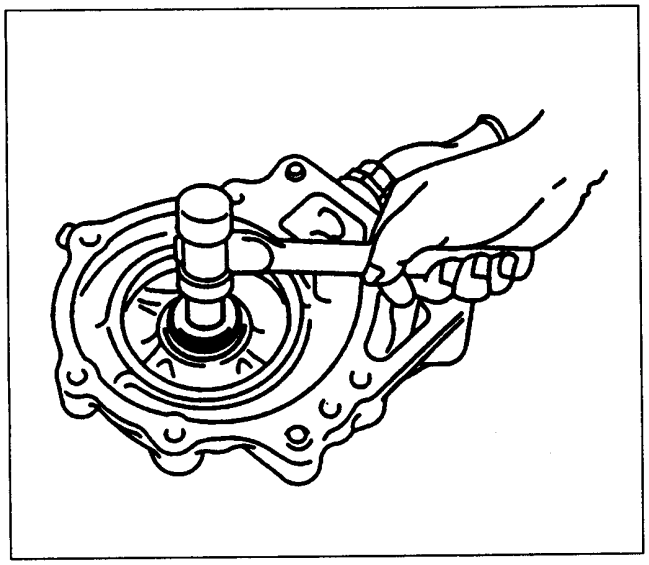


Figure 5 – Spindle and Bearing Removal

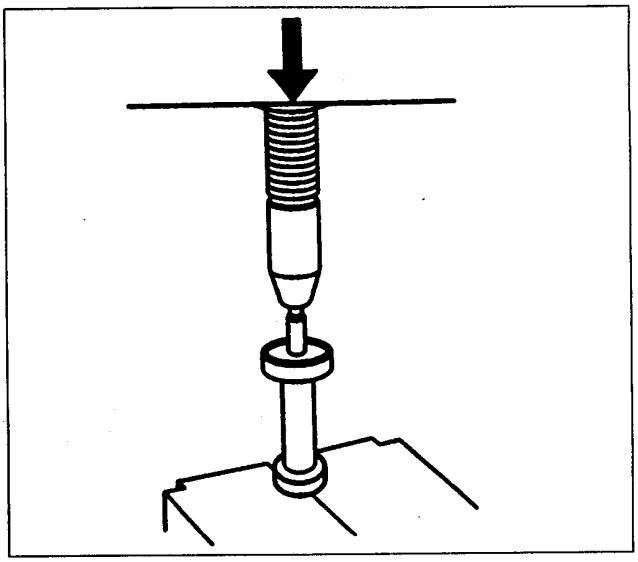


Figure 7 – Installing Bearings and Spacer

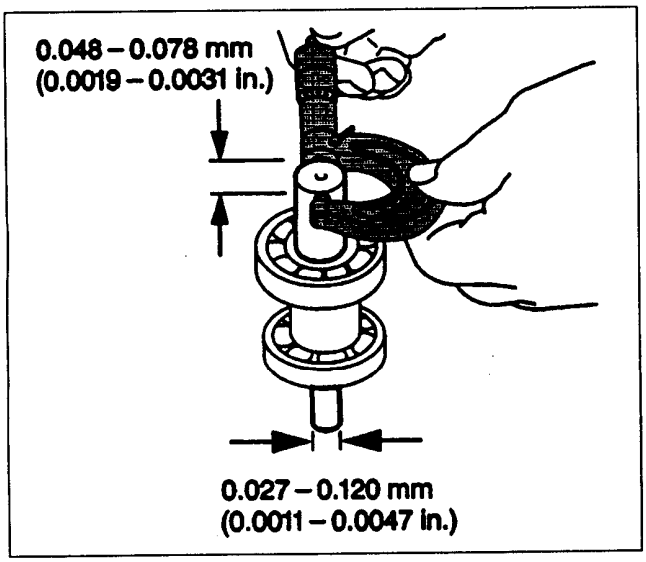


Figure 6 – Measuring and Shaft Interference

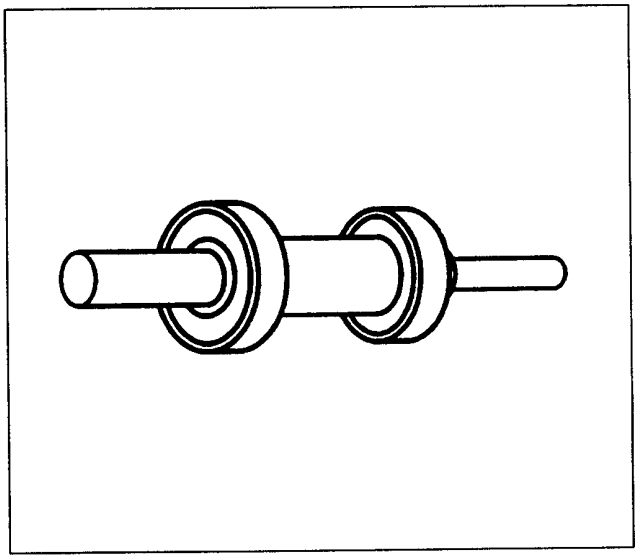


Figure 8 – Bearing Installed to Shaft

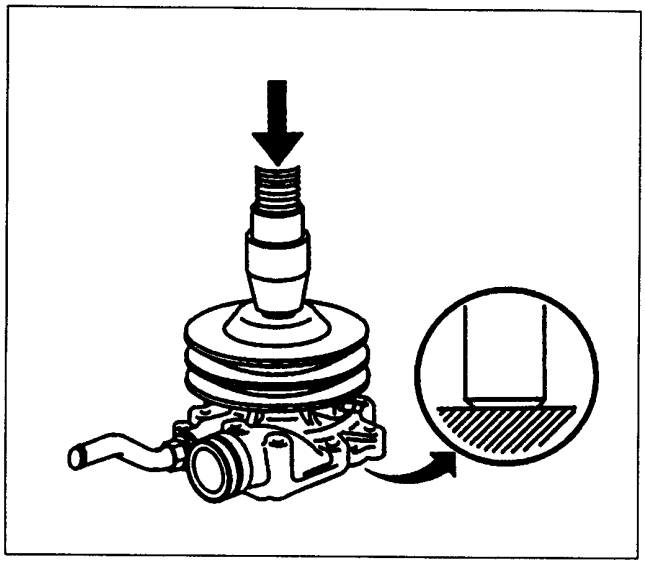


Figure 9 – Pulley Installation

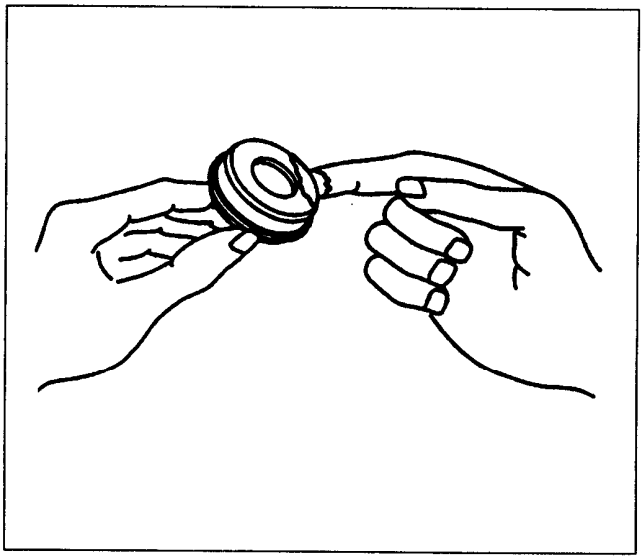


Figure 10 – Applying Liquid Gasket

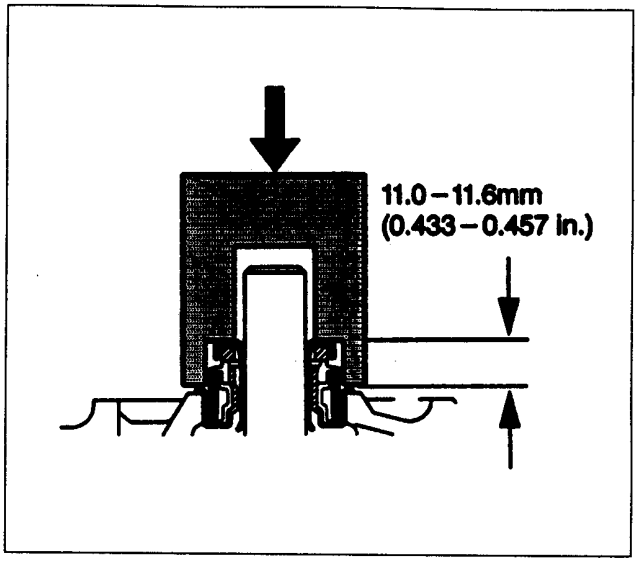


Figure 11 – Installing the Seal Unit

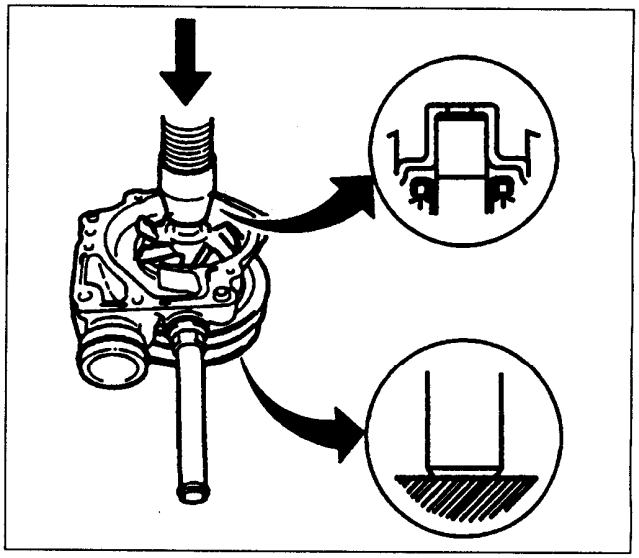


Figure 12 – Impeller Installation

SPECIFICATIONS

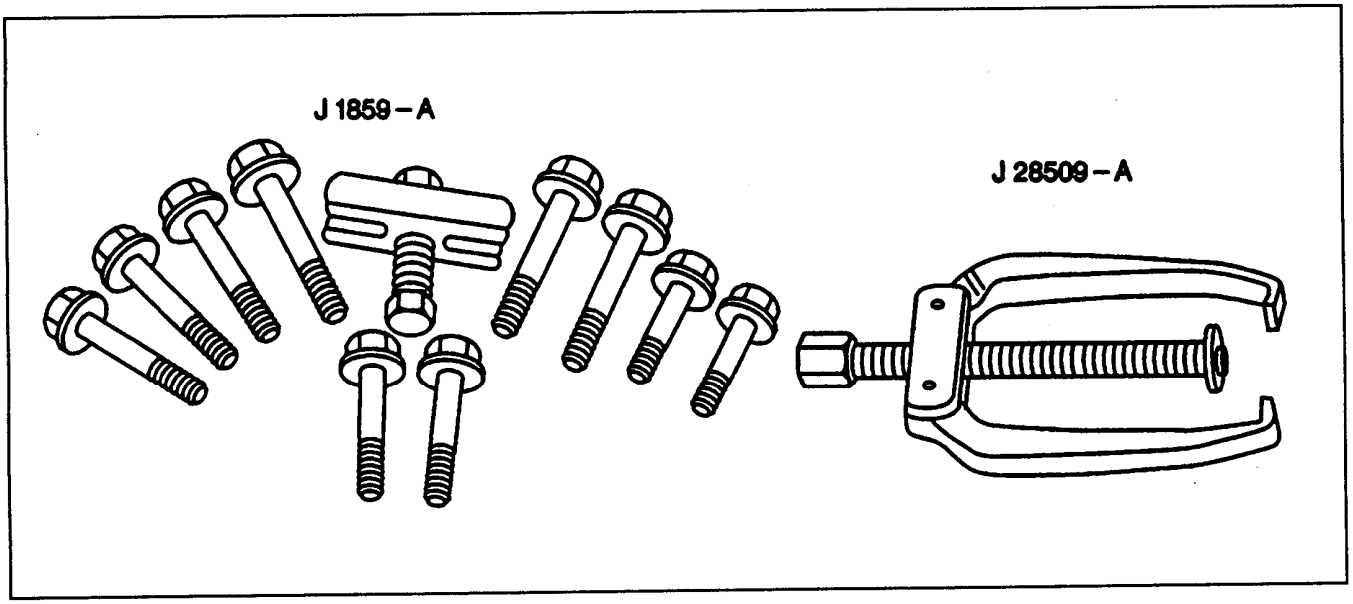
PUMP SPINDLE INTERFERENCES

Interference	mm	in.
Shaft to Pulley Center	0.048 – 0.078	0.0019 – 0.0031
Shaft to Impeller	0.027 – 0.120	0.0011 – 0.0047

PUMP SPINDLE INTERFERENCES

Seal Unit Installation	mm	in.
Seal Height	11.0 – 11.6	0.433 – 0.457

SPECIAL TOOLS



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SECTION 6C

FUEL SYSTEM

For information regarding fuel systems, refer to the appropriate Diesel Fuel Injection, Engine Emission and Electrical Diagnosis Service Manual.

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SECTION 6C2

DIESEL FUEL INJECTION

NOTICE: *Always use the correct fastener in the correct location. When you replace a fastener, use ONLY the exact part number for that application. ISUZU will call out those fasteners that require a replacement after removal. ISUZU will also call out the fasteners that require thread lockers or thread sealant. UNLESS OTHERWISE SPECIFIED, do not use supplemental coatings (paints, greases, or other corrosion inhibitors) on threaded fasteners or fastener joint interfaces. Generally, such coatings adversely affect the fastener torque and the joint clamping force, and may damage the fastener. When you install fasteners, use the correct tightening sequence and specifications. Following these instructions can help you avoid damage to parts and systems.*

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GENERAL DESCRIPTION

COMMON RAIL SYSTEM

This section covers the electronically controlled fuel injection system for 6HK1 diesel engine.

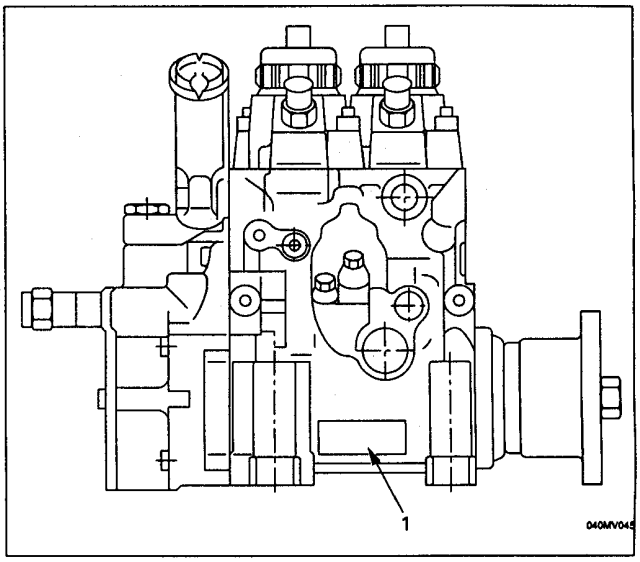
The 6HK1 (7.8L) diesel engine fuel system consists of the following.

- Fuel tank
- Fuel hoses and lines
- Water separator
- Fuel filter
- Fuel feed pump
- Fuel injection pump
- Fuel common rail
- Steel lines
- Six fuel injectors with solenoid valve

The fuel injection pump, fuel common rail and the fuel injectors are made by DENSO.

If an internal problem occurs in the fuel injection pump, the fuel injection pump must be removed from the engine and serviced by an authorized DENSO dealer. Do not open the fuel injection pump and injector assembly, or the warranty is void.

The fuel injection pump has an identification tag (1) attached to the fuel injection pump body (Figure 1).



Legend

(1) Identification Tag

Figure 1 – Identification Tag Location

SYSTEM OUTLINE

The COMMON RAIL SYSTEM detects engine conditions (engine speed, accelerator pedal angle, coolant temperature, etc.) by means of its sensors and generally control fuel injection amount, timing, and pressure by means of its microcomputer, thereby making the engine run in the best condition.

Further, the system performs the self-diagnosis/ lighting function to diagnose main components and, if abnormality found, worn the driver, the failsafe function to stop the engine depending on the parts to which trouble has occurred, and the backup function to switch over the control method to enable the vehicle to run continuously.

SYSTEM COMPOSITION

The system can be functionally divided into two systems, fuel and control.

(1) Fuel System

The high pressure fuel generated by injection pump is distributed to each cylinder. The solenoid valve in the injector opens and closes the nozzle needle valve, thereby controlling the start and end of fuel injection.

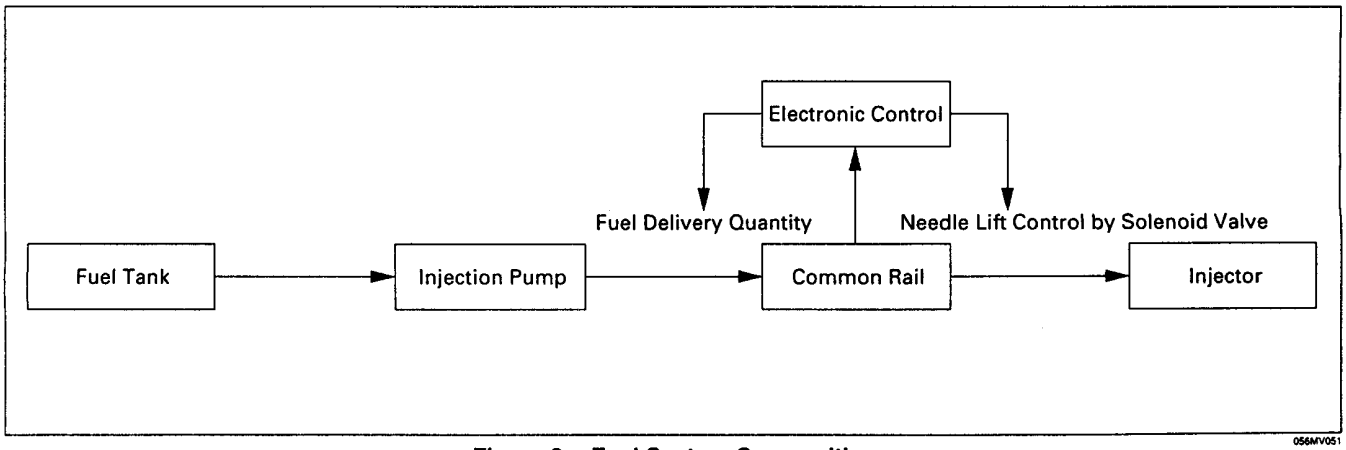


Figure 2 – Fuel System Composition

(2) Control System

ECM is used to compute and control from the signals received from the sensors installed to the engine and vehicle the timing and time for passing current to the injector so that the optimum quantity of fuel can be injected at the optimum timing.
The control system mainly comprises sensors, computer, and actuator.

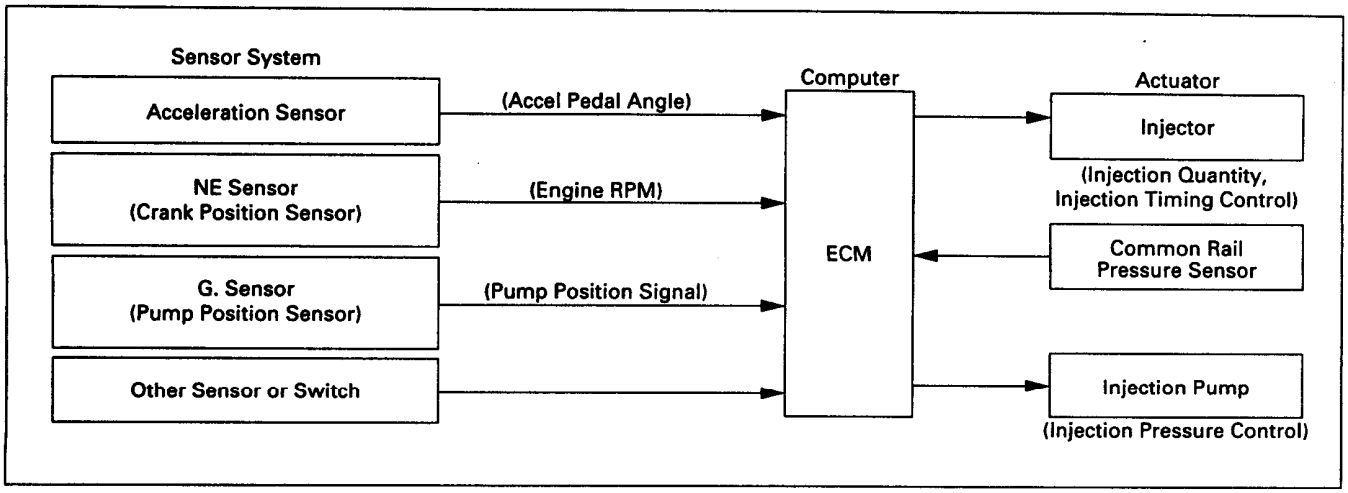


Figure 3 – Control System

(2) System Construction

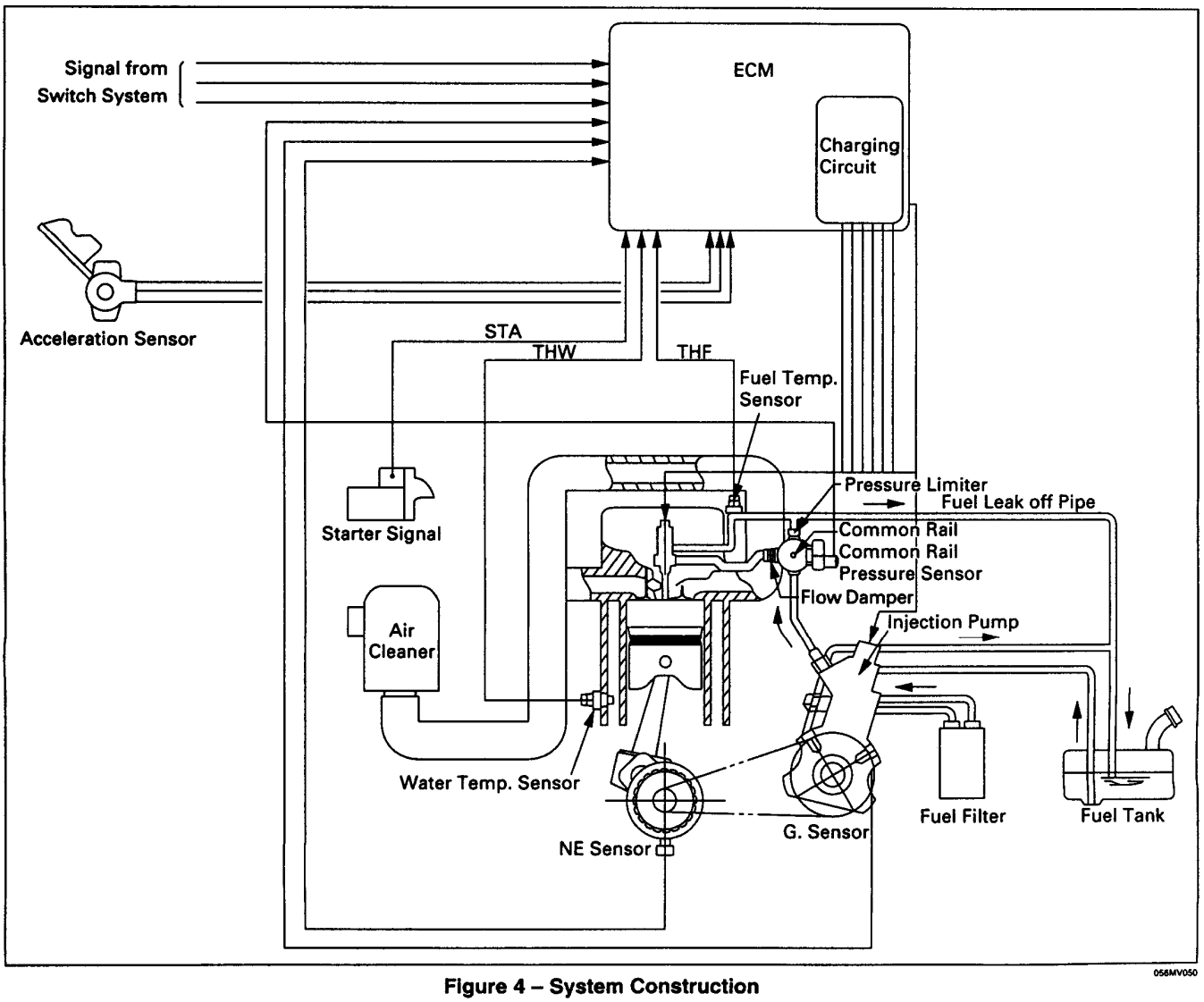


Figure 4 – System Construction

SYSTEM DESCRIPTION AND OPERATION

The COMMON RAIL SYSTEM consists of an injection pump, common rail, injector, ECM and sensors.

The injection pump generates the fuel pressure in the common rail. Fuel pressure is controlled depending on the fuel amount discharged from the injection pump. The fuel discharge amount is controlled by means of PCV provided in the injection pump which is opened/closed in response to electric signals from ECM.

The common rail receives and distributes the fuel pressure made by the injection pump to each cylinder. Fuel pressure is detected by means of a common rail pressure sensor installed to the common rail and is feedback controlled so that the instructed pressure value set according to engine speed and load can agree with an actual pressure value.

The fuel pressure in the common rail is applied through the injection pipe of each cylinder to the nozzle side and control chamber of the injector.

The injector controls injection amount and time by switching on and off a TWV (Two Way Valve). When the TWV is switched on (to carry current), the fuel circuit is changed over to such a status that the high pressure fuel in the control chamber may flow out through and outlet orifice. Owing to nozzle valve opening force caused by the nozzle side of high pressure fuel, the needle valve is lifted to start fuel injection. When the TWV is switched off (to cut current), the fuel circuit is changed over to such a status that the high pressure fuel is flowed back through the inlet orifice into the control chamber.

Therefore, the needle valve comes down to stop fuel injection.

Thus, fuel injection time can be electronically controlled by TWV switching on and fuel injecting amount, by TWV switching off.

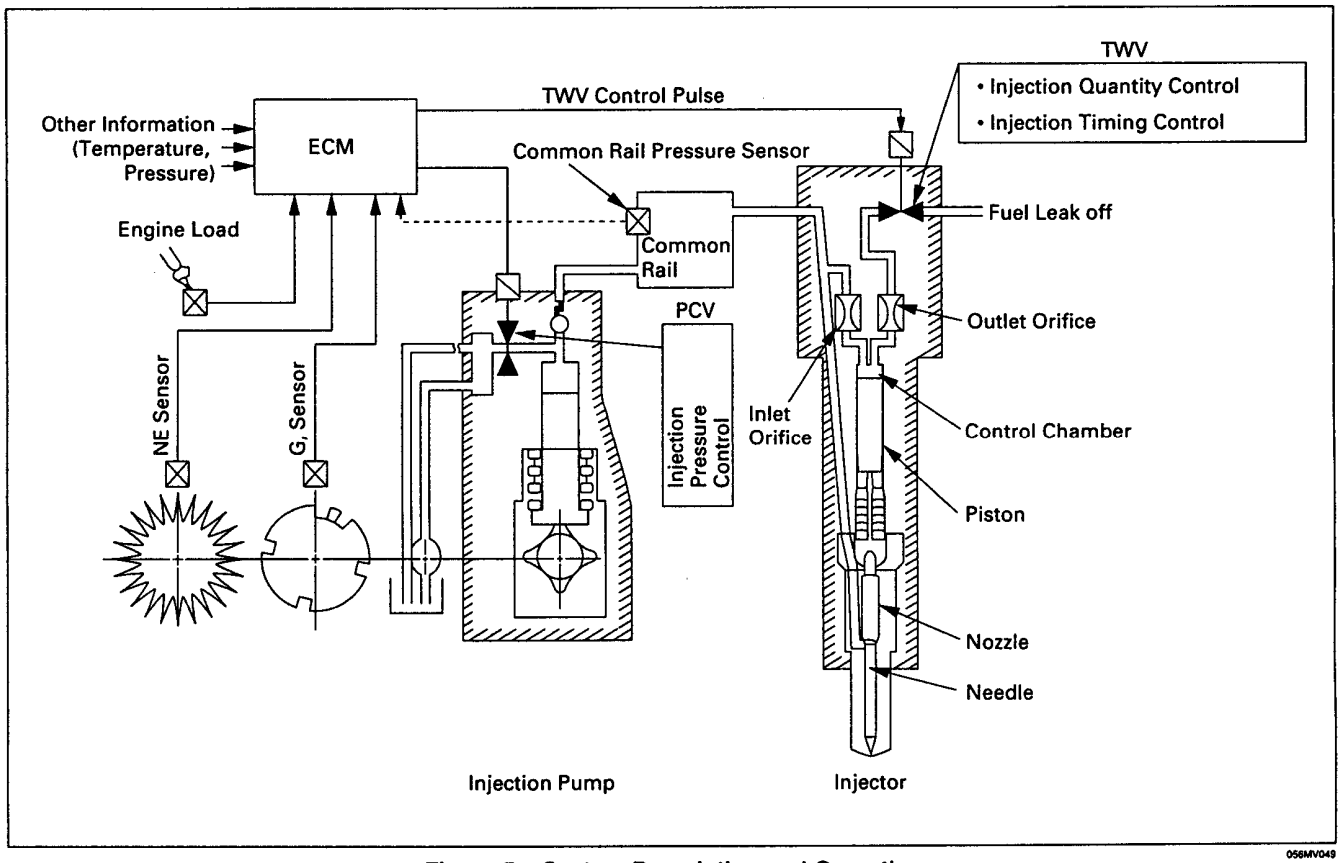


Figure 5 – System Description and Operation

VARIOUS CONTROLS

In comparison with the mechanical governor or timer used in the conventional type injection pump, fuel injection amount/timing can be controlled further properly.

ECM computes from signals coming from the sensors installed to engine and vehicle and controls the time point and length for carrying current to the injector so that the optimum injection can be performed at the optimum timing.

(1) Fuel Pilot Injection Control Function

This is a function to control either fuel pilot injection or not.

(2) Fuel Injection Amount Control Function

This is a function to control fuel injection based on signals from engine speed and accelerator opening sensors so that the optimum injection amount can be obtained. A substitute for the conventional mechanical governor.

(3) Fuel Injection Timing Control Function

This is a function to obtain the optimum injection timing from engine speed and fuel injection amount. A substitute for the conventional timer.

(4) Fuel Injection Pressure Control Function (Common Rail Pressure Control Function)

This is a function to measure fuel pressure with the common rail sensor and feed back the measurement to ECM thereby to control the discharge amount of the pump.

Pressure feedback control is carried out so that the optimum value (instructed value) set according to engine speed and fuel injection amount can be reached

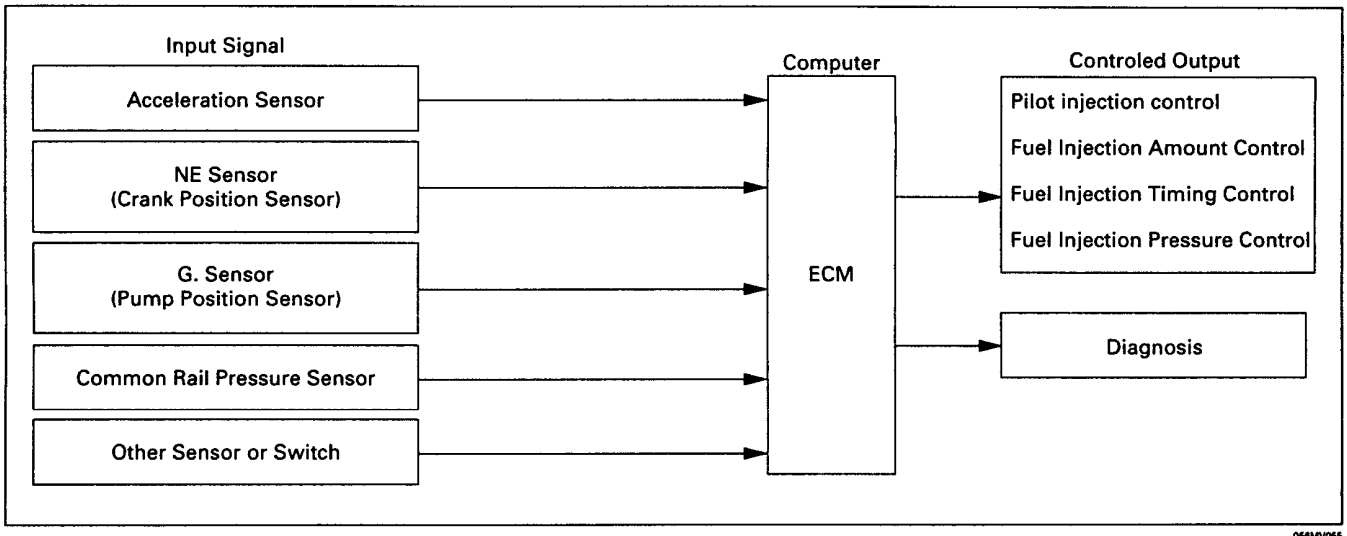


Figure 6 – Control System

FUEL INJECTION RATE CONTROL

(1) Main Injection

Same as the conventional system.

(2) Pilot Injection

This is a small amount of injection conducted prior to the conventional fuel injection (main injection).
Injection rate is increased as there is a rising tide of high pressure injection. But a time lag from fuel injection to combustion start (ignition delay) cannot be shortened over a certain value. As a result the fuel injected could be increased till ignition to cause instantaneous explosive combustion which would in turn increase NOx and noise. Pilot injection puts down an initial injection rate to the irreducible minimum to lessen the explosive combustion so that NOx and noise can be reduced.

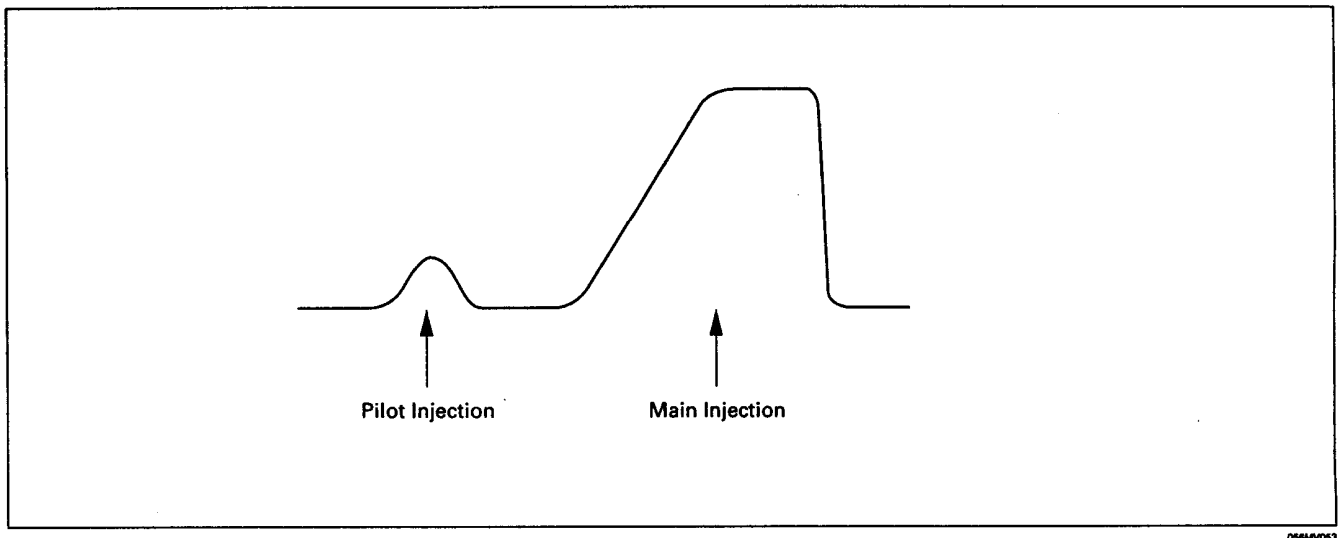


Figure 7 – Pilot Injection

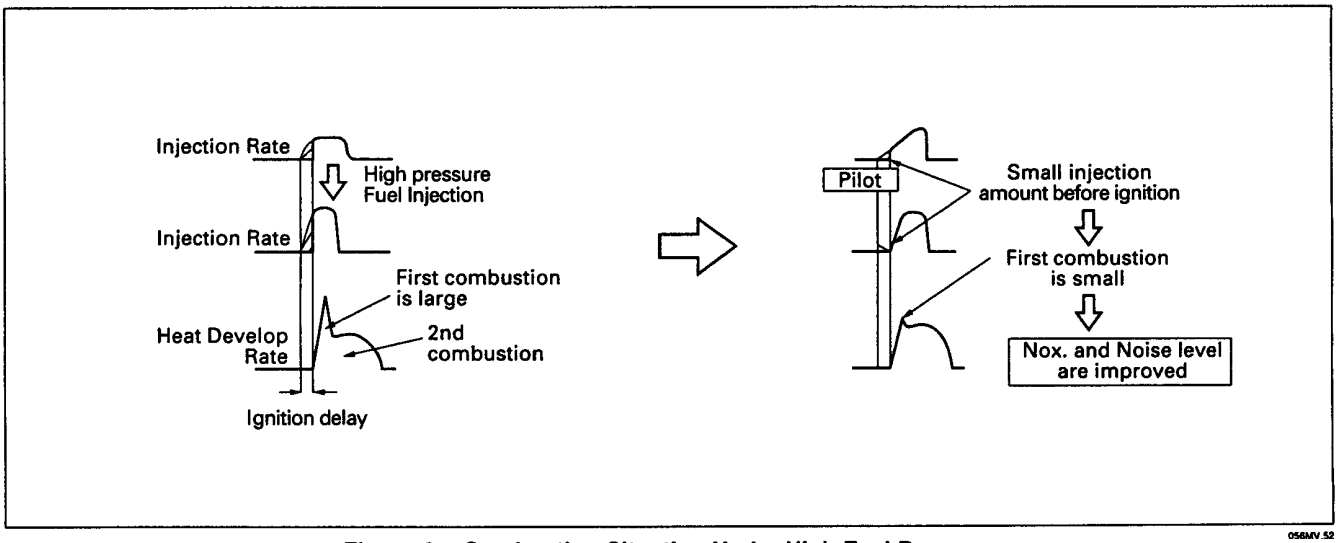


Figure 8 – Combustion Situation Under High Fuel Pressure

(3) Split Injection

This means two or more small amount fuel injections to be conducted prior to the conventional fuel injection (main injection) for increase engine start under cold weather.

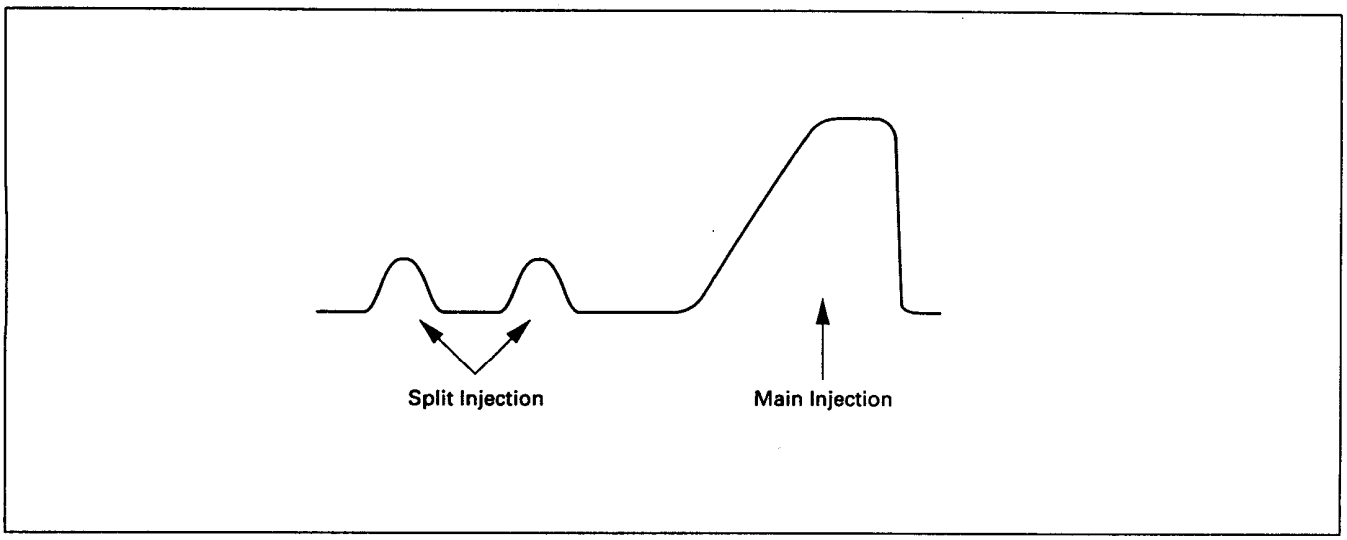


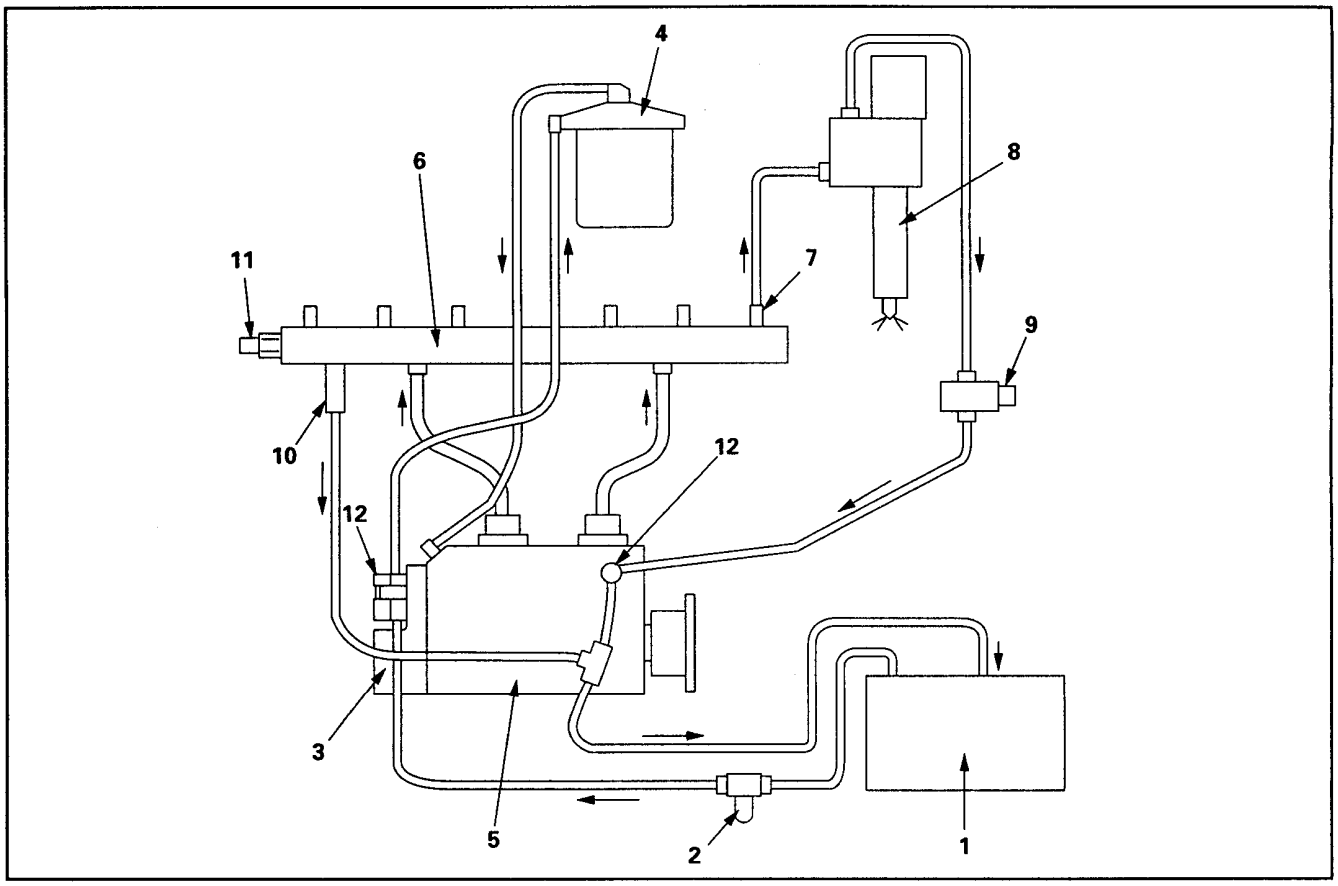
Figure 9 – Split Injection

FUEL INJECTION SYSTEM

SYSTEM OPERATION

Fuel is drawn through the fuel pre-filter (2) by the fuel feed feed pump (3), refer to (Figure 10). The fuel feed pumps the fuel into the fuel filter (4) and then into the fuel injection pump (5). The fuel injection pump then pressurizes and supplies the fuel to fuel common rail.

The pressured fuel distributes through the fuel injectors line to the fuel injectors (8). The high pressure fuel enters the fuel injector and forces the needle off its seat, same time the fuel enters the control room of fuel injectors. The fuel injection timing is controlled by ECM. The ECM command to open the fuel return line of solenoid valve on top of the injector, then the fuel is forced out of the fuel injector into the cylinder.

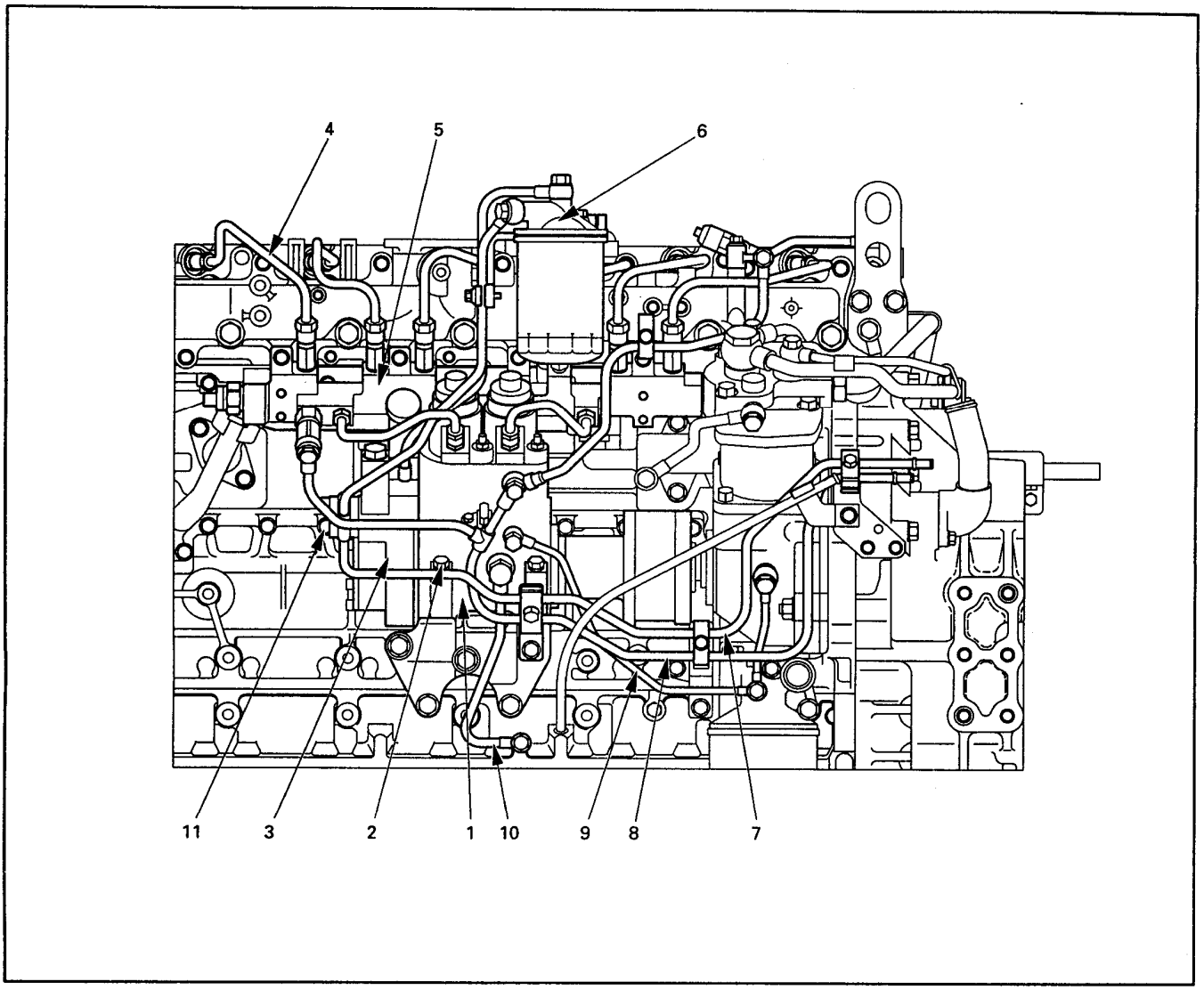


Legend

(1) Fuel Tank
(2) Fuel Pre-Filter
(3) Fuel Feed Pump
(4) Fuel Filter
(5) Injection Pump
(6) Fuel Common Rail
(7) Fuel Flow Dumper
(8) Injector Assembly
(9) Fuel Temperature Sensor
(10) Fuel Pressure Limiter
(11) Fuel Pressure Sensor
(12) Overflow Valve

Figure 10 — Fuel System Schematic

ON VEHICLE SERVICE



Legend

(1) Fuel Injection Pump
(2) Bolt
(3) Fuel Transfer Pump
(4) Injection Pipe
(5) Common Rail
(6) Fuel Filter
(7) Fuel Feed Pipe
(8) Fuel Return Pipe
(9) Oil Feed Pipe
(10) Oil Return Pipe
(11) Fuel Return Overflow Pipe

Figure 11 — Location of Fuel System

FUEL INJECTION PUMP

Removal

1. Tilt the cab.
2. Disconnect the negative battery cable.
3. Disconnect PCV harness connector.
4. Disconnect G sensor harness connector.
5. Remove clamp bolts from the fuel feed pipe (7), fuel return pipe (8) and fuel supply pipe to fuel filter.
6. Remove fuel feed pipe (7).
7. Remove fuel return pipe (8).
8. Remove oil feed pipe.
9. Remove oil return pipe.
10. Remove two fuel supply pipes between injection pump and common rail.
11. Disconnect coupling fixing bolts.
12. Remove fuel injection pump fixing bolts.
13. Remove fuel injection pump assembly.

Installation

1. Turn crankshaft to align number 1 cylinder TDC mark to pointer.

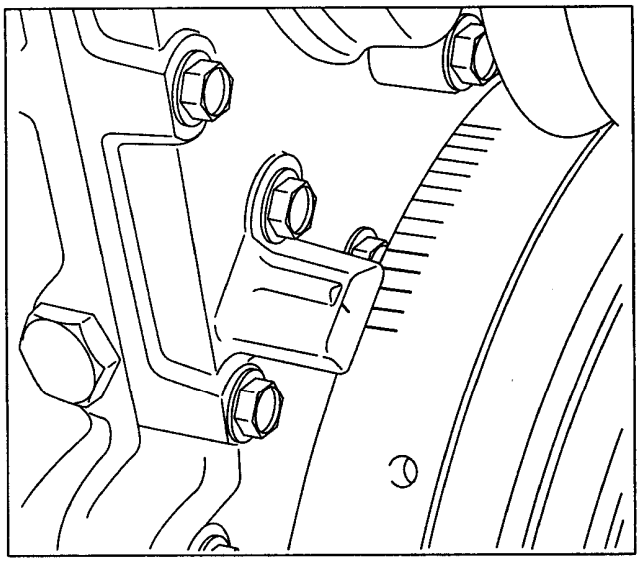


Figure 12 – TDC Mark

2. Turn coupling of injection pump for align timing mark on the injection pump and pointer on the air compressor body.

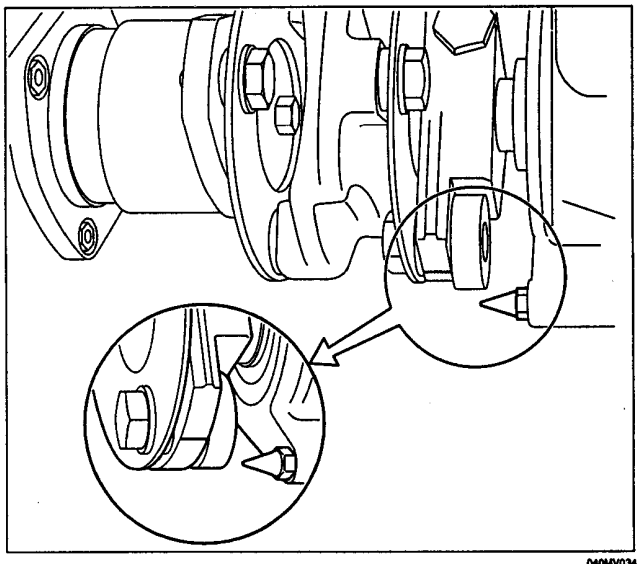
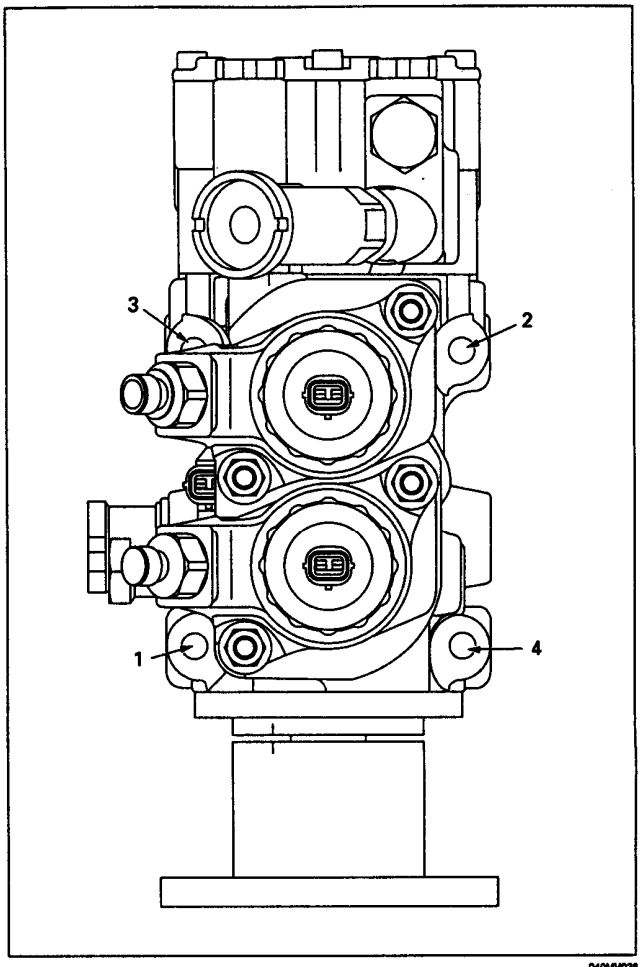


Figure 13 – Injection Pump Pointer

3. Install injection pump assembly onto the pump bracket.
4. Tighten injection pump fixing bolts to the specified torque.
   Torque : 25 N·m (18 lb·ft)



Legend
The number indicate to tighten order.

Figure 14 – Injection Pump Fixing Sequence

5. Tighten coupling bolts to the specified torque.
   Torque 1: 91 N·m (66 lb·ft)
   Torque 2: 61 N·m (46 lb·ft)
   Torque 3: 60 N·m (45 lb·ft)

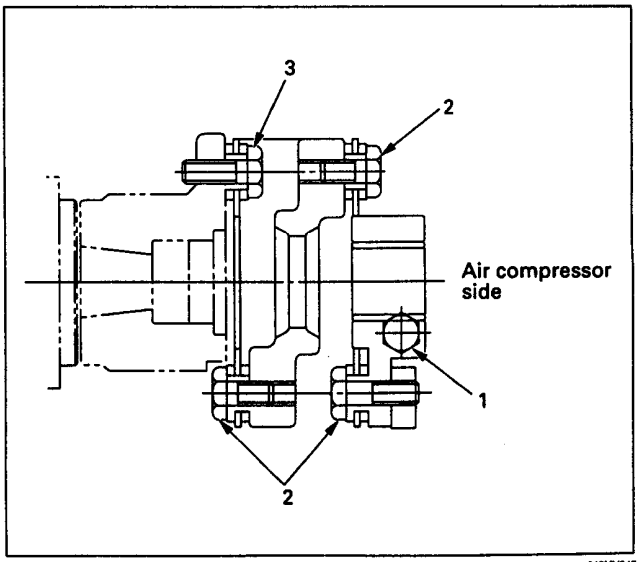


Figure 15 – Coupling Bolts

6. Install two fuel supply pipes between injection pump and commonrail.
7. Install oil return pipe.
8. Install oil feed pipe.
9. Install fuel return pipe.
10. Install fuel feed pipe.

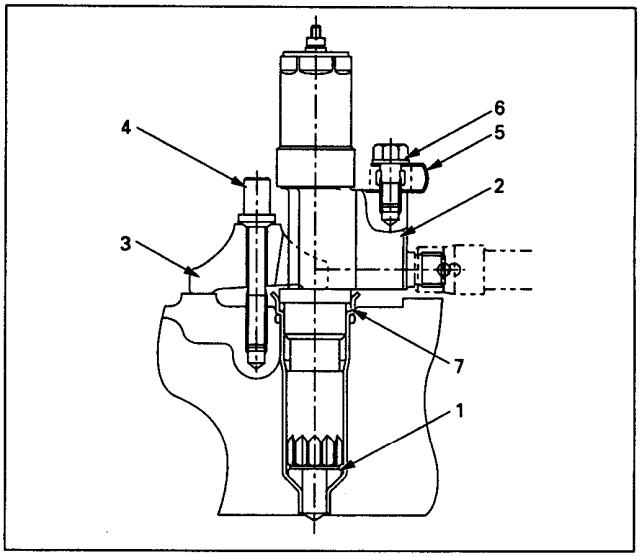
Caution: When install fuel feed pipe on the fuel feed pump, must use special gasket between feed pipe eye (on the relief valve) and return pipe eye (short return pipe). If use other gasket it will cause not start engine.

11. Tighten clamp bolts with clamp.
    Torque : 6 N·m (52 lb·in)
12. Reconnect G sensor harness connector.
13. Reconnect PCV harness connector.
14. Reconnect negative battery cable.
15. Down cab and lock.

FUEL INJECTOR

Removal

1. Tilt cab.
2. Disconnect the negative battery cable.
3. Disconnect two TWV harness connector at outside of lower case (Under the valve rocker arm cover).
4. Remove injection pipes between injector and injection pump.
5. Remove valve rocker arm cover.
6. Disconnect TWV harness connector from inside of lower case joint connector.
7. Loosen terminal nuts for TWV harness on the top of injector and remove TWV harness.
8. Remove TWV harness assembly from top of rocker arm assembly.
9. Loosen injector clamp bolt then remove injector assembly.



Legend
(1) Injector Gasket
(2) Injector Assembly
(3) Injector Clamp
(4) Clamp Bolt
(5) Gasket for Return Pipe
(6) Eye Bolt
(7) Injector Sleeve

Figure 16 – Fuel Injector

Installation

1. Standing put injector clamp on the valve spring seat as shown in the illustration.

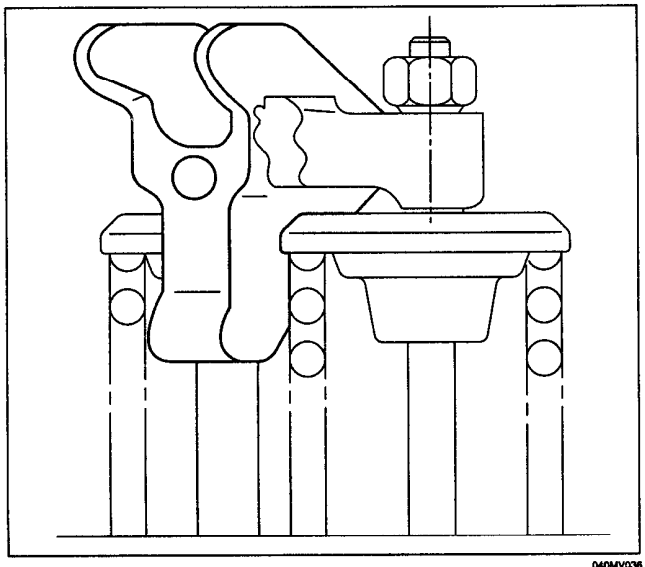


Figure 17 – Fuel Injector Clamp

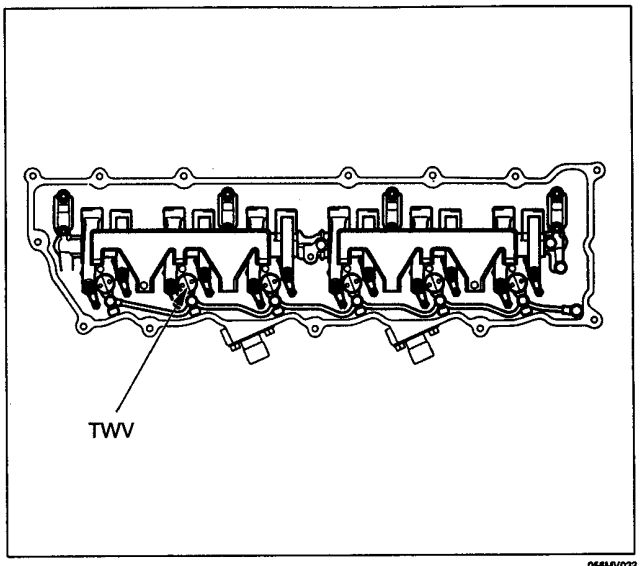


Figure 18 – TWV

2. When injector assembly comes installation portion, the injector clamp putting on the injector then install the injector assembly together with clamp into injector sleeve hole.
3. Temporary tighten injection pipe to injector.
4. Apply molybdenum disulfide grease to clamp bolt, tighten injector clamp bolt to specified torque.
   Torque : 31 N·m (22 lb·ft)
5. Tighten injection pipe to the specified torque.
   Torque : 44 N·m (33 lb·ft)
6. Install fuel return pipe, tighten eye bolt to the specified torque.
   Torque : 12 N·m (106 lb·in)

Note:

1. ***Be confirm that tightening torque of injection pipe (Item 5 above) and fuel return pipe eye bolt (Item 6 above) after tighten them for prevent to dilute of engine oil.***
2. ***Make sure that the gasket for return pipe (5) not ride on the injector body when tighten eye bolt. (The correct direction shown in the Figure 16).***

7. Install TWV harness assembly, tighten fixing bolt to specified torque.
   Torque : 22 N·m (16 lb·ft)
8. Install TWV harness to TWV terminals, tighten fixing nut to the specified torque.
   Torque : 2 N·m (17.7 lb·in)

Note: Do not over tight TWV terminal nuts.

9. Reconnect TWV harness to lower case joint connector.
10. Install valve rocker arm cover to tighten to the specified torque.
    Torque : 13 N·m (113 lb·in)
11. Reconnect two TWV harness connector at outside of lower case.
12. Reconnect the negative battery cable.
13. Down cab.

Bleeding Fuel System

Note: The injector assembly must be replaced only assembly.
When the fuel system is opened to the atmosphere, it must be bleed to remove all the air. Air in the fuel system will cause a no start or poor engine performance.

1. Loosen the primer pump knob (1) on the fuel injection pump.

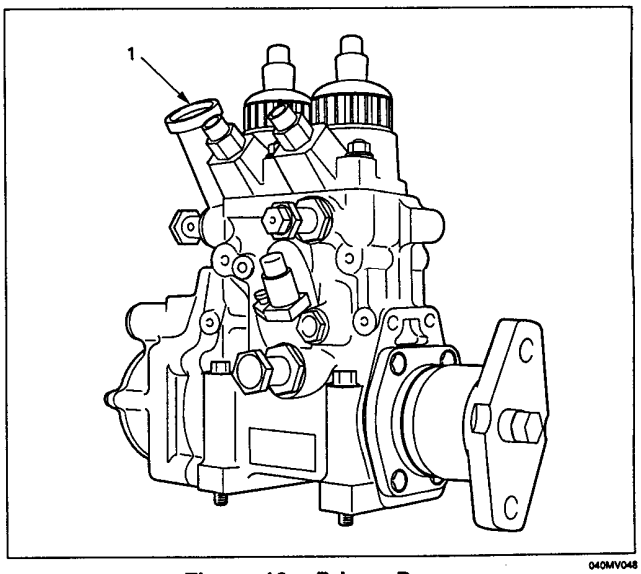


Figure 19 – Primer Pump

2. Loosen the feed line eye bolt (1) on the fuel filter.

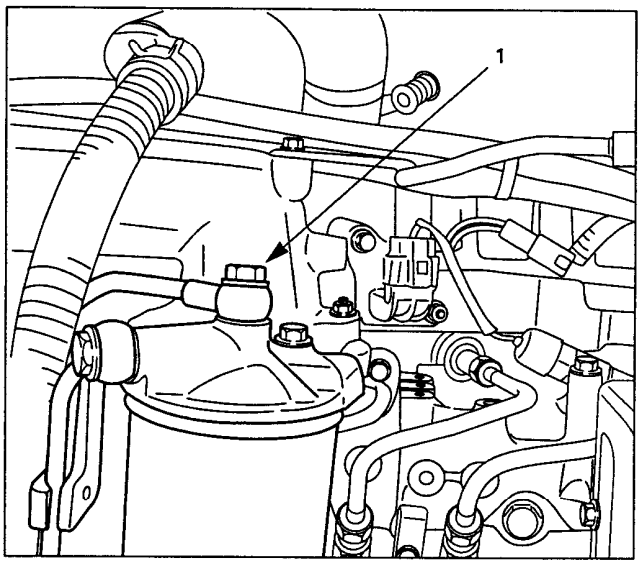


Figure 20 – Fuel Filter

3. Pump the primer pump (1, Figure 19), until a solid stream of fuel comes from the fuel filter feed line eye bolt (1, Figure 20).
4. Tighten the fuel filter eye bolt.
   Torque : 14 N·m (10 lb·ft)
5. Tighten primer pump knob (1) to close it.

Important tightening torque for fuel injection system

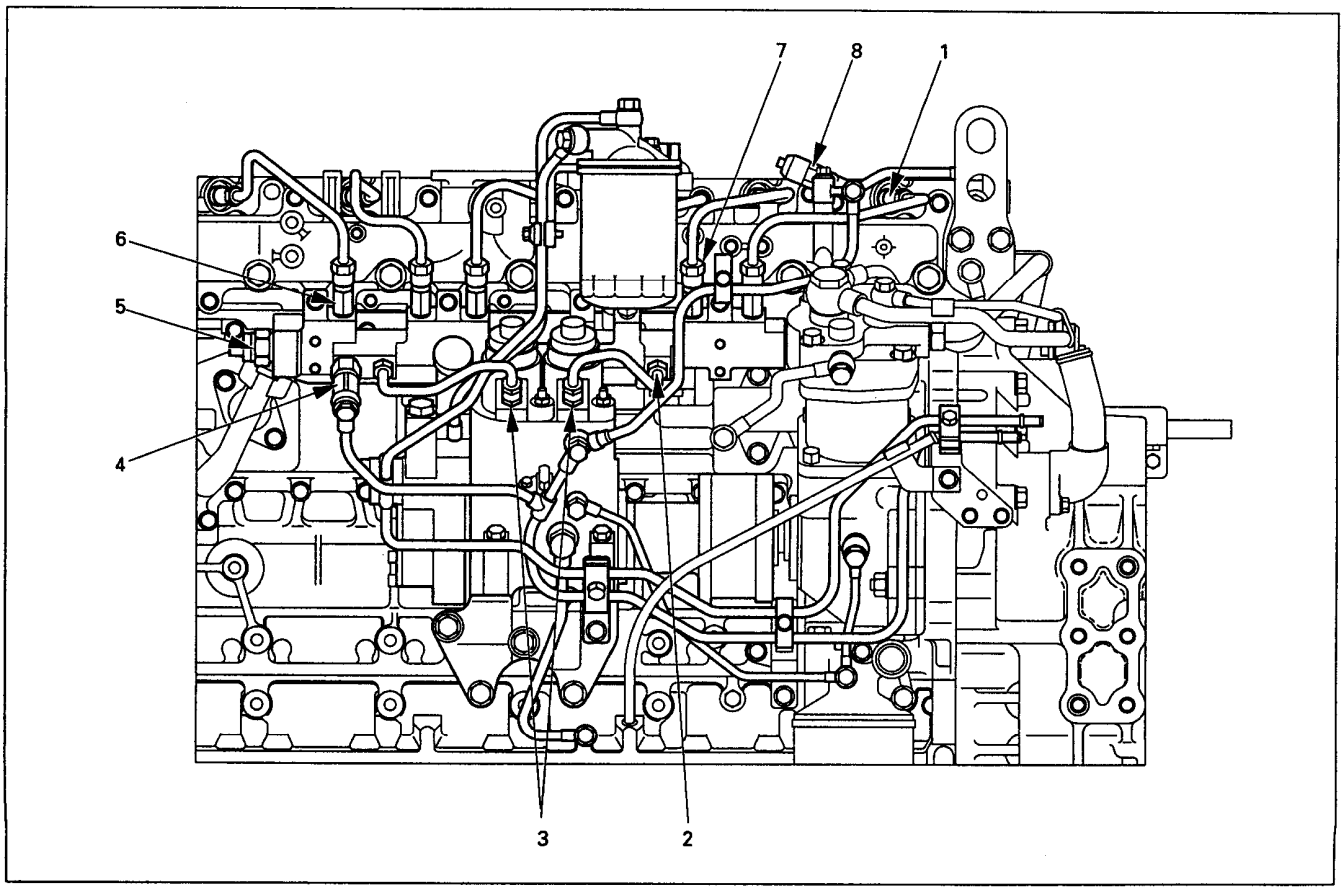


Figure 21 – Important Tightening Torque

Tightening torque

1. Injection pipe sleeve nut, injector side (6 places).
   Torque : 44 N·m (33 lb·ft)
2. High pressure fuel pipe sleeve nut, common rail side (2 places).
   Torque : 54 N·m (40 lb·ft)
3. High pressure fuel pipe sleeve nut, injection pump side (2 places).
   Torque : 44 N·m (33 lb·ft)
4. Fuel pressure limiter.
   Torque : 68.6 N·m (50.6 lb·ft)

5. Common rail pressure sensor.
   Torque : 68.6 N·m (50.6 lb·ft)
6. Flow damper (6 places)
   Torque : 98 N·m (72 lb·ft)
7. Injection pipe sleeve nut, common rail side (6 places)
   Torque : 44 N·m 33 lb·ft)
8. Fuel temperature sensor.
   Torque : 20 N·m (14.5 lb·ft)
9. Fuel return pipe eye bolt, top of injector (7 places)
   Torque : 12 N·m (106 lb·in)

SPECIFICATIONS

Fastener Tightening Specifications

Application	N·m	lb·ft	lb·in
Fuel injection pump bracket to cylinder block	50	37	
Fuel injection pump to pump bracket	25	18	
Fuel injection pump coupling bolt 1	91	66	
Fuel injection pump coupling bolt 2	61	46	
Fuel injection pump coupling bolt 3	60	45	
Fuel pipe clamp bolt	6		52
Fuel injector fixing bolt	31	22	
Fuel injection pipe sleeve nut	44	33	
Fuel return pipe eye bolt	12		106
TWV harness assembly fixing bolt	22	16	
TWV harness terminal nut	2		
Flow damper	98	72	
Pressure limiter	68.6	50.6	
Common rail pressure sensor	68.6	50.6	

BLANK

SECTION 6D6

DIESEL ELECTRICAL

NOTICE: *Always use the correct fastener in the correct location. When you replace a fastener, use ONLY the exact part number for that application. ISUZU will call out those fasteners that require a replacement after removal. ISUZU will also call out the fasteners that require thread lockers or thread sealant. UNLESS OTHERWISE SPECIFIED, do not use supplemental coatings (paints, greases, or other corrosion inhibitors) on threaded fasteners or fastener joint interfaces. Generally, such coatings adversely affect the fastener torque and the joint clamping force, and may damage the fastener. When you install fasteners, use the correct tightening sequence and specifications. Following these instructions can help you avoid damage to parts and systems.*

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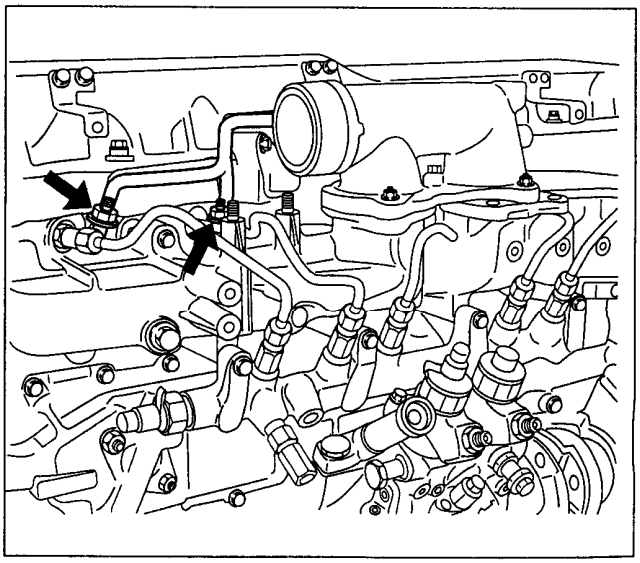
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GENERAL DESCRIPTION

GLOW PLUGS

Diesel engines relay on the heat of compression to initiate combustion. Cold engine start-ups may require extra engine cranking time to create the necessary heat to ignite the diesel fuel. One of the devices available to aid in cold starting the diesel engine are glow plugs. Six glow plugs are used to preheat the combustion chambers as an aid to starting (Figure 1). The glow plugs (Figure 2) are 10.5 volt heaters, operated at 12 volts, when the engine control switch is turned to the "H" position. This provides a pre-heat feature to the combustion chamber and improves cold engine start ups.

NOTICE: ***Never manually spray starting aid fluids into the air intake where the fluid may come in contact with the heater element. This could result in an explosion and/or fire.***



F01MV002

Figure 1 – Glow Plugs

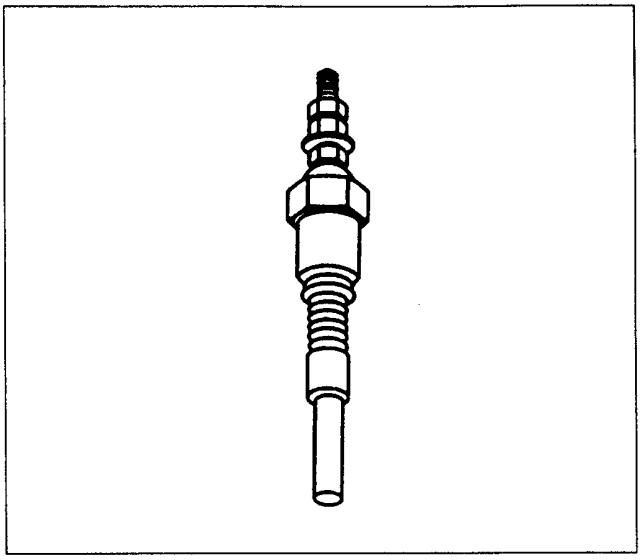


Figure 2 – Glow Plug

STARTING PROCEDURE

To initiate the glow plug operation, these starting procedures should be followed.

1. Turn the engine control switch to the "H" position. Wait until suitable time (according to atmospheric temperature) before cranking the engine.
2. Turn the engine control switch to the "START" position, and release the switch when the engine starts.
3. If the engine does not start after 15 seconds of cranking, repeat steps 1 through 3 until the engine starts.

GLOW PLUG OPERATION

When the engine control switch is turned to the "H" position, current flows through the glow plug relay, and to the glow plugs, heating the glow plugs to 800°C (1472°F). When the ambient temperature is about 0°C (32°F), the glow plugs will take 20 to 25 seconds to heat.

DIAGNOSIS

GLOW PLUG RELAY CHECK

Tools Required:

J 39200 Digital Multimeter

Test the relay circuit for voltage with the relay removed. Use a voltmeter and check for system voltage at cavities B and 30. Cavity 30 is hot at all times. Cavity B is energized by the engine control switch.

Use an ohmmeter to test cavities A and 31. Cavity A is the ground side for the relay. Cavity 31 is the load side (glow plugs) of the relay.

The relay's load side can be checked for high resistance with an ohmmeter. The reading should be 0.1 ohms or less. If the resistance is higher, replace the relay.

GLOW PLUG CHECK

Tools Required:

J 39200 Digital Multimeter

J 35590 Inductive Current Clamp

The glow plugs can be tested in two ways:

1. Take an amperage draw test with an inductive pick-up lead at each glow plug. The rated amp draw should be 6.0 – 7.5 amps per glow plug. Or install the inductive current clamp around the glow plug power supply wire, take the systems current draw reading and divide the reading by the number of glow plugs in the system.
2. A continuity check can also be made with an ohmmeter between the glow plug lead and ground, with the buss bars removed (Figure 3). If no continuity exists, the glow plug will not heat and should be replaced.

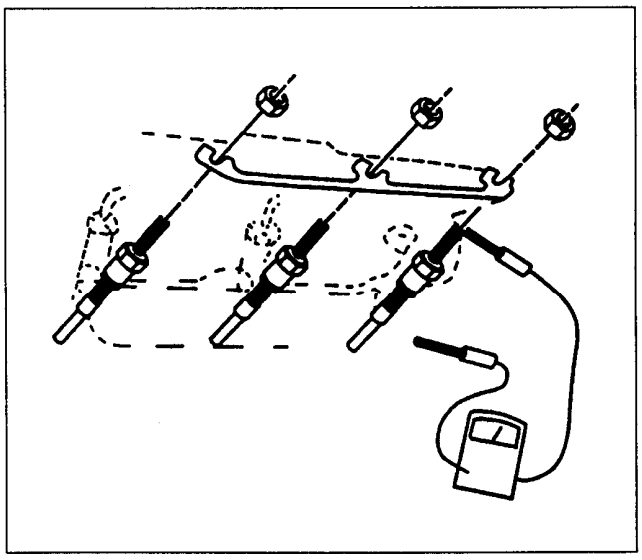


Figure 3 – Continuity Test

BUSS BAR CHECK

Tools Required:
J 39200 Digital Multimeter
J 35590 Inductive Current Clamp

Test for voltage at the buss bars with a voltmeter. Disconnect the negative battery cable and also disconnect the glow plug power supply wire from the buss bar (Figure 4). Connect the voltmeter positive lead to the glow plug power supply wire and the negative lead of the voltmeter to ground. Reconnect the negative battery cable. Turn the engine control switch to the "H" position. The reading should be over 10.5 volts.

A continuity check can be made with an ohmmeter between the buss bar and to the top of each glow plug. The reading should be 0.1 ohm or less. If not, check the glow plug nut contact to the buss bars. If the buss bars are corroded, clean them or replace them as necessary.

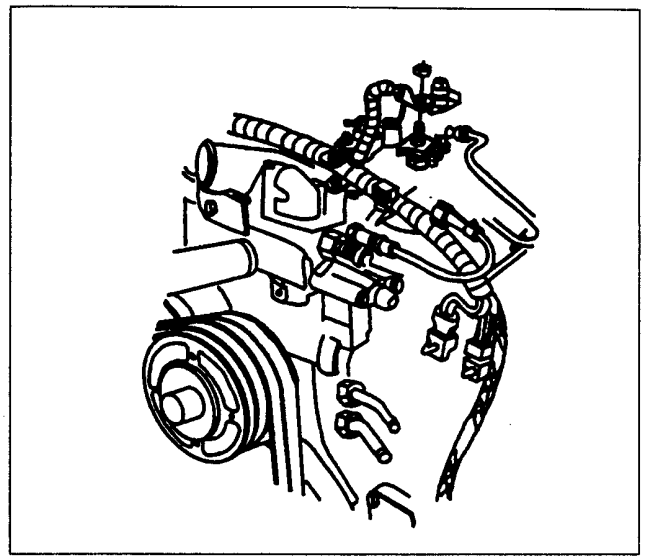


Figure 4 – Glow Plug Power Supply Wire

ON-VEHICLE SERVICE

GLOW PLUG RELAY

Remove or Disconnect

1. Negative battery cable. Refer to "Battery" in SECTION 6D1.
2. Console on the passenger side of instrument panel.
3. Glow plug relay.

Install or Connect

1. Glow plug relay
2. Console on the passenger side of instrument panel.
3. Negative battery cable.

GLOW PLUGS

Remove or Disconnect (Figures 1, 2 and 4)

1. Tilt the cab. Refer to "Cab Tilting" in SECTION 0A.
2. Negative battery cable. Refer to "Battery" in SECTION 6D1.
3. Glow plug power supply wire.
4. Glow plug buss bar.
5. Glow plug(s) from the cylinder head.

Install or Connect (Figures 1, 2 and 4)

1. Glow plug(s) to the cylinder head.

Tighten

- Glow plugs to cylinder head to 25 N·m (18 lb.ft.).

2. Glow plug buss bar.

Tighten

- Glow plugs to buss bar nut to 2 N·m (17 lb.in.).

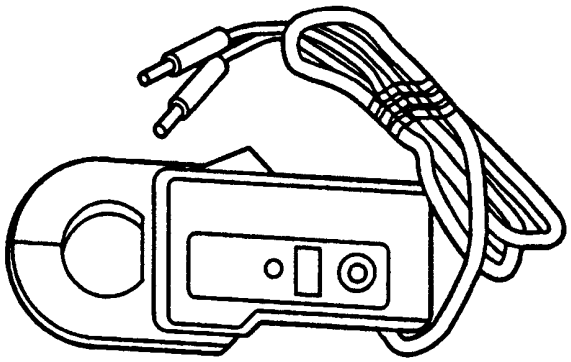
3. Glow plug power supply wire.
4. Negative battery cable.
5. Lower the cab.

SPECIFICATIONS

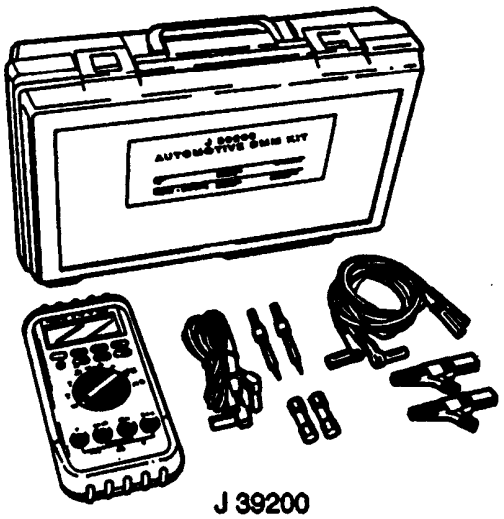
FASTENER TIGHTENING SPECIFICATIONS

Application	N·m	lb·ft	lb·in
Battery Top Post Terminal Nut	17	13	—
Buss Bar to Glow Plug Nut	2	—	17
Glow Plug to Cylinder Head	25	18	—

SPECIAL TOOLS



J 35590



J 39200

SECTION 6E

ENGINE EMISSION AND ELECTRICAL DIAGNOSIS

NOTICE: *Always use the correct fastener in the correct location. When you replace a fastener, use ONLY the exact part number for that application. ISUZU will call out those fasteners that require a replacement after removal. ISUZU will also call out the fasteners that require thread lockers or thread sealant. UNLESS OTHERWISE SPECIFIED, do not use supplemental coatings (paints, greases, or other corrosion inhibitors) on threaded fasteners or fastener joint interfaces. Generally, such coatings adversely affect the fastener torque and the joint clamping force, and may damage the fastener. When you install fasteners, use the correct tightening sequence and specifications. Following these instructions can help you avoid damage to parts and systems.*

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