SB4263E01
Dec. 2008

Service Manual

G643E LP Engine
G643LP Engine

G35S-5, G40S-5, G45S-5, G50C-5, G55C-5
GC35S-5, GC40S-5, GC45S-5, GC50C-5, GC55C-5
G40SC-5, G45SC-5, G50SC-5, G55SC-5
G50S-5, G60S-5, G70S-5

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Read and understand all safety precautions and warnings before operating or performing lubrication, maintenance and repair on this product.

Basic safety precautions are listed in the "Safety" section of the Service or Technical Manual. Additional safety precautions are listed in the "Safety" section of the owner/operation/maintenance publication.
Specific safety warnings for all these publications are provided in the description of operations where hazards exist. WARNING labels have also been put on the product to provide instructions and to identify specific hazards. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons. Warnings in this publication and on the product labels are identified by the following symbol.

⚠ WARNING

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.
Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

DOOSAN cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by DOOSAN is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product. Obtain the complete and most current information before starting any job. DOOSAN dealers have the most current information available.

Index

Chapter 1. GENERAL INFORMATION

Chapter 2. RECOMMENDED MAINTENANCE

Chapter 3. ENGINE MECHANICAL SYSTEM

Chapter 4. ENGINE ELECTRICAL SYSTEM

Chapter 5. ENGINE MANAGEMENT SYSTEM (EMS)

Chapter 6. LPG FUEL DELIVERY SYSTEM

Chapter 7. BASIC TROUBLESHOOTING

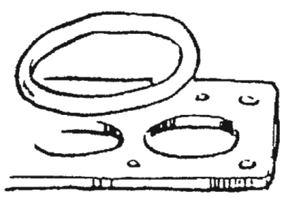
Chapter 8. ADVANCED DIAGNOSTICS

Appendix

Chapter 1. GENERAL INFORMATION

Precautions before Service

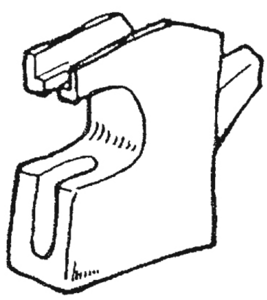
Removal and Disassembly



1EN0022

For prevention of wrong installation or reassembly and for ease of operation, put mating marks to the parts where no function is adversely affected.

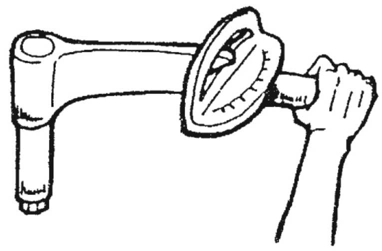
Special Tool



1EN0019

Be sure to use Special Tools when their use is specified for the operation.
Use of substitute tools will result in malfunction of the part or damage it.

Tightening Torque



1EN0020

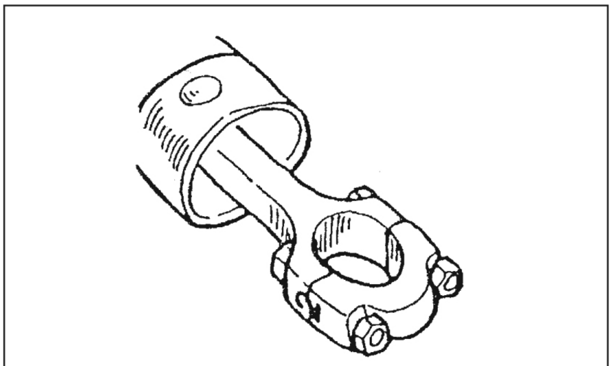
Tighten the part properly to specified torque.

Sealant

1EN0021

Use specified brand of sealant.
Use of sealant other than specified sealant may cause water or oil leaks.

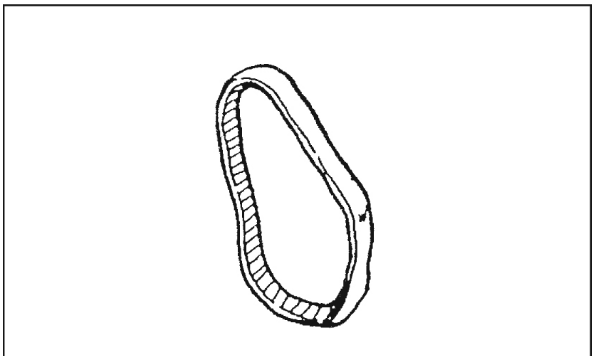
Replacement Part



1EN0018

When oil seal, O-ring, packing and gasket have been removed, be sure to replace them with new parts.
However, rocker cover gasket may be reused if it is not damaged.

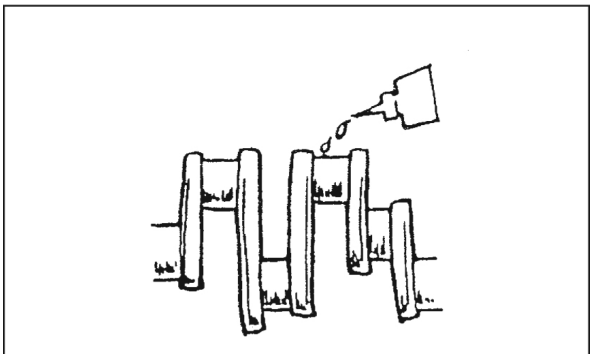
Rubber Parts



1EN0023

Do not stain timing belt and V-belt with oil or water. Therefore, do not clean the pulley and sprocket with detergent.

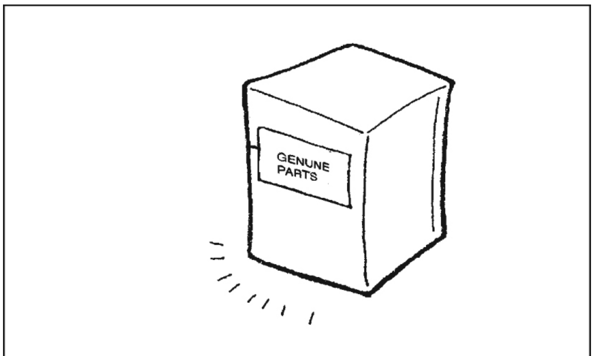
Oil and Grease



1EN0024

Before reassembly, apply specified oil to the rotating and sliding parts.

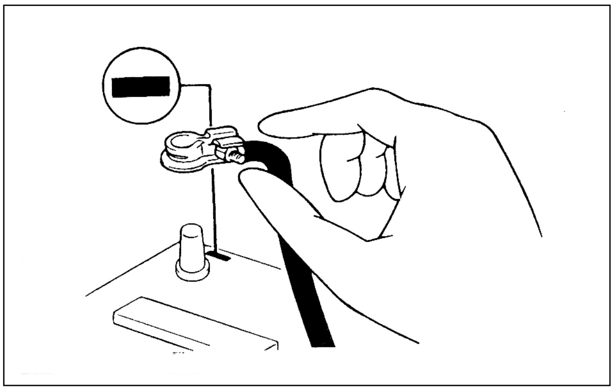
Genuine Part



1EN0025

When the part is to be replaced, be sure to use genuine part.
For selection of appropriate parts, refer to the Parts Catalog.

Electrical System



1. Be sure to disconnect the battery cable from the negative (-) terminal of the battery.

2. Never pull on the wires when disconnecting connectors.

3. Locking connectors will click when the connector is secure.

4. Handle sensors and relays carefully. Be careful not to drop them or hit them against other parts.

Precautions for catalytic Converter

⚠ CAUTION

If a large amount of unburned gasoline flows into the converter, it may overheat and create a fire hazard. To prevent this, observe the following precautions and explain them to your customer.

1. Use only unleaded gasoline.

2. Do net run the engine while the truck is at rest for a long time. Avoid running the engine at fast idle for more than 5 minutes and at idle speed for more than 10 minutes.

3. Avoid spark-jump tests. Do spark-jumps only when absolutely necessary. Perform this test as rapidly as possible and, while testing, never race the engine.

4. Do not measure engine compression for an extended time. Engine compression tests must be made as rapidly as possible

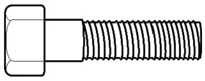
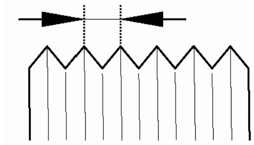
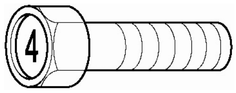
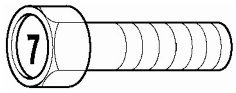
5. Do not run the engine when the fuel tank is nearly empty. This may cause the engine to misfire and create and extra load on the converter.

6. Avoid coasting with the ignition turned off and during prolonged braking

7. Do not dispose of a used catalytic converter together with parts contaminated with gasoline or oil.

Tightening Torque

Tightening Torque Table of Standard Parts

Bolt nominal diameter (mm)	Pitch (mm)	Torque (kg·m)	
		Head mark 4	Head mark 7
			
M5	0.8	0.3 ~ 0.4	0.5 ~ 0.6
M6	1.0	0.5 ~ 0.6	0.9 ~ 1.1
M8	1.25	1.2 ~ 1.5	2.0 ~ 2.5
M10	1.25	2.5 ~ 3.0	4.0 ~ 5.0
M12	1.25	3.5 ~ 4.5	6 ~ 8
M14	1.2	7.5 ~ 8.5	12 ~ 14
M16	1.5	11 ~ 13	18 ~ 21
M18	1.5	16 ~ 18	26 ~ 30
M20	1.5	22 ~ 25	36 ~ 42
M22	1.5	29 ~ 33	48 ~ 55
M24	1.5	37 ~ 42	61 ~ 70
M5	0.8	0.3 ~ 0.4	0.5 ~ 0.6
M6	1.0	0.5 ~ 0.6	0.9 ~ 1.1
M8	1.25	1.2 ~ 1.5	2.0 ~ 2.5
M10	1.25	2.5 ~ 3.0	4.0 ~ 5.0

NOTE: The torques shown in the table are standard vales under the following conditions.

1. Nuts and bolt are made of steel bar and galvanized.

2. Galvanized plain steel washers are inserted.

3. All nuts, bolts, plain washers are dry.

NOTE: The torques shown in the table are not applicable,

1. When spring washers, toothed washers and the like are inserted.

2. If plastic parts are fastened.

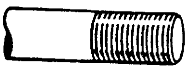
3. If oil is applied to threads and surfaces.

NOTE: If you reduce the torques in the table to the percentage indicated below under the following conditions, it will be the standard value.

1. If spring washers are used : 85%

2. If threads and bearing surfaces are stained with oil: 85%

General tightening torque for bolts, nuts and taperlock studs

The following charts give the standard toque values for bolts, nuts and taperlock studs of SAE Grade 5 or better quality. Exceptions are given in other sections of the Service Manual where needed.	thread size	Standard torque	
	inches	lb•ft.	N•m*
Use these torques for bolts and nuts with standard threads (conversions are approximate).  standaed thread	1/4	9 ± 3	12 ± 4
	5/16	18 ± 5	25 ± 7
	3/8	32 ± 5	45 ± 7
	7/16	50 ± 10	70 ± 15
	1/2	75 ± 20	100 ± 15
	9/16	110 ± 15	150 ± 20
	5/8	150 ± 20	200 ± 25
	3/4	265 ± 35	360 ± 50
	7/8	420 ± 60	570 ± 80
	1	640 ± 80	875 ± 100
	1-1/8	800 ± 100	1100 ± 150
	1-1/4	1000 ± 120	1350 ± 175
	1-3/8	1200 ± 150	1600 ± 200
	1-1/2	1500 ± 200	2000 ± 275
Use these torques for bolts and nuts on hydraulic valve bodies.	5/16	13 ± 2	20 ± 3
	3/8	24 ± 2	35 ± 3
	7/16	39 ± 2	50 ± 3
	1/2	60 ± 3	80 ± 4
	5/8	118 ± 4	160 ± 6
Use these torques for studs with taperlock threads.  taperlock stud	1/4	5 ± 2	7 ± 3
	5/16	10 ± 3	15 ± 5
	3/8	20 ± 3	30± 5
	7/16	30 ± 5	40 ± 10
	1/2	40 ± 5	55 ± 10
	9/16	60 ± 10	80 ± 15
	5/8	75 ± 10	100 ± 15
	3/4	110 ± 15	150 ± 20
	7/8	170 ± 20	230 ± 30
	1	260 ± 30	350 ± 40
	1-1/8	320 ± 30	400 ± 40
	1-1/4	400 ± 40	550 ± 50
	1-3/8	480 ± 40	650 ± 50
	1-1/2	550 ± 50	750 ± 70

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Recommended Lubricants and Capacities

Recommended Lubricants

Lubricant	Specification	Remarks
Engine Oil	API Classification SJ or above	SAE 10W30 or SAE 5W30
Coolant (Antifreeze)	Automotive antifreeze suitable for gasoline engines having aluminum alloy parts	Concentration level 50%(normal) Concentration level 40%(tropical)

Lubricant Capacities

Description		G(C)35/40/45S-5,G50/60/70S-5
Engine Oil (liters)	Oil Pan	4.3
	Oil Filter	0.5
	Total	4.8
Coolant (liters)	Engine	7.6
	Radiator & Hoses	11.4
	Total	19

Engine Model and Engine Serial Number

Engine Model	Fuel Type	Emission Regulation
G643E	LP	EPA/CARB* 2007 Compliant
G643	LP	

* EPA: Environmental Protection Agency

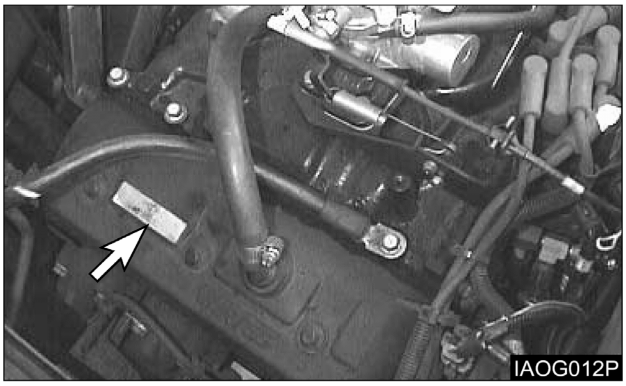
* CARB: California Air Resources Board

G643E Engine

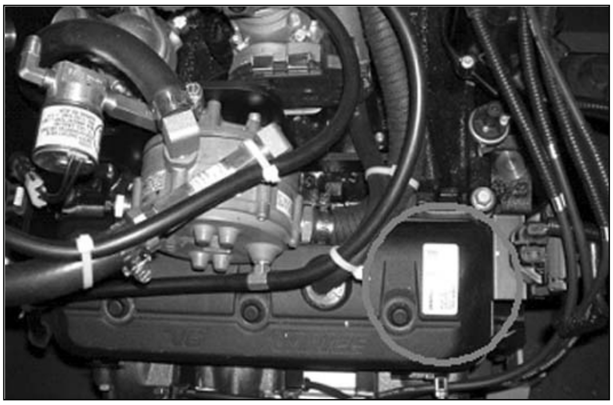
- Comply with EPA 2007 Emission Regulation
- Electronic Control by ECM
- Certified LP System available
  - Closed loop LP Carburetion system
- 3-way Catalytic Muffler is standard

G643 Engine

- Not comply with EPA 2007 Emission Regulation
- Electronic Control by ECM
- Standard LP System available
  - Open loop LP Carburetion system
- Muffler is standard



Indication of Engine Model and Serial Number



Engine Model	Engine Serial Number
G643E/G643	30700001 to 39999999

Features and Benefits of G643E/G643 Engine

- Valve seat inserts
  - Valve seat system
- SOHC valve system
- Timing chain system
- Distributor Ignition system
- Electronic control system by ECM (Engine control module)
  - Drive-by-wire system
  - Higher efficiency and lower fuel consumption
  - Min./Max. governor control
  - Automatic engine protection from overheating and/or low engine oil pressure
  - Automatic transmission protection from overheating (G643E Engine only)
  - Engine diagnostics by service-tool software
  - Forklift ground speed limit (optional)

General Specification

	G643E Engine	G643 Engine
GENERAL DESCRIPTION		
ENGINE TYPE:	90°4-Cycle V6, Water Cooled	
COMBUSTION SYSTEM:	Naturally Aspirated	
INTAKE MANIFOLD	Cast Iron, Dry	
EXHAUST MANIFOLD	Cast Iron, Dry	
VALVE CONFIGURATION:	Pushrod Actuated Overhead Valves - 2 Per Cylinder	
	Auto Lash adjustment by hydraulic valve lifter	
CAMSHAFT DRIVING:	Timing Chain System	
BALANCE SHAFT:	One Balance Shaft System	
DISPLACEMENT:	4294 cc (262 CID)	
BORE:	101.60 mm (4.00 in.)	
STROKE:	88.39 mm (3.48 in.)	
COMPRESSION RATIO:	9.4:1	
COMPRESSIONPRESSURE:	690 kPa (100 psi) Minimum	
FIRING ORDER:	1-6-5-4-3-2	
WEIGHT:	296 Kg (653 lbs.), Wet	
ENGINE ROTATION:	Counter-Clockwise (CCW) when viewed from Flywheel End	
FUEL TYPE:	LPG	
CRANK VENTILATION	PCV System	
IGNITION SYSTEM		
IGNITION TYPE:	Distributor System	
IGNITIOIN TIMING:	Electronic controlled by ECM	
IGNITION COIL:	12 V operation volt	
DISTRIBUTOR:	Delco EST Distributor with ignition module	
SPARK PLUGS:	BOSCH 4205, 0.9mm (0.035in.) Air Gap	
LUBRICATION SYSTEM		
OIL PRESSURE (MIN. HOT):	28 kPa (4 psi) @ 700 RPM 124 kPa (18 psi) @ 2000 RPM	
OIL TEMPERATURE:	Upper Limit: 130°C (266°F) Recommended: 99 - 110°C (210 - 230°F) Lower Limit: 80°C (176°F)	
CRANKCASE CAPACITY:	4.3 L (4.5 qts.)	
OIL FILTER:	0.47 L (0.5 qt.)	
ENGINE OIL SPECIFICATION:	API - SJ, SAE 10W30	
COOLING SYSTEM		
WATER PUMP ROTATION:	Serpentine Belt Drive - Clockwise (CW) when viewed from engine front	
THERMOSTAT:	Opening Temperature: 82°C (180°F) Fully Open Temperature: 96°C (205°F)	
COOLING WATER CAPACITY	7.6 L (block only)	

	G643E Engine	G643 Engine
LP FUEL SYSTEM		
LP FUEL SYSTEM	Closed loop LP Carburetion System	Open loop LP Carburetion System
MIXER:	Diaphragm Type Air Valve Assembly inside, Downdraft (Model: CA-100)	Diaphragm Type Air Valve Assembly inside, Downdraft (Model: CA-100)
REGULATOR:	Two-Stage Negative Pressure Regulator (Model: N-2007)	Two-Stage Negative Pressure Regulator (Model: N-2001)
FUELTRIMVALVE (FTV):	Dual Dither System	None
FUEL FILTRATION:	40 Microns Maximum	40 Microns Maximum
ENGINE ELECTRICAL		
ENGINECONTROLMODULE(ECM):	12 V operation volt, 48 pins of I/O	12 V operation volt, 24 pins of I/O
CRANK SENSOR	Hall effect Sensor	VR sensor built in Distributor
TMAP:	Intake Air Temp. & Manifold Absolute Press. Sensor	Intake Air Temp. & Manifold Absolute Press. Sensor
PEDAL ANGLE SENSOR:	Two-Output Signals (Installed on Accelerator Pedal)	Two-Output Signals (Installed on Accelerator Pedal)
OXYGEN SENSOR:	Heated Exhaust Gas Oxygen Sensor (HEGO) 12 V operation volt	None
ECT-ECM:	Engine Coolant Temperature Sensor for ECM	Engine Coolant Temperature Sensor for ECM
ECT-GAUGE	Engine Coolant Temp. Sensor for GAUGE on Instrument Panel	Engine Coolant Temp. Sensor for GAUGE on Instrument Panel
TPS:	Throttle Position Sensor (built in Throttle Body)	Throttle Position Sensor (built in Throttle Body)
THROTTLE BODY:	Electronic Throttle Body	Electronic Throttle Body
LP FUEL LOCK-OFF:	12 V operation volt	12 V operation volt
ENGINE OIL PR. S/W:	21.4 kPa (3.1 psi)	21.4 kPa (3.1 psi)
STARTER MOTOR:	12 Volt, 2.0 kW	12 Volt, 2.0 kW
ALTERNATOR:	12 Volt, 80 A	12 Volt, 80 A
EXHAUST SYSTEM		
CATALYTIC MUFFLER:	Three-way Catalyst with Metal Substrate	Muffler without Catalyst

G643/G643E Engine Power and Torque

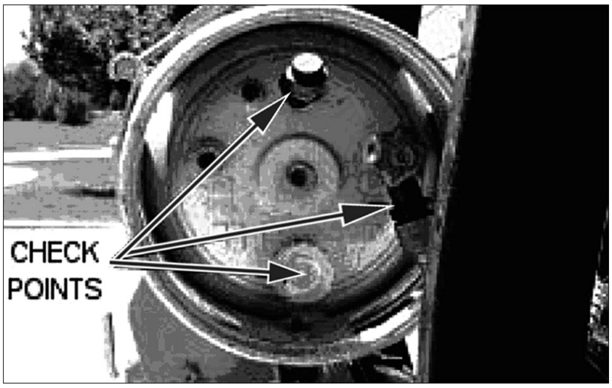
ENGINE MODEL	unit	G643E-LP	G643-LP
RATED POWER	kW	69.4	69.4
	hp	93.0	93.0
	PS	94.3	94.3
	rpm	2,450	2,450
MAX TORQUE	N-m	284	294
	lbf-ft	210	217
	kgf-m	29.0	30.0
	rpm	1600	1600
GOVERNED SPEED	rpm	2500	2500
LOW IDLE	rpm	750	750

Chapter 2. RECOMMENDED MAINTENANCE

Suggested maintenance requirements for an engine equipped with an MI-07 fuel system are contained in this section. The operator should, however, develop a customized maintenance schedule using the requirements listed in this section and any other requirements listed by the engine manufacturer.

General Maintenance

Test Fuel System for Leaks



- Obtain a leak check squirt bottle or pump spray bottle.
- Fill the bottle with an approved leak check solution.
- Spray a generous amount of the solution on the fuel system fuel lines and connections, starting at the storage container.
- Wait approximately 15-60 seconds, then perform a visual inspection of the fuel system. Leaks will cause the solution to bubble.
- Listen for leaks
- Smell for LPG odor which may indicate a leak
- Repair any leaks before continuing.
- Crank the engine through several revolutions. This will energize the fuel lock-off and allow fuel to flow to the pressure regulator/converter. Apply additional leak check solution to the regulator/ converter fuel connections and housing. Repeat leak inspection as listed above.
- Repair any fuel leaks before continuing.

Inspect Engine for Fluid Leaks

- Start the engine and allow it to reach operating temperatures.
- Turn the engine off.
- Inspect the entire engine for oil and/or coolant leaks.
- Repair as necessary before continuing.

Inspect Vacuum Lines and Fittings

- Visually inspect vacuum lines and fittings for physical damage such as brittleness, cracks and kinks. Repair/replace as required.
- Solvent or oil damage may cause vacuum lines to become soft, resulting in a collapsed line while the engine is running.
- If abnormally soft lines are detected, replace as necessary.

Inspect Electrical System

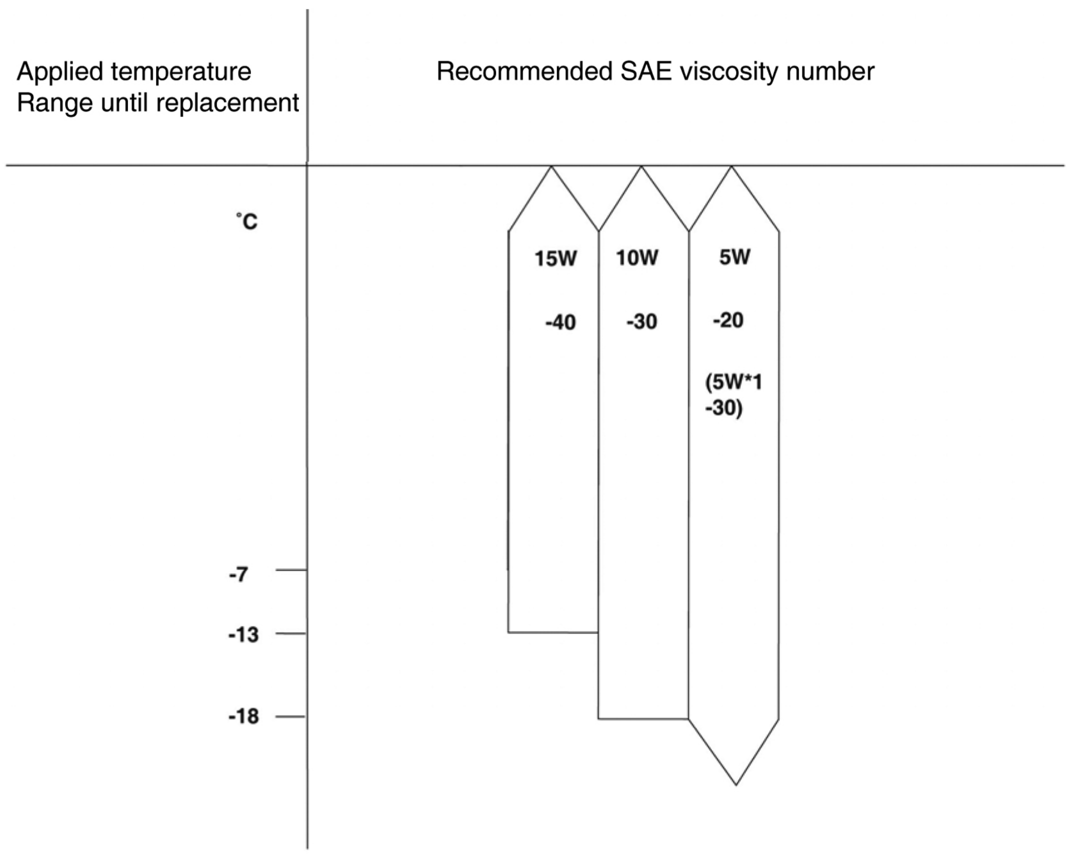
- Check for loose, dirty or damaged connectors and wires on the harness including: fuel lock-off, TMAP sensor, O2 sensors, electronic throttle, control relays, fuel trim valves, crank position sensor, and cam position sensor.
- Repair and/or replace as necessary.

Inspect Foot Pedal Operation

- Verify foot pedal travel is smooth without sticking.

Engine Oil Classification

Recommended API classification: Above SJ
Recommended SAE viscosity classification



*1. 10W-30 engine oil is recommended
If 10W-30 is not applicable, proper engine oil will be possible according to temperature ranges.

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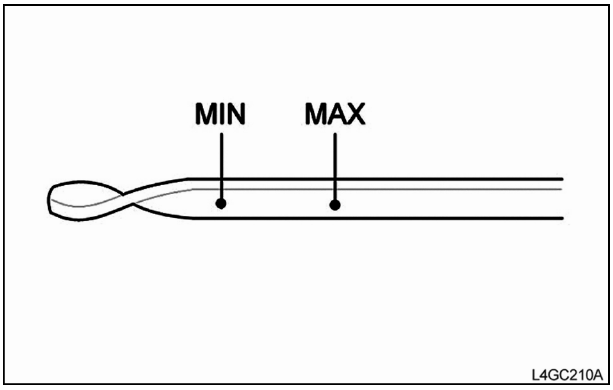
The following lubricants should be selected for all engines to enhance excellent performance and maximum effect.

1. Observe the API classification guide.

2. Proper SAE classification number should be selected within ambient temperature ranges. Do not use the lubricant with SAE classification number and API grade not identified on the container.

Checking Engine Oil Level



1. Check that the oil level is between “MIN” and “Max” marks on the engine oil level gauge.

2. If the oil level is below “MIN” mark, add oil until the level is within the specified ranges.

3. Check the engine for oil contamination and viscosity and replace if necessary.

Replacing Engine Oil and Filter

⚠ CAUTION

Prolonged and repeated contact with mineral oil will result in the removal of natural fats from the skin, leading to dryness, irritation and dermatitis. In addition, used engine oil contains potentially harmful contaminants which may cause skin cancer.
Exercise caution in order to minimize the length and frequency of contact of your skin to used oil. In order to preserve the environment, used oil and used oil filter must be disposed of only at designated disposal sites.

1. Drain engine oil.

1) Remove the oil filler cap.

2) Remove the oil drain plug, and drain the oil into a container.

2. Replace oil filter.

1) Remove the oil filter.

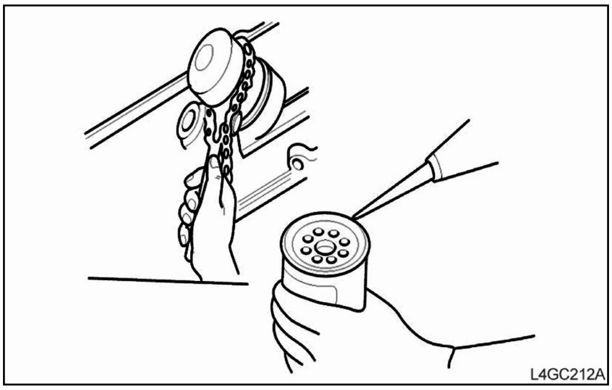
2) Check and clean the oil filter installation surface.

3) Check the part number of the new oil filter is as same as old one.

4) Apply clean engine oil to the gasket of a new oil filter.

5) Lightly screw the oil filter into place, and tighten it until the gasket contacts the seat.

6) Tighten it an additional 3/4 turn.



3. Refill with engine oil filter.

1) Clean and install the oil drain plug with a new gasket.

Torque	40~70 N•m

2)Fill with fresh engine oil.

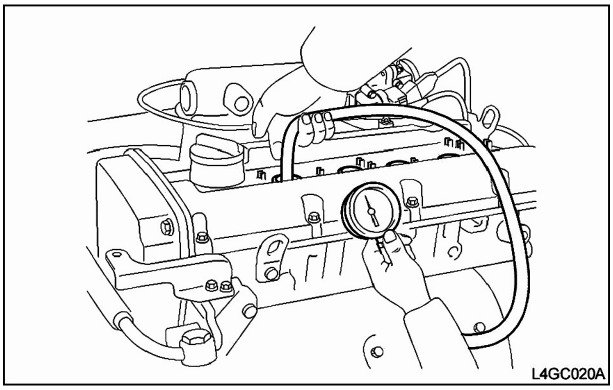
Capacity Drain and refill	4.3 L
Oil filter	0.5 L

3) Install the oil filler cap.

4. Start engine and check for oil leaks.

5. Recheck engine oil level.

Checking Compressed Pressure



1. Prior to inspection, check that the engine oil, starter motor and battery are normal.

2. Start the engine and run it until the engine coolant temperature reaches 80 ~ 95°C.

3. Stop the engine and disconnect the ignition coil and air cleaner element.

4. Remove the spark plug.

5. After opening the throttle valve completely, crank the engine to remove foreign material from the cylinder.

⚠ CAUTION

At this time, necessarily screen the spark plug hole with a rag. Because hot coolant, oil, fuel, and other foreign material, being penetrated in the cylinder through cracks can come into the spark hole during checking compressed pressure.
When cranking the engine to test compressed pressure, necessarily open the throttle valve before cranking.

6. Install the compression gauge to the spark plug hole.

7. With the throttle valve opened, crank the engine to measure the compressed pressure.

Standard (250~400 rpm)	Limit	690 kPa

8. If any of all cylinders is out of limit, add a small amount of engine oil to the spark plug hole, and re-proceed the procedures (no.6-7) to the cylinder.

At this time, if the compressed pressure is increased, it means that the piston, piston ring or cylinder surface are worn or damaged, and if the compressed pressure is decreased, it means that the valve is clogged, the valve contact is faulty, or the pressure leaks through gasket.

⚠ CAUTION

If a large amount of incomplete combustion gasoline comes into the catalytic converter, emergency such as a fire can occur due to overheating. So this job should be done quickly with the engine not operated.

Cooling System Maintenance

Coolant Recommendation

The engine cooling system is provided with a mixture of 50% ethylene glycol anti-freeze and 50% water (For the vehicles of tropical area, the engine cooling system is provided with a mixture of 40% ethylene glycol anti-freeze and 60% water at the time of manufacture.)
Since the cylinder head and water pump body are made of aluminum alloy casting, be sure to use a 30 to 60% ethylene glycol antifreeze coolant to assure corrosion protection and freezing prevention.

⚠ CAUTION

If the concentration of the antifreeze is below 30%, the anticorrosion property will be adversely affected. In addition, if the concentration is above 60%, both the antifreeze and engine cooling properties will decrease, adversely affecting the engine. For these reasons, be sure to maintain the concentration level within the specified range.

Coolant Water

Hard water, or water with high levels of calcium and magnesium ions, encourages the formation of insoluble chemical compounds by combining with cooling system additives such as silicates and phosphates.

The tendency of silicates and phosphates to precipitate out-of-solution increases with increasing water hardness. Hard water, or water with high levels of calcium and magnesium ions encourages the formation of insoluble chemicals, especially after a number of heating and cooling cycles.

DOOSAN prefers the use of distilled water or deionized water to reduce the potential and severity of chemical insolubility.

Acceptable Water	
Water Content	Limits (ppm)
Chlorides (Cl)	40 maximum
Sulfates (SO4)	50 maximum
Total Hardness	80mg/ℓ maximum
Total Solids	250 maximum
pH	6.0 ~ 8.0

ppm = parts per million

Antifreeze

DOOSAN recommends selecting automotive antifreeze suitable for gasoline engines using aluminum alloy parts. The antifreeze should meet ASTM-D3306 standard.

Check Coolant Level

- The items below are a general guideline for system checks. Refer to the engine manufacturer's specific recommendations for proper procedures.
- Engine must be off and cold.

⚠ WARNING—PROPER USE

Never remove the pressure cap on a hot engine.

- The coolant level should be equal to the "COLD" mark on the coolant recovery tank.
- Add approve coolant to the specified level if the system is low.

Inspect Coolant Hoses

- Visually inspect coolant hoses and clamps. Remember to check the two coolant lines that connect to the pressure regulator/converter.
- Replace any hose that shows signs of leakage, swelling, cracking, abrasion or deterioration.

Checking coolant leaks

1. After the coolant temperature drops below 38°C loosen the radiator cap.

2. Check that the coolant level reaches filler neck.

3. Install the radiator cap tester to the radiator filler neck and apply a pressure of 1.4kg/cm2 .
While maintaining it for 2 minutes, check the radiator, hose, and connecting part for leak.

⚠ CAUTION

Because the coolant in the radiator is too hot, never open the cap when it hot, or injury may occur due to an outburst of hot water.
Dry out the inspection part.
When removing the tester, take care not to spill the coolant.
When removing/installing the tester as well as testing, take care not to deform the filler neck.

4. Replace parts if leak is detected.

Specific gravity test

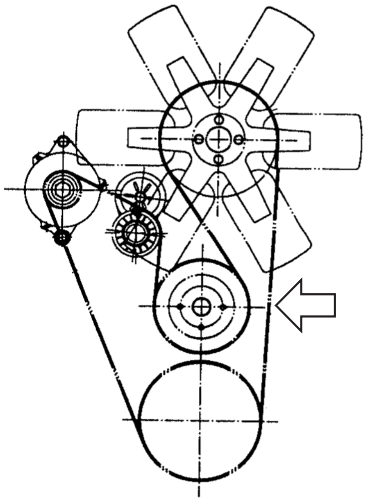
1. Measure specific gravity of the coolant using a hydrometer.

2. After measuring the coolant temperature, calculate specific gravity using the following table.

Relation between Coolant concentration and Specific Gravity

Temperature and Specific gravity of coolant (Temp.:℃)					**Freezing temp(℃)**	**Coolant Concentration Specific Volume**
10	20	30	40	50		
1.054	1.050	1.046	1.042	1.036	-16	30%
1.063	1.058	1.054	1.049	1.044	-20	35%
1.071	1.067	1.062	1.057	1.052	-25	40%
1.079	1.074	1.069	1.064	1.058	-30	45%
1.087	1.082	1.076	1.070	1.064	-36	50%
1.095	1.090	1.084	1.077	1.070	-42	55%
1.103	1.098	1.092	1.084	1.076	-50	60%

Checking and Adjusting Drive Belt



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1. Checking tension

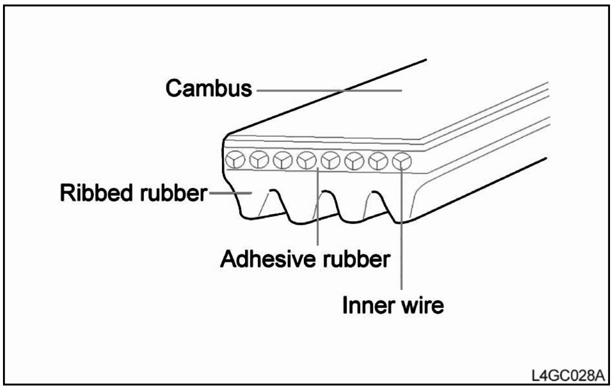
1) Press the middle of the water pump pulley and alternator pulley with 10kgf.

2) Inspect the belt deflection by pressing it.

3) If the belt deflection is out of the standard, Inspect the belt tensioner. (The belt tensioner is pre-set and spring loaded)

Item	Standard	
	New belt	Used belt
Drive belt deflection (L)	4.0~4.4mm	5.1~5.7mm

Checking Belt for Damage



Check the following items and replace the belt if defective.

1. Check the belt surface for damage, wear and crack.

2. Check the belt surface for oil or grease contamination.

3. Check the rubber part for wear or hardening.

4. Check the pulley surface for crack or damage.

Ignition System Maintenance

Inspect Battery System

- Clean battery outer surfaces with a mixture of baking soda and water.
- Inspect battery outer surfaces for damage and replace as necessary.
- Remove battery cables and clean, repair and/or replace as necessary.

Inspect Ignition System

- Remove and inspect the spark plugs. Replace as required.
- Inspect the ignition coil for cracks and heat deterioration. Visually inspect the coil heat sink fins. If any fins are broken replace as required.

Inspection of Ignition Timing

1. Inspection condition

Coolant temperature : 80-90°C(At normal Temperature)

Lamp and all accessories : OFF

Transmission : In neutral position

Parking brake : ON

2. Inspection

1) Connect the timing light.

2) Measure RPM.

RPM

Low Idle	750±15 rpm

NOTE: If RPM is not normal, it is impossible to measure the proper ignition timing, so measure it at a normal RPM.

3) Inspect the standard ignition timing.

G643E	BTDC 19±5˚
G643	BTDC 0±5˚

4) If ignition timing is out of the standard, inspect sensors concerned with ignition timing.

⚠ CAUTION

Because ignition timing is fixed by set data value in ECU, it is impossible to control on purpose. (G643E Engine)
Fist, check that sensors send output properly to help determine ignition timing control.

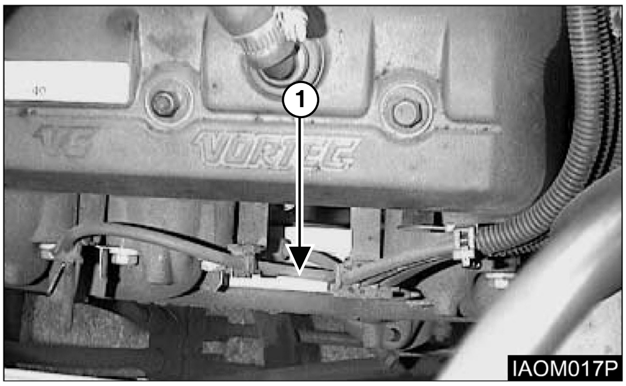
NOTE: Affective ECU input to Ignition timing control

- Coolant temperature sensor
- Oxygen sensor
- Battery voltage
- MAP sensor (Engine load)
- Crankshaft position sensor
- Throttle position sensor
- Intake Air Temperature sensor

5) Check that actual ignition timing is changed with engine RPM increased.

Inspection of Spark Plug

Inspection and clean



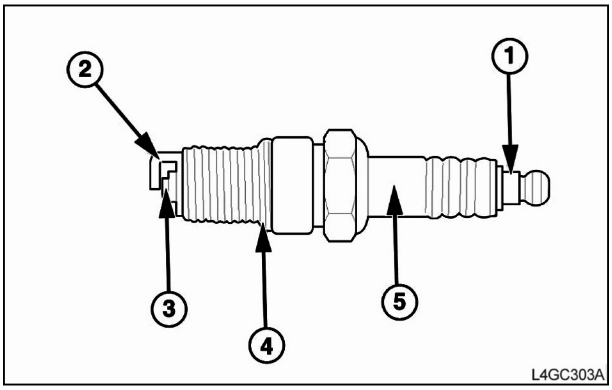
1) Ignition cable

1. Disconnect the ignition cables from spark plugs.

2. Remove all spark plugs from the cylinder head using a sparkplug wrench.

⚠ CAUTION

Take care not to come foreign materials into spark-plug mounting hole.



3. Check the spark plug as below.

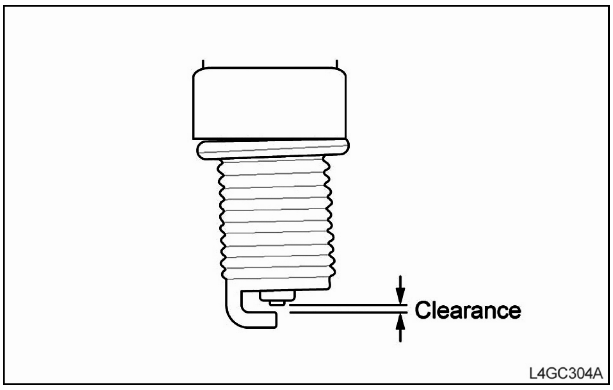
1) Insulator broken

2) Terminal worn

3) Carbon deposit

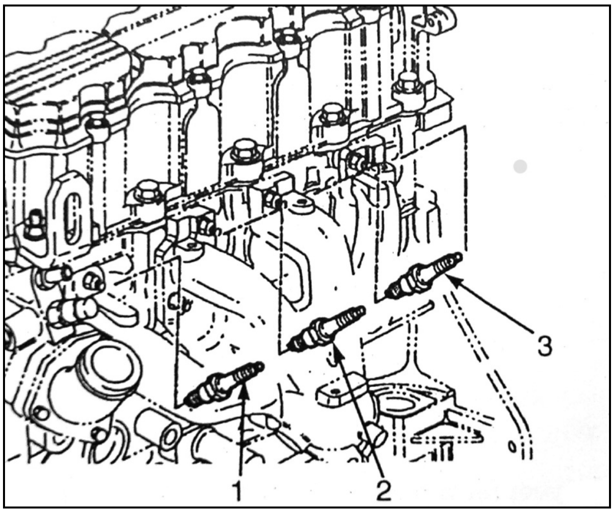
4) Gasket damaged or broken

5) Porcelain insulator of spark plug clearance



4. Check the plug clearance using a plug clearance gauge and if the value is not within the specified values, adjust it by bending the ground clearance. When installing a new sparkplug, install it after checking the uniform plug clearance.

Spark plug clearance	0.8~0.9 mm



Spark Plugs

5. Install the spark plug and tighten it to the specified torque.
Take care not to over tighten it to prevent cylinder head threads from damage.

Tightening torque	25~30 N•m

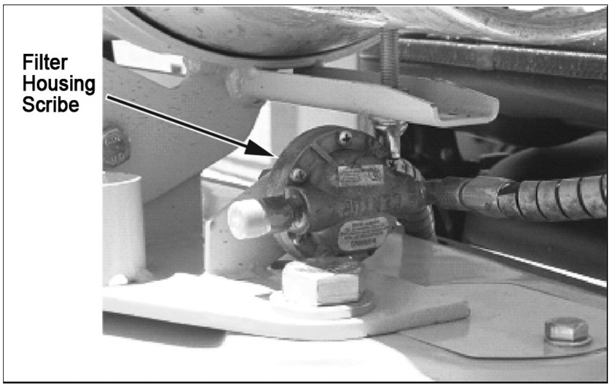
SPARK PLUG ANALYSIS

State	Contact point is black	Contact point is white
Description	• Density of the fuel mixture is thick • Lack of air intake	• Density of the fuel mixture is thin • Ignition timing is fast • Spark plug is tight • Lack of torque

Fuel System Maintenance

Replace LP Fuel Filter Element

Park the lift truck in an authorized refueling area with the forks lowered, parking brake applied and the transmission in Neutral.

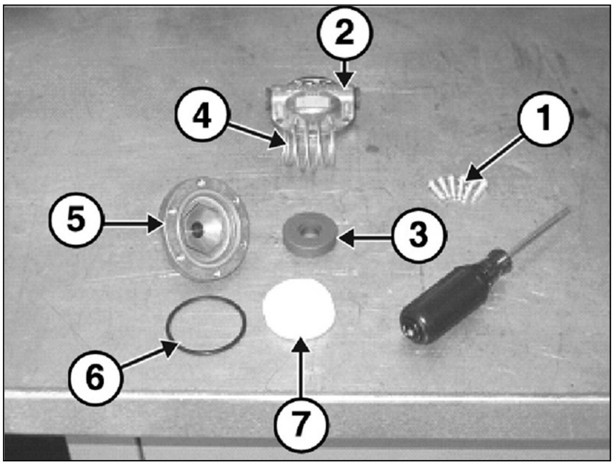


1. Close the fuel shutoff valve on the LP-fuel tank. Run the engine until the fuel in the system runs out and the engine stops.

2. Turn off the ignition switch.

3. Scribe a line across the filter housing covers, which will be used for alignment purposes when re-installing the filter cover.

FUEL FILTER DISASSEMBLY (Steps 4-7)



4. Remove the cover retaining screws (1).

5. Remove top cover (2), magnet (3), spring (4), and filter element (7) from bottom cover (5).

6. Replace the filter element (7).

7. Check bottom cover O-ring seal (6) for damage. Replace if necessary.

8. Re-assemble the filter assembly aligning the scribe lines on the top and bottom covers.

9. Install the cover retaining screws, tightening the screws in an opposite sequence across the cover.

10. Open the fuel valve by slowly turning the valve counterclockwise.

11. Crank the engine several revolutions to open the fuel lock-off. DO NOT START THE ENGINE. Turn the ignition key switch to the off position.

12. Check the filter housing, fuel lines and fittings for leaks. Repair as necessary.

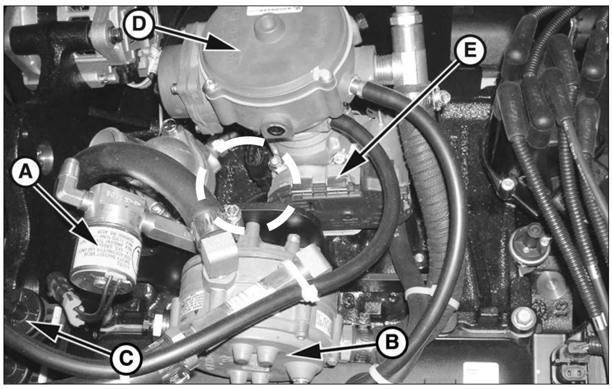
Testing Fuel Lock-off Operation

- Start engine.
- Locate the electrical connector for the fuel lock (A).
- Disconnect the electrical connector.
- The engine should run out of fuel and stop within a short period of time.

NOTE

The length of time the engine runs on trapped fuel vapor increases with any increase in distance between the fuel lock-off and the pressure regulator /converter.

- Turn the ignition key switch off and re-connect the fuel lock-off connector.



Pressure Regulator/Converter Inspection

- Visually inspect the pressure regulator/converter (B) housing for coolant leaks.
- Refer to Chapter 6 if the pressure regulator/converter requires replacement.

Fuel Trim Valve Inspection (FTV)

- Visually inspect the fuel trim valves (C) for abrasions or cracking. Replace as necessary.
- To ensure a valve is not leaking a blow-by test can be performed.

1. With the engine off, disconnect the electrical connector to the FTVs.

2. Disconnect the vacuum line from the FTVs to the pressure regulator/converter at the converter's tee connection.

3. Lightly blow through the vacuum line connected to the FTVs.
Air should not pass through the FTVs when de-energized.
If air leaks past the FTVs when de-energized, replace the FTVs.

Inspect Air/Fuel Valve Mixer Assembly

- Refer to Chapter 6 for procedures regarding the LP mixer (D).

Inspect for Intake Leaks

- Visually inspect the intake throttle assembly (E), and intake manifold for looseness and leaks. Repair as necessary.

Inspect Throttle Assembly

- Visually inspect the throttle assembly motor housing for coking, cracks, and missing cover-retaining clips. Repair and/or replace as necessary.

NOTE: Refer to Chapter 6 for procedures on removing the mixer and inspecting the throttle plate.

Checking the TMAP Sensor(G643E only)

- Verify that the TMAP sensor (F) is mounted tightly into the manifold or manifold adapter (E), with no leakage.
- If the TMAP is found to be loose, remove the TMAP retaining screw and the TMAP sensor from the manifold adapter.
- Visually inspect the TMAP O-ring seal for damage. Replace as necessary.
- Apply a thin coat of an approved silicon lubricant to the TMAP O-ring seal.
- Re-install the TMAP sensor into the manifold or manifold adapter and securely tighten the retaining screw.

Exhaust System Maintenance

Inspect Engine for Exhaust Leaks

- Start the engine and allow it to reach operating temperatures.
- Perform visual inspection of exhaust system from the engine all the way to the tailpipe. Any leaks, even after the post-catalyst oxygen sensor, can cause the sensor output to be effected (due to exhaust pulsation entraining air upstream). Repair any/all leaks found. Ensure the length from the post-catalyst sensor to tailpipe is the same as original factory.
- Ensure that wire routing for the oxygen sensors is still keeping wires away from the exhaust system. Visually inspect the oxygen sensors to detect any damage.(G643E only)

Maintenance Schedule

NOTE: The MI-07 fuel system was designed for use with LPG fuel that complies with HD5 or HD10 LPG fuel standards. Use of non-compliant LPG fuel may require more frequent service intervals and will disqualify the user from warranty claims.

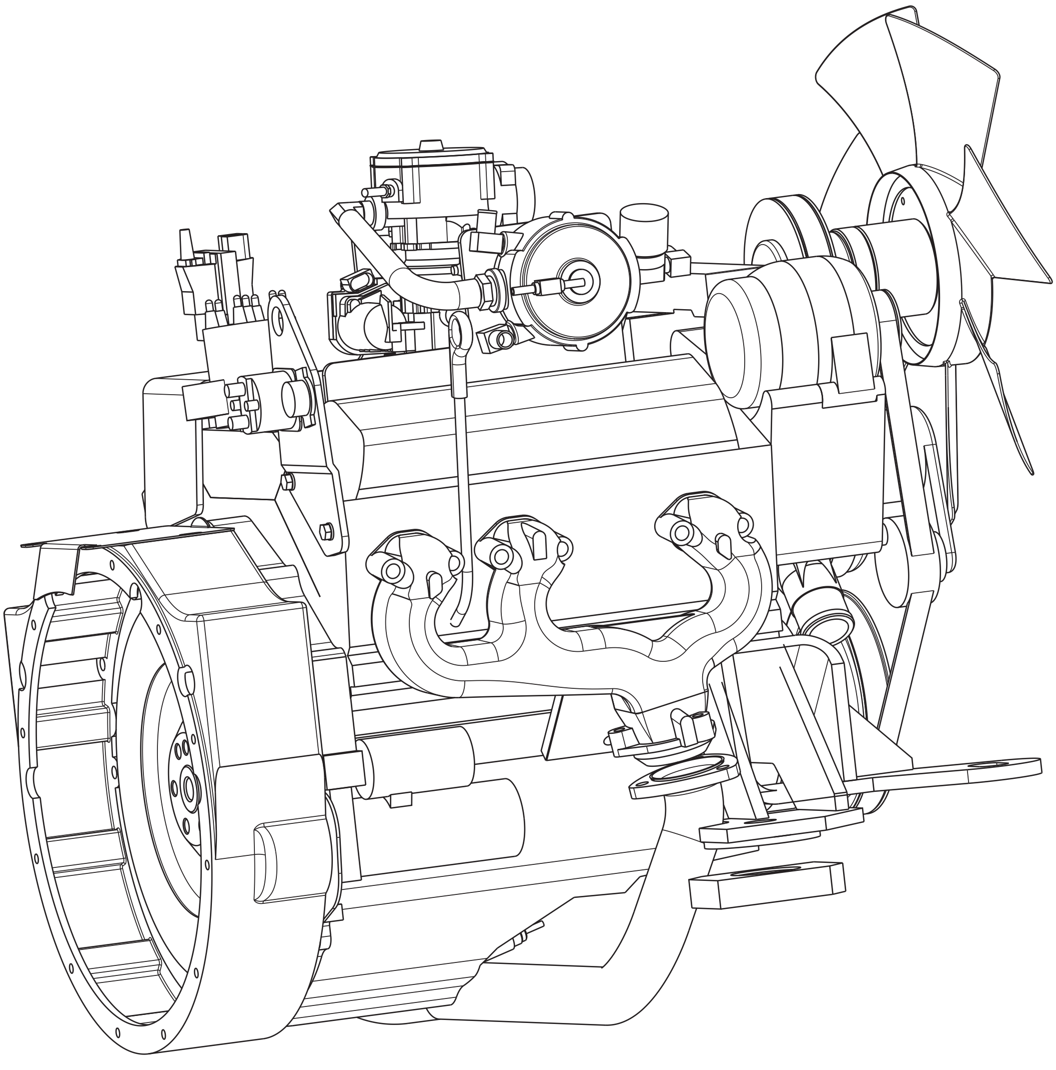
CHCK POINT	INTERVAL HOURS						
	Daily	Every 250 Hours or 1 month	Every 500 Hours or 3 month	Every 1000 Hours or 6 month	Every 1500 Hours or 9 month	Every 2500 Hours or 15 month	Every 3000 Hours or 18 month
General Maintenance							
Test fuel system for leaks.	Prior to any service or maintenance activity						
Inspect engine for fluid leaks.	X						
Inspect all vacuum lines and fittings			X				
Inspect electrical system; check for loose, dirty, or damaged wires and connections.			X				
Inspect isolation mounts on engine control module for cracks and wear; replace as necessary.			X				
Inspect all fuel fittings and hoses.				X			
Inspect foot pedal travel and operation	X						
Check for MIL lamp test at key-on. If MIL lamp remains illuminated(indicating a fault),use pedal to recover fault code(s).Repair faults.	x						
Engine Coolant							
Check coolant level.	X						
Inspect coolant hoses and fittings for leaks, cracks, swelling, or deterioration.				X			
Engine Ignition							
Inspect battery for damage and corroded cables.						X	
Inspect ignition system.					X		
Replace spark plugs						X	
Fuel Lock-Off/Filter							
Replace LP fuel filter element.					X		
Inspect lock-off and fuel filter for leaks.				X			
Ensure lock-off stops fuel flow when engine is off.				X			

CHCK POINT	INTERVAL HOURS						
	Daily	Every 250 Hours or 1 month	Every 500 Hours or 3 month	Every 1000 Hours or 6 month	Every 1500 Hours or 9 month	Every 2500 Hours or 15 month	Every 3000 Hours or 18 month
Pressure Regulator/Converter							
Test regulator pressures.				X			
Inspect pressure regulator vapor hose for deposit build-up. Clean or replace as necessary.				X			
Inspect regulator assembly for fuel/coolant leaks				X			
Fuel Trim Valve(G420FE only)							
Inspect valve housing for wear, cracks or deterioration.				X			
Ensure valve seals in the closed position when the engine is off.				X			
Replace FTV	When indicated by MIL						
Carburetor(Mixer)							
Check air filter indicator	X						
Check for air leaks in the filter system.				X			
Inspect air/fuel valve mixer assembly for Cracks, loose hoses, and fittings. Repair or Replace as necessary.			x				
Check for vacuum leaks in the intake system including manifold adapter and mixer to throttle adapter						x	
Repair or replace throttle assembly	When indicated by MIL						
Inspect air filter.			X				
Replace air filler element				X			
Check TMAP sensor for tightness and leaks.						X	
Exhaust & Emission							
Inspect engine for exhaust leaks	X						
Replace PCV valve and breather element.						X	
Replace HEGO sensors	When indicated by MIL						

Chapter 3. ENGINE MECHANICAL SYSTEM

General Information

Engine Outline



Specification

General
Type ....90 Degree V6
Displacement................................ 4.3L (262 CID)
RPO (VIN Code).........................L35 (W), LF6 (X)
Bore..101.6 mm (4.00 in)
Stroke...................................88.39 mm (3.480 in)
Compression Ratio 9.2:1
Firing Order 1-6-5-4-3-2

Lubrication System
Oil Capacity
Without Filter Change ....4.3 Liters
With Filter Change Add.......................0.5 Liters
Oil Pressure (Minimum Hot)
..................41.4 kPa (6.0 psi) at 1,000 engine rpm
.... 124.1 kPa (18.0 psi) at 2,000 engine rpm
.... 165.5 kPa (24.0 psi) at 4,000 engine rpm
OIl Filter System .... Full Flow
OIl Pump Type.................................. Gear Driven

Cylinder Bore
Diameter.101.618-101.643 mm (4.0007-4.0017 in)
Out-of Round .... 0.0508 m (.002 in) MAX.
Taper........................ 0.0254 mm (.001 in) MAX

Piston
Piston Bore Clearance
.... 0.06096 mm (.0024 in) MAX.

Piston Rings
Piston Compression Ring
Groove Clearance........ 0.010668 mm (.0042 in)
Gap .... 0.889 mm (.035 in) MAX.
Piston Oil Ring
Groove Clearance.... 0.2032 mm (.008 in) MAX.
Gap ....1.651 mm (.065 in)

Oil Pan
Engine Block Clearance
Tolerance................... 0.254 mm (.010 in) MAX.

Piston Pin
Diameter............ 23.545-23.548 mm (.927-.926 in)
Clearance in Piston.. 0.0254 mm (.001 in) MAX.
Fit In Connecting Rod
0.02032-0.04064 mm (.0008-.0016 in) Interference

Exhaust Manifold
Surface Flatness........ 0.254 mm (.010 in) MAX.

Intake Manifold
Surface Flatness........ 0.254 mm (.010 in) MAX.

Cylinder Head
Surface Flatness...... 0.1016 mm (.004 in) MAX.

Crankshaft
Crankshaft Journal
Diameter #1
...............62.199-62.217 mm (2.4488-2.4495 in)
Diameter 2, #3
...............62.192-62.215 mm (2.4485-2.4494 in)
Diameter #4
...............62.180-62.202 mm (2.4480-2.4489 in)
Taper.......................0.0254 mm (.001 in.) MAX.
Out-of Round...........0.025 mm (.0010 in.) MAX.
Crankshaft Bearing Clearance
Bearing #1
...................0.0254-0.0381 mm (.0010-.0015 in)
Bearing #2, #3
...................0.0254-0.0635 mm (.0010-.0025 in)
Bearing #4
...................0.0635-0.0889 mm (.0025-.0035 in)
Crankshaft End Play
.... 0.0508-0.2032 mm (.002-.008 in)

Connecting Rod
Connecting Rod Journal
Diameter.57.117-57.142 mm (2.2487-2.2497 in)
Taper........................0.0254 mm (.001 in) MAX.
Out-of-Round............0.0254 mm (.001 in) MAX.
Rod Bearing Clearance
...................0.0254-0.0762 mm (.0010-.0030 in)
Rod Side Clearance
.... 0.1524-0.4318 mm (.006-.017 in)

Camshaft
Journal Diameter
...................47.440-47.490 mm (1.8677-1.8697 in)
End Play...........0.0254-0.2286 mm (.001-0.009 in)
Lobe Lift .... ± 0.05 mm (.002 in)
Intake .... 7.018 mm (0.2763 in)
Exhaust .... 7.252 mm (0.2855 in)

Balance Shaft
Front Bearing Journal Diameter
...............55.985-55.001 mm (2.1648-2.1654 in)
Rear Bearing Journal Diameter
.................38.084-38.100 mm (1.4994-1.500 in)
Rear Bearing Journal Clearance
...................0.0254-0.09144 mm (.001-.0036 in)

Valve System
Valve Lifter ....Hydraulic Roller
Valve Rocker Arm Ratio 1.50:1
Valve Lash ....Net Lash No Adjustment
Face Angle...45 degree
Seat Angle..46 degree
Seat Runout ....0.0508 mm (.002 in) MAX.
Seat Width Intake
.... 1.016-1.651 mm (.040-.065 in)
Exhaust .... 1.651-2.489 mm (.065-.098 in)
Stem Clearance
Intake

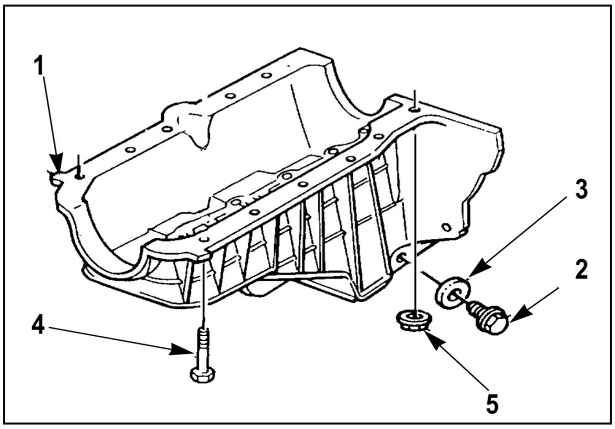
..... High Limit Production + 0.0257 mm (.001 in)
Exhaust
..... High Limit Production + 0.0508 mm (2.03 in)
Valve Spring Free Length.............52 mm (2.03 in)
Pressure
Closed
..... 338-374 N at 43 mm (76-84 lb. at 1.70 in)
Open
. 832-903 N at 32 mm (187-203 lb. at 1.27 in)
Installed Height
.... 42.92-43.43 mm (1.690-1.710 in)
Valve Lift
Intake..................................10.51 mm (.414 in)
Exhaust ....10.87 mm (.428 in)

Torque Specification

Balance Shaft Driven Gear Bolt
.......................20 N·m (15 lb·ft) (Plus 35 Degrees)
Camshaft Retainer Bolt..............12 N·m (106 lb·ft)
Camshaft Sprocket Bolts..............28 N·m (21 lb·ft)
Coolant Sensor............................20 N·m (15 lb·ft)
Connecting Rod Nut
.......................27 N·m (20 lb·ft) (Plus 70 Degrees)
Crankshaft Balancer Bolt ....100 N·m (74 lb·ft)
Crankshaft Bearing Cap Bolt......105 N·m (77 lb·ft)
Crankshaft Position Sensor Bolt.....9 N·m (80 lb·ft)
Crankshaft Rear Oil Seal Housing
Nut and Bolt................................15 N·m (11 lb·ft)
Crankshaft Rear Oil Seal Housing Stud
....4 N·m (35 lb·ft)
Cylinder Head Bolt
First Pass................................30 N·m (22 lb·ft)
Second Pass Torque Angle all Bolts in Sequence:
Short Length Bolt........................ 55 Degrees
Medium Length Bolt.................... 65 Degrees
Long Length Bolt .... 75 Degrees
Distributor Clamp Bolt ....25 N·m (18 lb·ft)
EGR Valve Bolt
First Pass................................10 N·m (89 lb·ft)
Final Pass................................25 N·m (18 lb·ft)
EGR Valve Pipe Bracket Bolt ....25 N·m (18 lb·ft)
EGR Valve Inlet Pipe Nut.............35 N·m (26 lb·ft)
Engine Block Drain Plug ....20 N·m (15 lb·ft)
Engine Block Oil Gallery Plug Left Rear
....20 N·m (15 lb·ft)
Engine Block Oil Gallery Plug Right Rear
....25 N·m (18 lb·ft)
Engine Block Oil Gallery Plug Left Side Rear
....20 N·m (15 lb·ft)
Engine Front Cover Bolt.............12 N·m (106 lb·ft)
Exhaust Manifold Stud and Bolt
First Pass................................15 N·m (11 lb·ft)
Final Pass................................30 N·m (22 lb·ft)
Engine Flywheel Bolt ....100 N·m (74 lb·ft)
Front Lift Bracket Stud ....40 N·m (30 lb·ft)
Ignition Coil Bolt...........................11 N·m (97 lb·ft)
Intake Manifold Bolts
First Pass ....3 N·m (27 lb·ft)
Second Pass .... 12 N·m (106 lb·ft)
Final Pass .... 15 N·m (11 lb·ft)

Oil Filter Bypass Valve Bolt..........27 N·m (20 lb·ft)
Oil Level Indicator Tube Bolt...... 12 N·m (106 lb·ft)
OIl Pan Nuts................................23 N·m (17 lb·ft)
Bolts.......................................25 N·m (18 lb·ft)
Studs in Engine Block..............25 N·m (18 lb·ft)
Oil Pan Drain Plug........................25 N·m (18 lb·ft)
Oil Pump Bolt ....90 N·m (66 lb·ft)
OIl Pump Cover Bolt.................. 12 N·m (106 lb·ft)
Oxygen Sensor Wire Support Bracket Nut
.... 11 N·m (97 lb·ft)
Spark Plugs
Cylinder Head (New) ....30 N·m (22 lb·ft)
Cylinder Head (All Subsequent Installation)
....20 N·m (15 lb·ft)
Spark Plug Wire Support .... 12 N·m (106 lb·ft)
Valve Lifter Guide Retainer Bolt... 16 N·m (12 lb·ft)
Valve Rocker Arm Cover Bolts... 12 N·m (106 lb·ft)
Water Outlet Bolt ....25 N·m (18 lb·ft)
Water Pump Bolt ....41 N·m (30 lb·ft)

Oil Pan



Tightning Specifications for Oil Pan

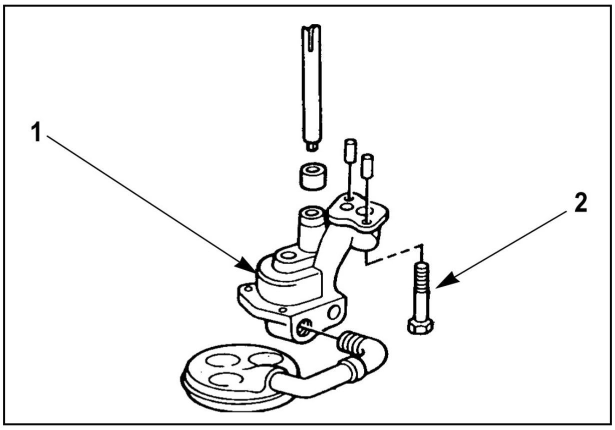
(1) ....Oil Pan

(2) Torque for Plug....................... 45 N·m (33 lb·ft)

(4) Torque for ten bolts................. 25 N·m (18 lb·ft)

(5) Torque for two nuts................. 25 N·m (18 lb·ft)

Oil Pump

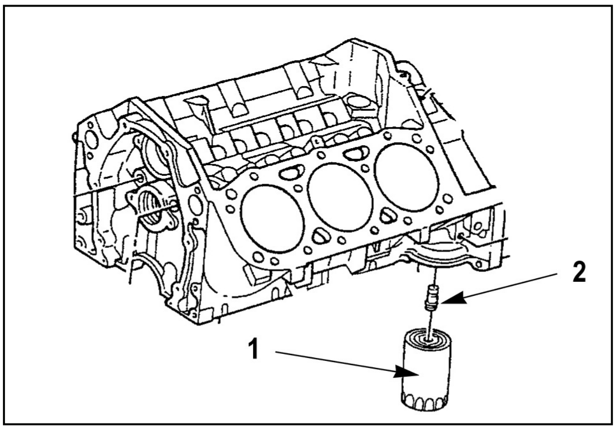


Tightening Specifications for Oil Pump to Main Bearing Cap Bolt

(1)...Oil Pump

(2) Torque for bolt .... 90 N·m (66 lb·ft)

Oil Filter



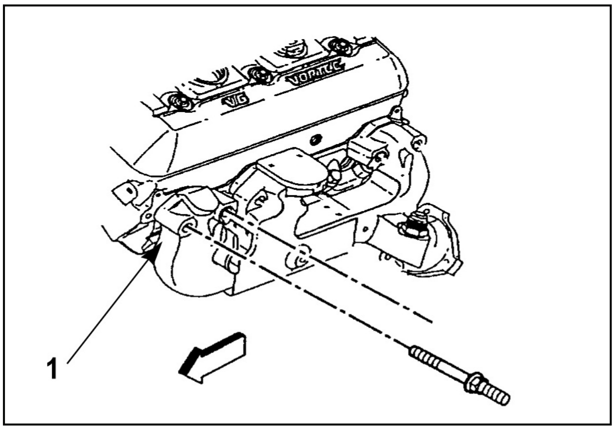
Tightening Specifications for Oil Filter

(1) Wipe clean the filter adapter in the area that the new filter makes contact. Put clean engine oil on the new filter gasket. Install filter until contack is made the tighten 3/4 turn more.

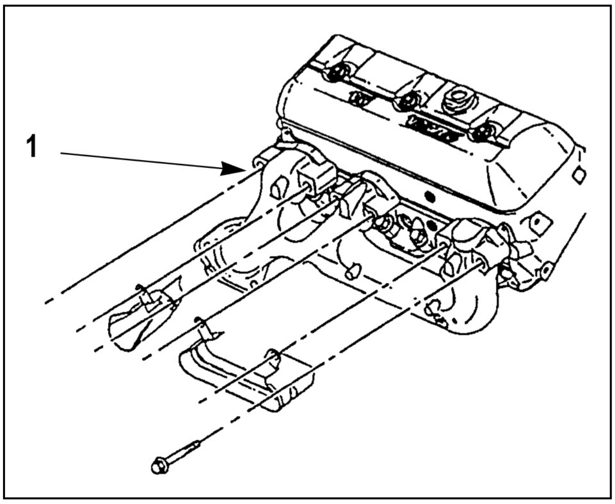
(2) Torque for adapter is

................................54 ± 14 N·m (40 ± 10 lb·ft)

Exhaust Manifolds



Exhaust Manifold Left Side



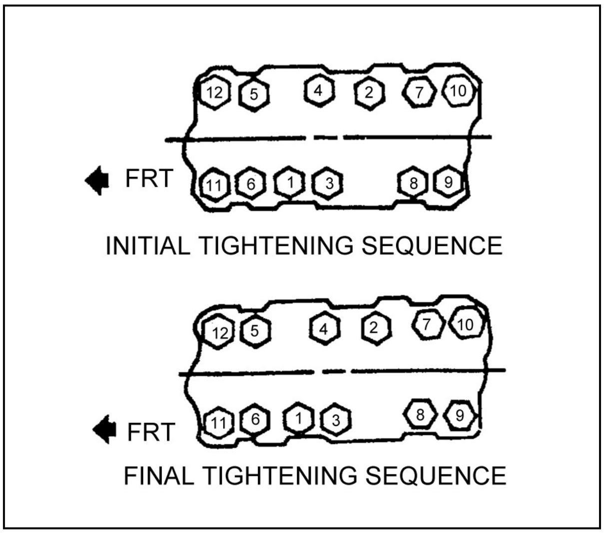
Exhaust Manifold Right Side

Tightening Specifications for Exhaust Manifold. Exhaust manifold tighten bolts in two steps, begin with the center bolts.

(1) Torque for exhaust manifold bolts .... 15 N·m (11 lb·ft)

(2) Torque for exhaust manifold bolts (second pass) .... 30 N·m (22 lb·ft)

Intake Manifolds



Tightening Specifications for Intake Manifolds

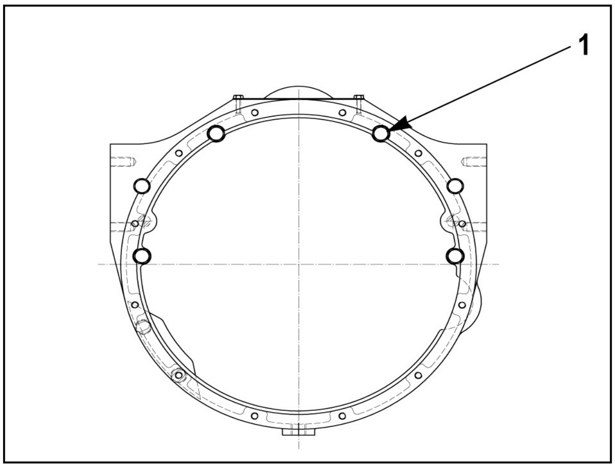
Intake manifold bolt in three steps using sequence shown in IAGS023S

First pass .... 3 N·m (27 lb·ft)

Second pass .... 12 N·m (106 lb·ft)

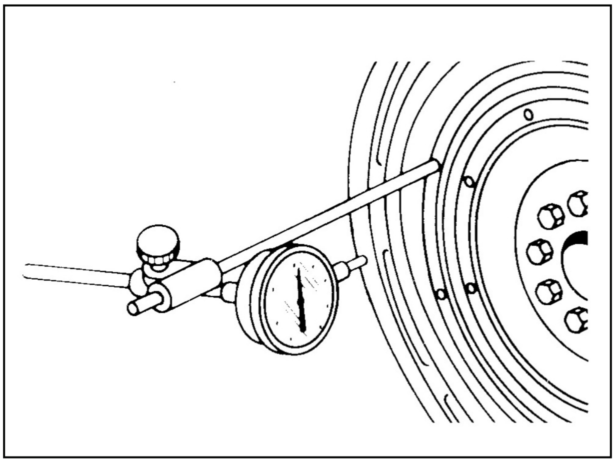
Third pass .... 15 N·m (11 lb·ft)

Flywheel Housing



(1) Flywheel housing bolts should be torqued to ....40 to 45 N·m (30 to 35 lb·ft)

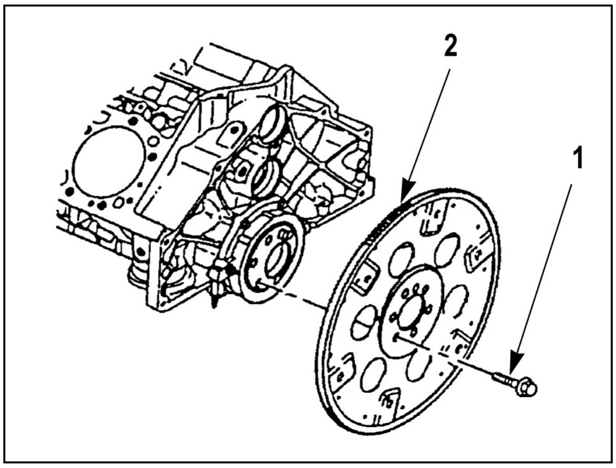
Flywheel Face Runout



Face Runout Check

Maximum permissible face runout of the flywheel housing......................................0.20 mm (.008 in) (See Flywheel Housing Checks in Testing And Adjusting).

Flywheel



(1) Torque for the bolts that hold the flyweel to the crankshaft100 N·m (74 lb·ft)

(2) Use a torch. Heat the ring around the entire circumference, then drive the gear off the flywheel using care not to damage the flywheel

---

NOTICE

Never heat the ring to a red hot condition this will change the metal structure

---

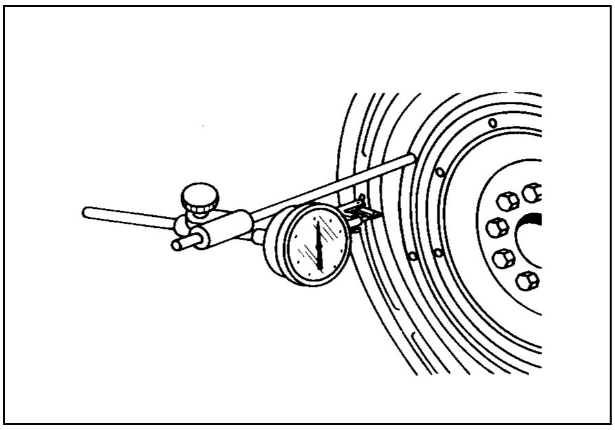
Uniformly heat the ring gear to a temperature that will expand the gear to permit installation. Temperature must not exceed 204℃ (400 °F).

As soon as the ring gear has been heated install it on the flywheel.

Flywheel Runout

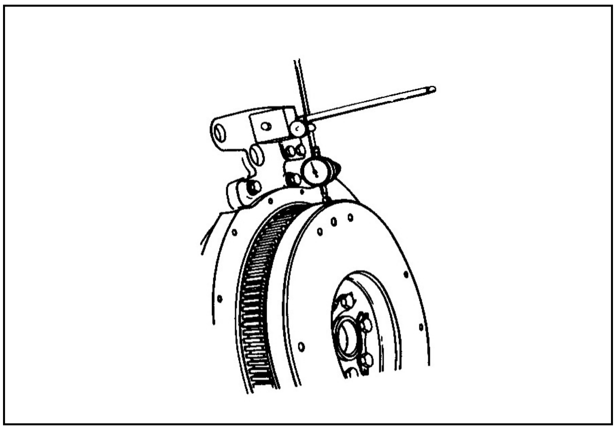
For checking procedure, see Flywheel And Flywheel Housing in the Testing And Adjusting section.

Face Runout (Axial Eccentricity).



Maximum permissible face runout of the flywheel ....0.19 mm (.0075 in)

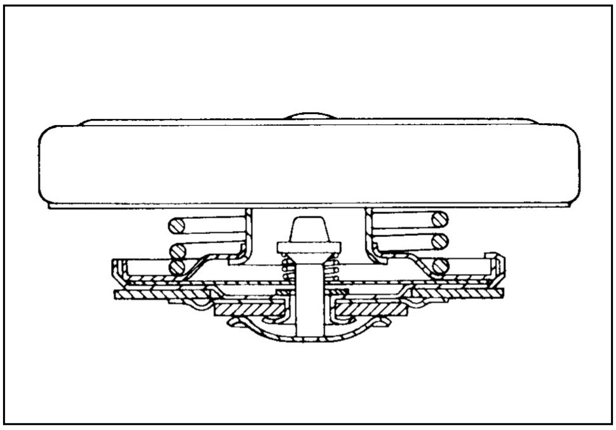
Outside Diameter Runout (Radial Eccentricity)



Outside Diameter Runout Check

Maximum permissible outside diameter runout of the flywheel .... 0.1 mm (.004 in)

Pressure Cap

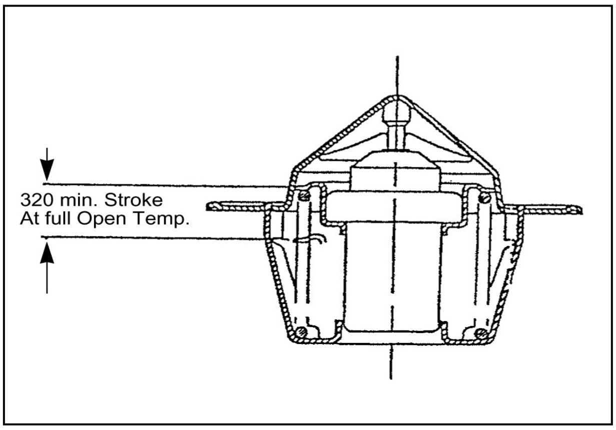


For testing procedure, see Cooling System Tests in the Testing And Adjusting section.

Pressure valve opening pressure ....85 to 110 kPa (12 to 16 psi)

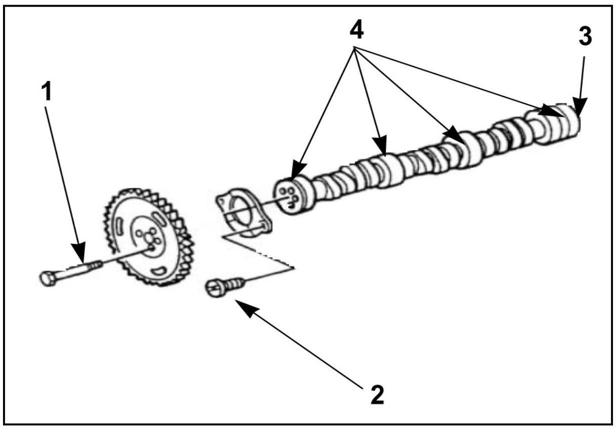
Vacuum valve opening pressure .... 0 to 5 kPa (0 to 0.7 psi)

Thermostat



Full open temperature...... 85 to 95℃ (185 to 195˚F)

Camshaft



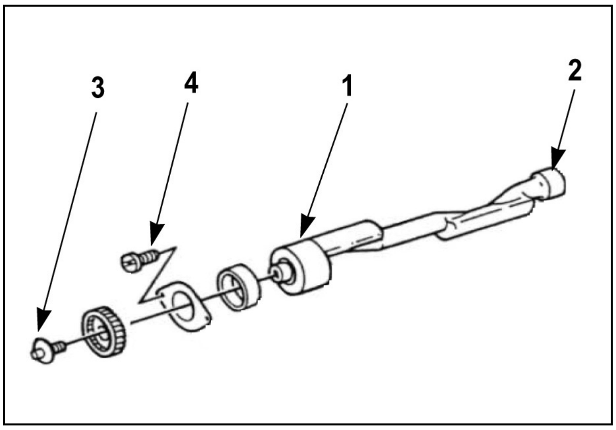
(1) Torque for camshaft sprocket bolts
.... 20 N·m (15 lb·ft)

(2) Torque for retainer mounting bolts
.... 12 N·m (106 lb·ft)

(3) End play for the camshaft
..............0.0254 to .02286 mm (.001 to .009 in)

(4) Diameter of the surface journals for the camshaft bearings new
..............51.03 to 51.05 mm (2.009 to 2.010 in)

Balance Shaft



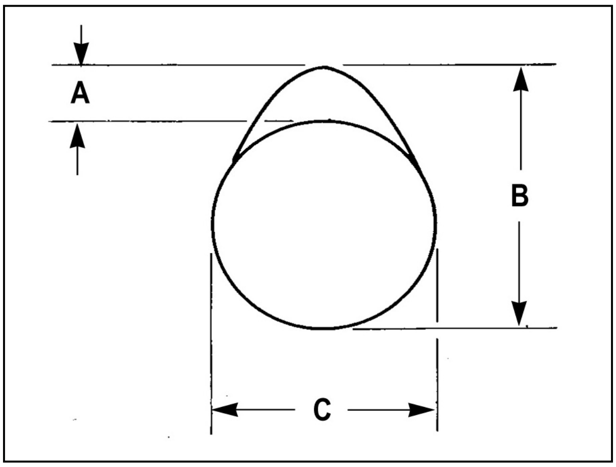
(1) Front Bearing Journal Diameter
...... 55.985 to 55.001 mm (2.1648 to 2.1654 in)

(2) Rear Bearing Journal Diameter
.... 38.084 to 38.100 mm (1.4994 to 1.500 in)
Rear Bearing Journal Clearence
.... 0.0254 to 0.09144 mm (.001 to .0036 in)

(3) Balance Shaft Drive Gear Bolt
.... 20 N·m (15 lb·ft)
Torque plus 35 Degrees

(4) Balance Shaft Retainer Bolt
.... 14 N·m (124 lb·ft)

NOTE : Balance shaft must be timed to camshaft gear.



Height of camshaft lobes

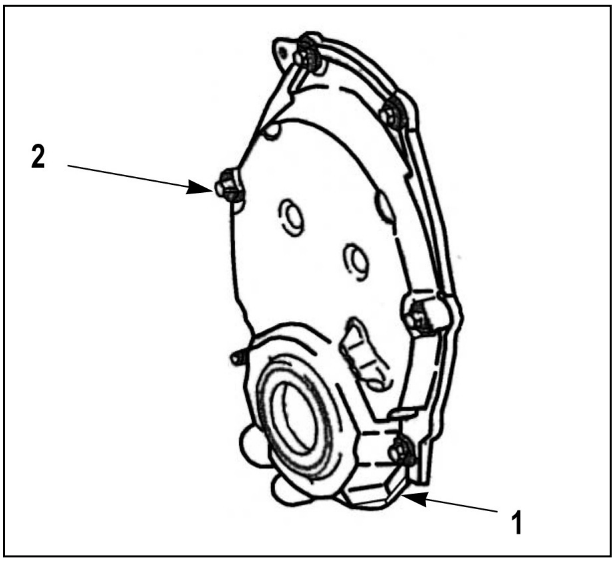
(A) Intake lobe ....7.018 mm (.2763 in)

(B) Exhaust lobe ....7.252 mm (.2855 in)

(C) Maximum permissible difference actual & specified lobe lift.................± 0.05 mm (.022 in)

See procedure under Testing And Adjusting section of manual on to due measurements

Front Gear Cover

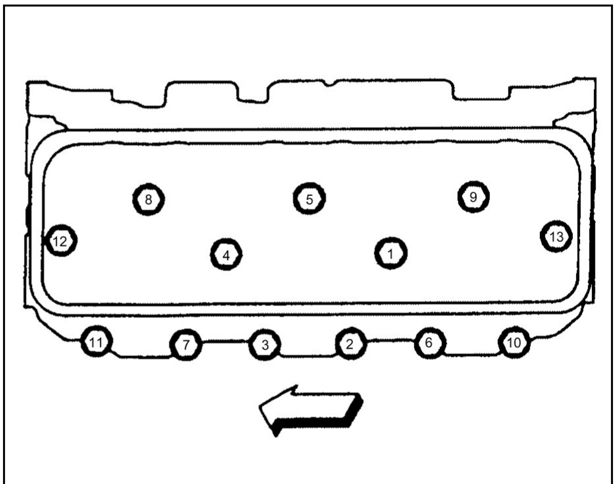


(1) The front gear cover (1) of the engine must be replaced if it is removed for any reason. The cover is made of high impact plastic but can warp do to heat. To prevent oil leaks replace the cover.

(2) The front gear cover bolts should be torqued to .... 15 N·m (11 lb·ft)

Cylinder Heads

Tools Needed	A
Torque Angle Meter	1



NOTE : When installing the cylinder heads use a new head gasket. Do not use sealer on the composite gasket.

Tighten the cylinder head bolts in the following sequence.

All bolts are torqued to a torque of **30 N·m (22 lb·ft)**. On the second pass a tool A degree wheel must be used.

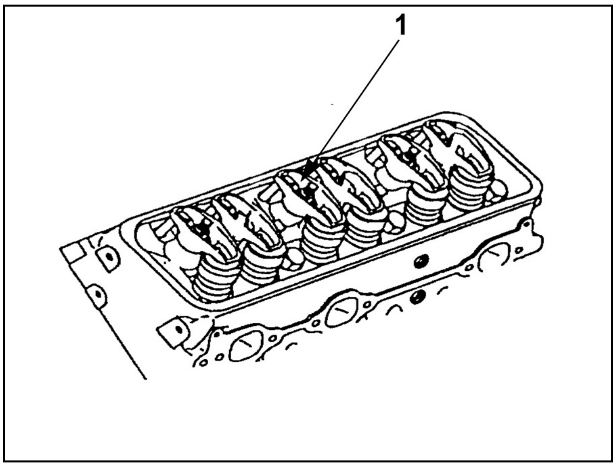
Bolts in sequence.

1. Short length bolts (11, 7, 3, 2, 6, 10) 55 degrees

2. Medium length bolts (12, 13) 65 degrees

3. Long length bolts (1, 4, 8, 5, 9) 75 degrees

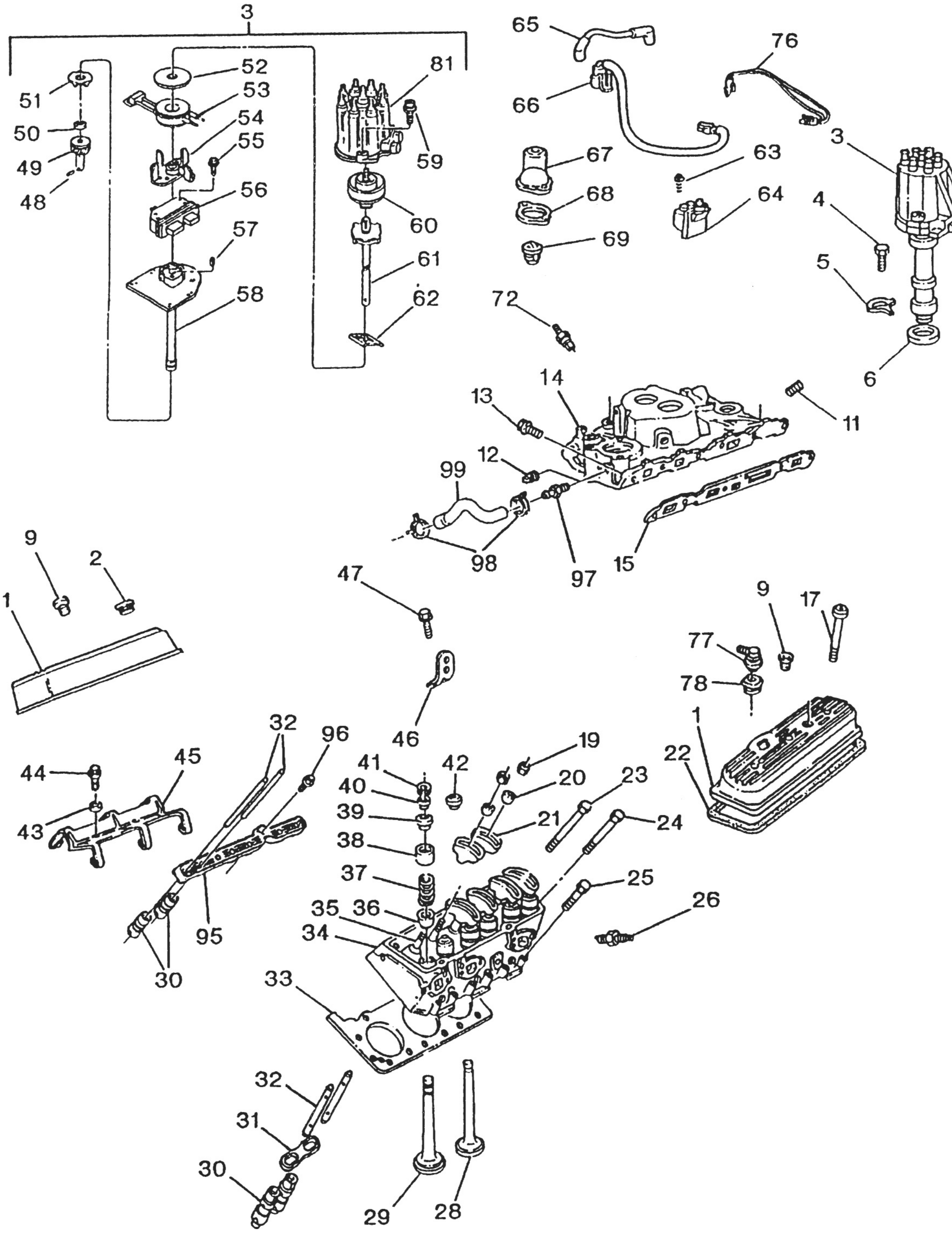
Valve Clearence



(1) The 4.3 liter engine has screw-in rocker arm studs with positive stop shoulders, NO valve adjustment is necessary. When the valve train requires service you simply tighten the rocker arm nuts to **25 N·m (18 lb·ft)**.

Engine Exploded View

UPPER ENGINE ILLUSTRATION

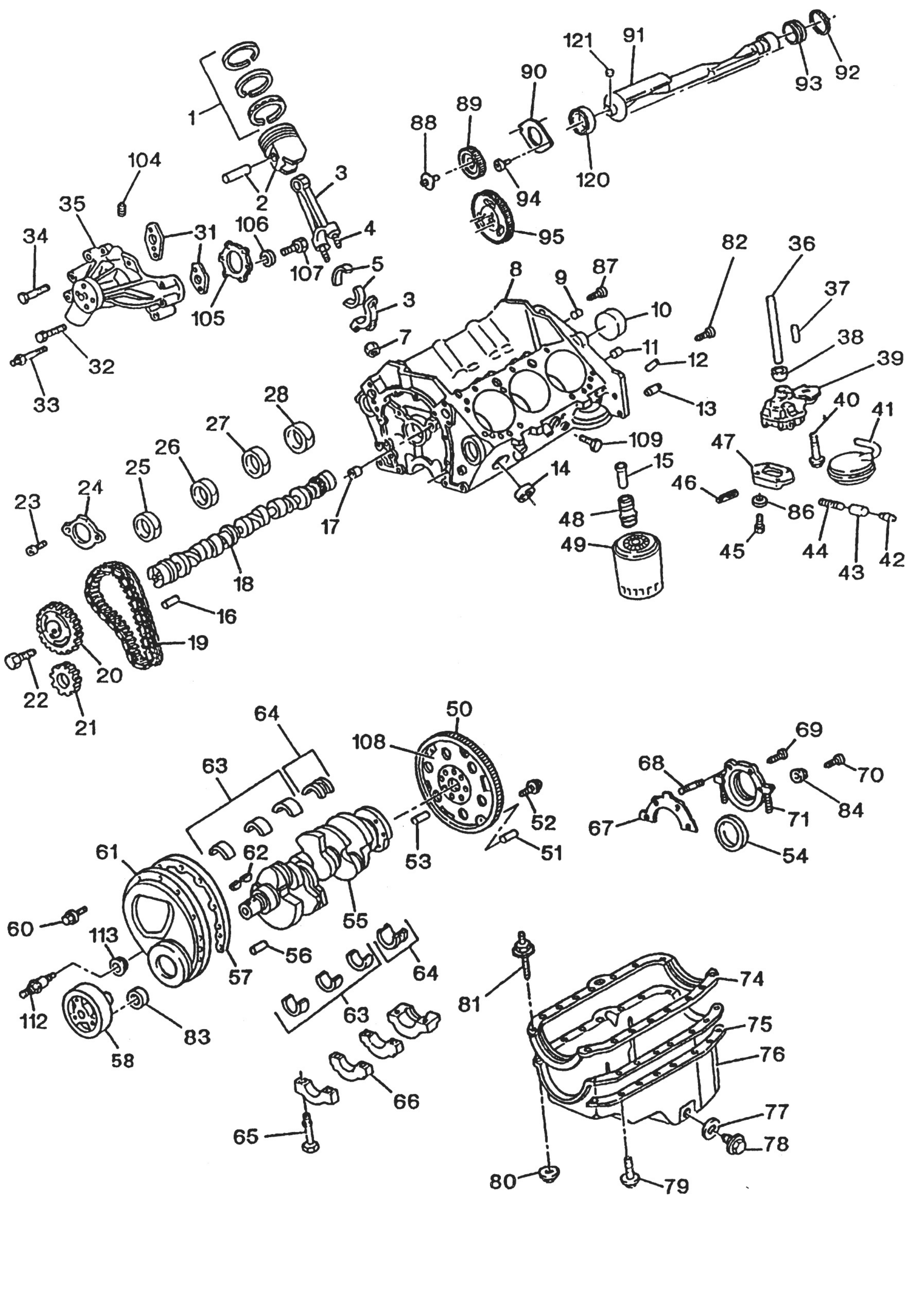


UPPER ENGINE PARTS

ITEM #	DESCRIPTION
1	COVER, VALVE ROCKER ARM (RH)
	COVER, VALVE ROCKER ARM (LH)
2	CAP, OIL FILL
3	DISTRIBUTOR
4	BOLT, DISTRIBUTOR CLAMP
5	CLAMP, DISTRIBUTOR
6	GASKET, DISTRIBUTOR
9	GROMMET, VALVE ROCKER ARM COVER
11	PLUG, INTAKE MANIFOLD VACUUM HOLE
12	PLUG, SQ HD FILL & DRAIN
13	BOLT, INTAKE MANIFOLD
14	MANIFOLD, INTAKE
15	GASKET KIT,
17	BOLT, VALVE ROCKER ARM COVER
19	NUT, VALVE ROCKER ARM
21	ARM, VALVE ROCKER
22	GASKET, VALVE ROCKER
23	BOLT, CYLINDER HEAD (LONG)
24	BOLT, CYLINDER HEAD (MEDIUM)
25	BOLT, CYLINDER HEAD (SHORT)
26	SPARK PLUG
28	VALVE, EXHAUST
29	VALVE, INTAKE
30	LIFTER, VALVE
32	ROD, VALVE PUSH
33	GASKET, CYLINDER HEAD
34	HEAD, CYLINDER
35	STUD, VALVE ROCKER ARM BALL
36	SEAL, INTAKE VALVE STEM OIL
37	SPRING, VALVE (W/O DAMPER)
39	SEAL, EXHAUST VALVE STEM OIL
41	KEY, VALVE STEM
42	CAP, VALVE SPRING
44	BOLT, VALVE LIFTER GUIDE
48	PIN, DIST. GEAR (PT OF 3)
49	GEAR, DIST. SHAFT (PT OF 3)
50	WASHER, DIST. SHAFT (PT OF 3)
51	WASHER, DIST. SHAFT THR (PT OF 3)
52	SHIELD, DIST. IGN. P/U COIL (PT OF 3)
53	COIL, DISTRIBUTOR PICK UP (PT OF 3)
54	OLE PIECE & PLATE, DISTRIBUTOR (PT OF 3)
55	BOLT, DISTR. IGNITION ICM (PT OF 3)

ITEM #	DESCRIPTION
56	MODULE, DIST. IGN. CONT. (PT OF 3)
61	SHAFT, DISTRIBUTOR (PT OF 3)
62	RETAINER, DIST. IGN P/U COIL
63	BOLT, IGNITION COIL
64	COIL, IGN. (INCL. BRKTS, COIL, SCREW & NUT)
67	OUTLET, WATER
68	GASKET, WATER OUTLET
69	THERMOSTAT, ENGINE COOL
72	SENSOR, ENGINE COOL TEMP
77	VALVE, PCV
78	GROMMET, PCV VALVE
81	CAP, DISTRIBUTOR (PT OF 3)
95	GUIDE, VALVE LIFTER PUSH ROD
96	BOLT, VALVE LIFTER GUIDE
97	NIPPLE, HTR INL HOSE
99	HOSE, WATER PUMP INLET (INCL. CLAMPS)
2A	GASKET KIT, INTAKE MANIFOLD

LOWER ENGINE ILLUSTRATION



LOWER ENGINE PARTS

ITEM #	DESCRIPTION	ITEM #	DESCRIPTION
1	RING KIT, PISTON (STD)	48	FITTING, O IL FILTER
	KIT, PISTON (0.50 MM O.S.)	49	FILTER, O IL
2	PISTON KIT, ENGINE (STD)	50	GEAR, FLYWHEEL RING
	PISTON KIT, ENGINE (0.50 MM O.S.)	58	BALANCER, CRANKSHAFT
3	ROD, CONN (INCL. BOLTS, CAP, NUT& ROD)	60	BOLT, ENGINE FRONT COVER
4	BOLT, CONN ROD	61	COVER, ENG FRT
5	BEARING KIT, CONN ROD (STD)		(INCLS BOLTS, COVER, GROMMETS & SEAL)
7	NUT, CONN ROD		(GASKET MOLDED TO COVER)
9	PLUG, ENGINE BLK OIL GAL (RR)(RH)	62	KEY, CRANKSHAFT BALANCER
	PLUG, ENGINE BLK OIL GAL (RR)(LH)	63	BEARING KIT, CRANKSHAFT (#1, 2, & 3)
10	PLUG, CM/SHF RR BRG HOLE	64	BEARING KIT, CRANKSHAFT (RR #4)
11	PIN, CR/SHF RR OIL SEAL HSG	65	BOLT, CRANKSHAFT BEARING CAP
12	PIN, CYL. HEAD LOC.	67	GASKET, CRANKSHAFT RR OIL SEAL HSG
13	PIN, TRANS. LOC.	68	STUD, CRANKSHAFT RR OIL SEAL RETAINER
14	PLUG, ENG BLK CORE HOLE	69	BOLT, CRANKSHAFT RR OIL SEAL HOUSING
15	VALVE, OIL FILTER BYPASS	70	BOLT, CRANKSHAFT RR OIL SEAL HOUSING
16	PIN, CM/SHF SPKT LOC.	71	HOUSING, CR/SHF RR OIL SEAL
17	PLUG, ENGINE BLK OIL GAL (FRT)(RH)	75	GASKET, OIL PAN
	PLUG, ENGINE BLK OIL GAL (FRT)(LH)	76	AN, OIL (INCL BAFFLE, BOLTS, GSKT, INSER PAN,
18	CAMSHAFT, ENGINE (INCL. #16)		PLUG, & SEALER)
19	CHAIN, CM/SHF TMG (IS A ROLLER CHAIN)	77	SEAL, OIL PAN DRAIN PLUG (O-RING)
20	SPROCKET, CM/SHF (SEE ITEM 2A @ END)	78	PLUG, OIL PAN DRAIN (W/MAGNET & SEAL)
21	SPROCKET, CR/SHF (SEE ITEM 2A @ END)	79	BOLT, OIL PAN (HFH 5/16 - 18 X 7/8)
22	BOLT, CM/SHF SPROCKET	80	NUT, OIL PAN (5/16 - 18 X 20)
23	BOLT, CM/SHF SPROCKET RETAINER	82	PLUG, ENG BLK OIL GAL (CUP 15/32 X 5/16)
24	RETAINER, CM/SHF	83	SEAL, CRANKSHAFT SEAL (61.5MM)
25	BEARING, CM/SHF (#1 POSITION)	84	NUT, CR/SHF RR OIL SEAL RET
26	BEARING, CM/SHF (#2 POSITION)	87	PLUG, KNOCK SENSOR HOLE
27	BEARING, CM/SHF (#3 POSITION)	88	BOLT, BALANCER SHAFT GR
28	BEARING, CM/SHF (#4 POSITION)	90	RETAINER, BALANCER SHAFT
31	GASKET, W /PMP (PART O F 35)	91	BALANCER (INCL'S ITEM 121)(INTERNAL)
32	BOLT, WATER PUMP	92	PLUG, BALANCER SHAFT RR BRG HOLE
35	PUMP, W/P (INCLS GASKET & PLUG)	93	BEARING KIT, BALANCER SHAFT
36	SHAFT, O IL PUMP DRIVE	94	BOLT, BALANCER SHAFT RETAINER
37	PIN, O IL PUMP DRIVE	105	GASKET, WATER PUMP COVER
38	RETAINER, O IL PUMP DRIVE SHAFT	106	WASHER, INT-EXT TOOTH
39	PUMP, O IL	107	BOLT, WATER PUMP COVER
40	BOLT, O IL PUMP	108	FLYWHEEL, ENGINE
41	SCREEN, O IL PUMP	109	PLUG, ENGINE BLOCK COOL DRAIN HOLE
42	PLUG, O /P RLF VLV BORE (PT O F 39 & 47)	113	GROMMET, ENGINE FRONT COVER
43	ALVE, O IL PRESSURE RELIEF (PT OF 39 &47	1A	GEAR KIT, BAL SHF (INCL DRIVE & DRIVEN GEAR)
44	SPRING, O IL PRESSURE RELIEF VALVE	2A	CHAIN KIT, TIMING (INCLS CHAIN, CR/SHF
45	BOLT, O IL PUMP COVER (PT OF 39)		SPROCKET & CM/SHF PROCKET)
46	PIN, O /P RLF VLV SPR ST (PT O F 39 & 47)		N.S.S. NOT SOLD SEPARATELY
47	COVER, O IL PUMP (PART O F 39)		

Engine Construction

The 4.3L (262 CID) engine is a liquid-cooled 90 V6 type with overhead valves, cast-iron block, cylinder heads, and cast-iron balance shaft.

Cylinder Block

The cylinder block has 6 cylinders arranged in a “V” shape with 3 cylinders in each bank. Starting at the front of the engine, cylinders in the right bank are numbered 1-3-5 and cylinders in the left bank are numbered 2-4-6 (when viewed from the front of the engine). The firing order of the cylinders is 1-6-5-4-3-2. The cylinders are encircled by coolant jackets.

Cylinder Heads

The cylinder heads have one intake and one exhaust valve for each cylinder. A spark plug is located between the valves in the side of the cylinder head. The valve guides are integral and the rocker arms are retained on individual threaded studs.

Crankshaft

The crankshaft is supported by four crankshaft bearings. The number four bearing at the rear of the engine is the end thrust bearing. The bearings are retained by bearing caps that are machined with the block for proper alignment and clearances.

Camshaft

The camshaft is supported by four full round, sleeve-type bearings. A sprocket on the crankshaft drives a timing chain which in turn drives the camshaft through a sprocket.

Pistons and Connecting Rods

The pistons are made of cast aluminum alloy using two compression rings and one oil control ring. Piston pins are offset 0.9 mm (0.0354 in.) toward the major thrust side (right side) to reduce piston slap as the connecting rod travels from one side of the piston to the other side after a stroke. The pins are a press fit in the connecting rod and a floating fit in the piston.

Balance Shaft

A cast-iron balance shaft is mounted in the crankcase above and in line with the camshaft.
A camshaft gear drives the gear attached to the balance shaft. The front end of the balance shaft is supported by a ball-type bearing. The rear end of the bearing uses a sleeve-type bearing.

Valve Train

The valve train is a ball pivot type. Motion is transmitted from the camshaft through the valve lifter and valve pushrod to the rocker arm. The valve rocker arm pivots on its ball and transmits the camshaft motion to the valve.

The valve lifters with roller followers keep all parts of the valve train in constant contact. Each lifter acts as an automatic adjuster and maintains zero lash in the valve train and eliminates the need for periodic valve adjustment.

Statement On Cleanliness And Care

An engine is a combination of many machined, honed, polished, and lapped surfaces with very fine tolerances.
Whenever valve train components, cylinder head, cylinder, crankshaft, or connecting rod components are removed for service, they should be retained in order. At the time of installation, they should be installed in the same locations and with the same mating surfaces as when removed.

Any time the air cleaner or TBI unit is removed, the intake opening must be covered. This will protect against the entrance of foreign material which could follow the intake passage into the cylinder and cause extensive damage when the engine is started.

When any internal engine parts are serviced, care and cleanliness are important. A liberal coating of engine oil should be applied to friction areas during assembly to protect and lubricate the surfaces on initial operation. Throughout this Section, it should be understood that proper cleaning and protection of machined surfaces and friction areas is part of the repair procedure. This is considered standard shop practice even if not specifically stated.

Use Of Rtv Sealer And Anaerobic Gasket Eliminator

Two types of sealer are commonly used in the engines covered by this manual. These are RTV sealer and anaerobic "gasket eliminator" sealer. It is important that these sealers be applied properly and in their proper place to prevent oil leaks. THE TWO TYPES OF SEALERS ARE NOT INTER-CHANGEABLE. Use the sealer recommended in the procedure.

RTV (room temperature vulcanization) sealer is used where a non-rigid part is assembled to a rigid part. Common examples are oil pans and rocker covers. Anaerobic gasket eliminator hardens in the absence of air. This sealer is used where two rigid parts (such as castings) are assembled together. When two rigid parts are disassembled and sealer or gasket is readily noticeable, the parts were probably assembled using gasket eliminator.

Using RTV Sealer

1. Do not use RTV when extreme temperatures are expected, such as exhaust manifold, head gasket or where gasket eliminator is specified.

2. When separating components sealed with RTV, use a rubber mallet and "bump" the part sideways to shear the RTV sealer. "Bumping" should be done at bends or reinforced areas to prevent distortion of parts. RTV is weaker in shear (lateral) strength than in tensile (vertical) strength.

NOTICE: Attempting to pry or pull components apart may result in damage to the part.

3. Surfaces to be resealed must be clean and dry. Remove all traces of oil and RTV with a chlorinated solvent (GM P/N 1050454 or equivalent). Do not use petroleum cleaners such as mineral spirits. They leave a film onto which RTV will not stick.

4. Apply RTV to one of the clean surfaces. Use a bead size as specified in the procedure. Run the bead to the inside of any bolt holes. Do not allow the sealer in any blind threaded holes, as it may prevent the bolt from seating properly or cause damage when the bolt is tightened.

5. Assemble while RTV is still wet (within 3 minutes). Do not wait for RTV to skin over.

6. Torque bolts to specifications. Do not overtorque.

Using Anaerobic Gasket Eliminator

1. Clean surfaces to be resealed with a chlorinated solvent (GM P/N 1050454 or equivalent) to remove all oil, grease, and old material.

2. Apply a continuous bead of gasket eliminator to one flange.

3. Spread the bead evenly with your finger to get a uniform coating on the complete flange.

4. Assemble parts in the normal manner and torque immediately to specifications.

IMPORTANT: Anaerobic sealed joints that are partially torqued and allowed to cure more than five minutes may result in incorrect shimming of the joint.

Replacing Engine Gaskets

⚠ CAUTION

Composite type gaskets are used in some areas of the engine assembly. These gaskets have a thin metal core. Use caution when removing or handling composite gaskets to help avoid personal injury.

Thread Repair

Figure 12-2

Tool Required:

- General purpose thread repair kits are available commercially.

Damaged threads may be reconditioned by drilling out, rethreading, and installing a suitable thread insert.

⚠ CAUTION

Wear safety glasses to avoid eye damage.

1. Determine size, pitch, and depth of damaged thread. If necessary, adjust stop collars on cutting tool and tap to required depth.

IMPORTANT: Refer to the kit manufacturer's instructions regarding the size of drill and tap to be used.

2. Drill out damaged thread.

3. Tap hole. Lubricate tap with light engine oil. Clean the thread.

IMPORTANT: Avoid build-up of chips. Back out the tap every few turns and remove chips.

4. Thread the thread insert onto the mandrel of the installer. Engage the tang of the insert on the end of the mandrel.

5. Lubricate the insert with light engine oil (except when installing in aluminum) and install.

IMPORTANT: When correctly installed, the insert should be flush to one turn below the surface.

6. If the tang of the insert does not break off when backing out the installer, break the tang off with a drift.

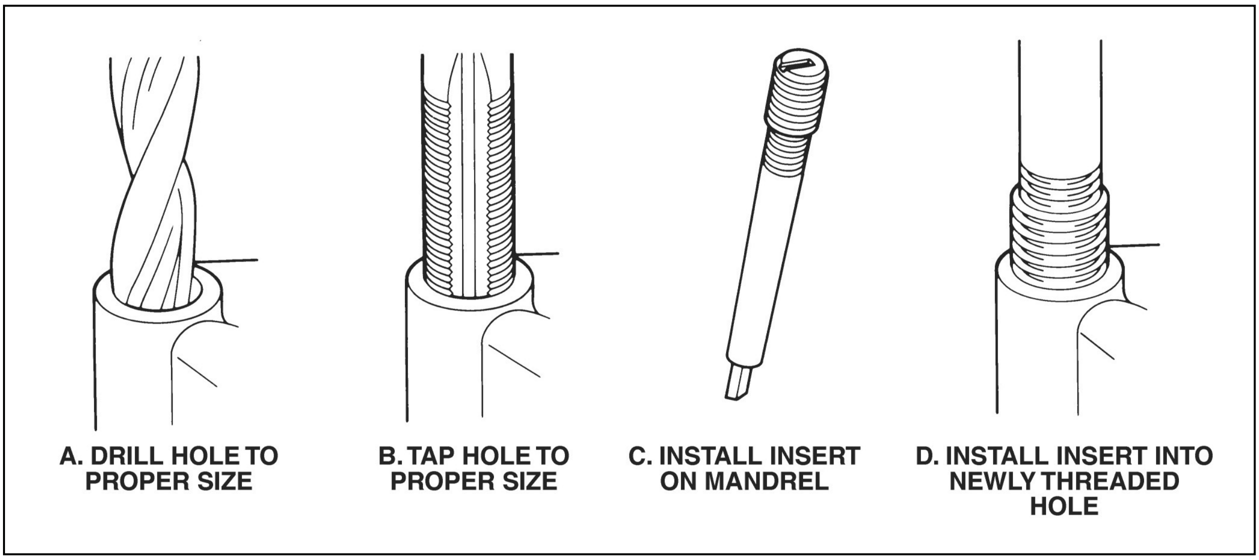
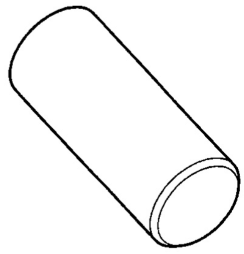
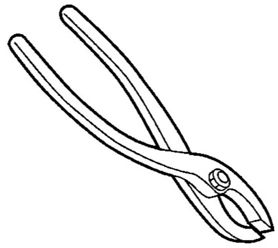
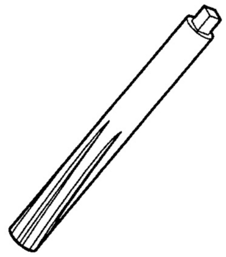
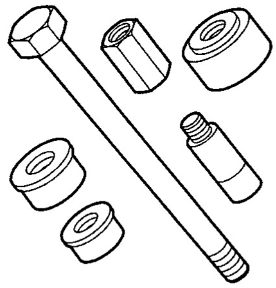
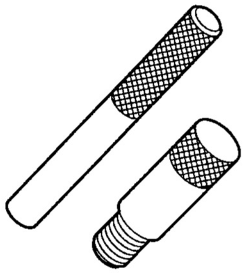
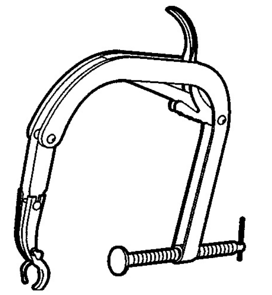
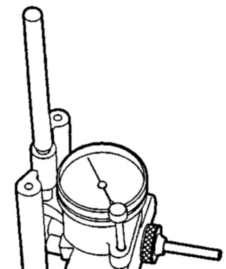
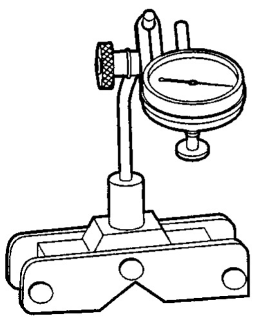
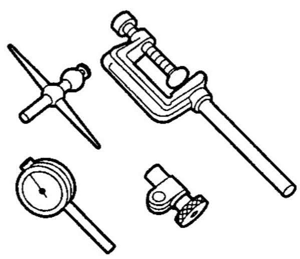
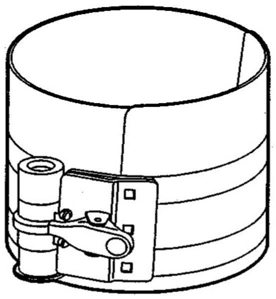
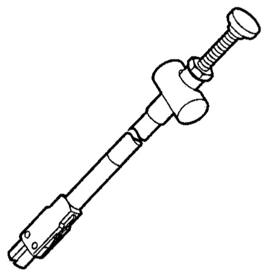
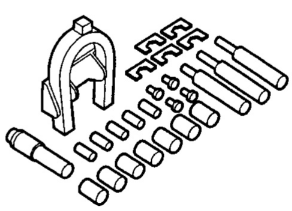
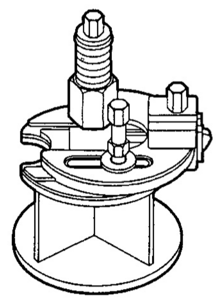
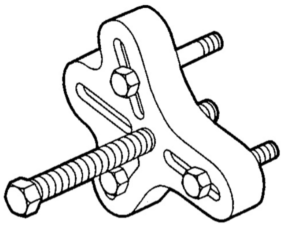
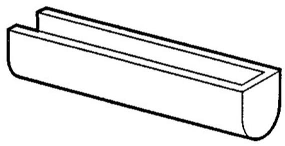
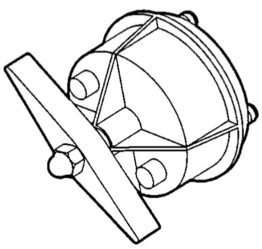


Figure 12-2 Repairing Thread Holes

Special Tools

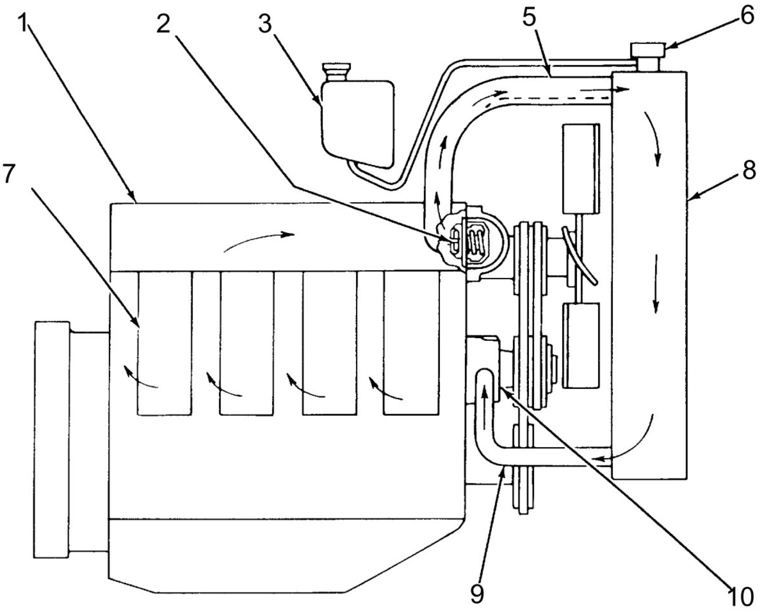
Tool #	Description
J 21882	Oil Pickup Tube and Screen Installer
J 23738-A	Valve Seal Leak Detector
J 24086-B	Piston Pin Remover and Installer Set
J 24270	Ridge Reamer
J 3049-A	Valve Lifter Remover
J 33049	Camshaft Bearing Remover and Installer
J 34673	Straightedge
J 35621	Crankshaft Rear Seal Installer
J 36669	Torque Angle Meter
J 36996	Bearing Remover
J 38834	Balance Shaft Bearing Service Kit
J 39046	Torsional Damper Puller and Installer
J 5239	Connecting Rod Guide Set
J 5590	Crankshaft Sprocket Installer
J 5715	0.0762 mm (0.003 in.) Reamer
J 5825-A	Crankshaft Sprocket Puller
J 5830-02	Reamer Set J 5830-1, 5830-2, and 5830-3
J 5830-1	0.08 mm (0.003 in.) Reamer
J 5830-2	0.38 mm (0.015 in.) Reamer
J 5830-3	0.76 mm (0.030 in.) Reamer
J 6036	0.3302 mm (0.013 in.) Reamer
J 6098-01	Camshaft Bearing Remover and Installer
J 6621	0.13 mm (0.005 in.) Reamer
J 7872	Magnetic Base Dial Indicator
J 8001	Dial Indicator
J 8037	Ring Compressor
J 8056	Valve Spring Tester
J 8062	Valve Spring Compressor
J 8087	Cylinder Bore Gage
J 8089	Wire Brush
J 8092	Driver Handle
J 8101	Valve Guide Cleaning Tool
J 9290-01	Valve Lifter Remover

	J 5590 Crankshaft Sprocket Installer		J 3049-A Valve Lifter Remover
	J 5715 or J 6036 Rocker Stud Hole Reamer		J 6098-01 Camshaft Bearing Remover/Installer
	J 5239 Connecting Rod Bolt Guide Set		J 8062 Valve Spring Compressor
	J 8087 Cylinder Bore Gauge		J 8089 Carbon Remover Brush
	J 7872 Magnetic Base Dial Indicator		J 8001 Dial Indicator

	J 8 037 Piston Ring Compressor		J 9290-01 Valve Lifter Remover (Slide Hammer Type)
	J 24086-C Piston Pin Remover/ Installer Set		J 24270 Ridge Reamer
	J 24420-C Universal Crankshaft Pulley Remover		J 21882 Oil Suction Pipe Installer
	J 35621 Crankshaft Rear Oil Seal Installer		

Cooling System

General Description



Cooling System Schematic

(1) Cylinder head. (2) Thermostat. (3) Recovery tank. (5) Radiator top hose. (6) Radiator pressure cap.

(7) Cylinder walls. (8) Radiator. (9) Radiator lower hose. (10) Water pump.

Water pump (10) is installed on the front of the cylinder block. The water pump is driven by a single V belt from the crankshaft pulley. The inlet opening of the water pump is connected to the radiator lower hose (9). The outlet flow from the water pump goes through passages inside the cylinder block.

The coolant from the water pump through the cylinder block passages has primary coolant flow to and around the seats for the exhaust valves. This method gives the coolant with the coolest temperature flow to the hottest area during engine operation.

Cylinder walls (7) are cooled by the coolant flow through the block. After the coolant goes through the cylinder block it flows through cylinder head (1) to the thermostat housing, where the bypass type thermostat (2) is installed. The thermostat controls the opening to radiator (8) to control the temperature in the cooling system.

If the coolant is cold (cool), the thermostat will be closed. The coolant circulates (makes a complete circuit) from the water pump and through the cylinder block until the temperature of the coolant is warm enough to make the thermostat open. When thermostat (2) is open the coolant will go through radiator top hose (5) and into the top tank of radiator (8). Coolant then goes through the cores of the radiator. The air from the fan will make the coolant cool as the coolant flows to the bottom of the radiator and out hose (9) where the coolant returns to water pump (10).

The radiator is equipped with a shroud to increase the efficiency of the fan and cause the air to be pushed through the radiator and away from the lift truck.

If the coolant is hot and the cooling system pressure is too high, some coolant flows to the top of radiator (8) through the tube to recovery tank (3). The cooling system pressure is controlled by cap (6). When the cooling system pressure goes above its rated pressure, a valve opens in pressure cap (6) which releases the cooling system pressure to the atmosphere. After the engine is at normal temperature for operation, a development of vacuum is present in the cooling system. Pressure cap (6) permits air in the radiator to remove the vacuum at the same time coolant from recovery tank (3) is pulled back into the radiator.

Testing & Adjusting

Adhere to the following warnings when performing any tests or adjustments while the engine is running:

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

⚠ WARNING

Exhaust fumes contain carbon monoxide (CO) which can cause personal injury or death. Start and operate the engine in a well ventilated area only. In an enclosed area, vent the exhaust to the outside.

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages. The first advantage is that the cooling system can have safe operation at a temperature that is higher than the normal boiling (steam) point of water. The second advantage is that this type system prevents cavitation (the sudden making of low pressure bubbles in liquids by mechanical forces) in the water pump. With this type system, it is more difficult for an air or steam pocket to be made in the cooling system.

The cause for an engine getting too hot is generally because regular inspections of the cooling system were not made. Make a visual inspection of the cooling system before testing with testing equipment.

Cooling System Visual Inspection

⚠ WARNING

Do not loosen the filler cap or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

1. After the engine is cool, loosen the filler cap (on a radiator with a pressure cap, turn it to the first stop) to let pressure out of the cooling system. Then remove filler or pressure cap.

2. Check coolant level in the cooling system.

3. Look for leaks in the system.

4. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.

5. Inspect the drive belts for the fan.

6. Check for damage to the fan blades.

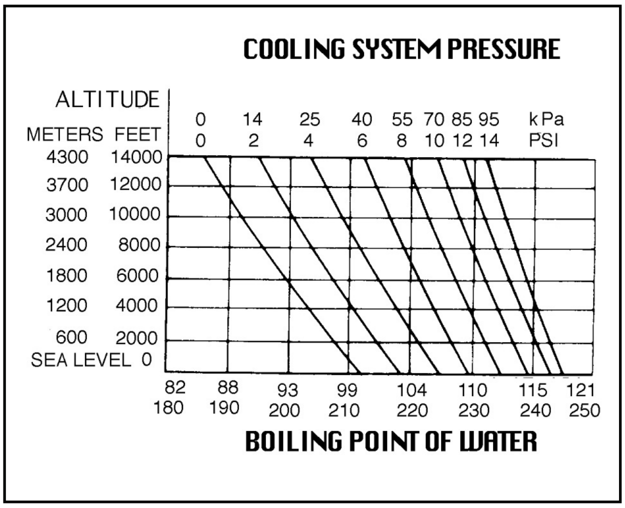
7. Look for air or combustion gas in the cooling system.

8. Inspect the filler cap and the surface that seals the cap. This surface must be clean.

9. Look for a large amount of dirt in the radiator core and on the engine.

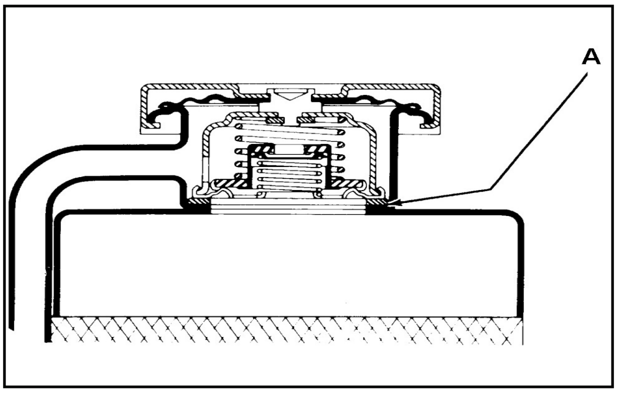
10. Check for loose or missing fan shrouds that cause poor flow of cooling air.

Cooling System Tests



Remember that temperature and pressure work together. When making a diagnosis of a cooling system problem, temperature and pressure must both be checked. Cooling system pressure will have an effect on cooling system temperatures. For an example, look at the chart to see the effect of pressure and height above sea level on the boiling (steam) point of water.

Pressure Cap Test



Pressure Cap Diagram
(A) Sealing surface of cap and radiator.

One cause for a pressure loss in the cooling system can be a bad seal on the pressure cap of the system. Inspect the pressure cap carefully. Look for damage to the seal or the sealing surface. Any foreign material or deposits on the cap, seal or seal or sealing surface must be removed.

To check the pressure cap opening pressure, do the following procedure.

⚠ WARNING

If the engine has been in operation and the coolant is hot, slowly loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap.

1. Remove pressure cap from the radiator.

2. Put the pressure cap on the Cooling System Pressurizing Pump Tool.

3. Look at the gauge for the pressure that makes the pressure cap open. It must be as follows:
A403658 .... 76 to 100 kPa (11 to 14.5 psi)

4. If the pressure cap is bad, install a new pressure cap.

Cooling System Leak Check

To test the cooling system for leaks, use the following procedure:

⚠ WARNING

If the engine has been in operation and the coolant is hot, slowly loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap.

1. Remove pressure cap from the radiator.

2. Make sure the radiator is full (hot) or nearly full (cold) of coolant.

3. Attach the Cooling System Pressurizing Pump Tool to the radiator filler neck.

4. Pump the pressure to 20 kPa (3 psi) more than the rated pressure of the cap.

5. Check the radiator for outside leakage.

6. Check all connections and hoses of the cooling system for outside leakage.

7. If there is no outside leakage and the pressure reading on the gauge is still the same after 5 minutes, the radiator and cooling system do not have leakage. If the reading on the gauge goes down and there is no outside leakage, there is leakage on the inside of the cooling system. Make repairs as necessary.

Thermostat

The thermostat is the wax pellet type. A jiggle valve (which improves air bleeding during water supply) is provided on the flange part. When the thermostat is closed, the circulation of coolant is stopped, thereby making warm-up faster.

Operation

When the temperature of the coolant is low, the valve is closed by the spring, with the result that the coolant circulates within the engine, without passing through the radiator.
When the temperature of the coolant rises and reaches a certain specified temperature, the valve opens and the coolant also circulates through the radiator.

When the temperature increases further and reaches a certain specified temperature, the valve opens fully, allowing even more coolant to circulate through the radiator.

Thus, in this way the degree of valve opening is varied according to the temperature of coolant, and the temperature of coolant is adjusted by varying the amount of coolant caused to circulate through the radiator.

Thermostat Test

To test the thermostat opening temperature, use the following procedure:

⚠ WARNING

The pan, water and thermostat will be very hot and can cause burns. Do not touch the pan, water or thermostat. Handle the components with an insulated device for protection.

1. Remove the thermostat from the engine.

2. Hang the thermostat in a pan of water. Put a thermometer in the water. Put the thermostat completely under water. Do not let the thermostat make contact with the pan.

3. Put heat to the pan of water. Make the water in the pan move around. This keeps all of the water at the same temperature.

4. The thermostat must start to open when the temperature is 82°C (180°F). The thermostat must be fully open at 96°C (205°F).

Cooling System Heat Problems

To check if there is a good reason for heat problems do the checks that follow:

1. The indications of a heat problem are as follows:

a. High coolant temperature indicator light is on or needle of coolant temperature gauge is in red range.

b. Coolant boils out (comes out because of too much heat) of the cooling system during operations.

c. Coolant boils out on the floor when the engine is stopped.

d. Coolant must be added at the end of each shift but Steps b and c are not present.

2. If indication in Step 1a is only present. It is possible the problem is only a damaged gauge, light or sender. Make a replacement of the defective part.

3. If indication in Step 1b is present, do the procedure that follows:

a. Run the engine at medium idle (1200 rpm) for three minutes after high idle operation. This cools off the hottest parts of the engine before it is stopped.
b. Install a coolant recovery system on the truck, if not already equipped.

4. If indications in Step 1b, 1c or 1d are present, but Step 1a is not and the high temperature indicator light does work, the problem can be a damaged radiator cap seal or there can be a leak in the cooling system. Complete the procedure that follows:

a. Do the Pressure Cap Test, Cooling System Leak Check, Thermostat Test and Belt Adjustment in the Testing And Adjusting.

b. Clean the radiator with hot water (steam clean) at low pressure and use detergent or air according to the different types of debris that caused the radiator to be dirty (plugged).

c. Check the engine high idle setting.

NOTE: Another condition that can cause heat problems is the ignition timing. Retarded (late) timing causes the engine to send more heat to the cooling system. Advanced (early) timing causes the engine to send less heat to the cooling system.

Cooling System Recommendation

Coolant Information

The engine cooling system is provided with a mixture of 50% ethylene glycol anti-freeze and 50% water (For the vehicles of tropical area, the engine cooling system is provided with a mixture of 40% ethylene glycol anti-freeze and 60% water at the time of manufacture.)
Since the cylinder head and water pump body are made of aluminum alloy casting, be sure to use a 30 to 60% ethylene glycol antifreeze coolant to assure corrosion protection and freezing prevention.

⚠ WARNING

If the concentration of the antifreeze is below 30%, the anticorrosion property will be adversely affected. In addition, if the concentration is above 60%, both the antifreeze and engine cooling properties will decrease, adversely affecting the engine. For these reasons, be sure to maintain the concentration level within the specified range.

To prevent damage to your engine, never add coolant to an overheated engine. Allow the engine to cool first.
If the lift truck is to be stored in, or shipped to, an area with freezing temperatures, the cooling system must be protected to the lowest expected outside (ambient) temperature.

The engine cooling system is protected with a commercially available automotive antifreeze, when shipped from the factory.

Check the specific gravity of the coolant solution frequently in cold weather to ensure adequate protection.

Clean the cooling system if it is contaminated, if the engine overheats or if foaming is observed in the radiator.

Old coolant should be drained, system cleaned and new coolant added as recommended with the commercially available automotive antifreeze.

Filling at over 20 liters per minute can cause air pockets in the cooling system.

After draining and refilling the cooling system, operate the engine with the radiator cap removed until the coolant reaches normal operatin temperature and the coolant level stabilizes. Add coolant as necessary to fill the system to the proper level.

Operate with a thermostat in the cooling system all year-round. Cooling system problems can arise without a thermostat.

Coolant Water

Hard water, or water with high levels of calcium and magnesium ions, encourages the formation of insoluble chemical compounds by combining with cooling system additives such as silicates and phosphates.

The tendency of silicates and phosphates to precipitate out-of-solution increases with increasing water hardness. Hard water, or water with high levels of calcium and magnesium ions encourages the formation of insoluble chemicals, especially after a number of heating and cooling cycles.

DOOSAN prefers the use of distilled water or deionized water to reduce the potential and severity of chemical insolubility.

Acceptable Water	
Water Content	Limits (ppm)
Chlorides (CI)	40 maximum
Sulfates (SO4)	50 maximum
Total Hardness	80mg/ℓ maximum
Total Solids	250 maximum
pH	6.0 ~ 8.0

ppm = parts per million

Using water that meets the minimum acceptable water requirement may not prevent drop-out of these chemical compounds totally, but should minimize the rate to acceptable levels.

Antifreeze

DOOSAN recommends selecting automotive antifreeze suitable for gasoline engines using aluminum alloy parts. The antifreeze should meet ASTM-D3306 standard.

Make proper antifreeze additions.

Adding pure antifreeze as a makeup solution for cooling system top-up is an unacceptable practice. It increases the concentration of antifreeze in the cooling system which increases the concentration of dissolved solids and undissolved chemical inhibitors in the cooling system. Add antifreeze mixed with water to the same freeze protection as your cooling system.

Engine Lubrication

General Description

Full pressure lubrication, through a full-flow oil filter is supplied by a gear-type oil pump. Oil is drawn up through the oil pump screen and passes through the pump to the oil filter. The oil filter is a full-flow paper element unit with an anti-drain back valve. An oil filter bypass valve is used to ensure adequate oil supply in the event the filter becomes plugged or develops excessive pressure drop.

Filtered oil flows into the main gallery and then to the camshaft, balance shaft, rear bearing, and crankshaft bearings. The valve lifter oil gallery supplies oil to the valve lifters. Oil flows from the valve lifters through the hollow valve pushrods to the rocker arms. Oil drains back to the crankcase through oil drain holes in the cylinder head. The camshaft timing chain is drip fed from the front camshaft bearing. The pistons and piston pins are lubricated by oil splash.

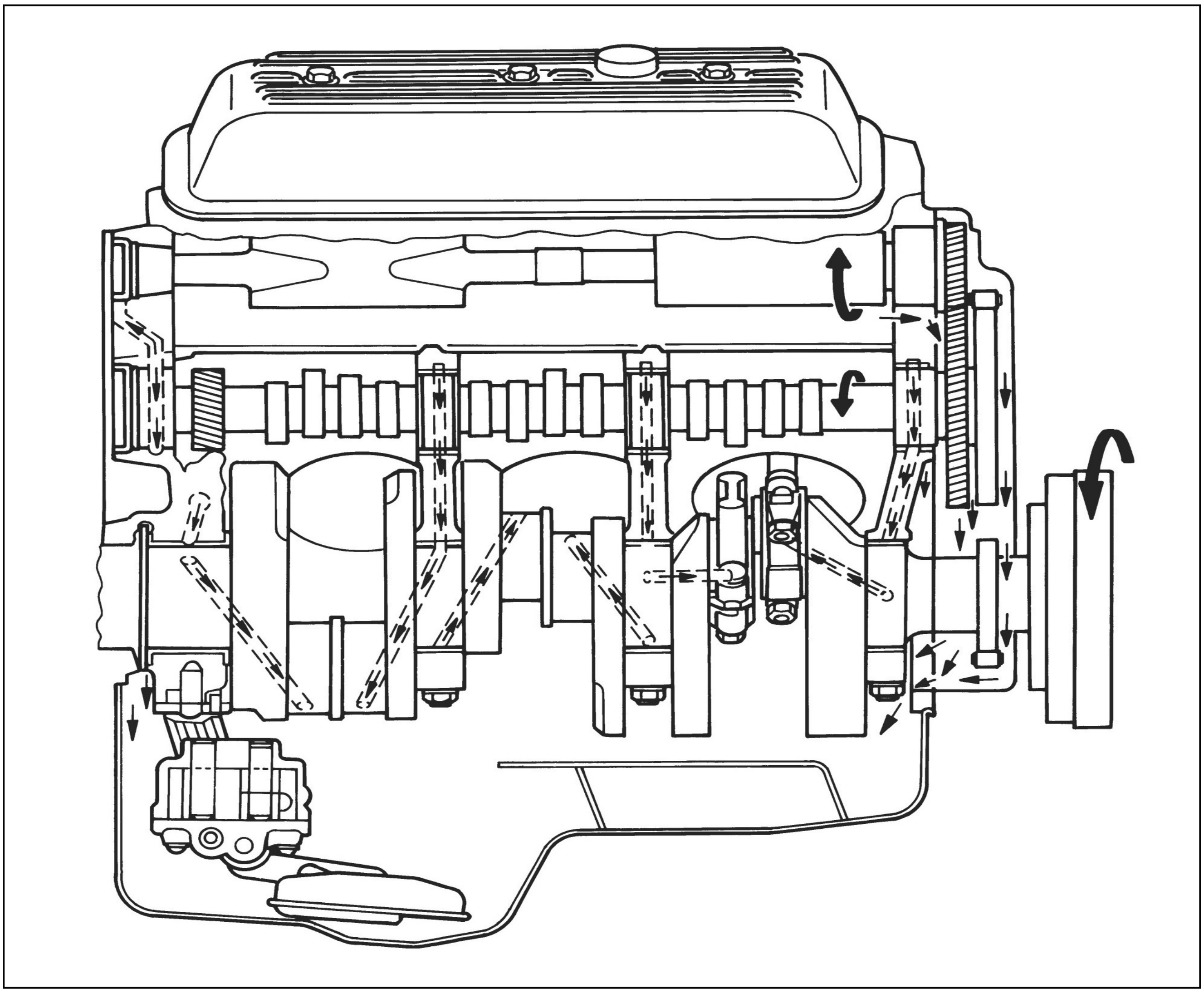


Figure 12-1 Engine Lubrication Flow

Testing and Adjusting

Adhere to the following warnings when performing any tests or adjustments while the engine is running.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

⚠ WARNING

Exhaust fumes contain carbon monoxide (CO) which can cause personal injury or death. Start and operate the engine in a well ventilated area only. In an enclosed area, vent the exhaust to the outside.

Engine Oil

Engine Oil Recommendation

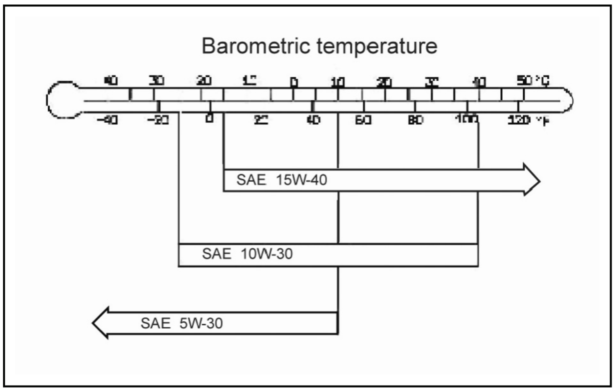
The following oil specifications provide the guidelines for the selection of commercial products : Use gasoline engine oil. Recommended API service classification is class SJ grade.

NOTICE

Failure to follow the oil recommendations can cause shortened engine life due to carbon deposits or excessive wear.

Prior to changing oil, select an oil based on the prevailing daytime temperature in the area in which the engine is operated. The chart in figure is a guide to selection the proper crankcase oil.

IMPORTANT: Oils containing “solid” additives, non-detergent oils, or low-quality oils are not recommended for use in G643(E) Engine.



Engine Oil Viscosity Recommendation

NOTE: In normal case, the recommended engine oil for G643(E) engine is SAE 10W - 30.

But, if the excessive valve noise occurs up to five minutes after a cold start and if the maximum ambient temperature is lower than 10°C (50°F), it is recommended to change engine oil to SAE 5W - 30 for that application.

Synthetic Oils

Synthetic engine oils are not recommended for use in G643(E) Engine. Synthetics may offer advantages in cold-temperature pumpability and high-temperature oxidation resistance.
However, synthetic oils have not proven to provide operational or economic benefits over conventional petroleum-based oils in G643(E) Engine. Their use does not permit the extension of oil change intervals.

Lubrication System Problems

One of the problems in the list that follows will generally be an indication of a problem in the lubrication system for the engine.

- Too much oil consumption.
- Low oil pressure.
- High oil pressure.
- Too much component wear.

Too Much Oil Consumption

• Engine outside oil leakage

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the oil pan gasket and all lubrication system connections. Check to see if oil comes out of the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase, and this will cause gasket and seal leakage.

• Combustion area oil leakage

Oil leakage into the combustion area of the cylinders can be the cause of blue smoke. There are three possible ways for oil leakage into the combustion area of the stems.

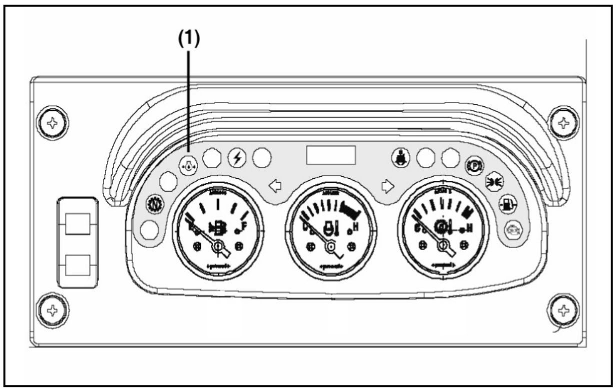
1. Oil leakage between worn valve guides and valve stems.

2. Worn or damaged piston rings, or dirty oil return holes.

3. Compression ring and/or intermediate ring not installed correctly.

NOTE: Too much oil consumption can also be the result if oil with the wrong viscosity is used. Oil with a thin viscosity can be caused by fuel leakage into the crankcase, or by increased engine temperature.

Low Oil Pressure



Instrument Panel
(1) Engine Oil Light

Before starting the engine, the engine oil light(1) on the instrument panel will turn on when the key switch is turned to the ON position. The light will turn off after the engine is started and while the engine is running, lidicating normal oil pressure. The light will turn on during operation only when there is insufficient engine oil pressure to properly lubricate the engine's internal parts.

If the oil light comes on, indicating the pressure is low, check for the causes that follow:

1. Low oil level in the crankcase.

2. Defect in the oil pressure indicator light or oil pressure sensor unit.

3. Restriction to oil pump screen.

4. Leakage at the oil line connections.

5. Worn connecting rod or main bearings. Worn gears in the oil pump.

6. Oil pressure relief valve worn or stuck in the OPEN position.

7. Oil filter bypass valve stuck open. Oil filter is restricted. Replace oil filter.

High Oil Pressure

Oil pressure will be high if the oil pressure relief valve in the oil pump cannot move from the closed position.

Too Much Component Wear

When some components of the engine show bearing wear in a short time, the cause can be a restriction in an oil passage. A broken oil passage can also be the cause.
If an oil pressure check is done and the oil pressure is correct, but a component is worn because it does not get enough lubrication, look at the passage for oil supply to that component. A restriction in a supply passage will not let enough lubrication get to a component and this will cause early wear.

Disassembly of Engine

English and Metric Fasteners

⚠ CAUTION

Late model engines use a combination of English and Metric threaded fasteners. The components effected are starter motor, engine mounts, and flywheel housing mounting. Verify that the proper fasteners are used whenever removing or replacing one of these components.

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 work and help prevent personal injury or component damage.

Special tools are listed and illustrated throughout this Section with a complete listing at the end of the 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 special 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

The various procedures in this manual assume that the engine accessories have been removed. These accessories may include one or more of the following:

- Hydraulic Pump
- Drive Belt Tensioner
- Alternator
- Cooling Fan
- Distributor
- Accessory Mounting Brackets
- Starter Motor
- Carburetor / Mixer Components

It is beyond the scope of this Section to cover in detail the many different accessory installations. Refer to the appropriate service manual section for this information.

Diagrams of emissions and vacuum hose routings, wiring harness routing, accessory drive belt layout, etc. should be made before removing accessories.

Cleaning

It is important that the engine be as clean as possible to prevent dirt from entering critical areas during disassembly.

Remove the engine accessories before cleaning, to provide better access to the engines exterior surfaces. After removing the TBI unit, distributor, etc., cover the openings with tape to prevent the entry of contaminants.

Methods used to clean the engine will depend on the means which are available. Steam cleaning, pressure washing, or solvent cleaning are some of the acceptable methods. Allow the engine to dry thoroughly before beginning any work.

Draining The Engine

Remove or Disconnect

1. Oil pan drain plug and washer.

IMPORTANT: Allow the oil to drain into a proper container.

2. Oil filter.

3. Coolant drain plug and/or knock sensor from the block.

IMPORTANT: Allow the coolant to drain from the block into a proper container.

Install or Connect

NOTICE: Refer to “Notice” on page 1.

1. Oil pan drain bolt.

2. Coolant drain plug and/or knock sensor into the block.

Tighten

- Coolant drain plug and/or knock sensor to 14 N·m (124 lb. in.).
- Drain plug to 25 N·m (18 lb·ft.).

Engine Flywheel Removal

Figure 12-3

Remove or Disconnect

1. Engine flywheel bolts.

2. Engine flywheel.

Exhaust Manifold Removal

Figure 12-4

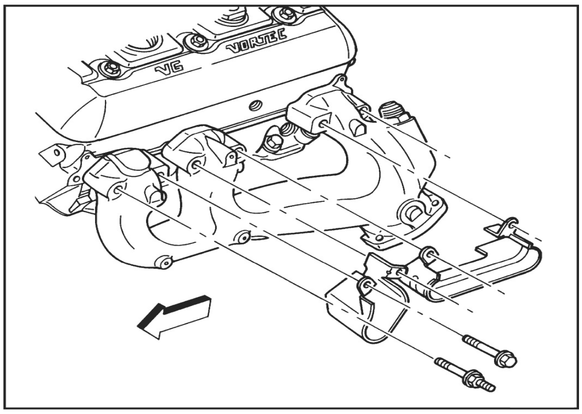


Figure 12-4 Exhaust Manifold

Remove or Disconnect

1. Exhaust manifold bolts and / or nut.

2. Heat shields.

3. Exhaust manifold.

4. Gaskets.

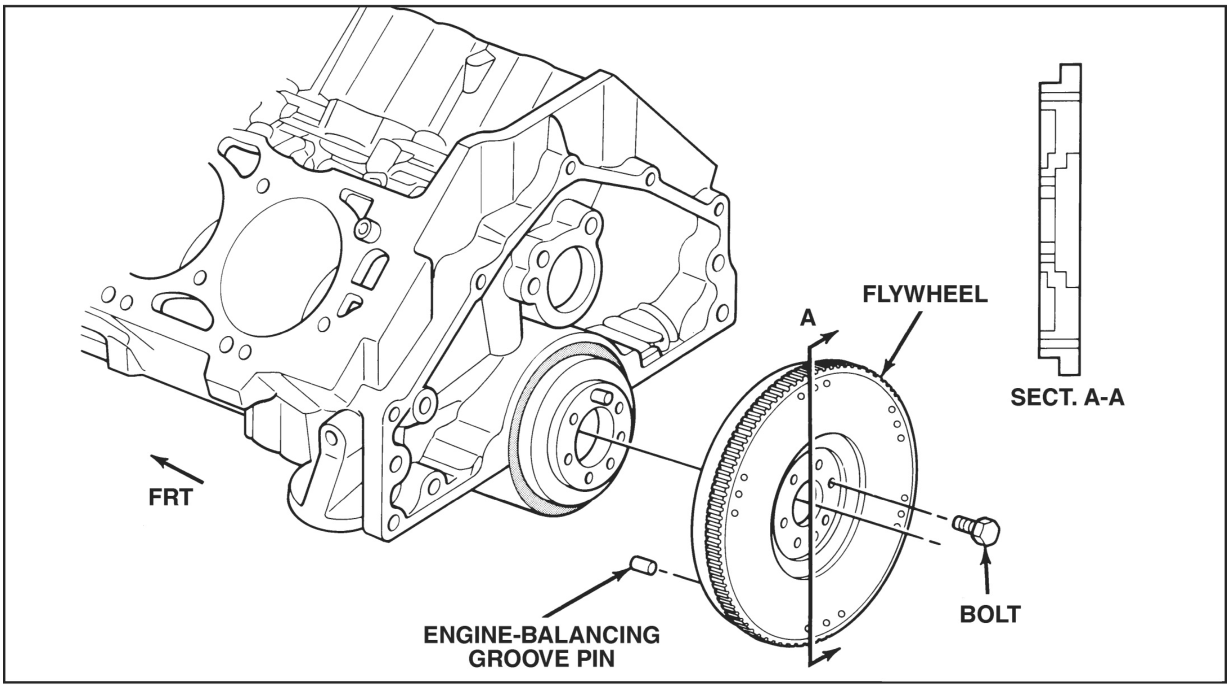


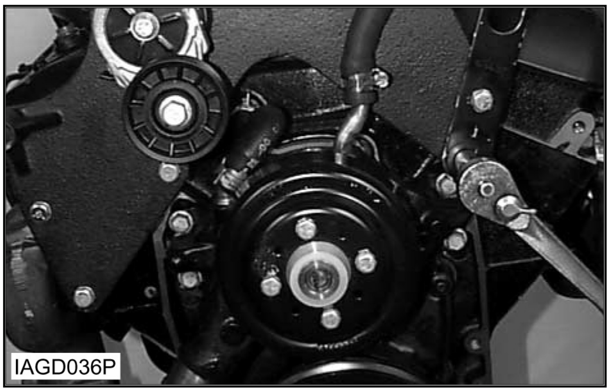
Figure 12-3 Engine Flywheel

High Mounted Fan Bracket Removal

Start By:

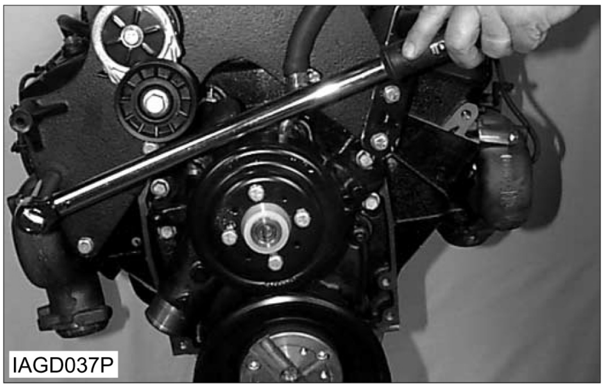
a. Remove fan belt.

b. Remove wires from alternator.



1. Remove (5) Bolts from bracket.

2. Remove the bracket assembly.



Note: For installation of the fan bracket, reverse the removal steps and torque mounting bolts to 50 N·m (37 lb·ft.).

Coolant Pump Removal

Remove or Disconnect

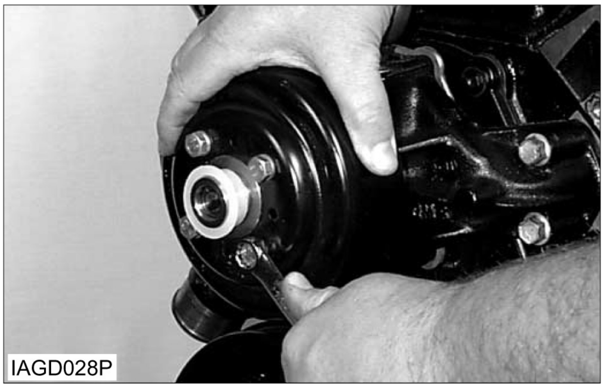
Start By:

a. Draining coolant from radiator.

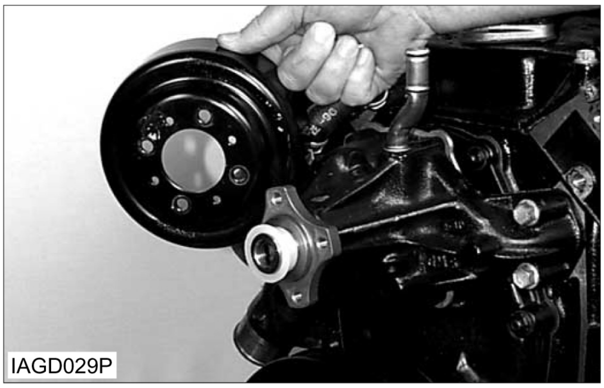
b. Remove by-pass hose and

c. LP hose from pump.

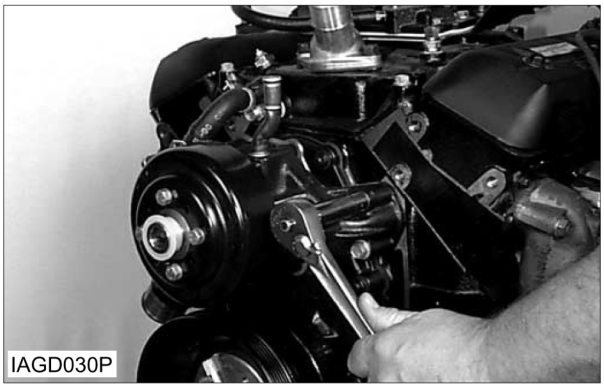
d. Remove fan belt.



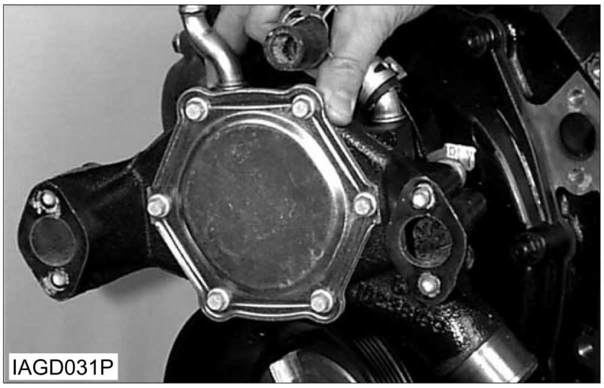
1. Remove bolts from pump pulley.



2. Remove pulley from pump.



3. Remove bolts from pump.



4. Remove pump from engine.

5. Remove gasket and clean surface.

Valve Rocker Arm Cover Removal

Figure 12-5

Remove or Disconnect

1. Valve rocker arm cover bolts.

2. Valve rocker arm covers.

3. Gaskets.

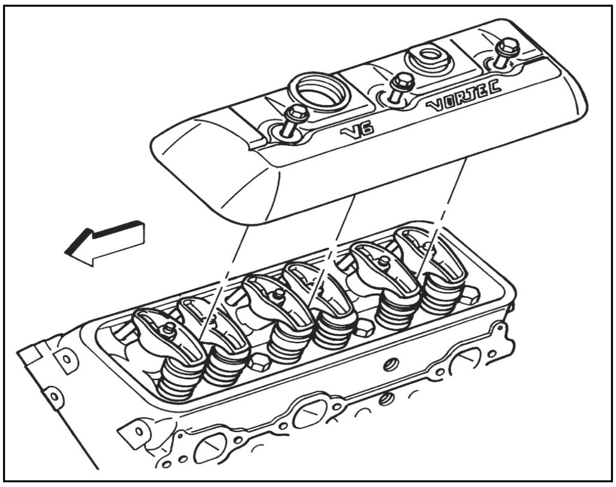


Figure 12-5 Valve Rocker Arm Cover

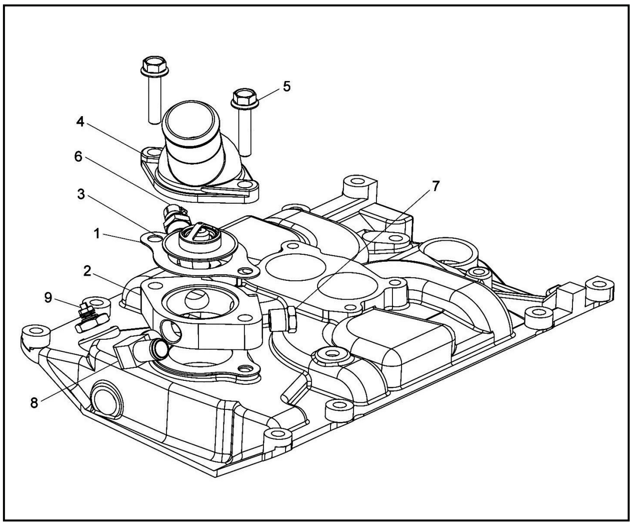
Thermostat Removal

Start By:

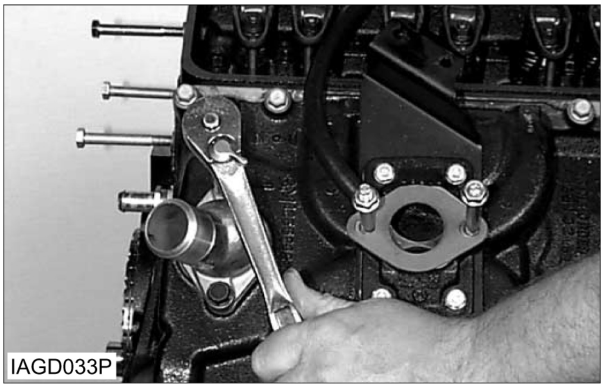
a. Draining coolant from radiator.

b. Removing upper radiator hose from thermostat housing.

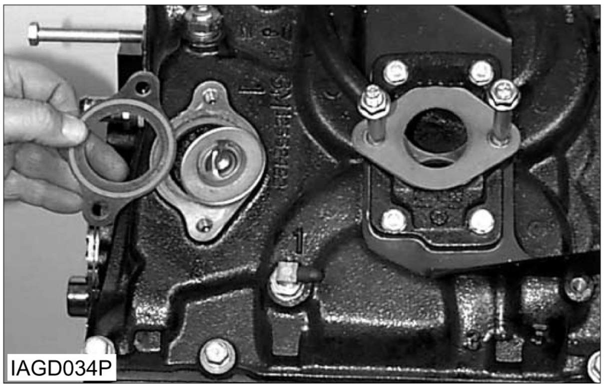
< **Components** >



1. Gasket-Thermostat Housing 2. Thermostat Housing Spacer
3. Thermostat Assembly 4. Housing-Thermostat 5. Bolt
6. ECT Sensor-SECM 7. Plug 8. Fitting
9. Water Temp Sender



1. Remove bolts. Remove thermostat housing and gasket.



2. Remove failed thermostat.

3. Clean both mounting surfaces, engine and thermostat housing of any gasket material.

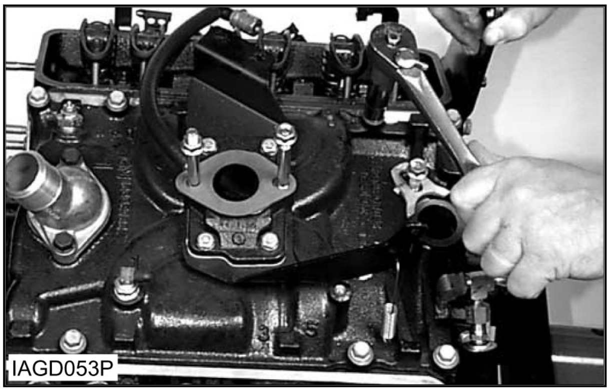
Intake Manifold Removal

Start By:

a. Remove fuel lines and linkage from carburetor.

b. Remove coolant bypass line from manifold.

c. Remove the distributor from the manifold.



1. Remove the bolts from manifold.

2. Remove the intake manifold from the engine.

3. Remove the intake manifold gaskets from location.

4. Clean mounting surface where RTV sealant was used.

Valve Train Component Removal

Tools Required:

J 3049-A Valve Lifter Remover (Plier Type)
J 9290-01 Valve Lifter Remover
(Slide Hammer Type)

Figures 12-6 through 12-8

Remove or Disconnect

IMPORTANT: Store all reusable components in an exact order so they can be reassembled in the same wear pattern location from which they were removed. Mark the front end of the retainer.

1. Rocker arm nuts, balls, and valve rocker arms.

2. Valve pushrods.

3. Bolt.

4. Valve lifter retainer.

5. Valve lifters.

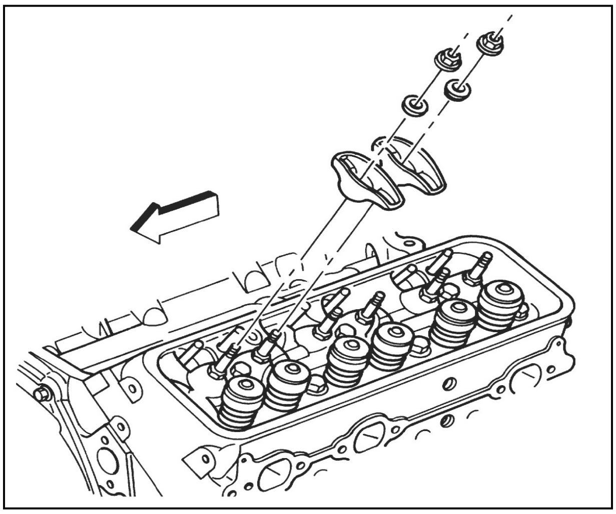


Figure 12-6 Valve Rocker Arm and Components

IMPORTANT:

- **Remove the lifters one at a time using a magnet. Place the lifters in the organizer rack, or tag them in some way to ensure they can be returned to the valve lifter bore from which they were removed.**
- **Some lifters may be stuck in their bores due to gum or varnish deposits. These lifters can be removed using either J 3049-A (figure 12-7) or J 9290-01 (figure 12-8).**

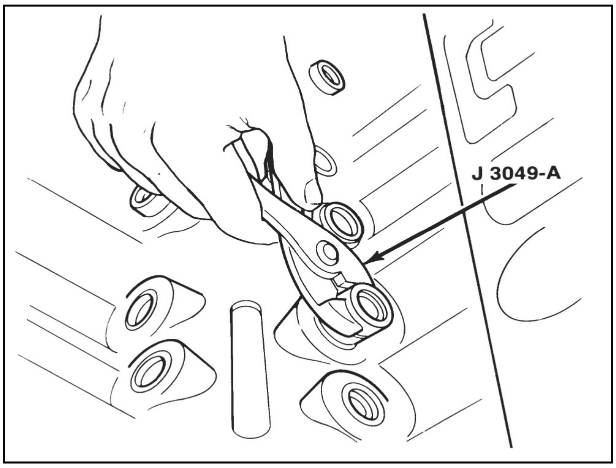


Figure 12-7 Removing Valve Lifter

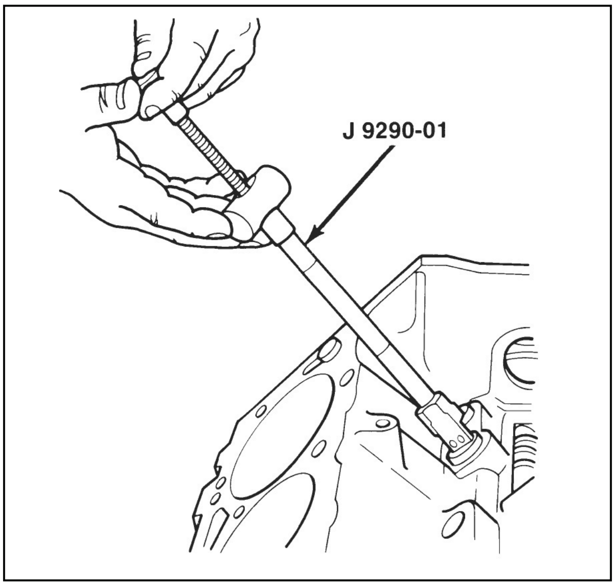


Figure 12-8 Removing Valve Lifter

Cylinder Head Removal

Remove or Disconnect

Start By:

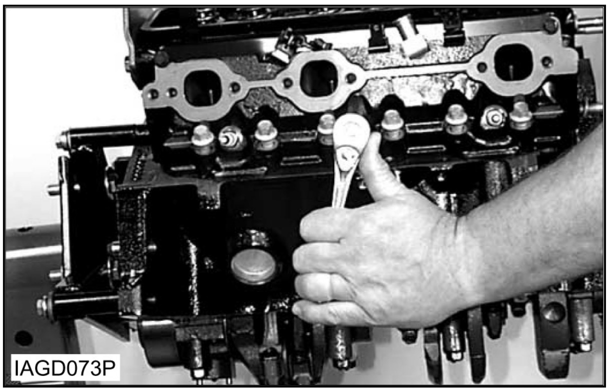
a. Removing high mounted fan bracket.

b. Remove distributor from intake manifold.

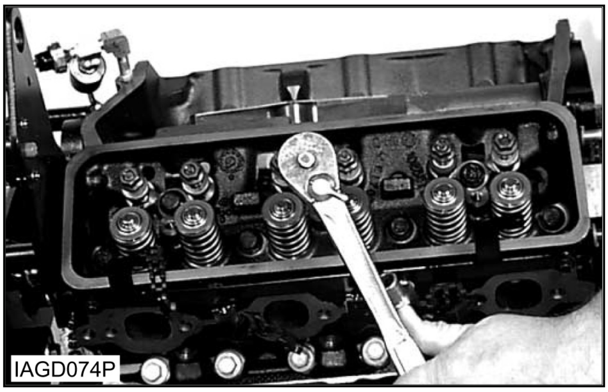
c. emove intake manifold assembly.

d. Remove exhaust manifold assemblies.

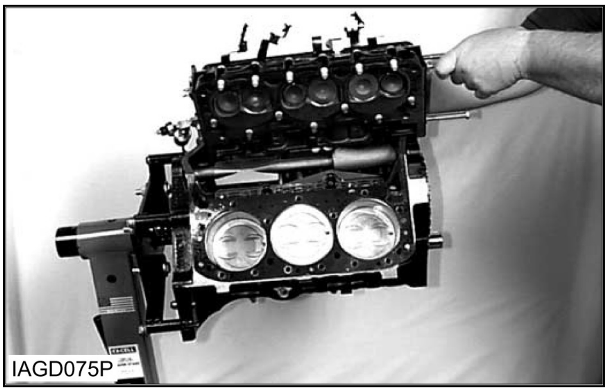
e. Remove rocker arm assemblies.



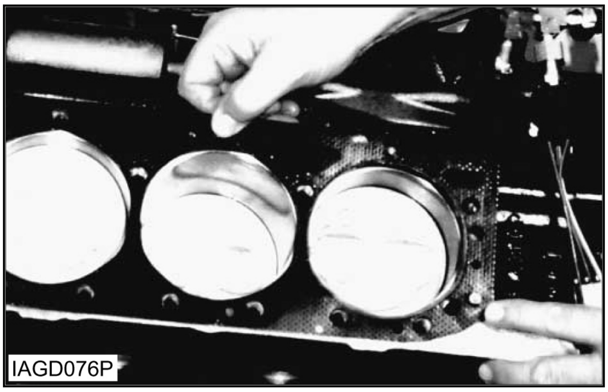
1. Remove spark plugs from cylinder head assemblies.



2. Remove bolts from cylinder head.



3. Remove cylinder heads from block.



4. Remove head gasket.

Torsional Damper Removal

Figure 12-9

Remove or Disconnect

Tool Required:

J 39046 Torsional Damper Puller and Installer

NOTICE: The inertial weight section of the torsional damper is assembled to the hub with a rubber sleeve. The removal procedures must be followed (with the proper tools) or movement of the inertia weight section of the hub will destroy the tuning of the torsional damper and the engine timing reference.

1. Torsional damper bolt.

2. Torsional damper using J 39046 (figure 12-12).

3. Crankshaft key.

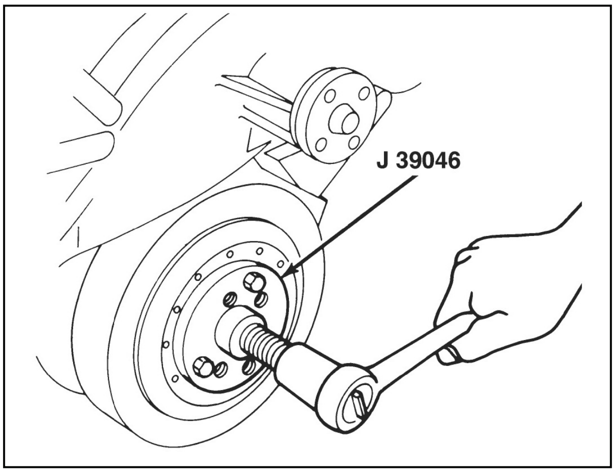


Figure 12-9 Removing Torsional Damper

Oil Pan Removal

Figures 12-10 and 12-11

Remove or Disconnect

1. Oil filter adapter bolts.
2. Oil filter adapter gasket.
3. Oil filter adapter O-ring seal, if equipped.
4. Oil filter adapter.
5. Oil pan nuts.
6. Oil pan bolts.
7. Oil pan.
8. Gasket.

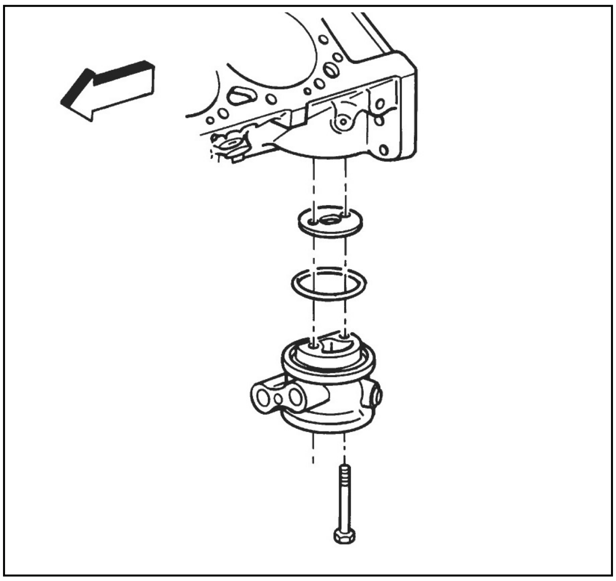


Figure 12-10 Oil Filter Adapter Equipped with Oil Cooler (Typical)

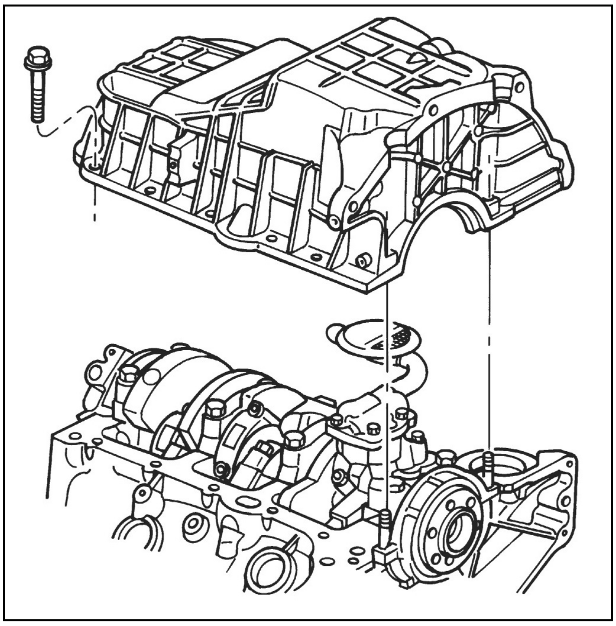


Figure 12-11 Oil Pan

Oil Pump Removal

Figure 12-12

Remove or Disconnect

1. Bolt from oil pump to main bearing cap.

2. Oil pump assembly.

3. Driveshaft and retainer.

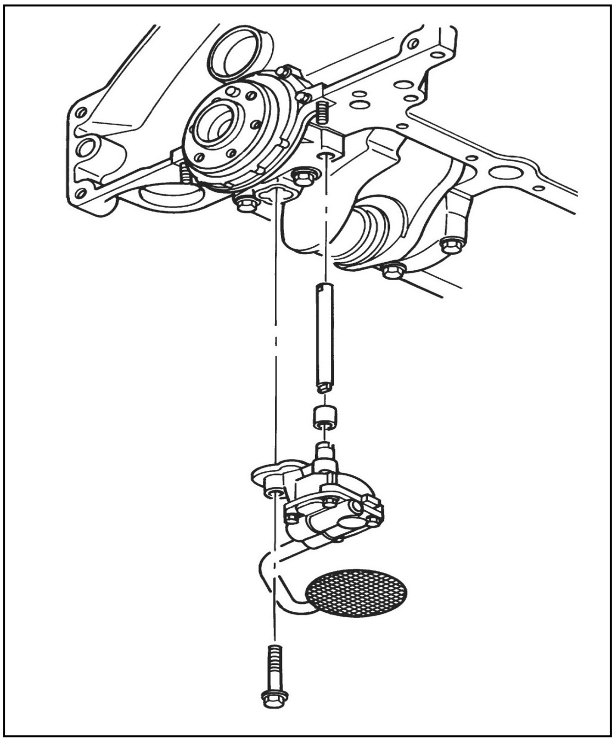


Figure 12-12 Oil Pump

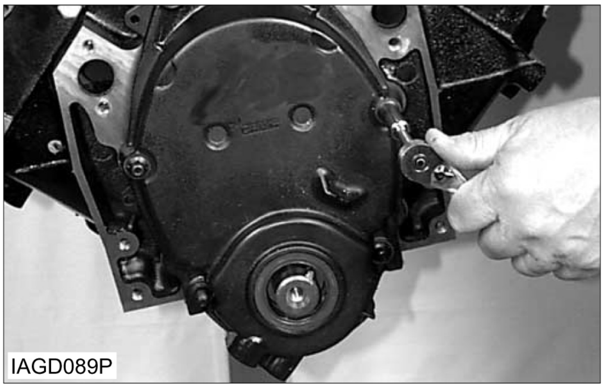
Engine Front Cover Removal

IMPORTANT: Once the composite cover is removed, DO NOT reinstall it. Always install a new engine front cover.

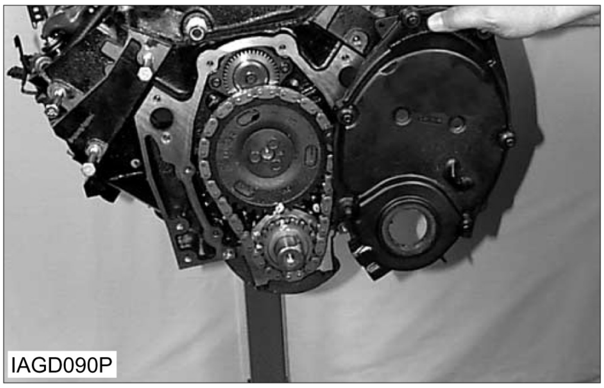
Start By:

a. Removing crankshaft pulley.

b. Remove crankshaft balancer.



1. Remove bolts from cover.



2. Remove cover from engine.

Timing Chain and Camshaft Sprocket Removal

Figure 12-13

Measure

- Check camshaft timing chain free play. If the camshaft timing chain can be moved back and forth in excess of 16 mm (0.625 in.), make a note that the camshaft timing chain should be replaced during assembly.

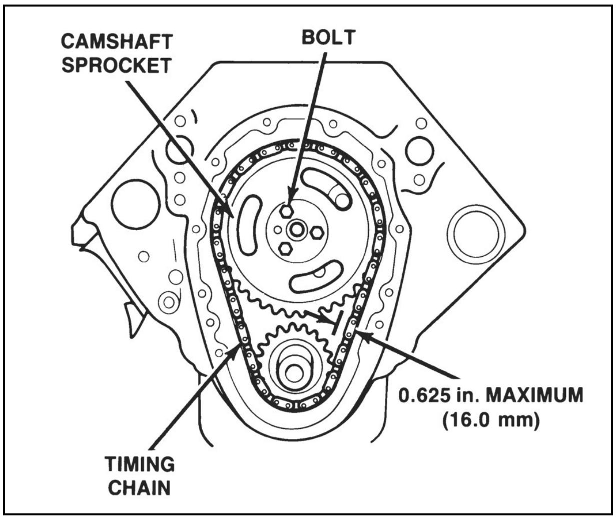


Figure 12-13 Timing Chain and Sprockets

Remove or Disconnect

1. Camshaft sprocket bolts.

2. Camshaft sprocket and camshaft timing chain together.

IMPORTANT: The sprocket has a light interference fit on the camshaft. Tap the sprocket on its lower edge to loosen it.

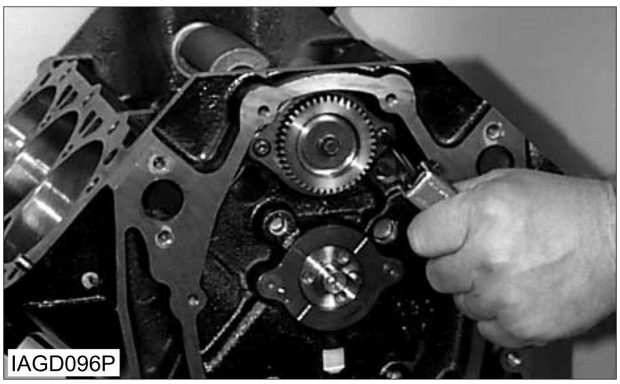
3. Balance shaft drive gear.

Camshaft Removal

Figure 12-14

Remove or Disconnect

1. Camshaft retainer bolts and camshaft retainer.



2. Camshaft.

   A. Install three 5/16 - 18 bolts 100 - 125 mm (4-5 in.) long into the camshafts threaded holes. Use these bolts to handle the camshaft (figure 12-14).

   B. Pull the camshaft out from the block being careful to prevent damage to the camshaft bearings.

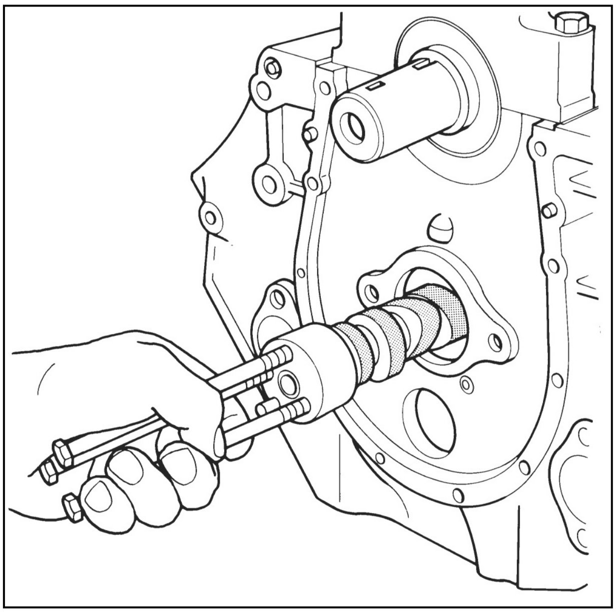


Figure 12-14 Removing Camshaft

Balance Shaft Removal

Figures 12-15 through 12-17

Tools Required:

J 38834 Balance Shaft Bearing Service Kit
J 36996 Bearing Remover

Remove or Disconnect

1. Bolt.

2. Driven gear.

3. Retainer bolts.

4. Retainer.

5. Balance shaft using a soft faced hammer (figure 12-16).

6. Balance shaft rear bearing using J 38834 and J 36996 (figure 12-17).

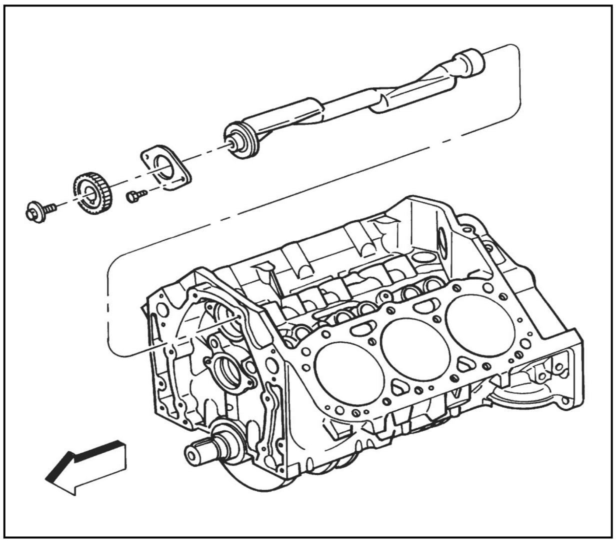


Figure 12-15 Balance Shaft and Components

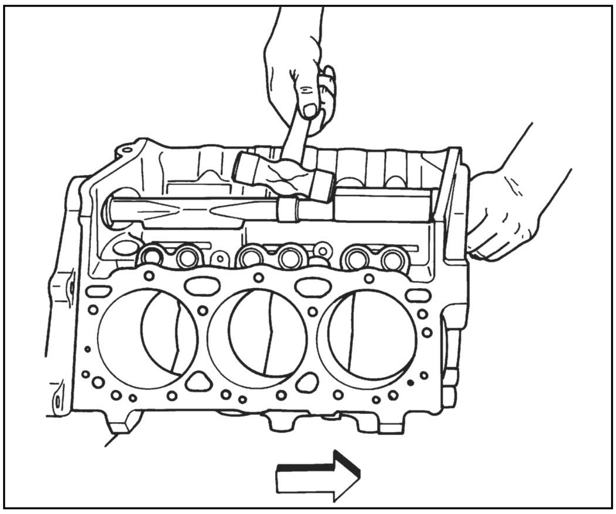


Figure 12-16 Removing Balance Shaft

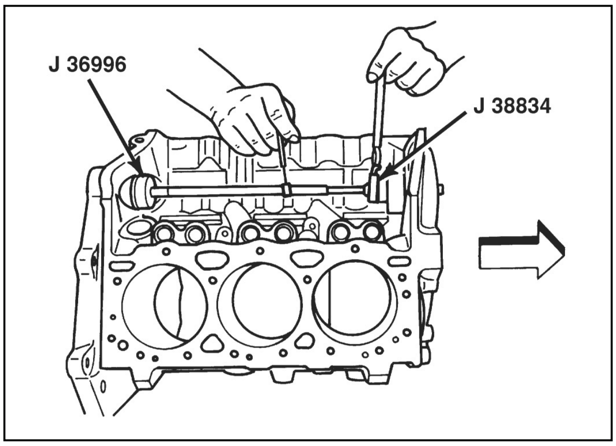


Figure 12-17 Removing Balance Shaft Rear Bearing

IMPORTANT: The balance shaft with front bearing are serviced as an assembly. Use only the correct tools for bearing and shaft installation. Inspect the balance shaft driven gear and the drive gear for nicks and burrs.

Piston and Connecting Rod Removal

Figures 12-18 and 12-19

Tools Required:

J 24270 Ridge Reamer

J 5239 Guide Set

Remove or Disconnect

1. Ridge or deposits from the upper end of the cylinder bores as follows:

   A. Rotate the crankshaft until the piston is at BDC.

   B. Place a cloth on top of the piston.

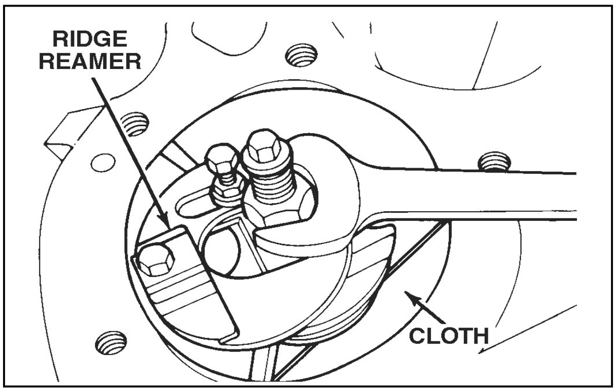


Figure 12-18 Removing Cylinder Ridge

   C. Perform the cutting operation with J 24270 (figure 12-18).

   D. Rotate the crankshaft until the piston is at TDC.

   E. Remove the cloth and cuttings.

   F. Repeat this procedure for each piston.

2. Mark the cylinder numbers on the tops of each piston.

IMPORTANT: Marking them from the front to the rear, with the engine in an upright position and viewed from the front:

- **The right bank is numbered 1-3-5.**
- **The left bank is numbered 2-4-6.**

3. Check the connecting rod and cap for identification marks.

IMPORTANT: Mark the parts if required. Marking them from the front to the rear, with the engine in an upright position and viewed from the front:

- **The right bank is numbered 1-3-5.**
- **The left bank is numbered 2-4-6.**

Store the connecting rod, bearings and cap together as mating parts, so they may be reassembled in the same position from which they were removed.

4. Connecting rod cap.

5. Connecting rod and piston.

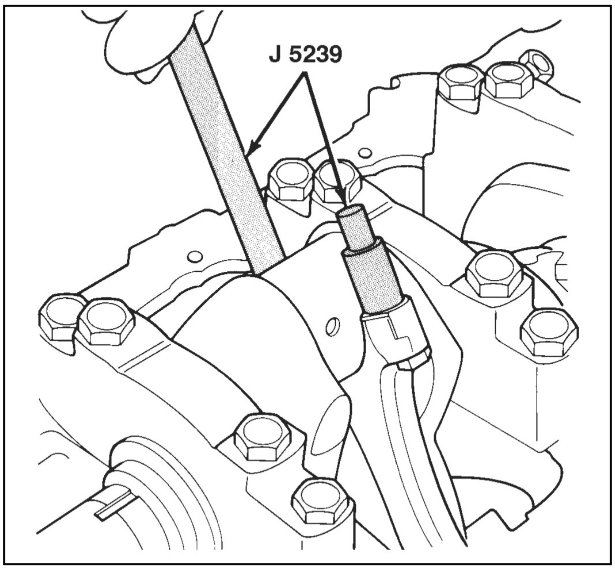


Figure 12-19 Removing Piston and Connecting Rod

IMPORTANT: Attach J 5239 to the connecting rod bolts (figure 12-19). Use the long guide rod of J 5239 to push the connecting rod and piston out of the bore through the top of the engine.

6. Connecting rod bearings.

Crankshaft Rear Oil Seal Removal

Figure 12-20

Remove or Disconnect

NOTICE: Take care when removing the rear crankshaft oil seal so as not to damage the crankshaft sealing surface.

1. Crankshaft rear oil seal. Insert a screwdriver into the notches provided in the seal retainer and pry the seal out.

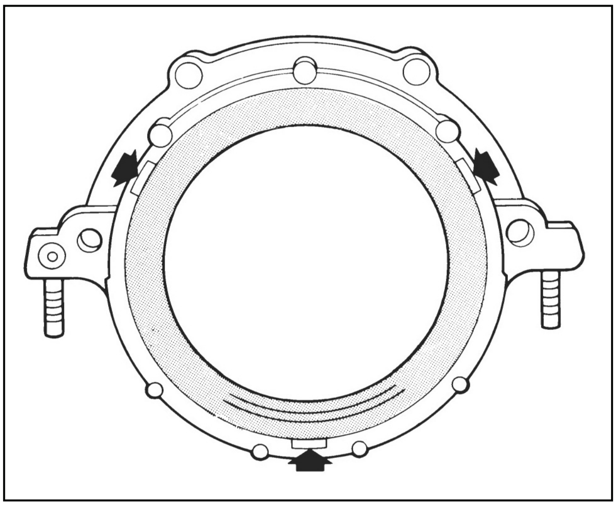


Figure 12-20 Seal Removal Notches

Crankshaft Rear Oil Seal Housing Removal

Figure 12-21

Remove or Disconnect

1. Bolts and nuts.
2. Oil seal housing.
3. Gasket.

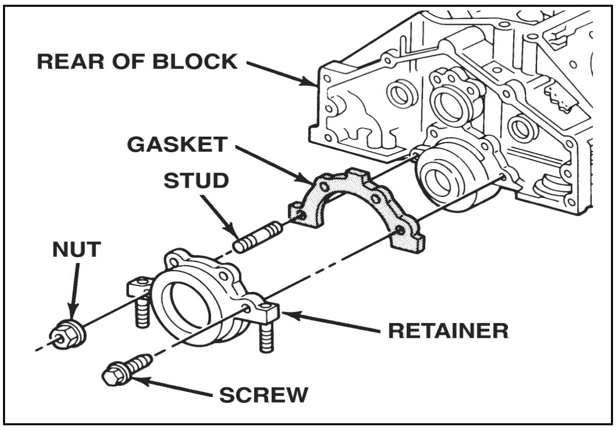


Figure 12-21 Removing Crankshaft Rear Oil Seal Housing

Crankshaft Removal

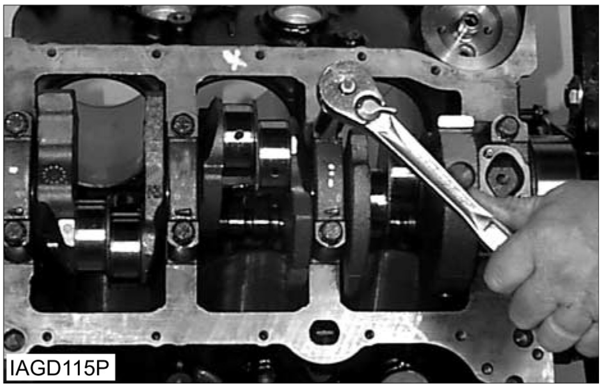
Inspect

- Check the main bearing caps for location markings. Mark the caps if necessary. The caps must be returned to their original locations during assembly.

Remove or Disconnect

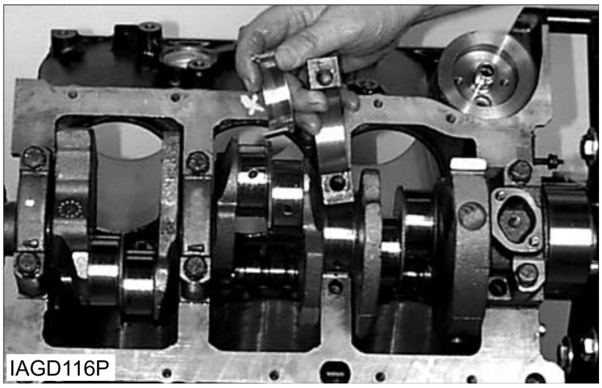
Notice

Be sure to mark bearings, rod and piston assemblies so when they are installed they will be in the correct location.



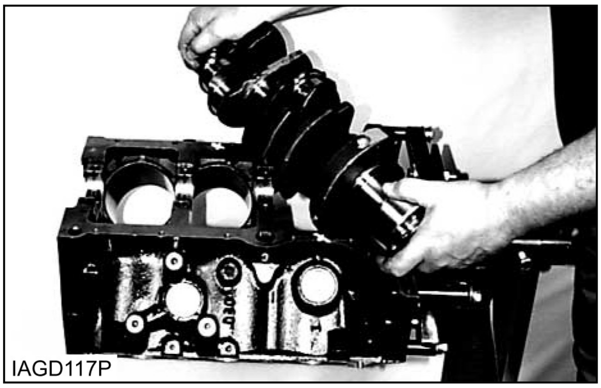
IAGD115P

1. Remove crankshaft bearing cap bolts.



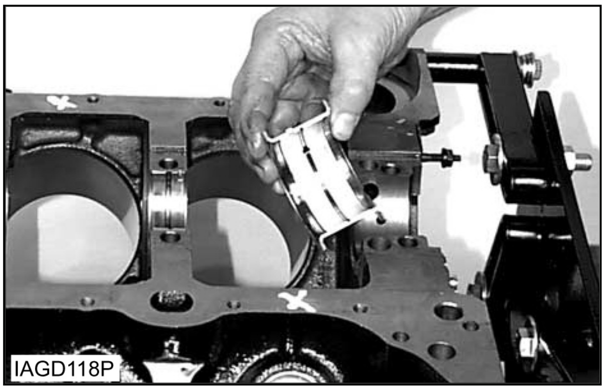
IAGD116P

2. Remove the crankshaft bearings and lower bearing inserts



IAGD117P

3. Remove the crankshaft from the cylinder block with extreme care, take care to avoid damage to crankshaft journals and thrust flange surfaces.



IAGD118P

4. Remove upper main bearing inserts.

Cleaning, Inspection, and Repair

A solvent tank large enough to hold the larger engine parts will be needed as well as various bristle brushes and gasket scrapers. A source of compressed air will also be helpful in the cleaning operations.

Special tools are listed and illustrated throughout this Section, with a complete listing at the end of the Section. These tools (or their equivalents) are specially designed to quickly and safely accomplish the operations for which they are intended.

They should not be used in operations for which they are not designed. These special tools, when they are properly used, will also minimize possible damage to engine.

Some precision measuring tools are required for inspection of certain critical components. These include micrometers, torque wrenches, feeler gages, dial indicator set, etc. The inspection work, when performed with the proper methods and tools, is most important.

The rebuilt engine cannot be expected to perform properly if the parts are worn beyond acceptable limits are reused.

NOTICE: Use only a razor-blade type scraper on engine component surfaces. Use extreme care so sealing surfaces are not scratched. Do not use any other method or technique to remove gasket material except where indicated. Do not use abrasive pads, sand paper or power tools to clean gasket surfaces. These methods of cleaning can damage the part. Abrasive pads also produce a fine grit that the oil filter cannot remove from the oil. THIS GRIT IS ABRASIVE AND HAS BEEN KNOWN TO CAUSE INTERNAL ENGINE DAMAGE.

NOTICE: If the engine is damaged internally and needs to be rebuilt, make sure all foreign material is completely flushed out of the cooling system / oil cooler system (if equipped). Failure to flush out the debris can result in damage to the rebuilt engine.

Cylinder Block

Figures 12-22 through 12-25

Remove or Disconnect

1. Oil pressure fitting and sensor.
2. Coolant drain plugs.
3. Camshaft and balance shaft cup plugs.
4. Front oil gallery cup plugs.
5. Rear oil gallery plugs.

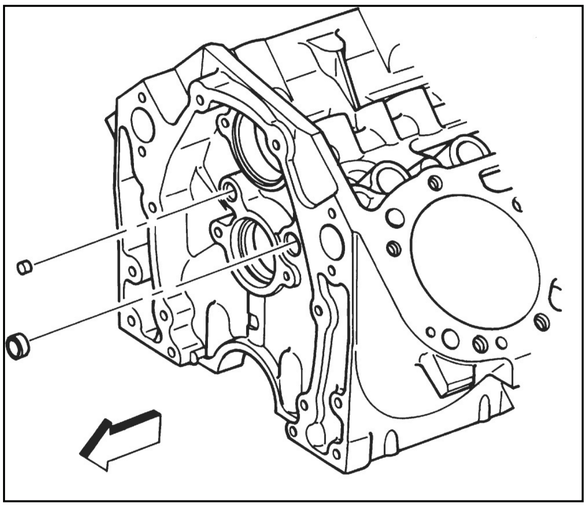


Figure 12-22 Front Cylinder Block Oil Gallery Plugs

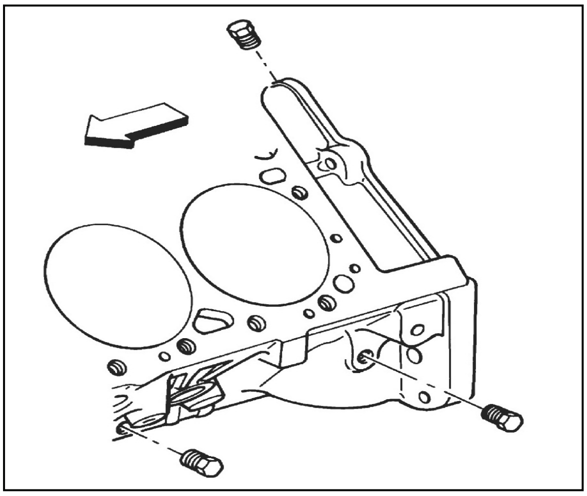


Figure 12-23 Left Side Cylinder Block Coolant Drain and Oil Gallery Plugs

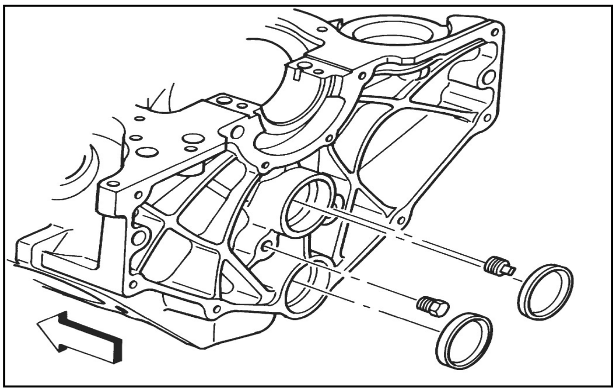


Figure 12-24 Rear Cylinder Block Oil Gallery Plugs

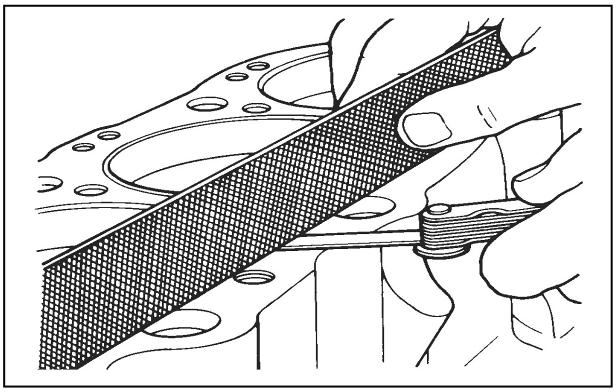


Figure 12-25 Measuring Cylinder Block Surface Flatness

Clean

- Sealing material from mating surfaces.
- Boil cylinder block in caustic solution. Flush with clean water or steam.
- Cylinder bores.
- Threaded holes.
- Oil galleries and passages.
- Scale deposits from coolant passages.
- Spray or wipe cylinder bores and machined surfaces with engine oil.

Inspect

- All expansion plugs for lack of fit or leakage.

- Valve lifter bores for deep scratches and deposits.

- Cracks in the block.
  - Cylinder walls.
  - Coolant jackets.
  - Engine mount bosses.
  - Main bearing webs.

- Main bearing bores and caps.
  - All main bearing bores should be rounded and uniform in ID at all of the bearing supports.
  - The area were the main bearing inserts contact the main bearing bore should be smooth.
  - If a main bearing cap is found to be damaged, replace the cap and line-bore the block.

- Cylinder head mounting surface for flatness, using a precision straightedge and feeler gage (figure 12-25).
  - Set the straightedge on the sealing surface to be inspected.
  - Take the feeler gage and at various locations, check the gap between the straightedge and the sealing surface.
  - If the gap is greater than 0.05 mm (0.002 in.) within 152 mm (6 in.) at any sealing location, the block must be replaced.
  - If the gap is found to be less than 0.05 mm (0.002 in.) at any sealing location and a cause for leakage is suspected, then the minor irregularities may be carefully machined from the block.

- Oil pan, timing cover, and intake manifold mounting surfaces for nicks. Minor irregularities may be cleaned up with a flat file.

Cylinder Bore

Inspect

- Cylinder bores for scoring or other damage.

- Cylinder bore taper and out-of-round.

Measuring Cylinder Bore Taper and Out-Of-Round

Figure 12-26

Tool Required:

J 8087 Cylinder Bore Gage (or equivalent)

IMPORTANT: If one or more cylinder bores are rough, scored or worn beyond limits, it will be necessary to smooth or true up such bores to fit new pistons. No attempt should be made to cut down oversize pistons to fit cylinder bores as this will destroy the surface treatment and affect the weight. The smallest possible oversize pistons should be used and the cylinder bores should be honed to size for proper clearances.

1. Refer to “Specifications” for tolerances.

2. Set the gage so the thrust pin must be forced in about 7 mm (0.250 in.) to enter the gage in the cylinder bore.

3. Center the gage in the cylinder and turn the dial to “0”.

4. Carefully work the gage up and down to determine taper and turn it to different points around the cylinder wall to determine the out-of-round condition. Measure the bore both parallel to and at right angles to the engine centerline. Measure at the top, middle, and bottom of the bore and note the readings.

5. Recondition the cylinder bore as necessary, as outlined later.

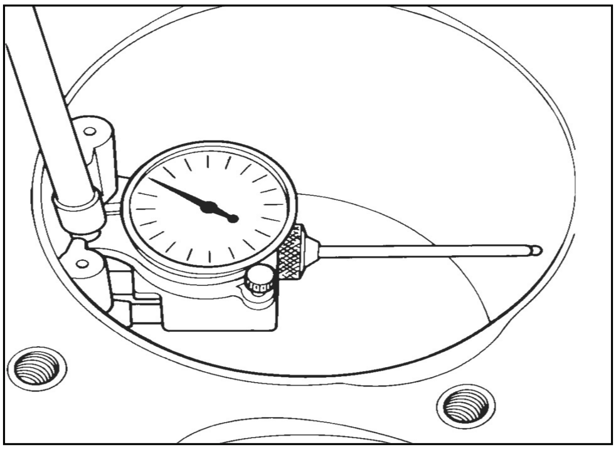


Figure 12-26 Checking the Cylinder Bore

Cylinder Bore Reconditioning

Figures 12-27 and 12-28

1. Measure the cylinder bore for out of round and taper as outlined previously.

2. Measure for wear at the top of the bore (point “A”) and at the bottom (point “B”).

   • Cylinder bores can be measured by setting the cylinder gage dial at zero in the cylinder at the point of desired measurement. Lock the dial indicator at zero before removing from the cylinder, and measure across the gage contact points with an outside micrometer, with the gage at the same zero setting when removed from the cylinder (figure 12- 28).

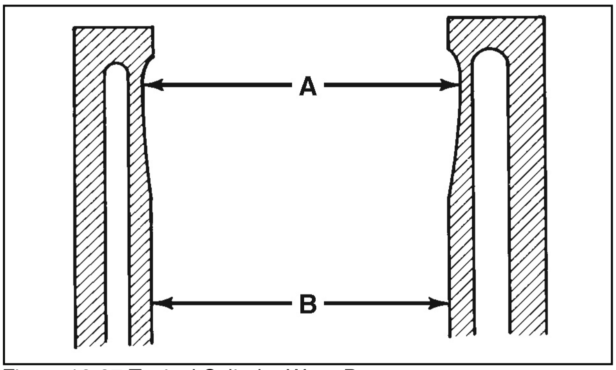


Figure 12-27 Typical Cylinder Wear Pattern

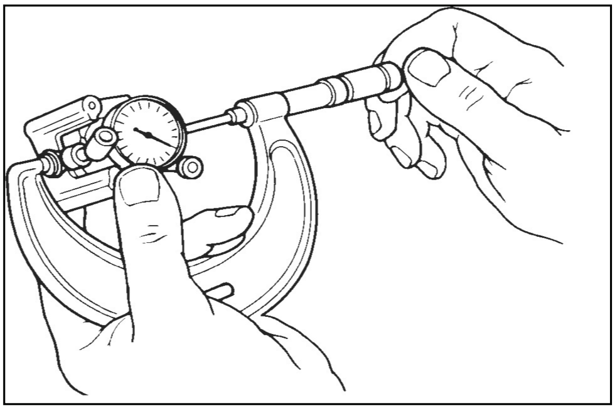


Figure 12-28 Measuring Cylinder Bore Gage

3. If the cylinders are found to exceed the specified out-of-round or taper, honing or boring will be necessary. Any cylinders that were found to have less than 0.13 mm (0.005 in.) wear or taper may not entirely clean up when fitted to a high limit piston. If it is desired to entirely clean up the bore in these cases, it will be necessary to rebore for an oversize piston. If more than 0.13 mm (0.005 in.) taper or wear, they should be bored and honed to the smallest oversize that will permit complete resurfacing of all cylinders.

4. Fine vertical scratches made by ring ends will not, by themselves, cause excessive oil consumption; therefore, honing to remove them is unnecessary.

5. Make sure the honing stones are clean, sharp, and straight. Move the hone up and down to produce a 45° to 65° cross-hatch pattern. Clean the bore thoroughly with soap and water. Dry and rub in clean engine oil, then remeasure.

6. If honing is not required, the cylinder bores should be cleaned with a hot water and detergent wash. Apply clean engine oil to the bore after cleaning.

Boring

1. Before the honing or reboring operation is started, measure all new pistons with the micrometer contacting at points exactly 90° from the piston pin centerline. Some pistons must be measured at a specified distance from the piston crown. Refer to the proper Section for additional instructions. Then select the smallest piston for the first fitting. The slight variation usually found between pistons in a set may provide for correction in case the first piston is fitted too loose.

2. Before using any type of boring bar, the top of the cylinder block should be filed to remove any dirt or burrs. This is very important. If not checked, the boring bar may be tilted which would result in the re-bored cylinder wall not being at right angles to the crankshaft.

3. The instructions furnished by the manufacturer of the equipment used should be carefully followed.

4. When reboring cylinders, all crankshaft bearing caps must be in place and tightened to the proper torque to avoid distortion of the bores in the final assembly. Always make sure the crankshaft is out of the way of the boring cutter when boring each cylinder. Crankshaft bearings and other internal parts must be covered or taped to protect them during the boring or honing operation.

5. When taking the final cut with a boring bar, leave 0.025 mm (0.001 in.) on the diameter for finish honing to give the required position to the cylinder clearance specifications. (The honing or boring operation must be done carefully so the specified clearance between pistons, rings, and cylinder bores is maintained).

Honing

1. When honing the cylinders, follow the hone manufacturer's recommendations for use, cleaning, and lubrication during honing. Use only clean, sharp stones of the proper grade for the amount of material to be removed. Dull, dirty stones cut unevenly and generate excessive heat. When using coarse or medium grade stones, use care to leave sufficient metal so that all stone marks may be removed with the fine stones used for finishing to provide proper clearance.

2. Occasionally, during the honing operation, the cylinder bore should be thoroughly cleaned and the piston selected for the individual cylinder checked for correct fit.

3. When honing to eliminate taper in the cylinder, full strokes of the hone in the cylinder should be made in addition to checking measurement at the top, middle and bottom of the bore repeatedly.

NOTICE: Handle the pistons with care and do not attempt to force them through the cylinder until the cylinder has been honed to the correct size as the piston can be distorted through careless handling.

4. When finish honing a cylinder bore to fit a piston, the hone should be moved up and down at a sufficient speed to obtain very fine uniform surface finish marks in a cross-hatch pattern at the specified angle of 45° to 65°.

5. The finish marks should be clean but not sharp, free from imbedded particles and torn or folded metal.

6. By measuring the piston to be installed at the sizing point specified in the proper Section, and adding the average of the clearance specification, the finish hone cylinder measurement can be determined. It is important that the block and the piston be measured at room temperature.

7. It is of the greatest importance that refinished cylinder bores are trued up to have the less than specified out-of-round taper. Each bore must be final honed to remove all stone or cutter marks and provide a smooth surface.

8. Refer to “Specifications” in the proper Section piston to bore clearance tolerances.

9. After final honing and before the piston is checked for fit, clean the bores with hot water and detergent. Scrub with a stiff bristle brush and rinse thoroughly with hot water. It is essential that a good cleaning operation be performed. If any of abrasive material is allowed to remain in the cylinder bores, it will wear the new rings and cylinder bores in addition to the bearings lubricated by contaminated oil. After washing, the dry bore should then be brushed clean with a power-driven fiber brush.

10. Permanently mark the piston for the cylinder which it has been fitted.

11. Apply clean engine oil to each bore to prevent rusting.

NOTICE: Refer to “Notice” on page 1.

Install or Connect

1. Front oil gallery plugs. Coat plug outside diameter with sealant (GM P/N 12346004) or equivalent.
2. Rear oil gallery plugs.

Tighten

- Left rear plug to 20 N·m (15 lb. ft.).
- Right rear plug to 25 N·m (18 lb. ft.).
- Left side plug to 20 N·m (15 lb. ft.).

IMPORTANT: Do not have residue on camshaft bearing or seizure may result.

3. Camshaft and balance shaft cup plugs to proper depth. Coat plug outside diameter with sealant (GM P/N 12346004) or equivalent.

4. Oil filter adapter, gasket, and bolts.

Tighten

- Bolts to 25 N·m (18 lb·ft.).

5. Coolant drain plugs.

Tighten

- Plugs to 20 N·m (15 lb·ft.)

6. Oil pressure fitting and sensor.

Tighten

- Fitting to 11 N·m (97 lb. in.) plus turn for alignment if necessary.

Piston Disassembly

NOTICE: The connecting rod, bearing and cap need to be stored together as mating parts, so they may be reassembled in the same position from which they were removed.

Figures 12-29 through 12-31

Tool Required:
- J 24086-B Piston Pin Remover and Installer Set

Remove or Disconnect

1. Piston rings. In most cases, the rings should be discarded and replaced with new ones at assembly.
2. Connecting rod bearing inserts. If the inserts are to be reused, place them in a rack so they may be reinstalled in their original connecting rod and cap.
3. Piston pin.
- Place the piston / connecting rod on support fixture J 24086-20. Make sure the connecting rod is fully supported.
- Press out the piston pin.

Clean

1. Piston.
- Remove all varnish and carbon deposits. DO NOT USE A WIRE BRUSH.
- Remove the carbon from the ring grooves.
- Oil control ring groove holes.

Inspect

1. Piston pin bore in the piston and connecting rod. Check for scuffing, burrs, etc.
2. Piston for scratches wear, etc.
3. Connecting rod for cracks, nicks, etc. If a suitable jig is available, check the connecting rod for a bent or twisted condition.

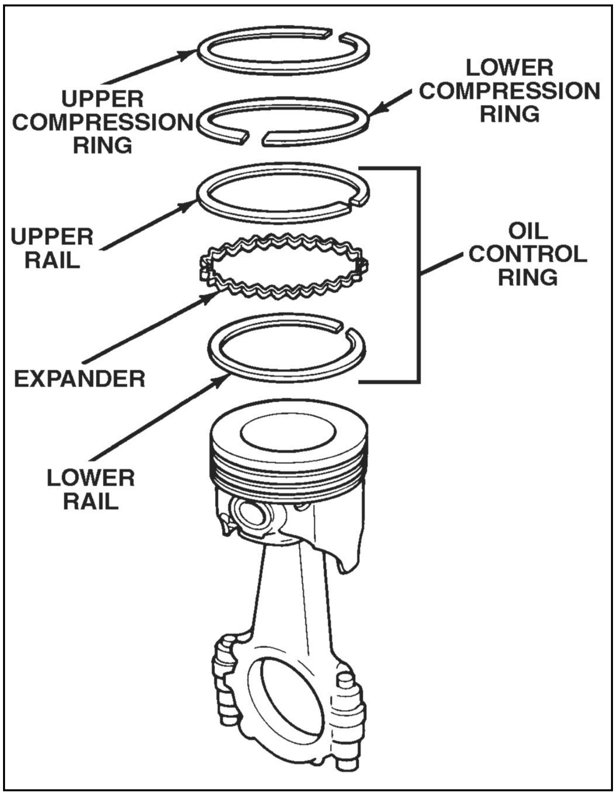


Figure 12-29 Piston Rings and Components

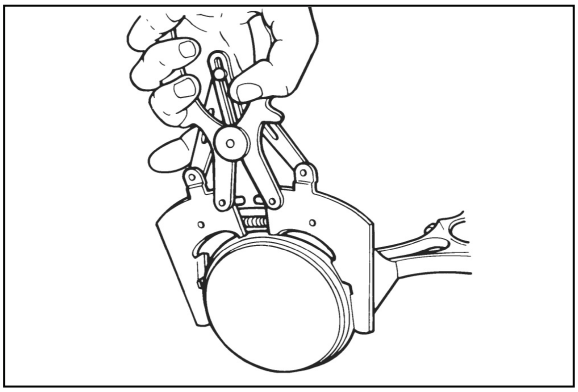


Figure 12-30 Removing Piston Rings

4. Piston.
   • Ring land for cracking, wear, etc.
   • Ring grooves for burrs, nicks, etc.
   • Skirts and pin bosses for cracking.
   • Skirts for scuffing.

5. Connecting rod bearing inserts for scratches or deep pitting.

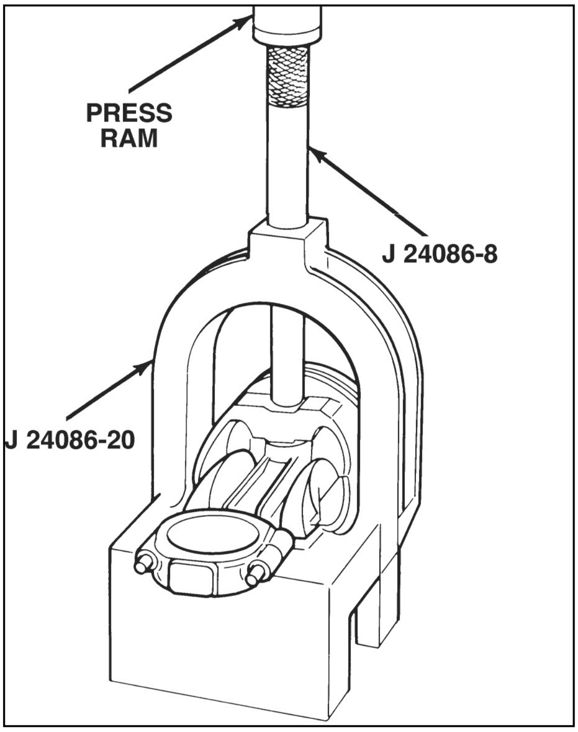


Figure 12-31 Removing Piston Pin

Measuring Piston Pin-To-Piston Clearance

Figures 12-32 and 12-33

Measure

1. Piston pin diameter. Check against "Specifications."

2. Piston pin-to-piston clearance.

   A. Measure the piston pin hole diameter.

   B. Subtract the piston pin diameter from the piston pin hole diameter to obtain the clearance.

   C. Replace the piston and piston pin if the clearance exceeds specifications. The piston and piston pin are a matched set and not available separately.

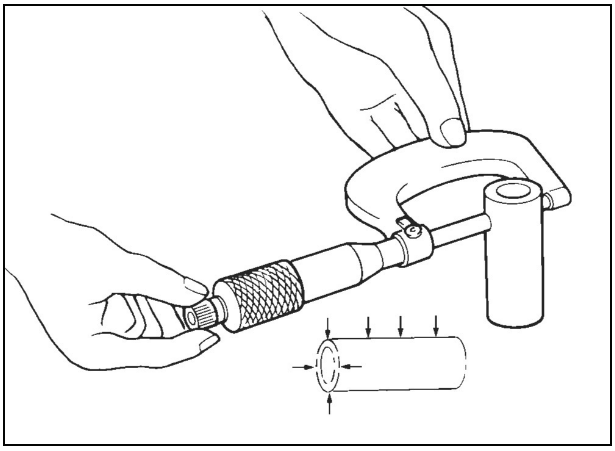


Figure 12-32 Measuring Piston Pin Diameter

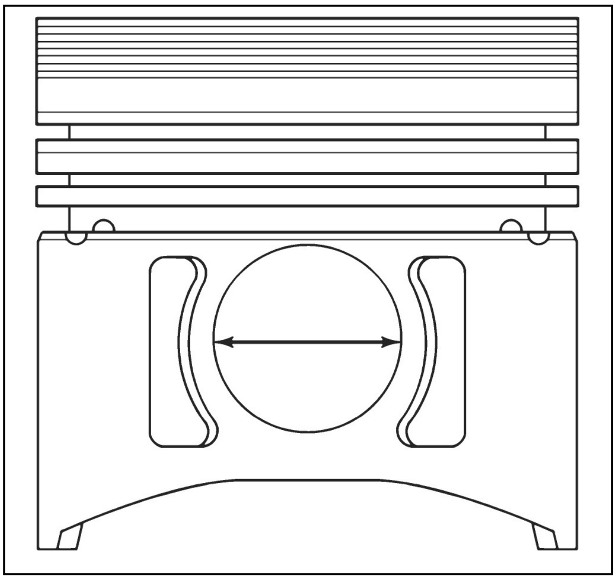


Figure 12-33 Measuring Piston Pin Bore Diameter

Piston Selection

Figures 12-34 and 12-35

1. Check the used piston to cylinder bore clearance.

   Measure

   A. Cylinder bore diameter. Use a telescoping bore gage, located 65 mm (2.5 in.) below the top of the cylinder bore (figure 12-34).

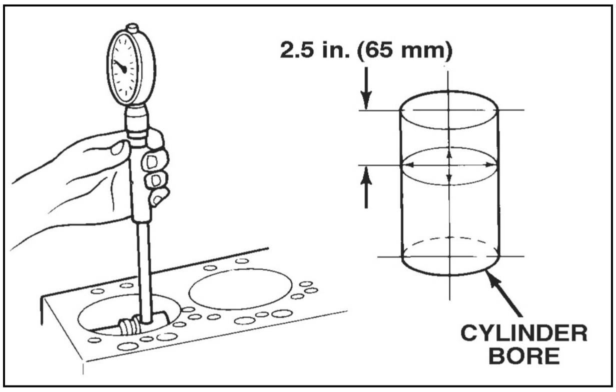


Figure 12-34 Measuring Cylinder Bore Diameter

   B. Piston diameter. Measure the piston skirt at a right angle to the piston pin, at the centerline of the piston pin (figure 12-35).
   C. Subtract the piston diameter from the cylinder bore diameter to determine piston to bore clearance.
   D. Refer to "Specifications" in the proper Section. Determine if the piston clearance is in the acceptable range.

2. If the used piston is not acceptable, determine if a new piston will fit the cylinder bore.
3. If a new piston does not bring the clearance within tolerances, the cylinder bore must be reconditioned.
4. Mark the piston to identify the cylinder for which it was fitted.

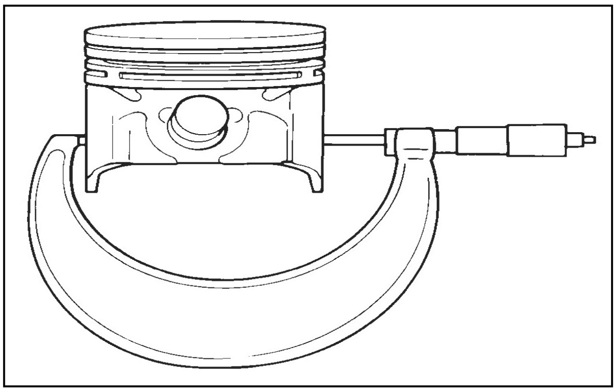


Figure 12-35 Measuring Piston Skirt

Piston Assembly

Assembling the Piston and Connecting Rod

Figure 12-36

Tool Required:

J 24086-B Piston Pin Remover and Installer Set

Install or Connect

1. Piston and connecting rod.

   A. The valve cutouts in the piston crown must be opposite the connecting rod bearing tangs.
   B. Lubricate the piston pin holes in the piston and connecting rod with engine oil.
   C. Install the pin guide to hold the piston and connecting rod together. Be sure to use the proper pin guide. Refer to the instructions supplied with the tool.

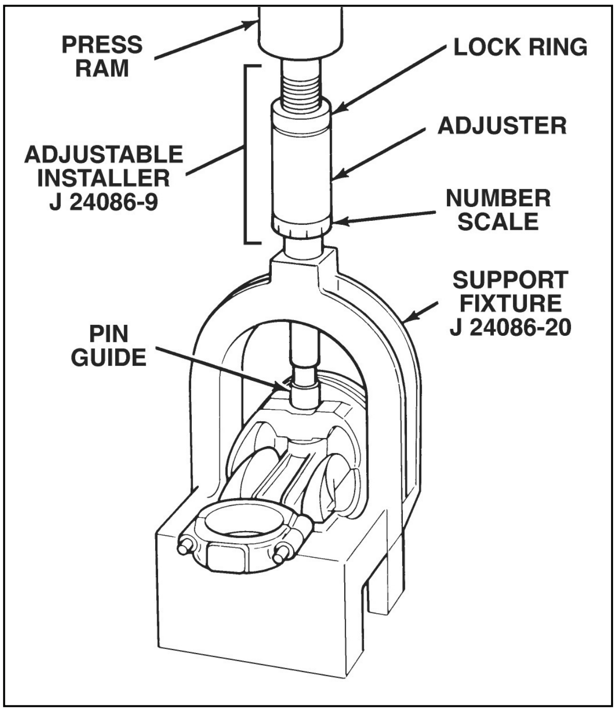


Figure 12-36 Installing Piston Pin

2. Piston pin.

   A. Insert the piston pin into the piston pin hole.
   B. Place the assembly on the support fixture.

C. Adjust the piston pin installer (J 24086-9) to the correct length, using the letter-number scale on the installer adjuster. This is necessary to ensure that the piston pin is pressed into the piston to the correct depth. Refer to the instructions supplied with the tool for the proper setting.
D. Lock the adjuster in place with the lock ring.

NOTICE: After the installer hub bottoms on the support assembly, do not exceed 35,000 kPa (5,000 PSI) pressure, as this could cause damage to the tool.

E. Place the adjuster in the support fixture. Press the piston pin into place (until the adjustable installer bottoms in the support fixture).
F. Remove the piston and connecting rod assembly from the tool and check the piston for freedom of movement on the piston pin.

Installing the Piston Rings

Figures 12-37 through 12-39

Measure

1. Ring end gap as follows:

A. Select rings comparable in size to the piston being used.
B. Slip the compression ring into the cylinder bore and press it down about 7 mm (0.250 in.) above ring travel. Make sure the ring is square with the cylinder wall.
C. Measure the space or gap between the ends of the ring with a feeler gage.
D. Refer to “Specifications” in the proper Section for correct gap.
E. If the gap between the ends of the ring is not as specified, remove the ring and try another for fit.

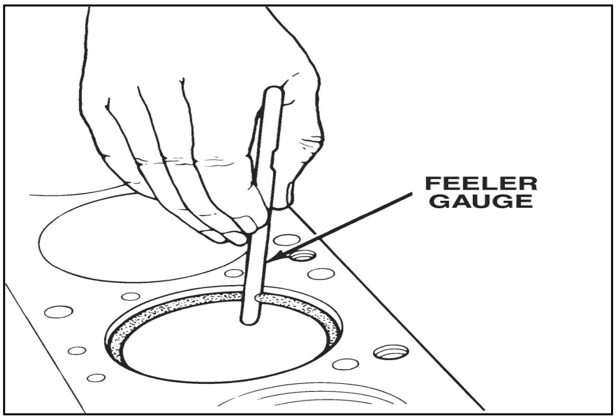


Figure 12-37 Measuring Ring End Gap

Inspect

1. Ring fit as follows:

A. Fit each compression ring to the piston on which it is going to be used.

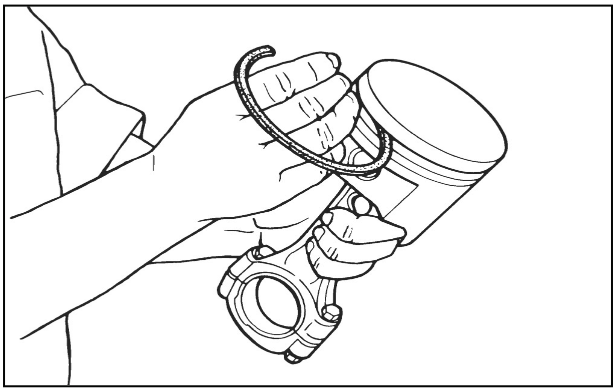


Figure 12-38 Checking Ring Fit

B. Slip the outer surface of the top and second compression ring into the respective piston ring groove, to make sure that the ring is free. If binding occurs at any point, the cause should be determined. If binding is caused by the ring groove, correct by depressing the groove with a fine cut file. If the binding is caused by a distorted ring, try a new ring.

NOTICE: All compression rings are marked on the upper side of the ring. When installing the compression rings, make sure the MARKED SIDE IS TOWARD THE TOP OF THE PISTON.

NOTICE: The oil control rings are three piece types, consisting of two rails and an expander.

Assemble

1. Expander.

2. Lower rail.

3. Upper rail.

4. Lower compression ring.

5. Upper compression ring.

- Flex all rings to make sure they are free. If binding occurs at any point the cause should be determined. If binding is caused by the ring groove, correct by dressing the groove with a fine cut file. If binding is caused by a distorted ring, try a new ring.
- Ring gaps must be 180° apart.
- Rail gaps must be 180° apart.

Measure

- Ring clearance. Use a feeler gage and compare with “Specifications”.

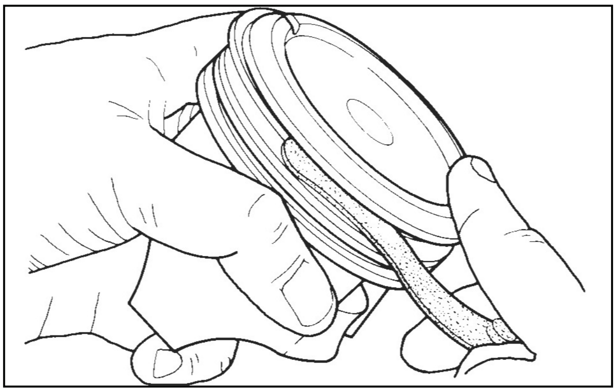


Figure 12-39 Measuring Ring-to-Land Clearance

Intake and Exhaust Manifolds

Figure 12-40

Clean

- Mating surfaces on intake manifold and cylinder head.
- Excessive carbon buildup in the exhaust passages of the intake manifold.
- Scale and deposits from the coolant passages of the intake manifold.
- EGR passage of excessive carbon deposits.

Inspect

- Manifolds for cracks, broken flanges, and gasket surface damage.
- Alignment of manifold flanges. Use a straightedge and feeler gage. If the flanges do not align, the manifold is warped and should be replaced.

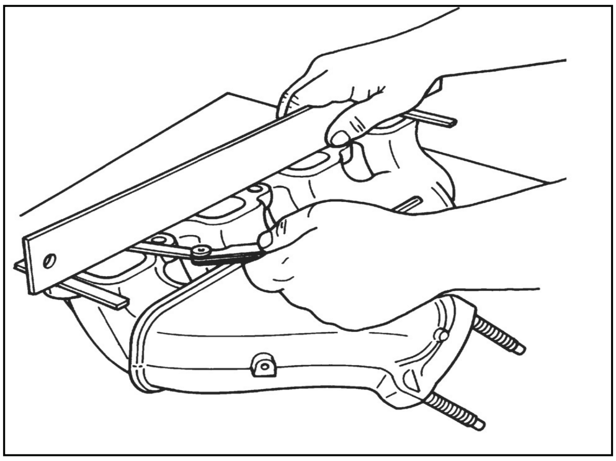


Figure 12-40 Checking Manifold Flange Alignment

Camshaft

Figures 12-41 and 12-42

Tool Required:

J 7872 Dial Indicator or Equivalent

IMPORTANT: Do not attempt to repair the camshaft, replace it if damaged. Whenever the camshaft is replaced, a new set of lifters must also be installed.

Inspect

- Bearing surfaces and lobes for wear.
- Sprockets.
- Keyway and threads for galling, gouges, or overheating.
- Camshaft journal diameters (figure 12-41). Refer to “Engine Specifications” for proper diameters.
- Camshaft runout (figure 12-42). Mount the camshaft in V-blocks or between centers. Using J 7872, check the intermediate camshaft journal. Compare camshaft runout with “Specifications”. If the camshaft is excessively bent, replace the camshaft and camshaft bearings.

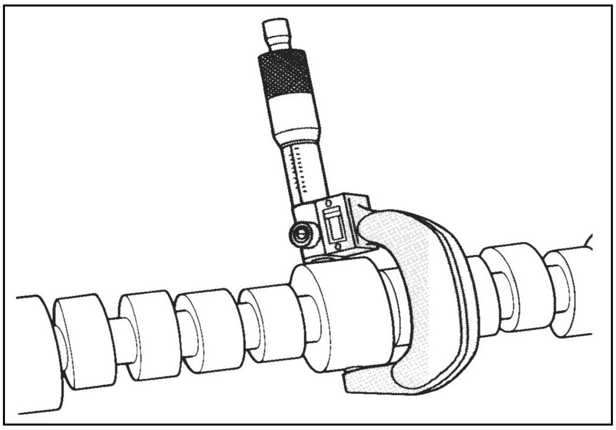


Figure 12-41 Measuring Camshaft Journals

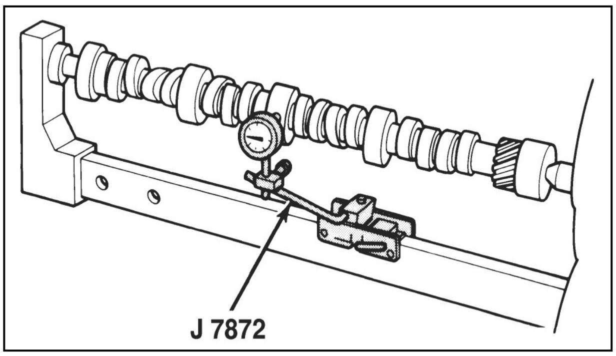


Figure 12-42 Measuring Camshaft Runout

Camshaft Bearings

Camshaft Bearing Removal

Figure 12-43

Tool Required:

- J 33049 Camshaft Bearing Remover and Installer

Remove or Disconnect

1. Rear camshaft plug.

2. All camshaft bearings. Use J 33049 (figure 12-43).

   A. Insert the tool with the correct collet into the camshaft bearing you want to replace.

   B. Turn the tool until the collet has tightened in the bearing.

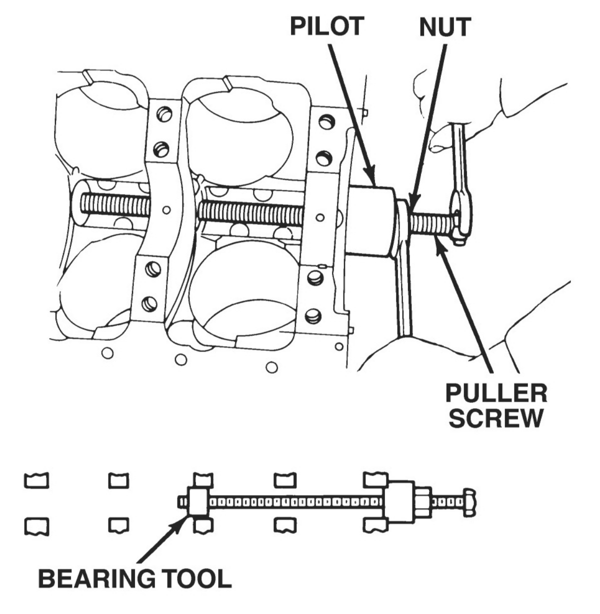


Figure 12-43 Removing / Installing Camshaft Bearings

   C. Push the center cone against the block and into the bearing bore to center the tool.

   D. Drive the bearing from the block.

   E. Repeat this procedure to remove the remaining inner camshaft bearings. Note that the rear bearing must be removed from the front of the block and the front bearing from the rear. This allows the tool to remain centered.

Cleaning and Inspection

Clean

- Camshaft bearing bores in the block.

Inspect

- Camshaft bearings for scratches, pits, or loose fit in their bores. Replace the camshaft bearings if necessary.
- Camshaft lobes and journals for scratches, pitting, scoring, and wear. Minor irregularities may be cleaned up with emery cloth.

Camshaft Bearing Installation

Figure 12-43

Install or Connect

Tool Required:

- J 33049 Camshaft Bearing Remover and Installer

NOTICE: The outer camshaft bearings must be installed first. These bearings serve as guides for the pilot, and help center the inner bearings during the installation process.

NOTICE: Make sure to fit the correct cam bearing into the bore. The cam bearing bores vary in size.

1. Rear camshaft bearings. Drive the bearings into place using J 33049 from front of engine (figure 12-43).

IMPORTANT: Make sure the camshaft bearing hole (or holes) align with the oil hole (or holes) in the block. On some engines, the oil holes may be difficult to see. If so, use a piece of 2 mm rod to check alignment.

2. Front camshaft bearing using tool J 33049 (figure 12-43).

IMPORTANT: Make sure the camshaft bearing hole (or holes) align with the oil hole (or holes) in the block.

3. Inner camshaft bearings using tool J 33049. Reverse of removal procedure.

4. Camshaft rear plug.

A. Coat a new camshaft plug with sealer GM P/N 12345493 or equivalent.

B. Install the plug. The plug must be installed deep enough in camshaft bore.

Balance Shaft

Inspect

- Balance shaft front roller bearing and rear sleeve for damage or excessive wear. The bearings are serviced as an assembly. Use the correct tools for properly servicing the bearings.

- Balance drive and driven gears for nicks or burrs. Replace gears that are damaged.

- Front and rear bearing journal diameters. Replace the balance shaft if the diameter exceeds the specifications. Refer to “Specifications”.

- Rear sleeve bearing journal clearance. Replace the balance shaft if the clearance exceeds the specification. Refer to “Specifications”.

Timing Chain and Sprockets

Inspect

- Sprockets for chipped teeth and wear.
- Timing chain for damage.
- It should be noted that excessively worn sprockets will rapidly wear a new chain. Likewise, an excessively worn chain will rapidly wear a new set of sprockets.

Crankshaft Sprocket Replacement

Figure 12-44

Tools Required:

J 5825-A Crankshaft Sprocket Puller
J 5590 Crankshaft Sprocket Installer

Remove of Disconnect

1. Crankshaft Sprocket. Use J 5825-A (figure 12-44).

2. Key, if necessary.

Install or Connect

1. Key, if necessary.

2. Crankshaft sprocket. Use J 5590 (figure 12-44).

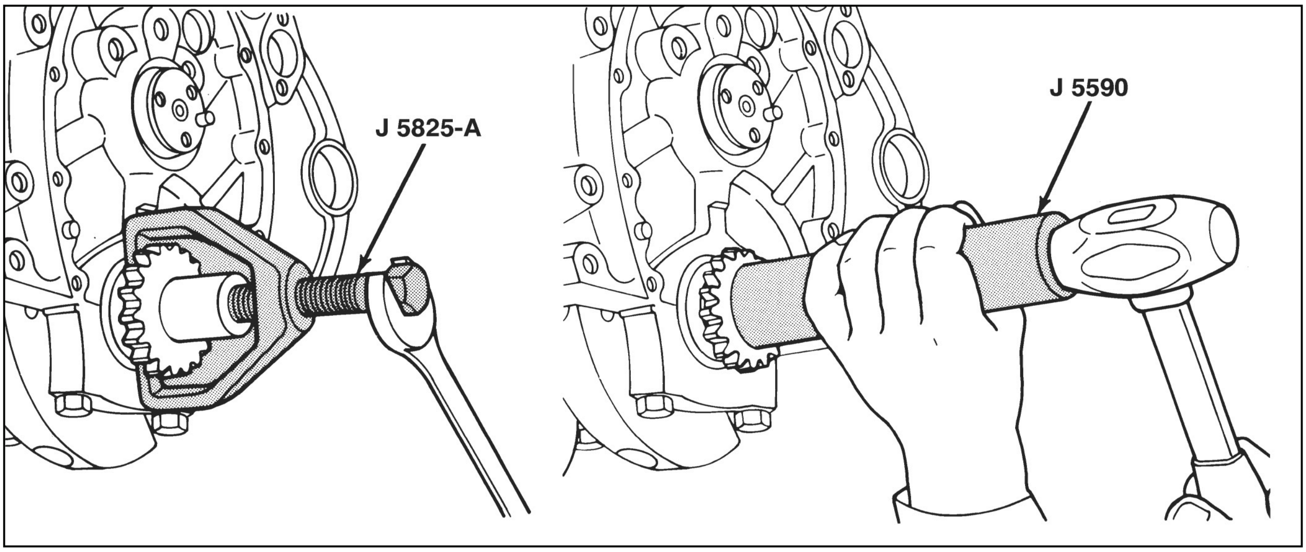


Figure 12-44 Crankshaft Sprocket Replacement

Coolant Pump

Clean

- Old gasket from the gasket surface.

NOTICE: Do not immerse the pump in solvent. The solvent may enter the pump's permanently lubricated bearings and cause premature bearing failure.

Inspect

- Coolant pump shaft for rotation and end play. The shaft and fan hub should turn straight and smoothly. If the hub wobbles or the shaft is noisy or feels "lumpy" when turned, replace the coolant pump. If the shaft end play exceeds 0.381 mm (0.015 in.), replace the coolant pump.

- Coolant pump body at the drain (weep) hole. Slight staining around the weep hole is normal. Only replace the pump if coolant is dripping from the weep hole while the engine is running or while the system is pressurized.

Oil Pan and Valve Rocker Covers

Figure 12-45

Clean

- Parts in solvent. Remove all sludge and varnish.

- Old gaskets from the gasket surfaces.

Inspect

- Gasket flanges for bending or damage.

- Rubber grommets and parts on the valve rocker cover for deterioration.

- Oil pan for rock damage or cracks.

- Oil pan baffle for lack of fit.

- Drain plug threads for stripping.

Oil Pump

Figures 12-46 and 12-47

Remove or Disconnect

1. Driveshaft and retainer.

IMPORTANT: Do not remove pickup pipe and screen unless replacement is required.

- **The pickup pipe has a press fit in to the pump cover.**

- **Do not remove the screen from the pipe. The pickup screen and pipe are serviced as a complete assembly only.**

2. Oil pump screen pickup.

3. Screws.

4. Pump cover.

IMPORTANT: Mark where the idler gear, drive gear and shaft mesh together so they can be reinstalled with the same gear teeth indexed.

5. Idler gear, drive gear and shaft.

6. Retaining pin.

7. Pressure regulator spring.

8. Pressure regulator valve.

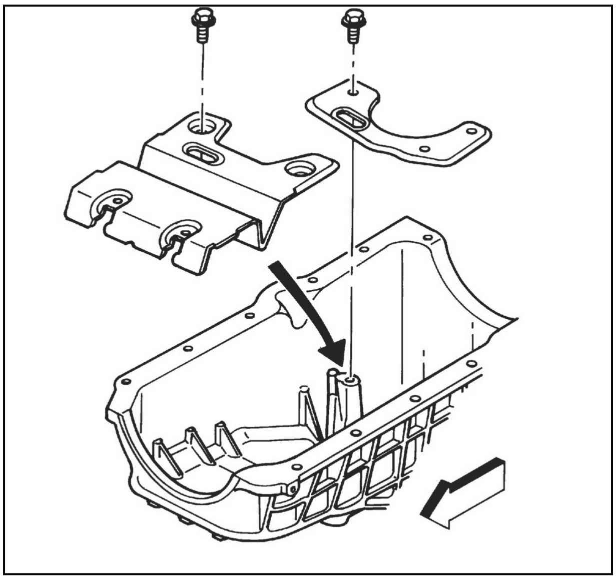


Figure 12-45 Inspecting Oil Pan and Components

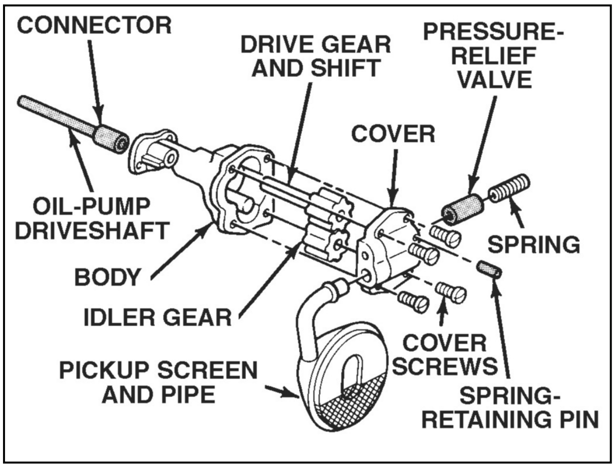


Figure 12-46 Oil Pump and Components

Clean

- All parts in clean solvent and dry them with compressed air.

Inspect

- Pump body for cracks, wear, or other damage.
- Inside of the cover for cracks and wear that would permit oil to leak past the ends of the gears.
- Idler and drive gears for wear.
- Drive gear and shaft for lack of fit in the pump body.

IMPORTANT: The pump gears, cover, and body are not serviced separately. If any of the parts are damaged or worn, the entire oil pump assembly must be replaced.

Inspect

- Oil pump screen damage or loose fit of the pipe.
- Pressure regulator valve for fit. The regulator valve should slide freely in its bore without sticking or binding.

Install or Connect

Tool Required:

J 21882 Pickup Tube and Screen Installer

1. Pressure regulator valve into the pump cover.

IMPORTANT: Replace the pressure relief valve spring when reusing the oil pump assembly.

2. Pressure regulator spring into the pump cover.

3. Retaining pin into the pump cover.

4. Drive gear and shaft into the pump body.

5. Idler gear into the pump body.

IMPORTANT: Match together the index marks on the two gears made during disassembly.

6. Pump cover.

NOTICE: Refer to “Notice” on page 1.

7. Bolts.

Tighten

- Bolts to 12 N·m (106 lb. in.)

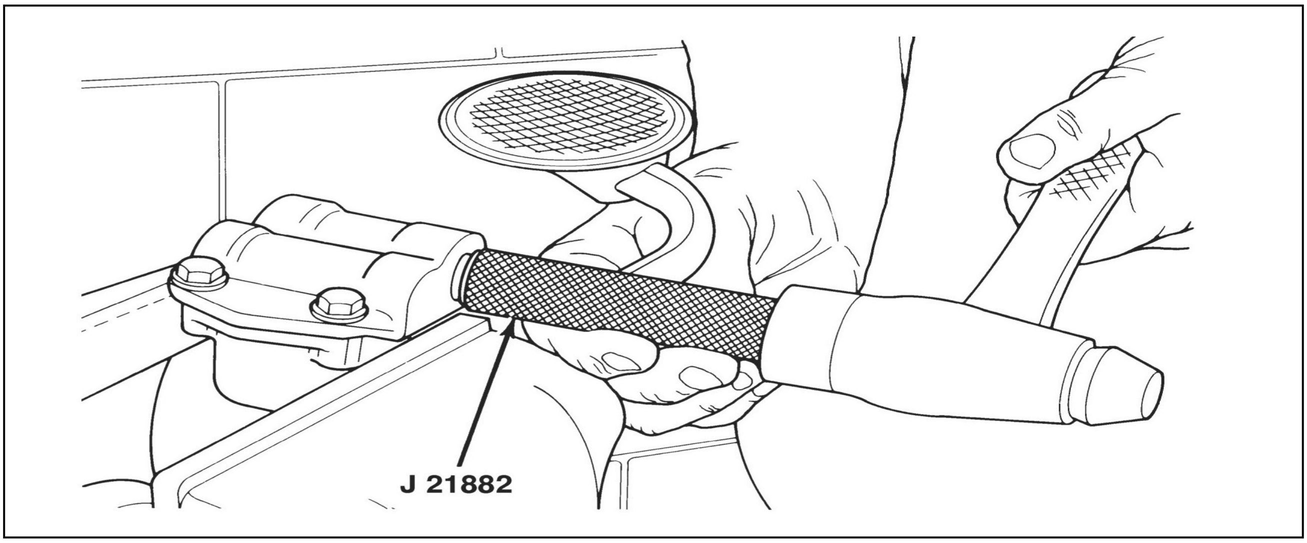


Figure 12-47 Installing Oil Pump Screen

Inspect

- With the shaft extension installed on the pump, turn the drive shaft by hand to check for smooth operation.

NOTICE: Be careful of twisting, shearing, or collapsing the pipe when installing it to the pump. A damaged pipe can cause lack of lubrication and engine failure.

8. Pickup screen and pipe.

A. If the pickup screen and pipe assembly was removed, it should be replaced with a new part. Loss of press fit condition could result in an air leak and loss of oil pressure.

B. Mount the oil pump in a soft-jawed vise.

C. Apply sealer to the end of the pipe.

D. Tap the pickup screen and pipe into place, using J 21882 and a hammer.

E. The pump screen must be parallel with the bottom of the oil pan when installed.

9. Oil pump drive shaft and connector.

Valve Train Components

IMPORTANT: Store all reusable components in an exact order, so they may be reassembled in the same position from which they were removed.

Clean

- All parts in clean solvent and dry them with compressed air.
- Make sure the oil passages through the pushrods are clear.

Inspect

- Valve rocker arms and balls at their mating surfaces. These surfaces should be free from wear or damage.
- Valve rocker arm areas that contact the valve stems and the socket areas that contact the ends of the pushrods. These areas should be free of wear or damage.
- Valve rocker arm nuts.
- Valve pushrod ends for scoring, roughness, or bends.
  - Roll the pushrod on a flat surface to determine its straightness. If the rod is bent, the rod will not roll freely. Replace if necessary.

Valve Lifters

This engine uses hydraulic valve lifters. Valve lifters are serviced only as an assembly. No internal parts are available. Service is limited to disassembly and cleaning. Discard valve lifters that are excessively worn or damaged.

IMPORTANT: Whenever the camshaft needs to be replaced, a new set of hydraulic lifters must also be installed.

Cylinder Head

Disassembly

Figures 12-48 and 12-49

Tool Required:

J 8062 Valve Spring Compressor

Remove or Disconnect

1. Compress the springs with J 8062 (figure 12-48).

2. Keys.

3. Valve spring cap.

4. Spring.

5. Seal.

6. Valves.

IMPORTANT: Place the valves in an organizer rack so they can be replaced in their original position at reassembly.

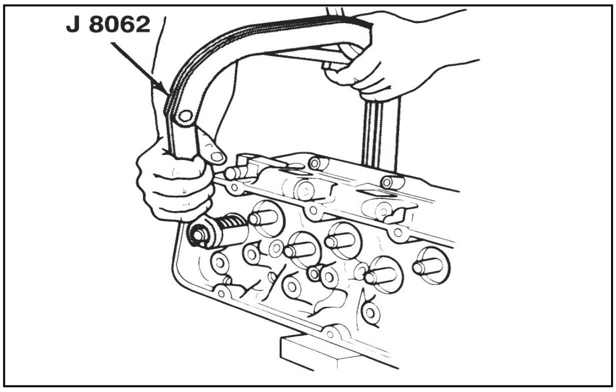


Figure 12-48 Compressing Valve Springs

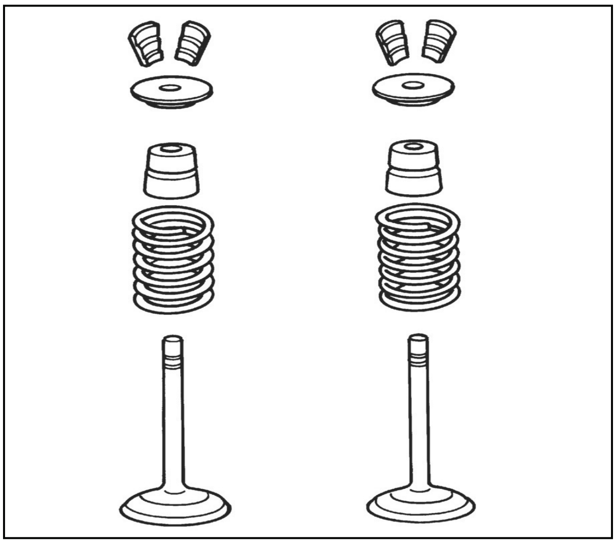


Figure 12-49 Valves and Components

Cleaning, Inspection, and Measurement

Figures 12-50 through 12-54

Tool Required:

J 8089 Wire brush

Clean

- Carbon from the combustion chambers using J 8089.
- Valve stems and heads on a wire wheel.
- Carbon and old gasket from the cylinder head gasket surface.
- Valve guides using a valve guide cleaner.

Inspect

- Cylinder head for cracks in the exhaust ports, combustion chambers, or external cracks to the coolant chamber. Gasket surfaces should be free of damage.
- Valves for burning, pitting, or warpage. Refer to “Valve Grinding” in this Section. Check the valve stems for scoring or excessive wear. Stems must not be bent.
- Valve rocker arm studs for wear, damage, or improper fit.
- Valve seats for pitting or other damage. Grind or reface as needed.
- Rotators (if used). The rotators should move smoothly without binding.
- Cylinder head for surface flatness (figure 12-51).

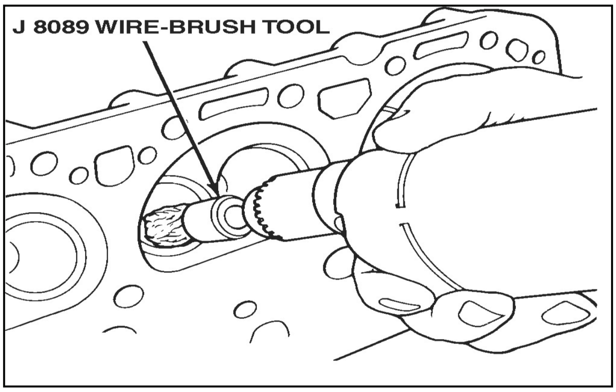


Figure 12-50 Cleaning the Combustion Chambers

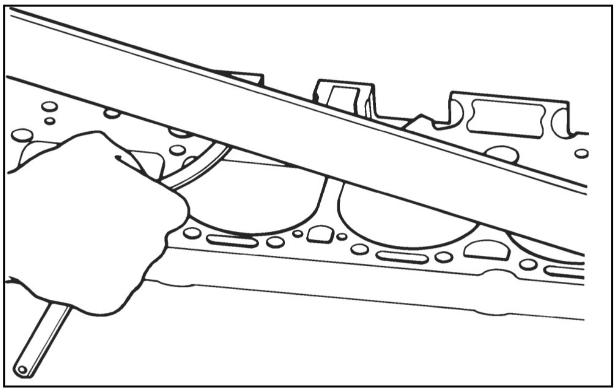


Figure 12-51 Measuring Cylinder Head Surface

Measure

Tools Required:

J 8001 Dial Indicator (or equivalent)
J 8056 Valve Spring Tester

1. Valve stem to guide bore clearance.

NOTICE: Excessive valve stem to guide bore clearance will cause excessive oil consumption and may cause valve breakage. Insufficient clearance will result in noisy and sticky functioning of the valve and disturb the engine's smoothness.

A. Clamp a dial indicator (J 8001 or equivalent) on one side of the cylinder head rocker arm cover gasket rail.

B. Observe dial indicator movement while moving valve from side to side (crosswise to the head). The dial indicator measurement must be taken just above the valve guide bore.

C. Drop the valve head about 1.6 mm (0.063 in.) off the valve seat.

D. Move the stem of the valve from side to side using light pressure to obtain a clearance reading. If clearance exceeds specifications, ream the valve guide bores for oversize valves as outlined later.

2. Valve spring tension. Use J 8056 or equivalent.

- Compress the springs, with dampers removed, to the specified height and check against the specifications chart.
- Springs should be replaced if not within 44 N (10 lb.) of the specified load.

3. Valve spring length. Replace the spring if the length is not as specified.

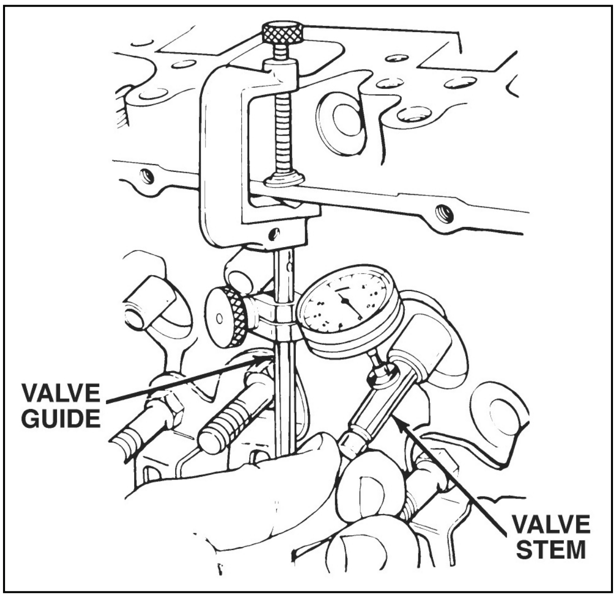


Figure 12-52 Measuring Stem-to-Bore Clearance (Typical)

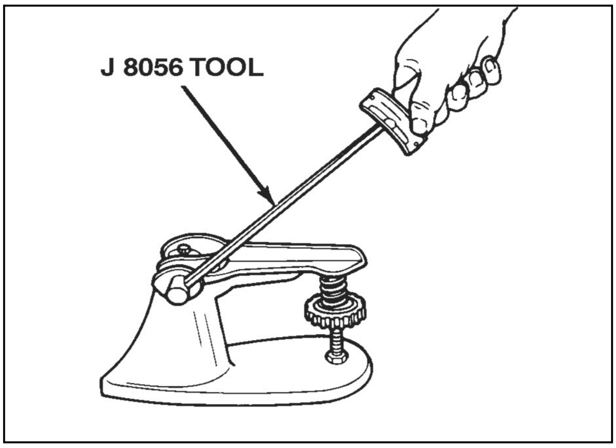


Figure 12-53 Measuring Valve Spring Tension

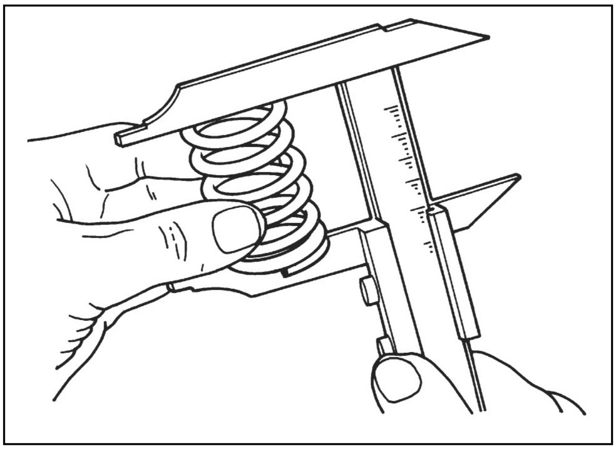


Figure 12-54 Measuring Valve Spring Length

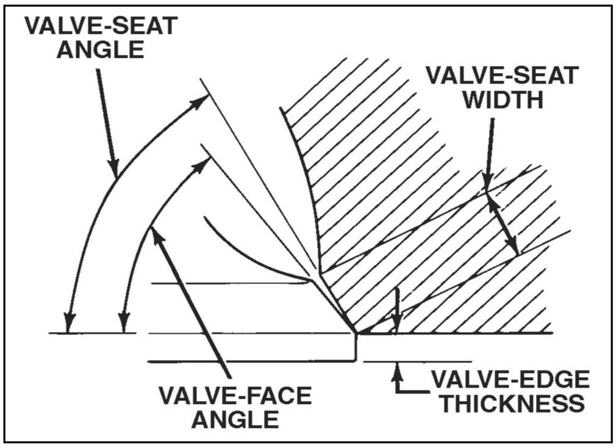


Figure 12-55 Valve / Seat Grinding

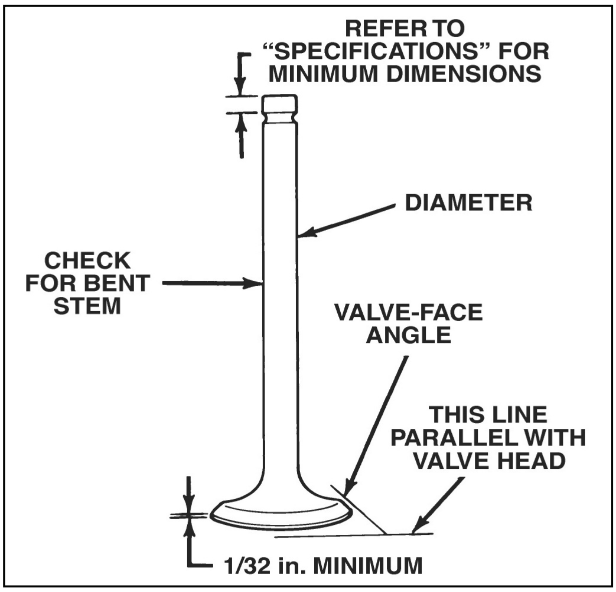


Figure 12-56 Critical Valve Dimensions

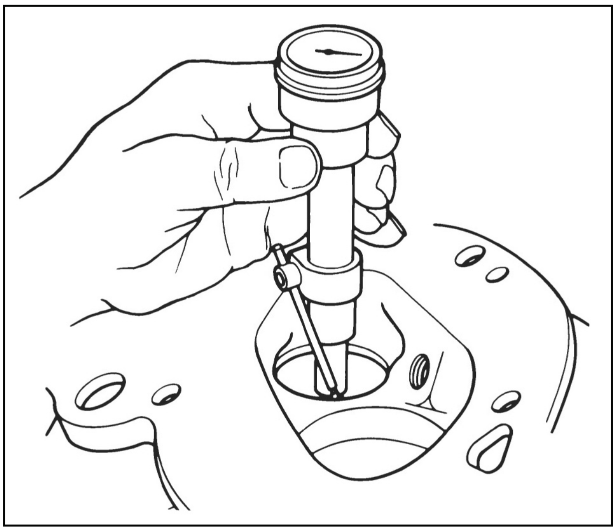


Figure 12-57 Measuring Valve Seat Concentricity

Repair

Figures 12-55 through 12-58

Valve Grinding

Pitted valves must be refaced to the proper angle. Valve stems that show excessive wear, or valves that are warped excessively must be replaced. When an excessively warped valve head is refaced, a sharp or thin valve margin may result because of the amount of metal that must be removed. Undersize valve margins lead to breakage, burning, or preignition due to heat localizing on this knife edge (figure 12-55). Refer to "Specifications". If the edge of the valve head is less than specification after grinding, replace the valve.

Several different types of equipment are available for refacing valves. The manufacturer's instructions for how to use the equipment should be carefully followed to attain the proper results.

Valve Seat Grinding

Reconditioning the valve seats is very important. The seating of the valves must be perfect for the engine to deliver the power and performance it was designed to produce.

Another important factor is the cooling of the valve head. Good contact between each valve and its seat will ensure that heat will be carried away properly.

Several different types of equipment are available for refacing valves. The manufacturer's instructions for how to use the equipment should be carefully followed to attain the proper results.

Regardless of what type of equipment is used, it is essential that valve guide bores be free from carbon or dirt to ensure proper centering of the pilot in the guide. Refer to “Specifications” for valve seat angle specifications.

Reaming Valve Guide

The valve guides used in this engine are simply holes bored in the cylinder head. The valve guides are not replaceable.

If the valve stem-to-bore clearance as previously measured is excessive, the valve guides should be reamed and a valve with an oversize stem installed. Oversize valves are available. Refer to “Specifications”.

Select a reamer that will provide a straight, clean bore through the entire length of the valve guide (figure 12-58).

Valve Rocker Arm Stud Replacement

Remove or Disconnect

1. Valve rocker arm stud by unscrewing.

Install or Connect

1. Valve rocker arm stud into cylinder head.

Tighten

• Rocker arm stud to 47 N·m (35 lb·ft.).

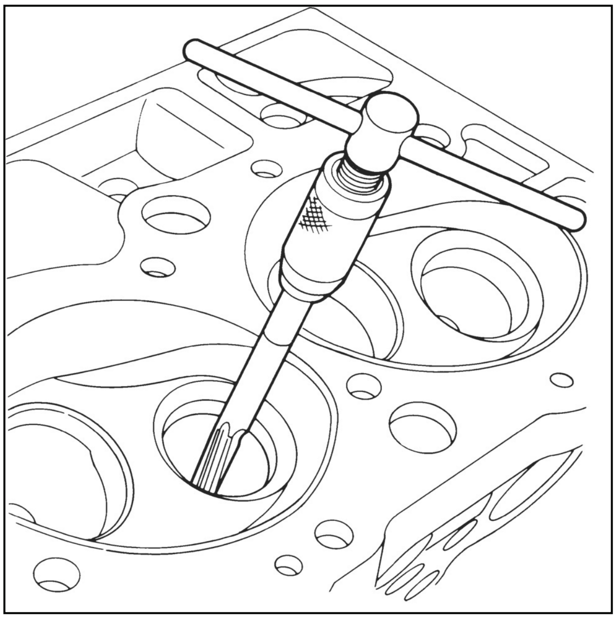


Figure 12-58 Reaming Valve Guides

Assembly

Figures 12-48, 12-49, 12-59 and 12-60

Install or Connect

1. Valves.

A. Lubricate the valve stems with clean engine oil.
B. Insert the valves into the proper valve guides until the face of the valve contacts the valve seat.

2. Seal.

A. Install the seal over the valve stem.
B. Hold the valve against the valve seat.
C. Push the seal down the valve stem until it bottoms out against the head.

3. Springs.

4. Valve spring cap.

A. Compress the valve spring using J 8062 (figure 12-48), enough so the lower valve stem groove can be seen clearly.
B. Apply a small amount of grease to the area of the upper valve stem groove.
C. Assemble the two valve keys into the upper groove using the grease to hold them in place.
D. Release the compressor tool J 8062, making sure the valve keepers stay in place.
E. Repeat the preceding steps on the remaining valves.

Measure

1. Valve spring installed height of each spring as follows:

   A. Use a narrow thin scale. A cutaway scale may be helpful.

   B. Spring seat in the cylinder head to the top of the valve spring cap.

   C. If this measurement exceeds the amount in "Specifications," install valve seat spring shims, approximately 1.58750 mm (0.0625 in.) thick, between the spring and cylinder head. NEVER shim the spring so as to give an installed height under the specified amount.

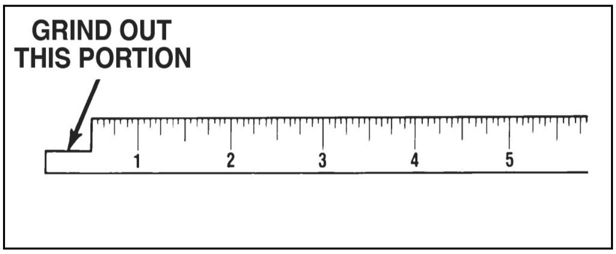


Figure 12-59 Cutaway Scale

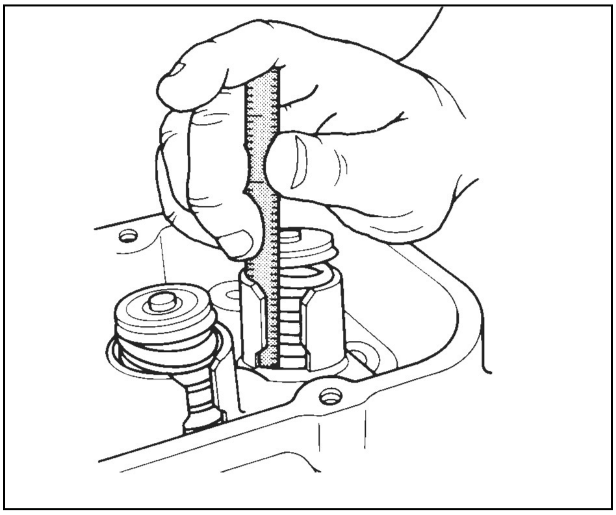


Figure 12-60 Measuring Valve Spring Installed Height

Thermostat and Coolant Outlet

Remove or Disconnect

1. Bolts.
2. Stud.
3. Coolant outlet.
4. Gasket.
5. Thermostat (with gasket).

Inspect

• Coolant outlet for cracks.

Install or Connect

1. Thermostat
2. New gasket.
3. Coolant outlet.

NOTICE: Refer to "Notice" on page 1.

4. Bolt.
5. Stud.

Tighten

• Bolts to 28 N·m (21 lb·ft.).

• Stud to 28 N·m (21 lb·ft.).

Torsional Damper

Inspect

Torsional damper weight for signs of shifting on the hub. Replace as needed. The area of the torsional damper hub shaft that contacts the front crankshaft seal for roughness or nicks. Replace the damper if this condition exists. If damper is replaced, new damper weights of the same size must be installed on the new damper in the same location as the old damper.

Crankshaft Bearings

Figures 12-61 through 12-63

Cleaning and Inspection

Clean

- Crankshaft with solvent.
  - Do not scratch the bearing journals.
  - Remove all sludge from the oil passages with compressed air.
- Crankshaft bearing.
  - Wipe free of oil with a soft cloth.

Inspect

- Crankshaft for cracks.
  - Use the magnaflux method if available.
  - Crankshaft, crankshaft bearing journals, and thrust surfaces for scoring, nicks or damage caused by lack of lubrication.
  - Main bearing inserts for scoring or other damage. In general, the lower crankshaft bearings (except the #1 bearing) show the greatest wear and distress from fatigue. Upon inspection, if a lower crankshaft bearing is suitable for reuse, it can be assumed that the upper crankshaft bearing is also satisfactory. If a lower bearing shows evidence of wear or damage, both the upper and lower crankshaft bearings must be replaced.

Measuring Bearing Clearance

Crankshaft bearings are of the precision insert type and do not use shims for adjustment. If clearances are excessive, new upper and lower bearings will be required. Service bearings are available in standard size and undersize.

Selective fitting of crankshaft bearings is necessary in production to obtain close tolerances. For example, you may find one-half of a standard crankshaft bearing with one-half of an undersize crankshaft bearing.

To determine the correct replacement bearing size, the bearing clearance must be measured accurately. Either of the following two methods may be used, however, the micrometer method gives more reliable results and is preferred.

Micrometer Method

Measure

1. The crankshaft journal diameter with a micrometer in several places, approximately 90° apart. Average the measurements.

2. Compute taper and runout. Refer to “Specifications” for allowable limits.

Install or Connect

3. Crankshaft bearings into the crankshaft cap and engine block.

4. Install crankshaft caps and bolts.

5. Tighten bolts to specification.

Measure

6. Bearing inside diameter (I.D.) using an inside micrometer.

7. Compare crankshaft bearing clearance with “Specifications”.

8. If bearing clearances exceed specification, install new crankshaft bearings.

A. Measure inside diameter with an inside micrometer at 90° to the split line of the crankshaft bearing.
B. Subtract journal diameter from bearing inside diameter to obtain bearing clearance. Refer to “Specifications” for bearing inside clearance. Replace or repair the crankshaft if clearance exceeds specification.

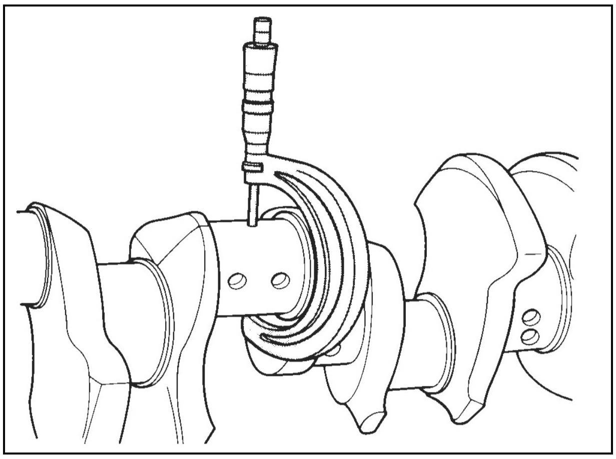


Figure 12-61 Measuring Crankshaft Journals

Plastigage Method

Install or Connect

1. Main bearing inserts and crankshaft.

2. Gauging plastic.

   A. Begin with the rear main bearing.
   B. Wipe the oil from the crankshaft journal and the lower main bearing insert.
   C. Place a piece of gauging plastic the full width of the lower bearing insert (parallel to the crankshaft) on the journal (figure 12-62). Do not rotate the crankshaft while the gauging plastic is between the bearing and journal.

3. Main bearing cap and bolts.

4. Tighten bolts to specification.

Remove or Disconnect

- Main bearing cap. DO NOT REMOVE THE GAUGING PLASTIC FROM THE JOURNAL OR LOWER MAIN BEARING INSERT.

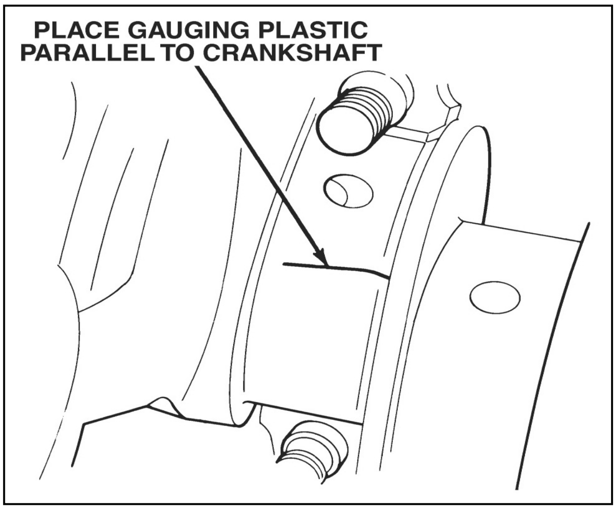


Figure 12-62 Placing Gauging Plastic on Journal

Measure

- Gauging plastic as follows:

  a. The flattened gauging plastic will be found adhering to either the lower bearing insert or journal.
  b. On the edge of the gauging plastic envelope there is a graduated scale. Without removing the gauging plastic, measure its compressed width (at the widest point) with the graduations on the gauging plastic envelope (figure 12-63).

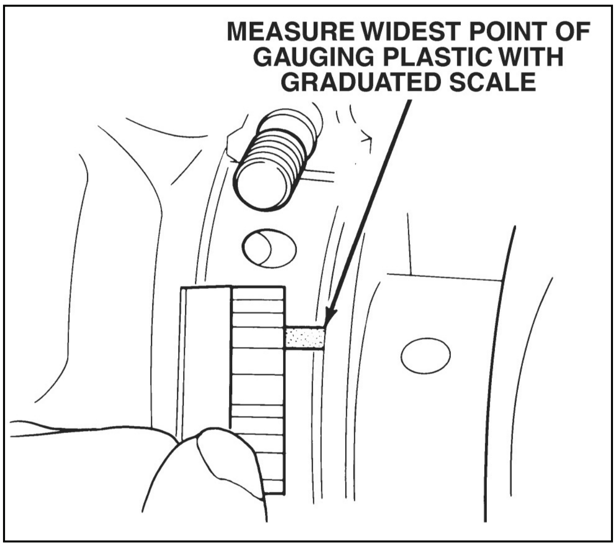


Figure 12-63 Measuring Gauging Plastic

  c. If the flattened plastic tapers toward the middle or ends, there is a difference in clearance indicating taper, low spot, or other irregularity of the bearing or journal.
  d. Normally, crankshaft bearing journals wear evenly and are not out-of-round. However, if a bearing is being fitted to an out-of-round 0.0254 mm (0.001 in.) (maximum) journal, be sure to fit to the maximum diameter of the journal. If the bearing is fitted to the minimum diameter and the journal is excessively out-of-round, interference between the bearing and the journal will result in rapid bearing failure.
  e. If the bearing clearance is within specifications, the bearing is satisfactory. If the clearance is not within specifications, replace the bearing. Always replace both upper and lower bearings as a unit.
  f. A standard or undersize bearing combination may result in the proper clearance. If the proper bearing clearance cannot be achieved using standard or undersize bearings, it will be necessary to replace the crankshaft.

NOTICE: Crankshaft bearings must not be shimmed, scraped, or filed. Do not touch the bearing surface with bare fingers. Skin oil will etch the bearing surface.

  g. Remove the flattened gauging plastic.

  h. Measure remaining journals.

Crankshaft Runout

Figure 12-64

Measure

Tool Required:

J 7872 Magnetic Base Dial Indicator

1. Crankshaft run-out.

A. Mount the crankshaft in V-blocks at crankshaft journals 1 and 4.
B. Use a dial indicator as shown (figure 12-64).
C. If the main journals are misaligned, the crankshaft is bent and must be replaced. The main bearings must also be replaced at the same time.
D. Grind or replace the crankshaft if necessary. In general, the lower inserts (except the # 1 bearing) show the greatest wear and distress from fatigue. Upon inspection, if a lower insert is suitable for reuse, it can be assumed that the upper insert is also satisfactory. If a lower insert shows evidence of wear or damage, both the upper and lower inserts must be replaced.

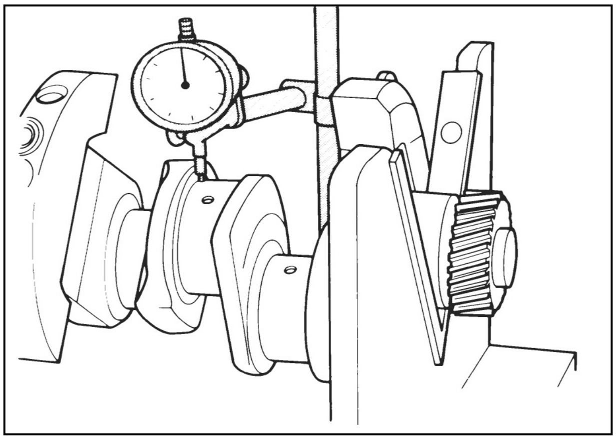


Figure 12-64 Measuring Crankshaft Runout

Crankshaft End Play

Figure 12-65

Measure

- Crankshaft end play as follows:

a. Install crankshaft bearings, crankshaft, caps, and bolts.

b. Tighten bolts to specification.

c. Firmly thrust end of the crankshaft first rearward then forward. This will line up the rear main bearing and crankshaft thrust surfaces.

d. With the crankshaft wedged forward, measure at the front end of the rear main bearing with a feeler gage (figure 12-65). Refer to "Specifications".

IMPORTANT: If correct end play cannot be obtained, be certain that the correct size rear main bearing has been installed. Some production engines may use crankshaft bearings that are wider across the thrust faces than standard size bearings. Refer to "Specifications" for available bearing sizes.

Inspect

- Crankshaft for binding. Turn crankshaft to check for binding. If the crankshaft does not turn freely, loosen the crankshaft bearing bolts, one pair at a time until the tight bearing is located. Burrs on the bearing cap, foreign matter between the bearing and the block or the bearing cap, or a faulty bearing could cause a lack of clearance at the bearing.

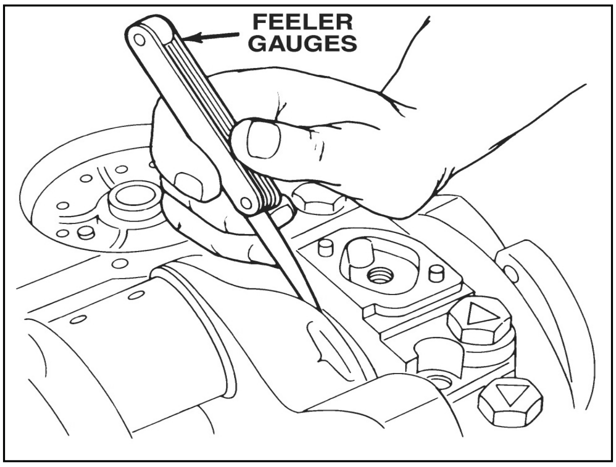


Figure 12-65 Measuring Crankshaft End Play

Connecting Rod Bearings

Follow all procedures outlined for crankshaft bearing cleaning, inspection, and measurement. Refer to "Specifications".

Connecting Rod Side Clearance

Figure 12-66

Measure

- Connecting rod side clearance as shown in figure 12-66. Refer to “Specifications”.

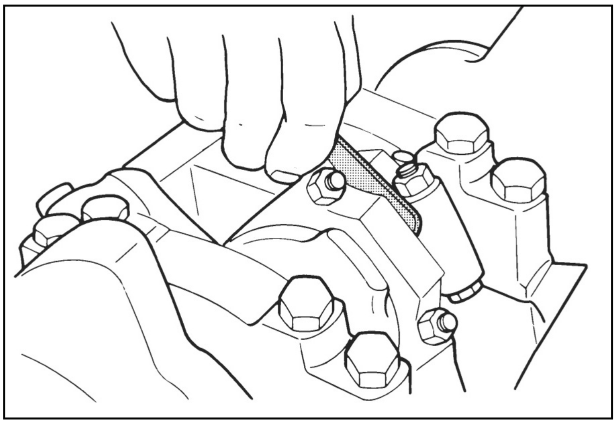


Figure 12-66 Measuring Connecting Rod Side Play

Assembly of Engine

English and Metric Fasteners

⚠ **CAUTION**

Late model engines use a combination of English and Metric threaded fasteners. The components effected are starter motor, engine mounts, and flywheel housing mounting. Verify that the proper fasteners are used whenever removing or replacing one of these components.

Prior to Assembly

The importance of cleanliness during the assembly procedure cannot be overstressed. Dirt will cause premature wear of the rebuilt engine. Lubricate all moving parts lightly with engine oil or engine assembly lubricant (unless otherwise specified) during assembly. This will provide initial lubrication when the engine is started.

Crankshaft And Crankshaft Bearing Installation

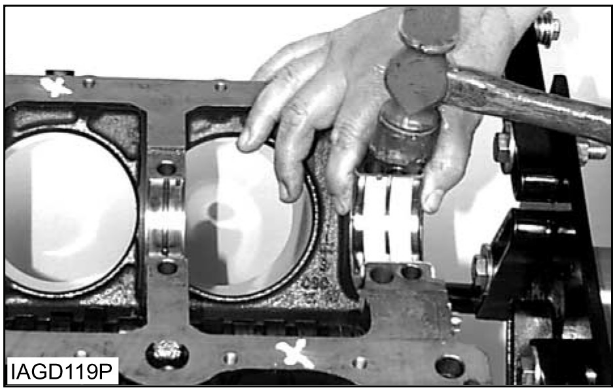
Install or Connect

IMPORTANT: If any undersized bearings are used, they must be fitted to the proper journals.

Start by:

a. Making sure everything is clean

b. Then lubricate all moving parts before they are installed.

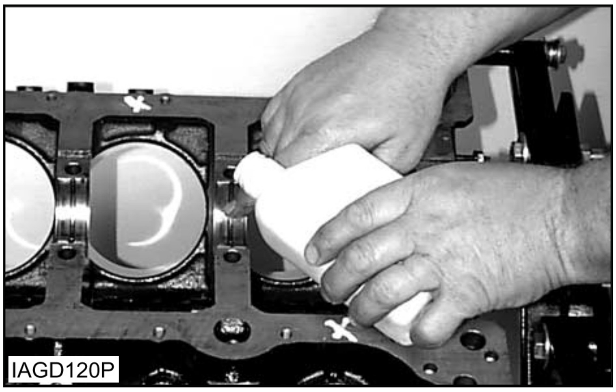


IAGD119P

1. Install upper crankshaft bearings to the block.

NOTICE

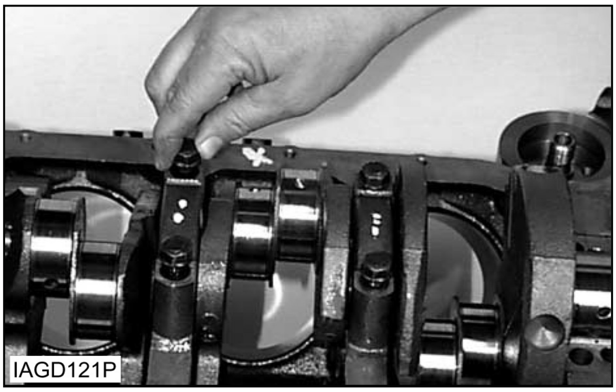
If any undersized bearing are used, they must be fitted to the proper journals.



IAGD120P

2. Lubricate all moving parts lightly with engine oil or engine assembly lubricant.

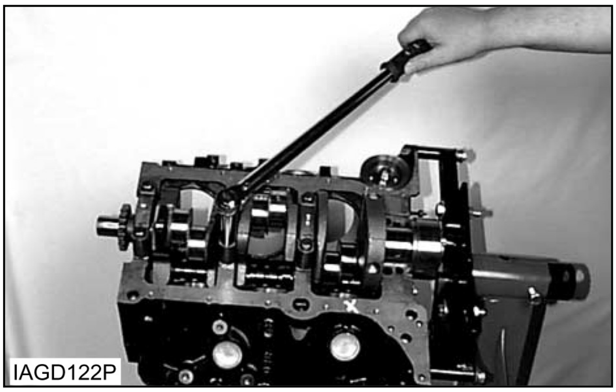
3. Install crankshaft to cylinder block.



IAGD121P

4. Assemble lower crankshaft bearing to crankshaft bearing caps.

5. Install crankshaft bearing caps (except rear cap) and bolts to the block.



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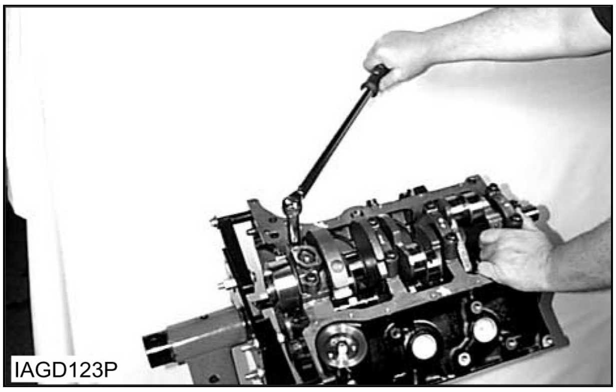
6. Torque crankshaft bearing cap bolts (except rear cap) to : **105 N·m (77lb·ft)**



7. Install rear crankshaft bearing and bolts Torque to : **105 N·m (77lb·ft)**

Crankshaft Rear Oil Seal Housing Installation

Figure 12-67

Clean

• Gasket surfaces on the block and seal retainer.

Install or Connect

1. New gasket to the block.

IMPORTANT: It is not necessary to use sealant to hold the gasket in place.

2. Seal retainer.
3. Screws and nuts.

NOTICE: Refer to “Notice” on page 1.

Tighten

• Screws and nuts to 15 N·m (11 lb·ft.)

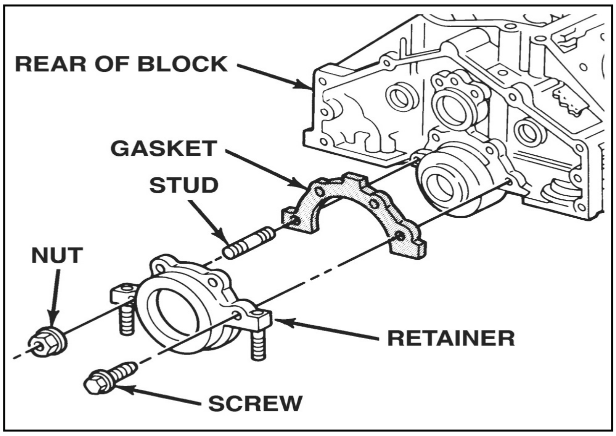


Figure 12-67 Crankshaft Rear Oil Seal Housing and Components

Crankshaft Rear Oil Seal Installation

Figure 12-68

Tool Required:

J 35621 Seal Installer

Install or Connect

1. Crankshaft rear oil seal.
   - **A**. Lubricate the inner and outer diameter of the seal with engine oil.
   - **B**. Install the seal on J 35621.
   - **C**. Position J 35621 against the crankshaft. Thread the attaching screws into the tapped holes in the crankshaft.
   - **D**. Tighten the screws securely with a screwdriver. This will ensure that the seal is installed squarely over the crankshaft.
   - **E**. Turn the handle until it bottoms.
   - **F**. Remove J 35621.

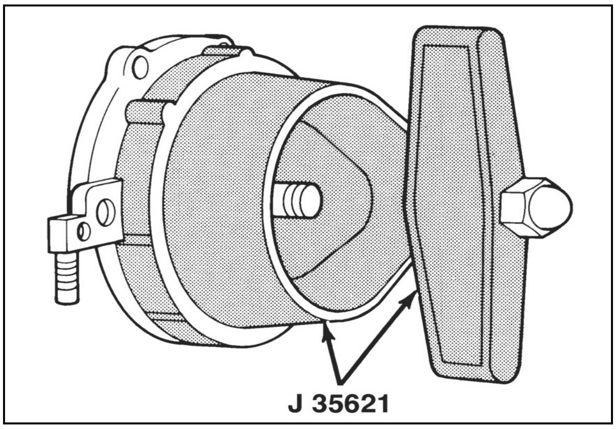


Figure 12-68 Installing Crankshaft Rear Oil Seal

Piston and Connecting Rod Installation

Connecting Rod Bearing Selection

Figures 12-69 and 12-70

Tools Required:

J 5239 Connecting Rod Guide Set
J 8037 Ring Compressor
J 36660 Torque Angle Meter

IMPORTANT: Connecting rod bearings are of the precision insert type and do not use shims for adjustment. DO NOT FILE RODS OR ROD CAPS. If clearances are excessive, install a new bearing. Service bearings are available in standard size and 0.050 mm (0.002 in.), 0.254 mm (0.010 in.), 0.508 mm (0.020 in.), undersize for use with new and used standard size crankshafts.

Install or Connect

1. Lubricate the cylinder walls lightly with engine oil.

2. Make sure the piston is installed in the matching cylinder.

3. Connecting rod bearings.

A. Make sure that the bearing inserts are of the proper size.
B. Install the bearing inserts in the connecting rod and connecting rod cap.
C. Lubricate the bearings with engine oil.

4. Piston and connecting rod into the proper bore.

A. With the connecting rod cap removed, install J 5239 onto the connecting rod bolts (figure 12-69).
B. Locate the piston ring end gaps (figure 12-70). Lubricate the piston and rings with engine oil.

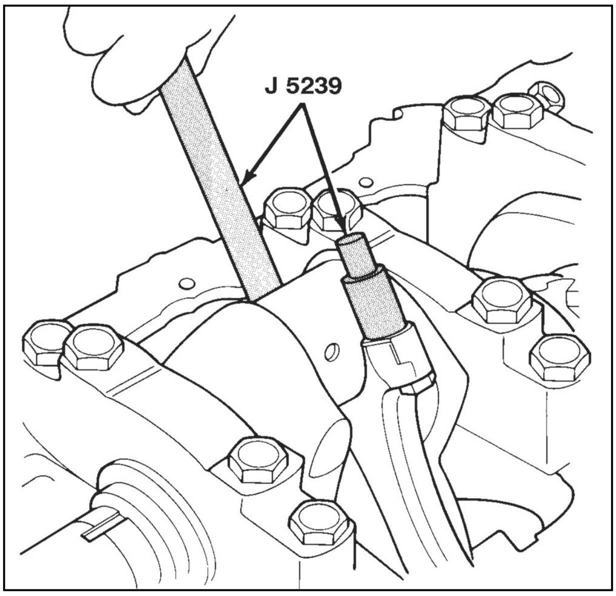


Figure 12-69 Guiding Connecting Rod

C. Without disturbing the ring end gap location, install J 8037 over the piston.
D. The piston must be installed so that the notch in the piston faces the front of the engine.
E. Place the piston in its matching bore. The connecting rod bearing tang slots must be on the side opposite the camshaft. Using light taps with a hammer handle, tap the piston down into its bore (figure 12-71). Guide the connecting rod to the crankpin with J 5239 (figure 12-69). Hold the ring compressor against the block until all rings have entered the cylinder bore.
F. Remove J 5239 from the connecting rod bolts

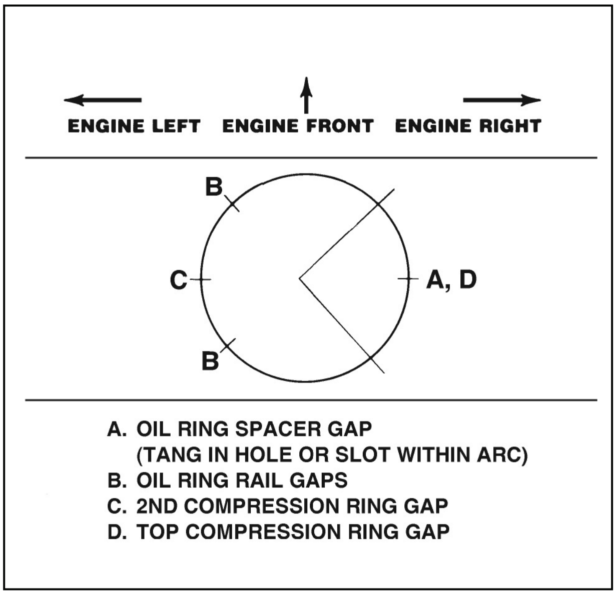


Figure 12-70 Piston Ring End Gap Location

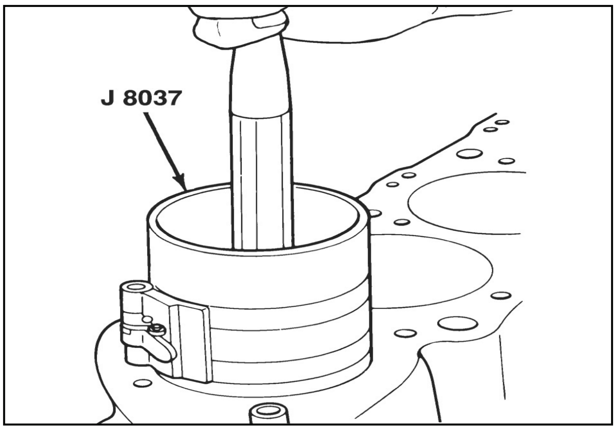


Figure 12-71 Installing Piston

IMPORTANT: Each connecting rod and bearing cap should be marked, beginning at the front of the engine. Cylinders 1, 3, and 5 are the right bank and 2, 4, and 6 are the left bank (when viewed from the front of the engine). The numbers on the connecting rod and bearing cap must be on the same side when installed in the cylinder bore. If a connecting rod is ever transposed from one block or cylinder to another, new connecting rod bearings should be fitted and the connecting rod should be numbered to correspond with the new cylinder number.

NOTICE: Refer to "Notice" on page 1.

5. Connecting rod cap with bearing insert and nut.

Tighten

- Connecting rod bolt nuts to 27 N·m (20 lb·ft.).
- Connecting rod bolt nuts an additional 70° using J 36660.

Measure

- Connecting rod side clearance as outlined previously.

Balance Shaft Installation

Figures 12-72 through 12-76

NOTICE: Refer to "Notice" on page 1.

Tools Required:

J 38834 Balance Shaft Bearing Service Kit
J 36996 Balance Shaft Installer
J 8092 Driver Handle
J 36660 Torque Angle Meter

Install or Connect

1. Balance shaft rear bearing using J 38834 (figures 12-72 and 12-73).

2. Balance shaft into block using J 36996 and J 8092 (figure 12-74).

A. Dip the front balance shaft bearing into clean engine oil before assembly.
B. Retaining ring on balance shaft front bearing must be seated on case.

3. Install balance shaft bearing retainer and bolts.

Tighten

- Balance shaft retainer bolts to 14 N•m (124 lb.in.).

4. Balance shaft driven gear (2) and bolt (1).

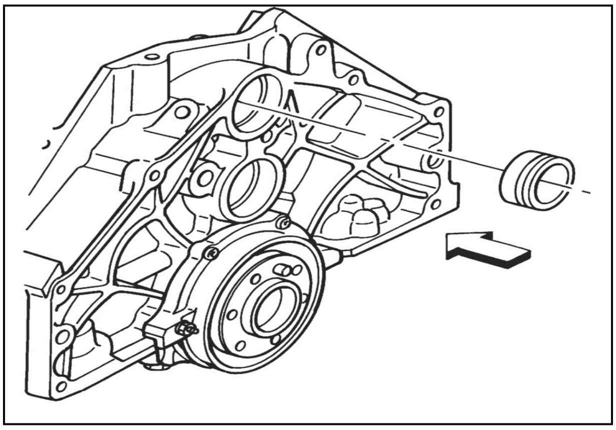


Figure 12-72 Rear Balance Shaft Sleeve Bearing

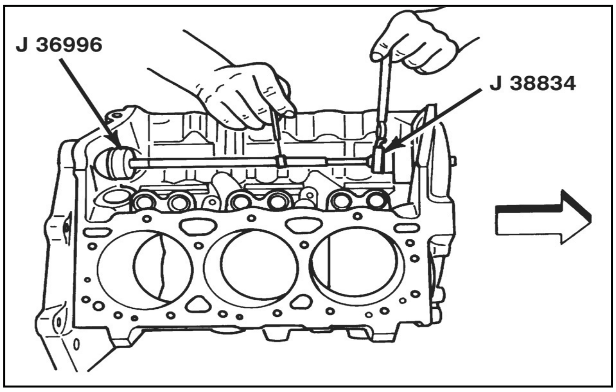


Figure 12-73 Installing Balance Shaft Rear Bearing

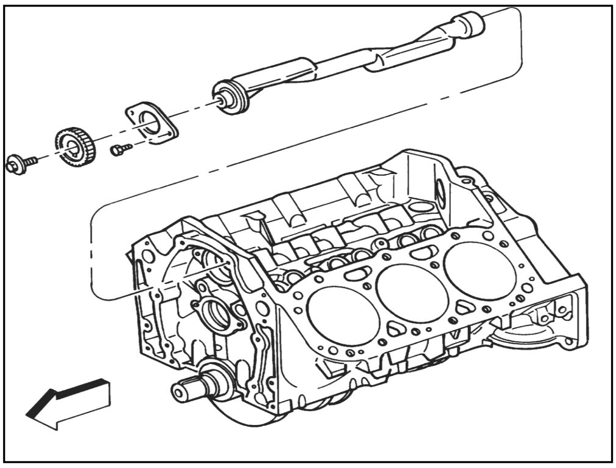


Figure 12-74 Balance Shaft and Components

Tighten

- Balance shaft driven gear bolt to 20 N·m (15 lb. ft.) plus an additional turn of 35° using J 36660.

IMPORTANT: Rotate balance shaft by hand to make sure there is clearance between the balance shaft and retainer. If balance shaft does not rotate freely, check to be sure retaining ring on front bearing is seated on case. Turn the camshaft so, with the balance shaft drive gear temporarily installed, the timing mark on the drive gear is straight up. With the balance shaft drive gear removed, turn the balance shaft so the timing mark on the driven gear points straight down.

5. Balance shaft drive gear onto camshaft.

IMPORTANT: Make sure the timing marks on the balance shaft drive gear and driven gear line up (figure 12-76).

6. Balance shaft drive gear bolt.

Tighten

- Bolt to 16 N·m (12 lb. ft.).

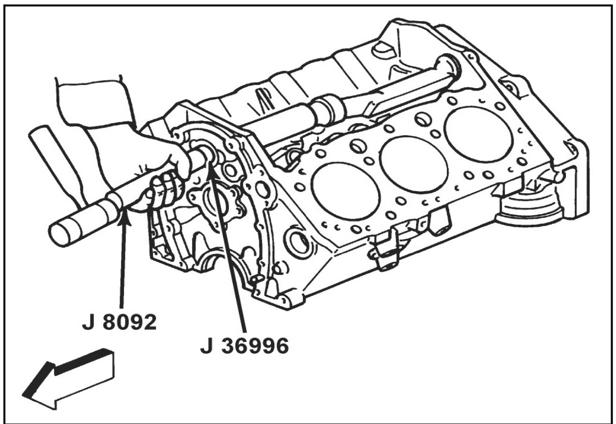


Figure 12-75 Installing Balance Shaft

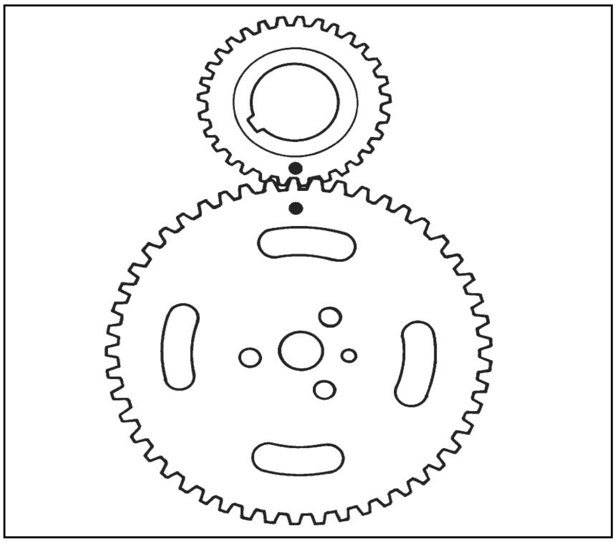


Figure 12-76 Balance Shaft Drive Gear-to- Driven Gear Timing Marks

Camshaft Installation

Figure 12-77

Install or Connect

IMPORTANT: Coat camshaft lobes and journals with Engine Oil Supplement (GM P/N 1052367) or equivalent. Apply Engine Oil Supplement (GM P/N 1052367) or equivalent, to all the teeth on the distributor drive gear.

1. Install three 5/16 x 18 bolts 100 - 125 mm (4 - 5 in.) long into the camshaft threaded holes. Use these bolts to handle the camshaft.

2. Camshaft to the engine (figure 12-77). Handle the camshaft carefully to prevent damage to the camshaft bearings.

NOTICE: Refer to “Notice” on page 1.

3. Camshaft retainer and retainer bolts. Coat camshaft retainer plate with Engine Oil Supplement (GM P/N 1052367) or equivalent.

Tighten

- Bolts to 14 N·m (124 lb. in.).

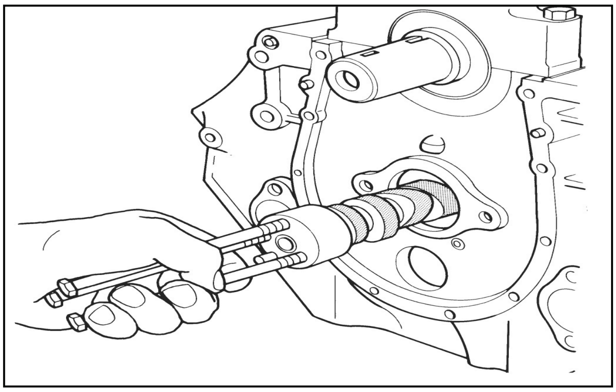


Figure 12-77 Installing Camshaft

Timing Chain and Camshaft Sprocket Installation

Figure 12-78

Install or Connect

1. Camshaft sprocket and timing chain (figure 12-78).

IMPORTANT: Line up the timing marks on the camshaft sprocket and crankshaft sprocket (view A, figure 12-78). The number 4 cylinder is at top dead center of the compression stroke with the timing marks in this position.

2. Camshaft sprocket bolts and nut.

Tighten

- Camshaft sprocket bolts and nut to 28 N·m (21 lb·ft.).

Engine Front Cover Installation

IMPORTANT: Once the composite front engine cover is removed, DO NOT reinstall it. Always install a new engine front cover.

Install or Connect

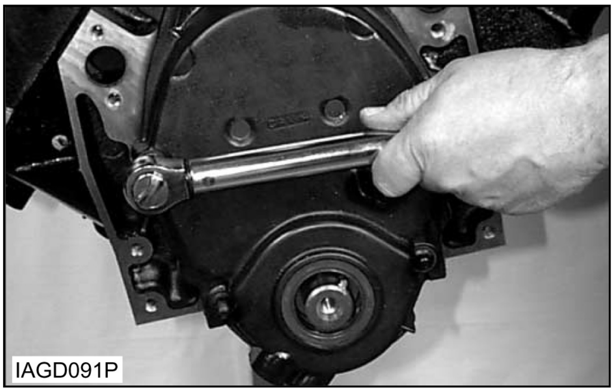
1. Engine front cover to engine.

2. Front cover bolts.

NOTICE: Refer to "Notice" on page 1.

Tighten

- Front cover to block bolts to 9 N·m (80 lb. in.).



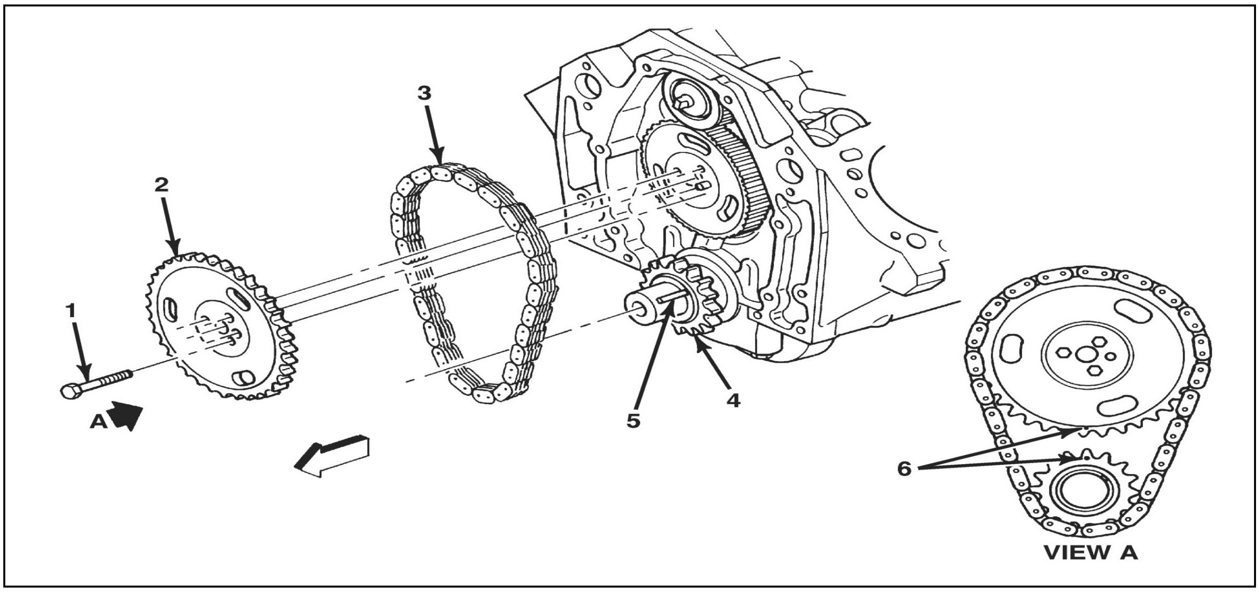


Figure 12-78 Camshaft Timing Chain and Sprockets

Torsional Damper Installation

Figure 12-79

Tool Required:

J 39046 Torsional Damper Puller and Installer

Install or Connect

1. Apply RTV sealant GM P/N 12345739 to crankshaft keyway (if removed).
2. Crankshaft key (if removed).

NOTICE: The inertial weight section of the torsional damper is assembled to the hub with rubber type material. The correct installation procedures (with the proper tool) must be followed or movement of the inertial weight section of the hub will destroy the tuning of the torsional damper.

3. Stud (part of J 39046) to the crankshaft. Thread the stud fully into the tapped hole in the crankshaft.

4. Torsional damper over the end of the stud. Align the keyway in the torsional damper shaft with the crankshaft key.

5. Bearing, washer, and nut.

   A. Turn the nut to pull the torsional damper into place (figure 12-79).
   B. Remove the tool.

6. Torsional damper bolt and washer.

NOTICE: Refer to “Notice” on page 1.

Tighten

• Bolt to 95 N·m (70 lb. ft.).

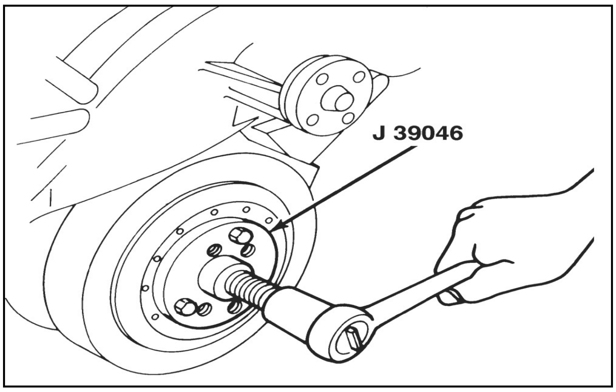


Figure 12-79 Installing Torsional Damper

Oil Pump Installation

Figure 12-80

Install or Connect

1. Oil pump to the engine.

   • Align the slot in the oil pump shaft with the tang on the distributor shaft.
   • The oil pump should slide easily into place.
   • No gasket is used.

2. Oil pump to main bearing cap bolt.

NOTICE: Refer to “Notice” on page 1.

Tighten

• Oil pump to main bearing cap bolt to 90 N·m (66 lb. ft.).

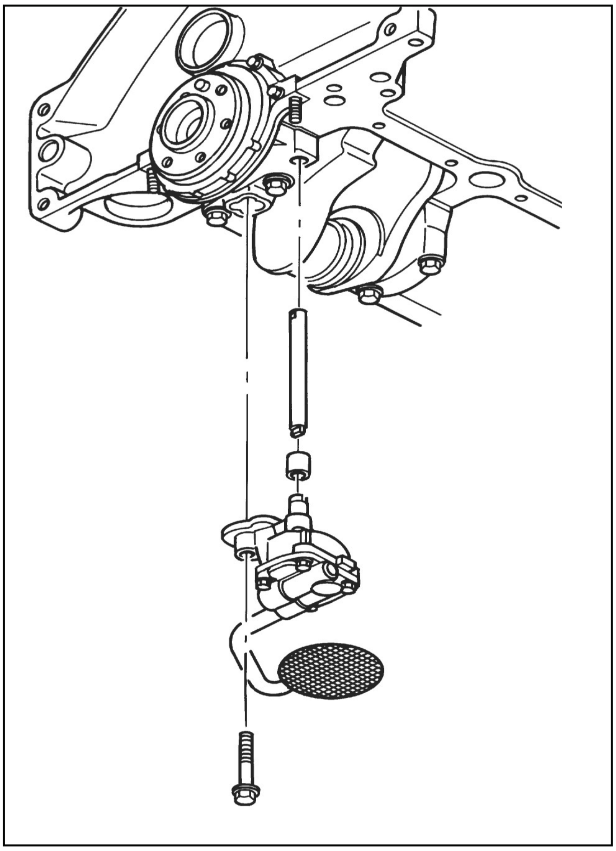


Figure 12-80 Oil Pump Installation

Oil Pan Installation

Figures 12-81 through 12-85

Tool Required:

J 34673 Straightedge or equivalent

Install or Connect

1. Apply RTV sealant (GM P/N 12346141) or equivalent to the front cover to block joint and to the crankshaft rear retainer seal to block joint. Apply the sealant about 25 mm (1.00 in.) in both directions from each of the four corners (figures 12-81 and 12-82).

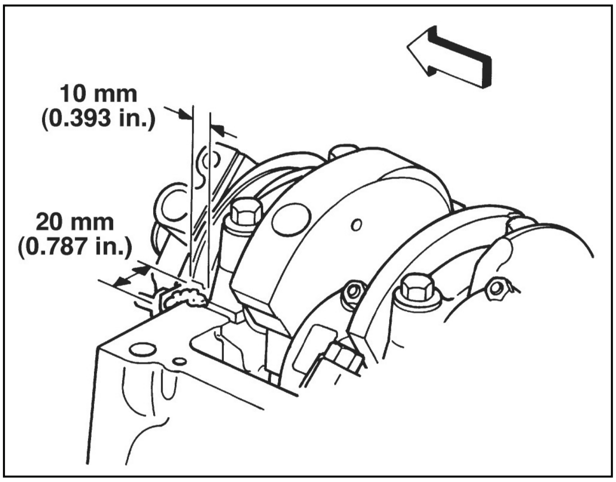


Figure 12-81 RTV Sealing Points - Front of Oil Pan

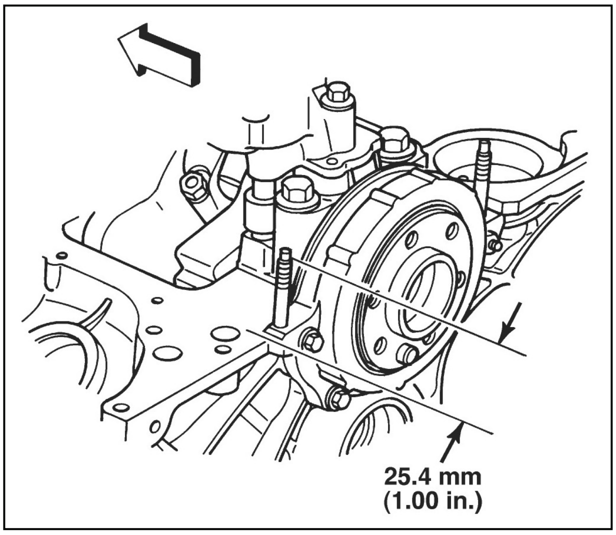


Figure 12-82 RTV Sealing Points - Rear of Oil Pan

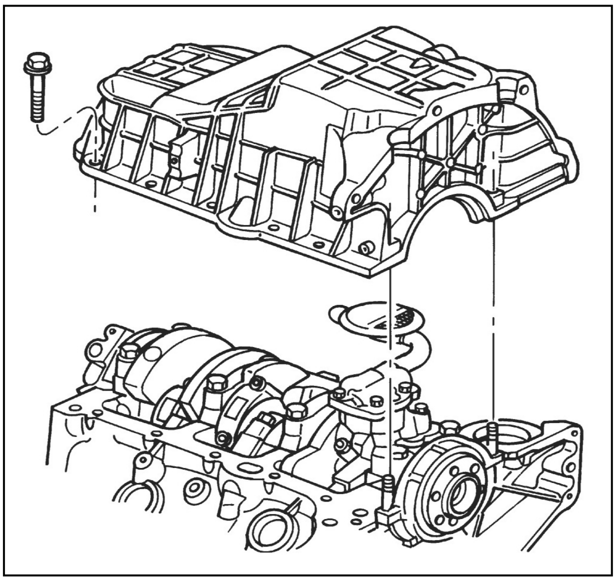


Figure 12-83 Installing Oil Pan to Engine Block

2. Oil pan gasket onto pan.

3. Oil pan to cylinder block (figure 12-83).

4. Slide oil pan back against straightedge using J 34673 or equivalent.

5. Oil pan bolts and nuts but do not tighten.

NOTICE: Refer to "Notice" on page 1.

Tighten

- Bolts to 25 N·m (18 lb·ft.) in the sequence shown (figure 12-84).
- Nuts to 23 N·m (17 lb·ft.).

6. Oil filter gasket.

7. Oil filter adapter O-ring seal, if equipped.

8. Oil filter adapter bolts (figure 12-85).

Tighten

- Bolts to 25 N·m (18 lb·ft.).

Inspect

- Oil filter adapter bypass valve and spring for operation.
- Bypass valve for cracks. If bypass valve looks damaged in any way, replace the oil filter adapter assembly.

9. Lubricate new oil filter seal with clean engine oil.

10. Oil filter.

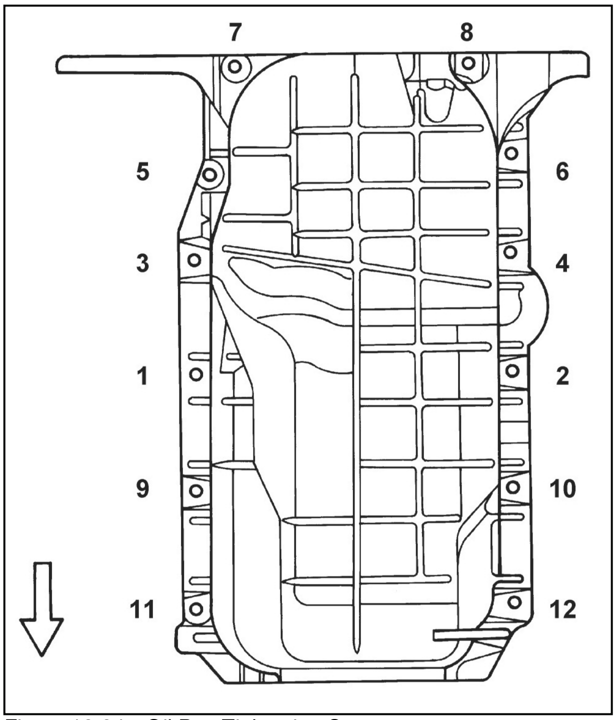


Figure 12-84 Oil Pan Tightening Sequence

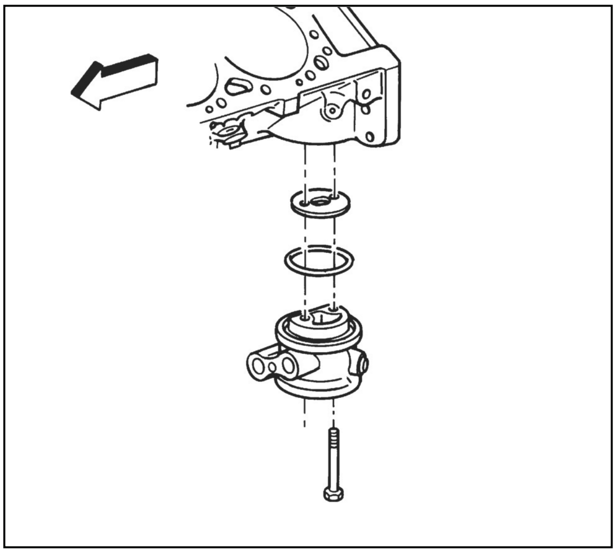


Figure 12-85 Oil Filter Adapter Installation With Oil Cooler (Typical)

Cylinder Head Installation

Figure 12-86

Tool Reqired:

J 36660 Torque Angle Meter

Clean

• Gasket surfaces on the block and cylinder head

Install or Connect

1. Head Gasket

IMPORTANT: Do not use sealer on head gaskets. Place the gasket over the block dowel pins with the head up.

2. Cylinder head. Carefully guide the cylinder head into place over the dowel pins and gasket.

Notice: Refer to “Notice” on page 1.

3. Cylinder head bolts. Coat threads of the cylinder head bolts with sealing compound (GM P/N 12346004) or equivalent and install fingertight.

Tighten

A. Bolts to 30 N·m (22 lb.ft.).
B. Bolts in sequence using J 36660 to:
- Short length bolt (11, 7, 3, 2, 6, 10) 55°
- Medium length bolt (12, 13) 65°
- Long length bolt (1, 4, 8, 5, 9) 75°

4. Spark plugs.

Tighten

• Spark plug - new cylinder head to 30 N·m (22 lb·ft.).
• All other subsequent installations to 20 N·m (15 lb·ft.).

Valve Train Component Installation

Figure 12-87 and 12-88

IMPORTANT: Replace all valve roller lifters, change the engine oil and filter, and add GM Engine Oil Supplement GM P/N 1052367 (or equivalent) to the engine oil whenever a new camshaft is installed. Lubricate the valve lifters bodies and roller with GM Engine Oil Supplement GM P/N 1052367 (or equivalent)

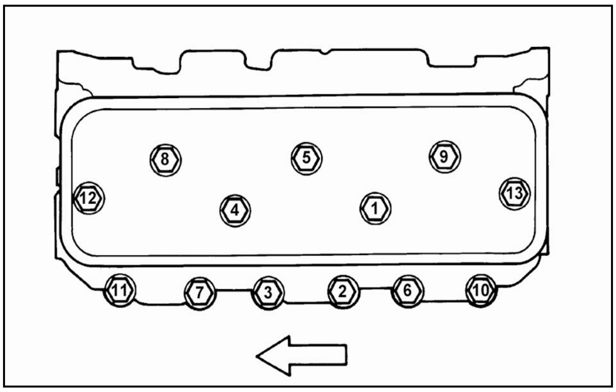


Figure 12-86 Cylinder Head Bolt Tightening Sequence

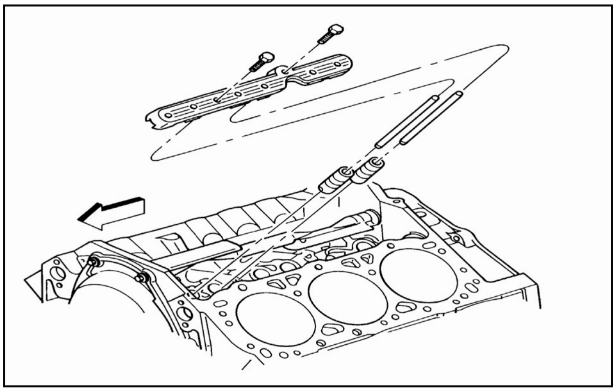


Figure 12-87 Valve Train Components

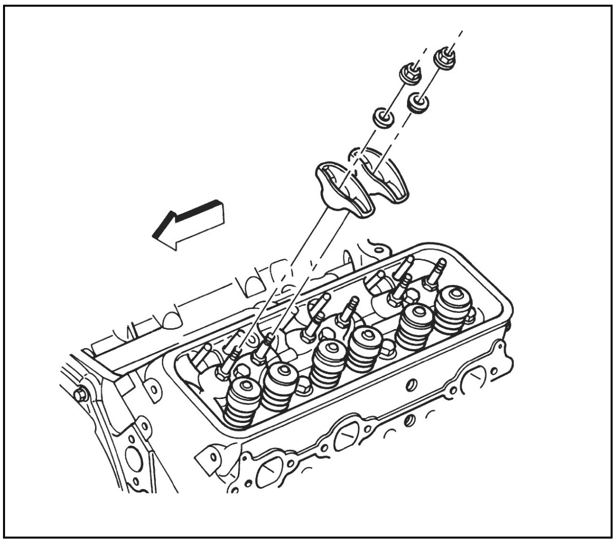


Figure 12-88 Valve Rocker Arms and Components

Install or Connect

1. Valve lifters to the block.
2. Valve lifter guide and bolts. Note previously made mark on the valve lifter guide. Reference mark should be pointing toward front of engine.

Tighten

- Guide bolts to 16 N·m (12 lb·ft.).

3. Valve pushrods.

   A. Seat the valve pushrods into the socket of the valve lifters.
   B. Coat the mating surfaces of the valve rocker arms and balls with Engine Oil Supplement GM P/N 1052367 (or equivalent).

4. Valve rocker arms with balls on to the proper stud.
5. Valve rocker arm nuts onto the studs (figure 12-88). Align the push rod into the valve rocker arm while tightening valve rocker arm nut. No lash adjustment is needed.

Tighten

- Valve rocker arm nuts to 25 N·m (18 lb·ft.).

Valve Adjustment

The 4.3L engine has screw-in rocker arm studs with positive stop shoulders, no valve adjustment is necessary. When the valve train requires service, you simply tighten the rocker arm nuts to 25 N·m (18 lb. ft.).

Intake Manifold Installation

Figures 12-89 and 12-90

Install or Connect

1. Gaskets to the cylinder head with the port blocking plates facing the rear of the engine.
2. RTV to the front and rear sealing surfaces on the block. Apply a 13 mm (1/2 in.) bead of RTV (GM P/N 1052366) or equivalent to the front and rear of the block as shown in figure 12-89. Extend the bead 4 mm (5/32 in.) up each cylinder head to seal and retain the gaskets.
3. Intake manifold to the engine.
4. Intake manifold bolts.

Tighten

- Intake manifold bolts in three steps using sequence shown in figure 12-90.

  - Bolts in sequence to 3 N·m (27 lb. in.).
  - Bolts in sequence to 12 N·m (106 lb. in.).
  - Bolts in sequence to 15 N·m (11 lb·ft.).

Rocker Arm Cover Installation

Figure 12-91

Install or Connect

1. New gasket.
2. Valve rocker arm cover.
3. Valve rocker arm cover bolts.

Tighten

- Rocker arm cover bolts to 12 N·m (106 lb. in.).

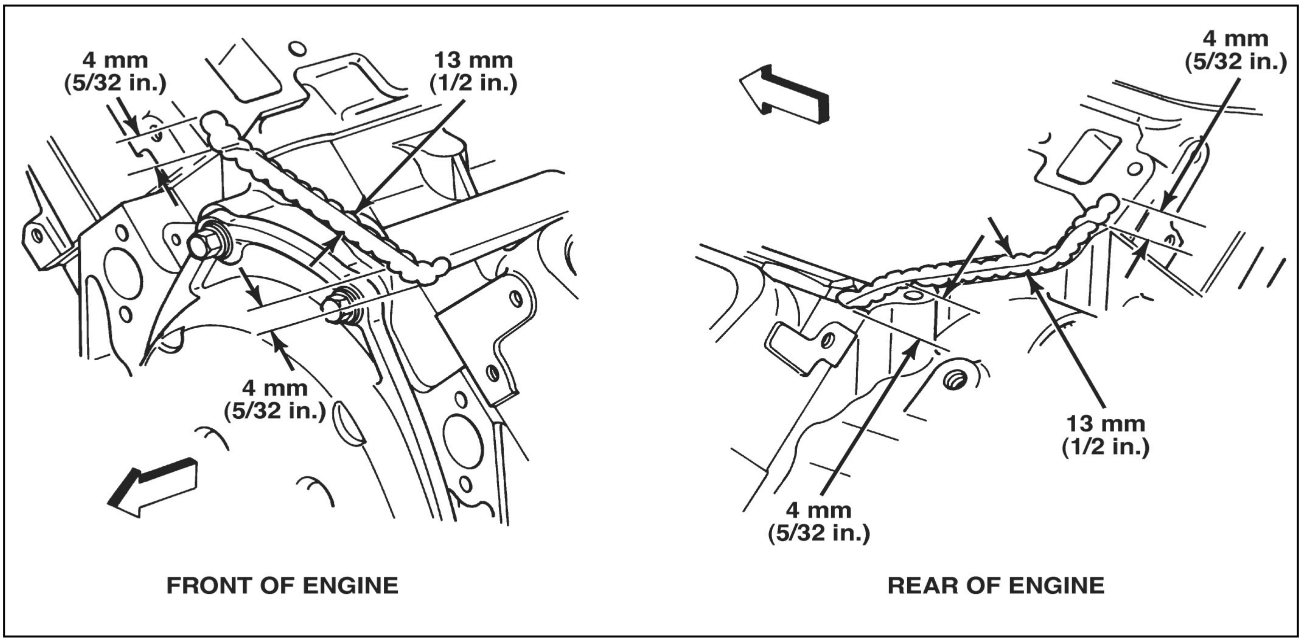


Figure 12-89 Intake Manifold Sealer Application

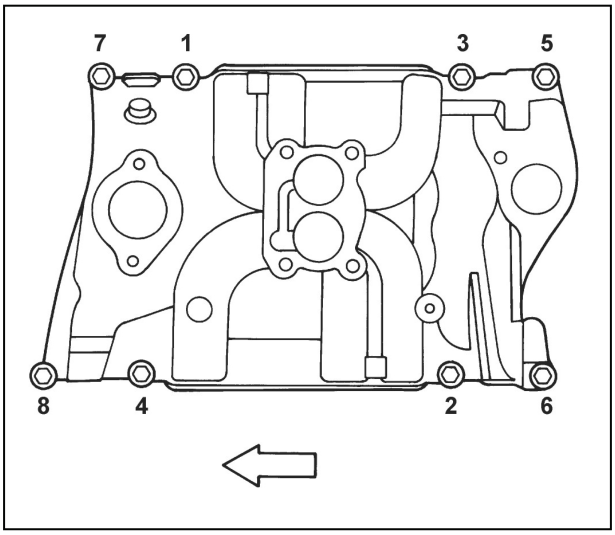


Figure 12-90 Intake Manifold Tightening Sequence

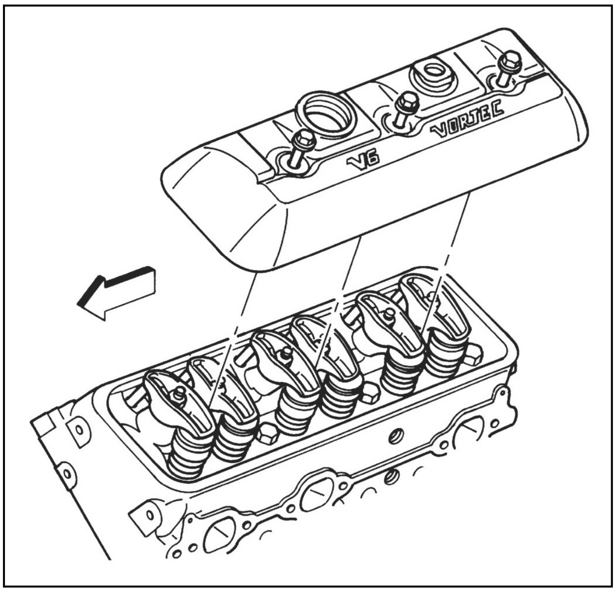


Figure 12-91 Valve Rocker Arm Cover Installation

Exhaust Manifold Installation

Figures 12-92

Install or Connect

1. Exhaust manifold gaskets.

2. Exhaust manifold.

3. Heat shield.

4. Exhaust manifold bolts and / or nuts.

Tighten

• Bolts in two steps, beginning with the two center bolts:

   A. Bolts to 15 N·m (11 lb·ft.).

   B. Bolts to 30 N·m (22 lb·ft.).

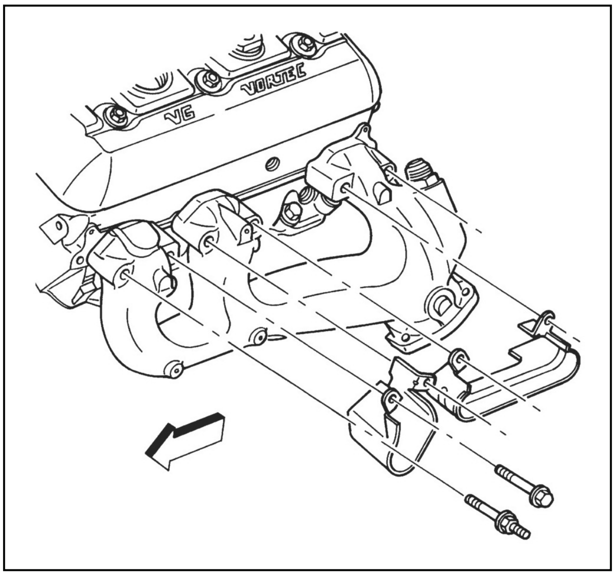


Figure 12-92 Exhaust Manifold

Flywheel Housing Installation

1. Place the flywheel housing to location.

2. Install the eight bolts that hold the flywheel housing to location. Tighten the bolts to a torque of **40 to 45 N·m (30 to 35 lb·ft.)**

3. See Testing and Adjusting for correct procedure to check flywheel housing runout.

Engine Flywheel Installation

Figure 12-93

Install or Connect

1. Flywheel.

2. Flywheel bolts.

Tighten

• Bolts to 100 N•m (74 lb·ft.).

3. Check flywheel runout using a dial indicator. If runout is excessive, remove flywheel, check and clean mounting surfaces and install flywheel. Check runout again.

Measure

• Maximum flywheel runout: 0.20 mm (0.008 in.)

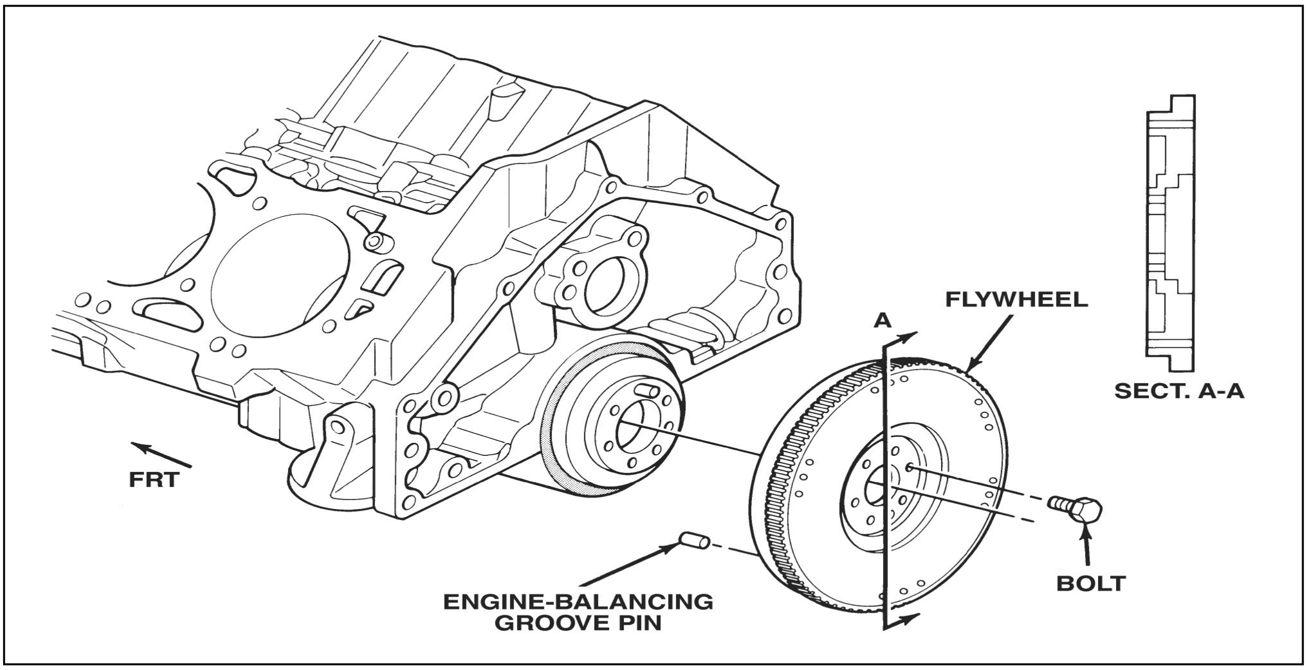


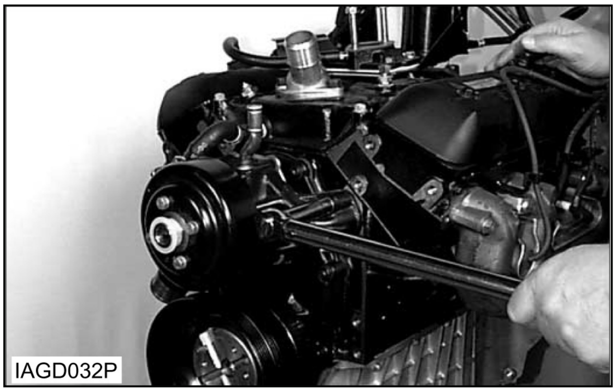
Figure 12-93 Engine Flywheel

Coolant Pump Installation

Install or Connect

1. Install gasket to block

2. Install pump to location.



IAGD032P

3. Assemble bolts to pump and toque to: **40 N·m (30 lb·ft.)**

4. Assemble pulley to pump.

5. Assemble bolts to pulley and torque to **25 N·m ± 6 (18.0 ± 4.5 lb·ft.)**

Engine Accessory Installation

Install the engine accessories (distributor, oil filter, generator, etc.). Connect all vacuum hoses and electrical equipment the same way as removed.

Engine Setup and Testing

After overhaul, turn the engine over manually and inspect for any unusual noises or evidence that parts are binding. If parts are binding disassemble engine to determine the source.

1. Install oil filter (if not already installed).

2. Fill the crankcase with the proper quantity and grade of engine oil.

IMPORTANT: If a new camshaft or hydraulic lifters were installed, add Engine Oil Supplement GM P/N 1052367 (or equivalent) to the engine oil.

3. Fill the cooling system with the proper quantity and grade of coolant.

4. Crank the engine several times. Listen for anyunusual noises or evidence that parts are binding.

5. Refer to “Specifications” for ignition timing adjustment.

6. Start the engine and listen for unusual noises.
7. Run the engine at about 1000 RPM until it is at operating temperature.

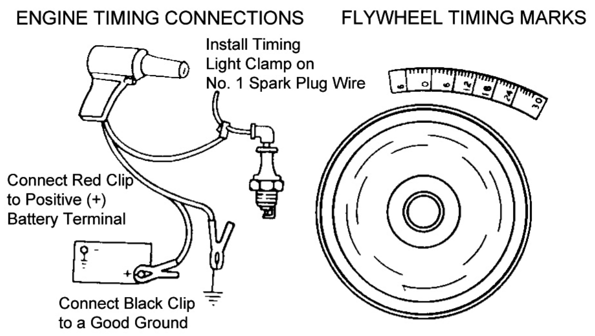
8. Listen for sticking lifters and other unusual noises.

9. Check for oil and coolant leaks while the engine is running.

Chapter 4. ENGINE ELECTRICAL SYSTEM

Specifications

Ignition Timing



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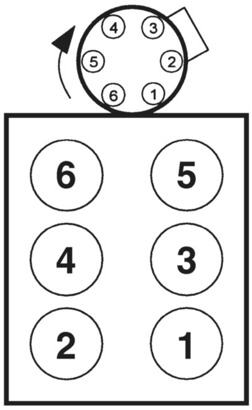
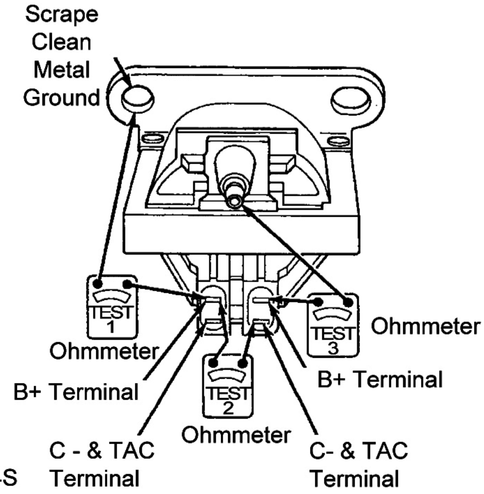
The correct timing is when the flywheel housing pointer is in alignment with the correct mark on the flywheel or when the single digit mark on the flywheel is in alignment with the correct timing mark on the timing plate.

Ignition Sequence (Firing Order)



Engine firing order..................................1-6-5-4-3-2

Ignition Coil



IAGS004S

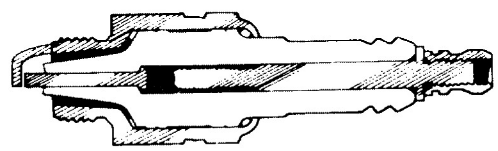
Rating..12 Volts

Resistance between B+ and ground (coil mounting bracket) .... in finite

Resistance between B+ and C-................. 0.4 ohms

Resistance between B+ coil high voltage tower....... .... 8,000 ohms

Spark Plug



IAGS009S

Spark plug gap (gasoline & LP) ..... 0.8 mm (.035 in)

Torque for spark.............................30 N·m (22 lb·ft)

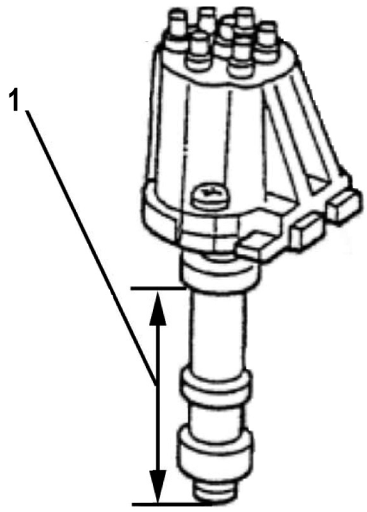
Spark plug wire Resistance

0-15 inch .... 3,000-10,000 ohms

15-25 inch .... 4,000-15,000 ohms

25-35 inch .... 6,000-20,000 ohms

Distributor

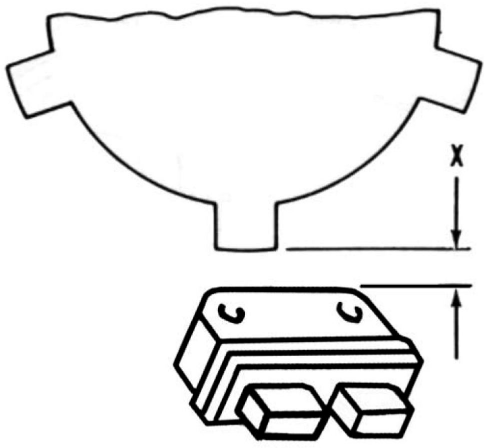


IAGS013S

(1) Shaft end play ...197 to 198 mm (7.75 to 7.80 in)

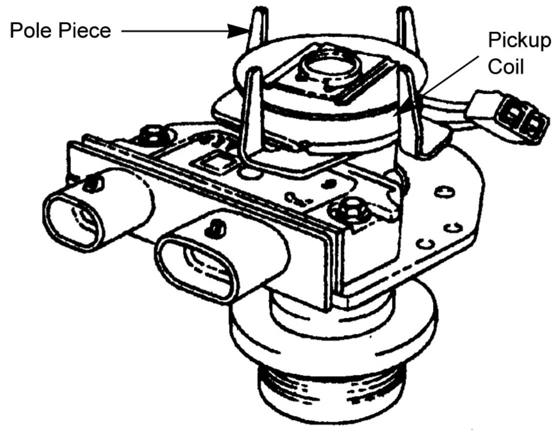
The distributor end play will be checked with the distributor in an inverted position from normal. Measure from the mounting surface to the face of the gear.

Sensor Gap



IAGS014S

The Air gap (X) between the trigger wheel and the module is preset by General Motors. Therefore no adjustment can be made or is required.



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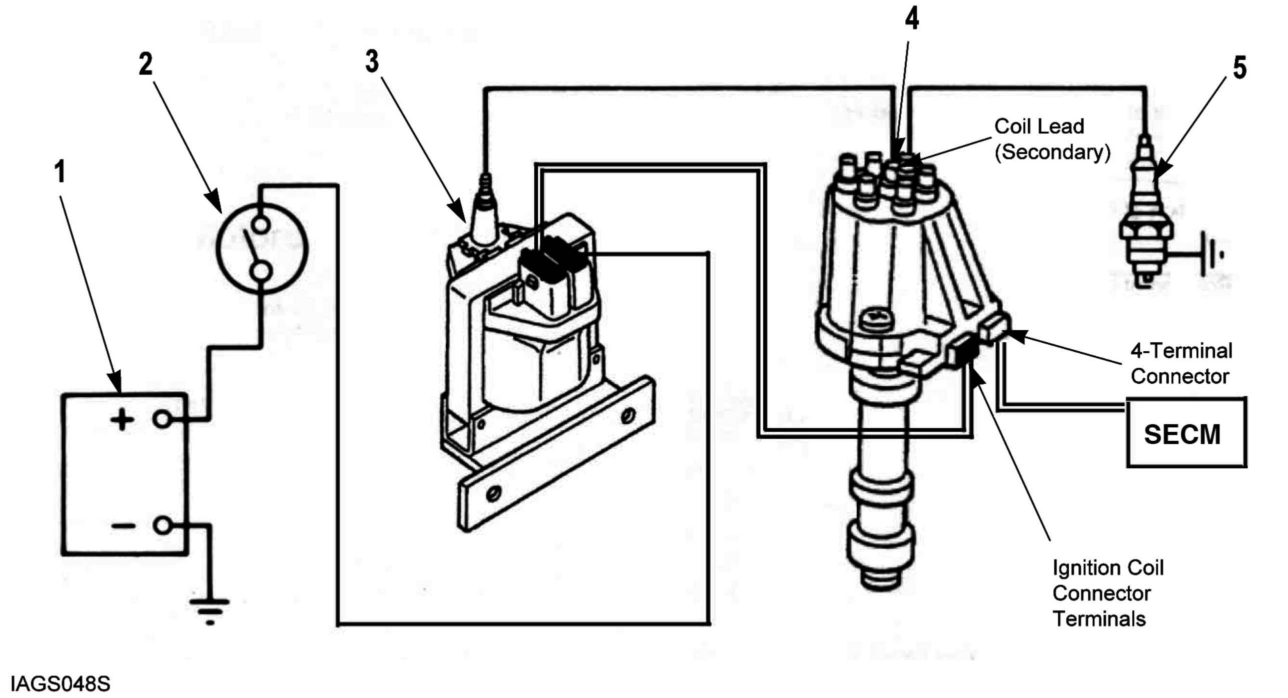
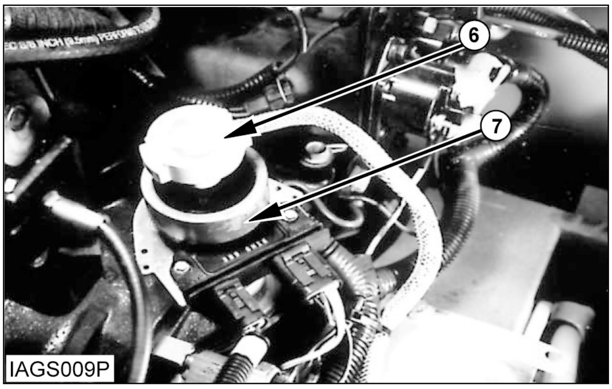
Ignition System

General Description



Ignition System Schematic
(1) Battery. (2) Ignition switch. (3) Coil. (4) Distributor. (5) Spark plug.



Distributor Components
(6) Sensor. (7) Trigger wheel

The ignition system has battery (1), ignition switch (2), coil (3), distributor (4) with inner electronics circuits and spark plugs (5). The battery and ignition switch have terminals and closed contacts to permit battery current flow through the ignition system. These components must have closed current connections to complete the operation of the ignition circuit. Coil (3) and spark plugs (5) are of the standard type. The ignition coil changes the low voltage current into high voltage current to make a spark at the gap of the spark plug. The coil has two windings around a soft iron core. The primary has a small number of turns of heavy wire, and the secondary has many thousand turns of a very fine wire. The primary winding is on the outside of the secondary windings. The distributor has a sensor (6), trigger wheel (7) with lobes and the electric circuit that is a sealed unit inside the distributor housing.

Ignition System Control

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

• SECM

• Distributer with ignition module ∗

• Ignition coil(s) ∗

• Crankshaft position sensor ∗

• Crankshaft timing wheel ∗

• Spark plugs ∗

(∗) Customer-supplied components

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

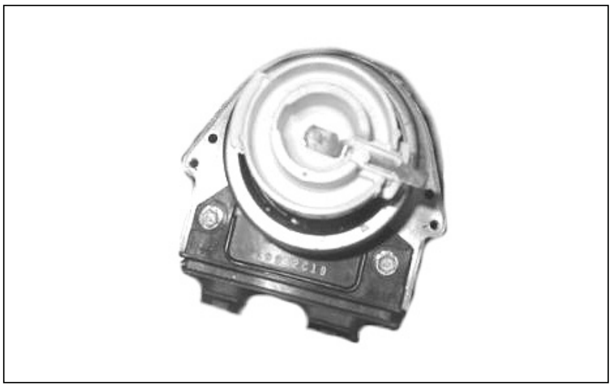
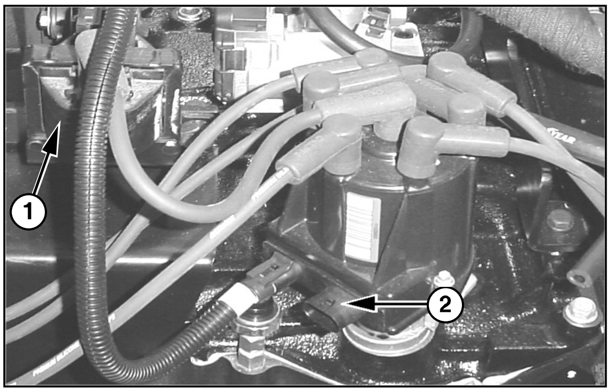


Figure 14. GM Distributor

The MI-07 system is capable of operating with either a distributor based ignition system or a distributorless ignition system. The current application uses a distributor based ignition system. The distributor will have no internal advance mechanisms giving the SECM consistent authority over ignition timing. The spark is sent to the appropriate cylinder in the conventional way via the rotor arm and spark plug wires. The SECM uses the signal from the GM (General Motors) Delco Ignition Module to determine the engine position and RPM at any time. It uses this information together with the information from the TPS sensor and TMAP to calculate the appropriate ignition timing settings.

The General Motors (GM) distributor (Figure 14) used in the Delco EST ignition system, incorporates a Variable Reluctance (VR) sensor, which transmits a reference signal to the GM ignition module (Figure 15) located on the distributor. A variable reluctance sensor is an electromagnetic device consisting of a permanent magnet surrounded by a winding of wire. The sensor is used in conjunction with a ferrous signal rotor on the distributor shaft. The signal rotor has six lobes, one for each cylinder. Rotation of the signal rotor near the tip of the sensor changes the magnetic flux, creating an analog voltage signal in the sensor coil.

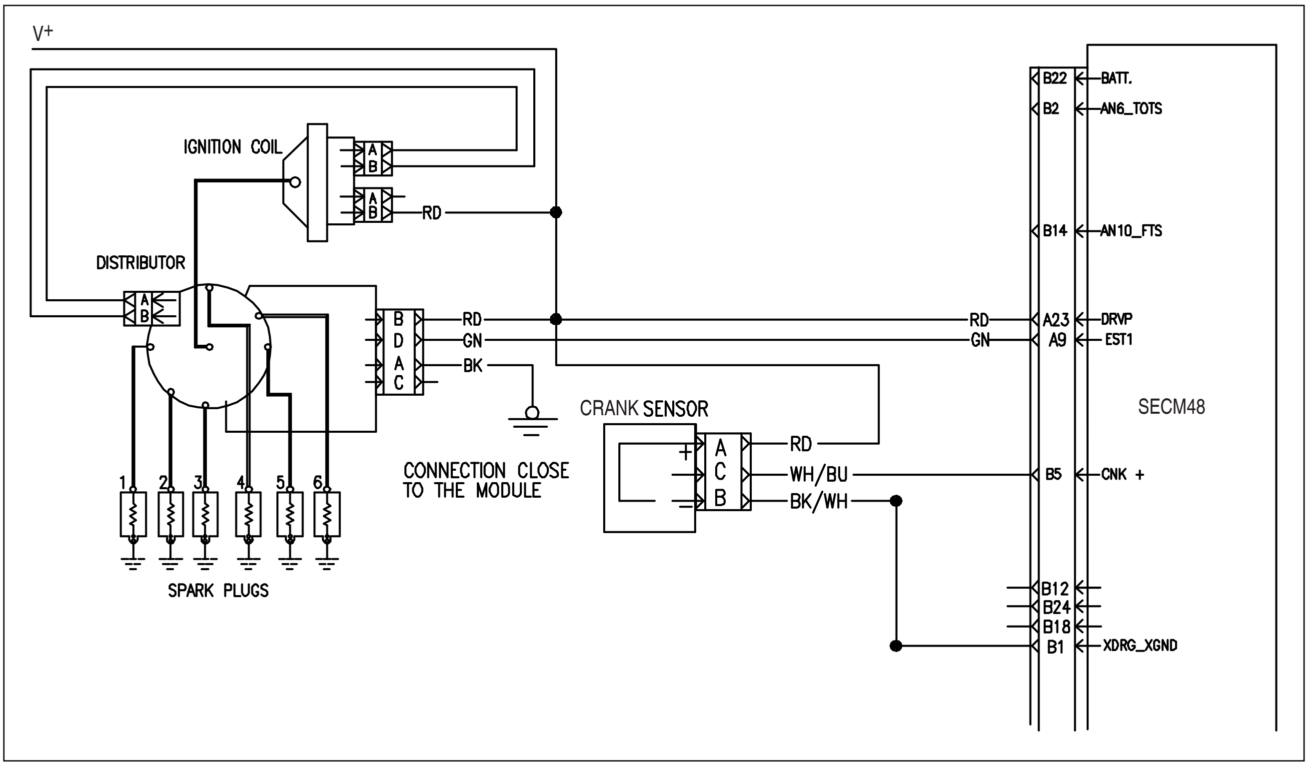


(1) Ignition Coil. (2) Ignition Module.

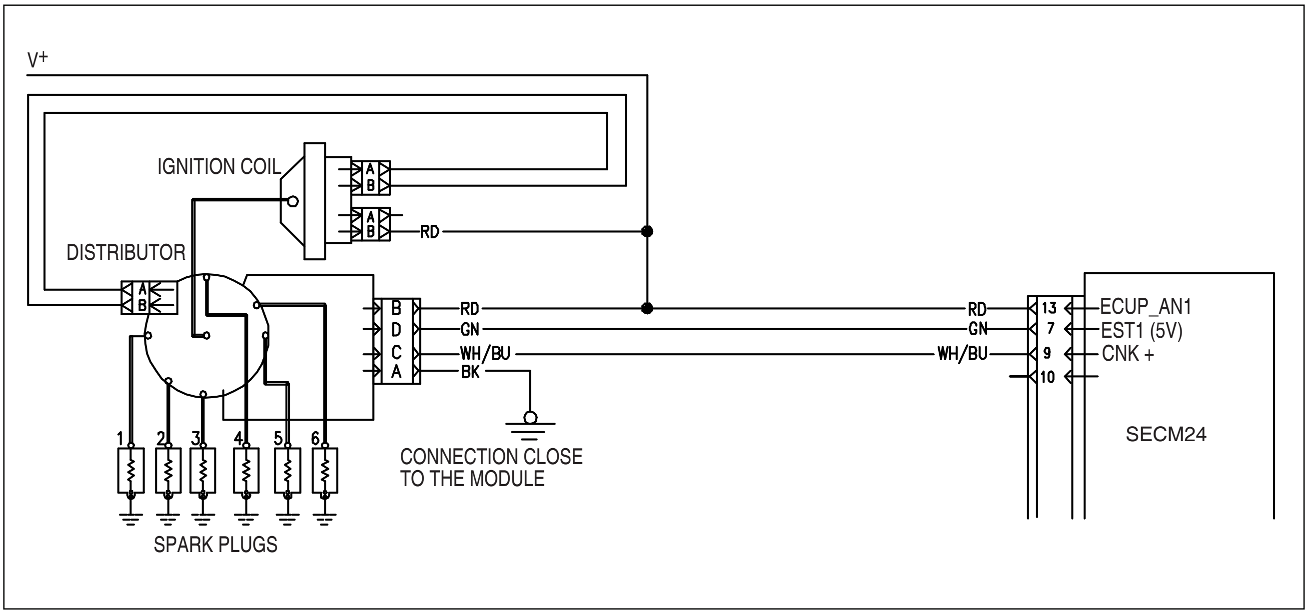
Figure 15. GM Ignition Module

The rising edge of the VR signal is converted to a rising 5-volt signal by the ignition module. As the VR signal passes back through zero volts, a falling edge is created producing a square wave or digital signal, similar to the signal produced by a Hall effect sensor. This falling edge signal provides a stable engine position reference at all engine speeds for the SECM.

Ignition System Schematic for G643E



Ignition System Schematic for G643



Ignition System Inspection

Adhere to the following warnings when performing any tests or adjustments while the engine is running.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

⚠ WARNING

Exhaust fumes contain carbon monoxide (CO) which can cause personal injury or death. Start and operate the engine in a well ventilated area only. In an enclosed area, vent the exhaust to the outside.

If the engine will not start, do the steps for ignition Component Checks. Check the starting and the fuel systems for correct operation. If these systems are correct, use the procedures given in ignition System Test to check the ignition system.

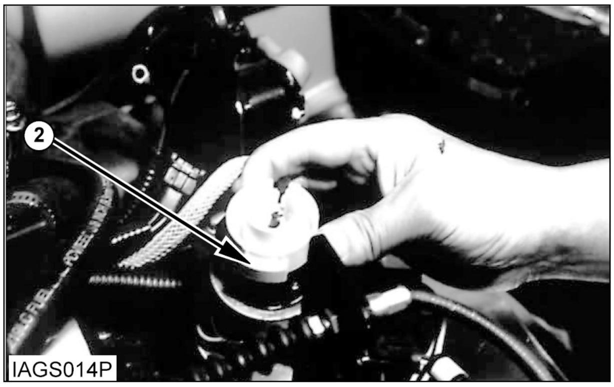
Ignition Component Checks

Distributor Cap Inspection
(1) Distributor cap.

The procedures that follow are given as a guide. Use these procedures to find possible solutions for ignition problems.

Tools Needed	
Digital Mutimeter or Equivalent	1

1. Inspect distributor cap (1). Look for breaks, cracks or dirt inside and on the outside. Clean the distributor cap inside and out.



Inspection of Distributor Rotor
(2) Distributor rotor.

NOTE: Current models do not have a resistor in the rotor and do not need to be checked for resistance.

2. Inspect the rotor (2) for breaks and cracks. Check the rotor blade and the spring for tension. Check the rotor for fit on the distributor shaft. Replace the rotor if the spring tensionor its fit on the distributor is not correct

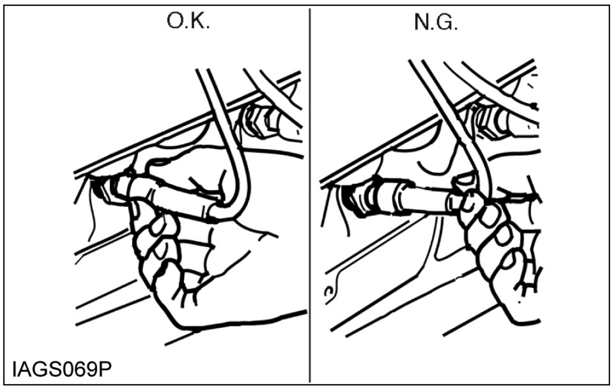
For the correct resistance value of rotor, see Distributer in Specifications.

Spark Plug Wires Inspection

3. Inspect the spark plug wires and the ignition coil wire for wear, burnt and high voltage leaks. Check the resistance of the spark plug wires, with a Digital Multimeter.

For the correct resistance value, see Spark Plug And Spark Plug Wires in Specifications.

NOTE: The Electrical System Analyzer can be used on the ohmmeter scale for the spark plug resistance test.



Spark Plug Inspection
(3) Spark plug.

4. During installation of the spark plug wires, makesure the wire terminals make good connections inthe distributor cap and on the spark plugs. Inspectspark plug (3) insulator for cracks. Clean the sparkplug of any oil or dirt before installation.

Inspection of Spark Plug Wires

General Description

The spark plug wires are a carbon-impregnatedcord conductor encased in an 8 millimeter diameter silicone rubber jacket. Silicone wiring will withstand very high temperature and is an excellent insulator for the higher voltages.

Silicone is soft, pliable, and therefore, more susceptible to scuffing and cutting. It is extremely important that the spark plug cables be handled with care. They should be routed so as not to cross each other, or be in contact with, other parts of the engine to prevent rubbing.

NOTICE: For proper operation, it is necessary to keep ignition wires and distributor clean and free of any dirt or corrosion.

Resistance Testing

1. Disconnect both ends of ignition cable (rotate boot and pull at the boot only) being tested and clean terminals.

2. Set ohmmeter on high scale and connect ohmmeter to each end of cable being tested. Twist cable gently while observing ohmmeter.

3. If ohmmeter reads above 25,000 ohms or flucuates from infinity to any value, replace cable being tested.

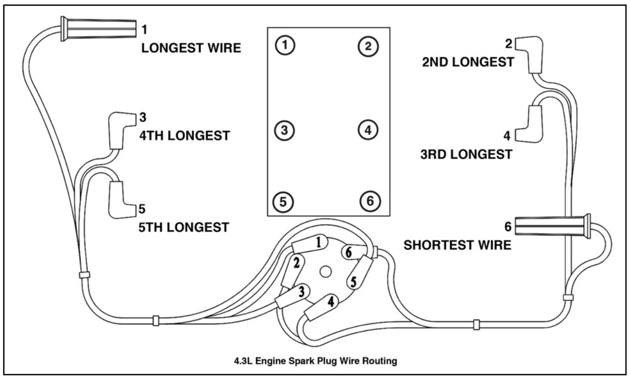
4. If the resistance of each cable is not within the following bands, replace the cable being test-ed.

0 to 15 inch cable................. 3,000 / 10,000 Ohms

15 to 25 inch cable............... 4,000 / 15,000 Ohms

25 to 35 inch cable............... 6,000 / 20,000 Ohms

Spark Plug Wire Routing



Inspection of Spark Plug

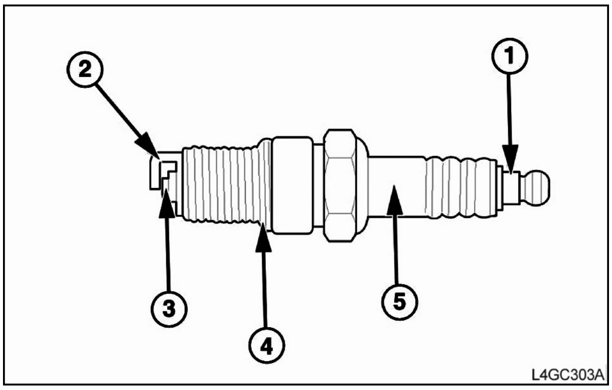
Inspection and clean

1. Disconnect the ignition wires from the ignition coil ass'y.

2. Remove all spark plugs from the cylinder head using a spark plug wrench.

⚠ CAUTION

Take care not to come foreign materials into spark-plug mounting hole.



3. Check the spark plug as below.

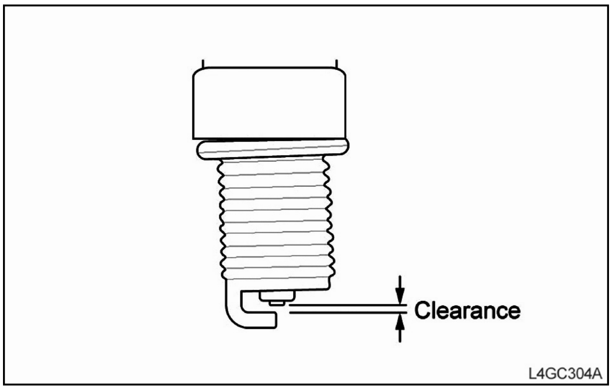
1) Insulator broken

2) Terminal worn

3) Carbon deposit

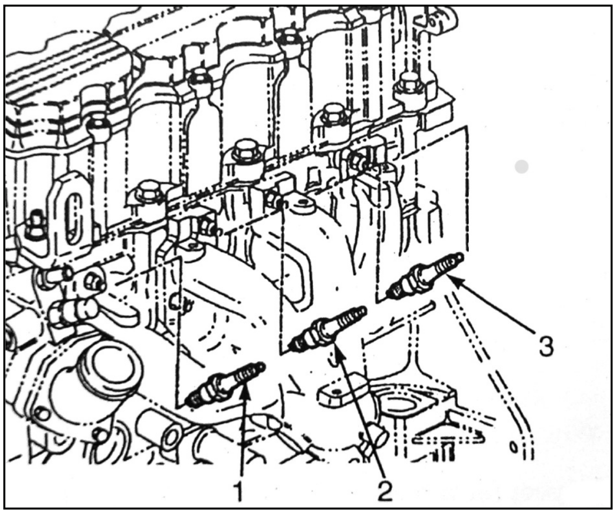
4) Gasket damaged or broken

5) Porcelain insulator of spark plug clearance



4. Check the plug clearance using a plug clearance auge and if the value is not within the specified values, adjust it by bending the ground clearance. When installing a new sparkplug, install it after checking the uniform plug clearance.

Spark plug clearance	0.8 ~ 0.9 mm



5. Install the spark plug and tighten it to the specified torque.
Take care not to over tighten it to prevent cylinder head threads from damage.

Tightening torque	30 N·m

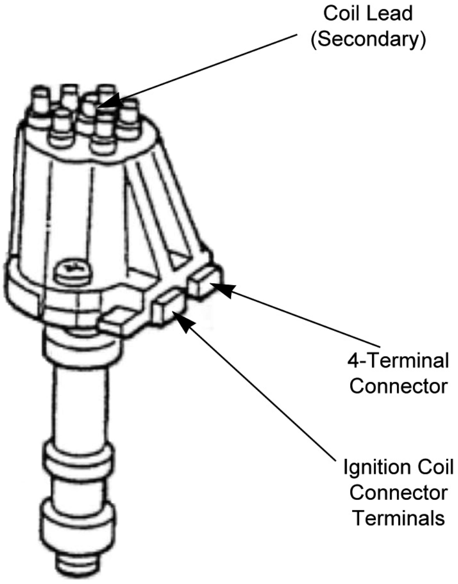
Spark Plug Analysis

State	Contact point is black	Contact point is white
Description	• Density of the fuel mixture is thick • Lack of air intake	• Density of the fuel mixture is thin • Ignition timing is fast • Spark plug is tight • Lack of torque

Inspection of EST Distributor

Description

The Delco EST ignition system consists of the distributor, ignition coil, wiring and spark plugs. The distributor contains a module, pickup coil and conventional cap and rotor. There are no points or condenser to adjust or change and no moving parts except for the distributor shaft and rotor. Spark advance and dwell are controlled by the distributor module. The distributor module and pickup coil are self-contained solid-state devices which are not repairable. If necessary, they may be replaced separately but must be serviced as a complete unit.



IAGS055S

Delco Distributor Component Testing

NOTICE

In the test procedures that follow, check the ignition coil and each component of the distributor separately to identify defective or good components. These tests can be made with the distributor and coil mounted on the engine or on the repair bench.

Delco Distributor Module Testing

NOTICE

An approved module tester must be used in order to check the module. Use a Kent-Moore Module Tester or equivalent.

1. Remove module from distributor.

2. Connect red battery-cable clamp to positive (+)terminal and black battery-cable clamp to negative(-) terminal of a fully charged 12V battery.

3. Connect the adapter to yellow 2-way terminal connector, and the adapter to black 3-wayconnector of the tester (IAGS054S).

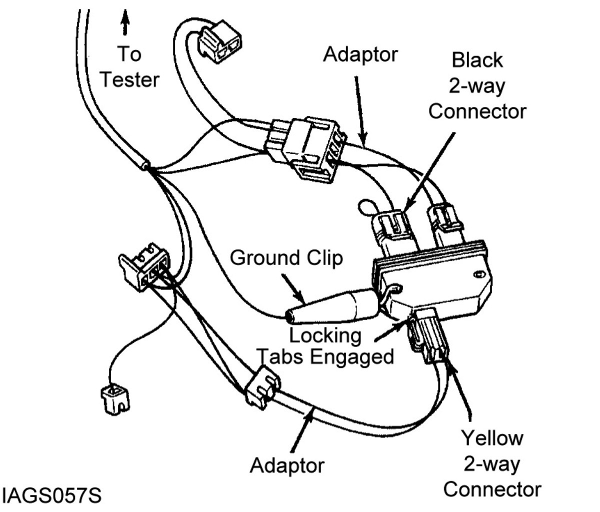
4. Connect black 4-way and 2-way connectors to module terminals. Connect yellow 2-way connector to yellow module terminals and engage locking tabs.

5. Connect module ground clip of the tester to the metal base of the module.

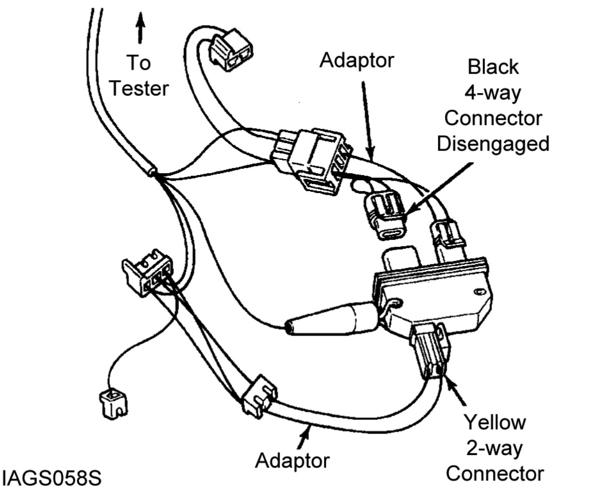
6. Hold the toggle switch in the 3-terminal test position. If a momentary indication of the red "Fail" light and then a steady indication of the green "Pass" light occurs, go on to the next step. If a steady indication of the red "Fail" light occurs, the module is defective and should be replaced.

7. Disconnect black 4-way connector from module. Disconnect yellow 2-way connector, rotate it 180 degrees so the lock and tab are opposite each other, and reconnect it to the module terminals (IAGS058S).

8. Hold the toggle switch in the 3-terminal test position. A momentary indication of the red "Fail" light and then a steady indication of the green "Pass" light mean the module is good. A steady indication of the red "Fail" light means the module is defective and should be replaced.

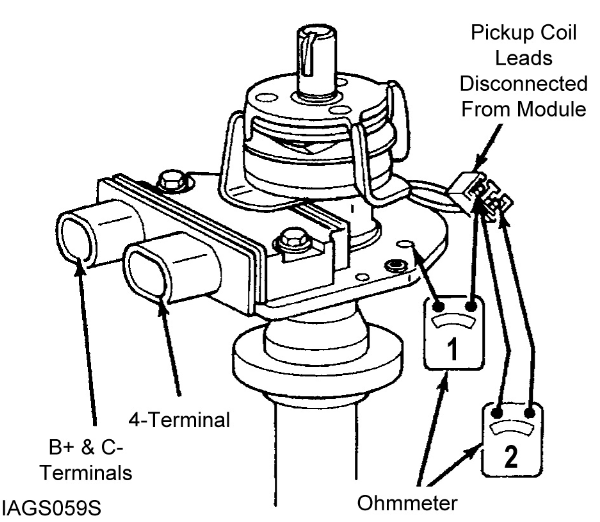


Test 1 Tester Connections



Test 2 Tester Connections

Pickup Coil Testing



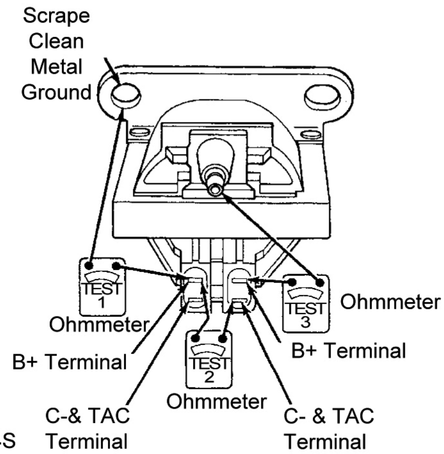
1. Remove The distributor cap and rotor.

2. Disconnect the pickup coil leads from the module.

3. Connect an ohmmeter between the pickup coil lead and housing (test 1, IAGS059S). Reding should be infinite (no continuity).

4. Connect an ohmmeter to both pickup coil leads (test 2, IAGS059S). Reading should be a constant, unchanging value between 500-1500 ohms. Flex leads by hand at coil and connector to locate intermittent opens. Replace pickup coil if not within specifications.

Inspection of Ignition Coil



IAGS004S

1. Connect ohmmeter between "B+" or "C-" terminals and ground (coil-mounting bracket). On high scale, reading should be infinite (test 1, IAGS004S).

2. Connect ohmmeter between "B+" and "C-"terminals. On low scale, reading should be nearly zero (approximately 0.4 ohm) (test 2, IAGS004S).

3. Connect ohmmeter between "B+" or "C-" terminals and coil high-voltage tower. On high scale, reading should be approximately 8000 ohms. Reading should not be infinite(test 3, IAGS004S).

NOTICE

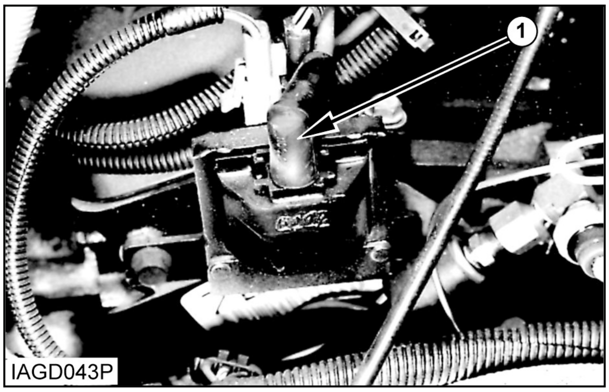
On tests 2 and 3, reading may vary slightly depending on coil temperature.

4. If reading is not within specification, replace coil.

Disassembly and Assembly

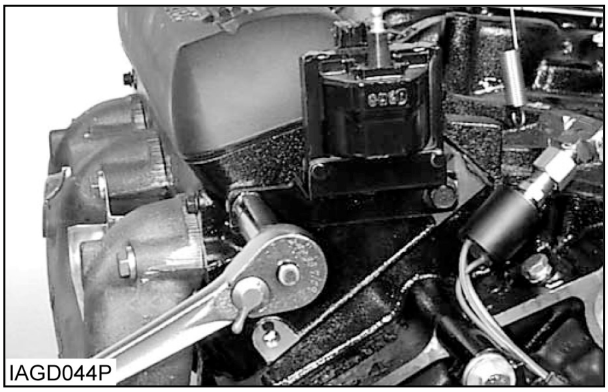
Ignition Coil

Remove & Install Coil



IAGD043P

1. Disconnect wire connectors (1) from the coil.

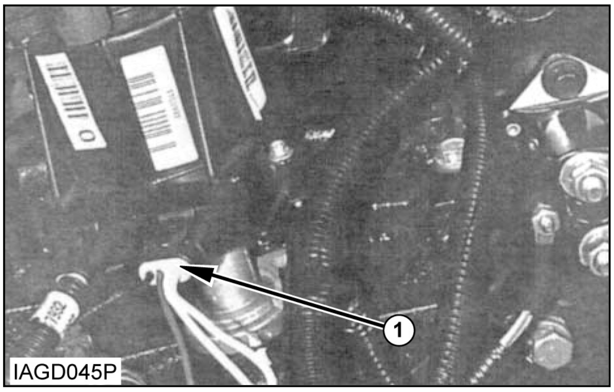

IAGD044P

2. Remove two bolts from coil mounting bracket and remove the coil.

NOTE: For installation of the coil, reverse the removal steps.

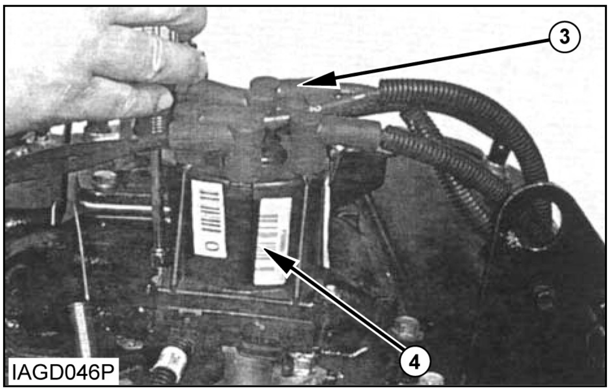
EST Distributor

Remove Distributor

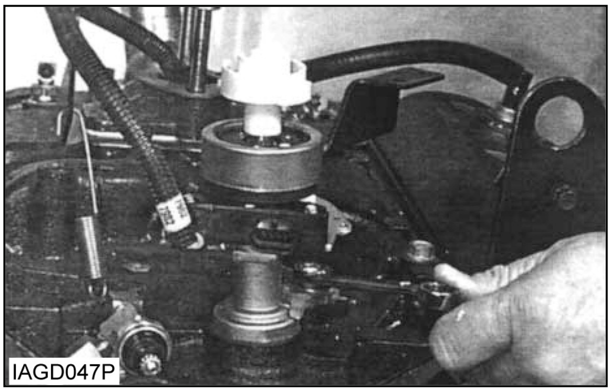


1. Disconnect coil harness (1) from distributor.

2. Bring the engine to TDC on the compression stroke before removing the distributor.



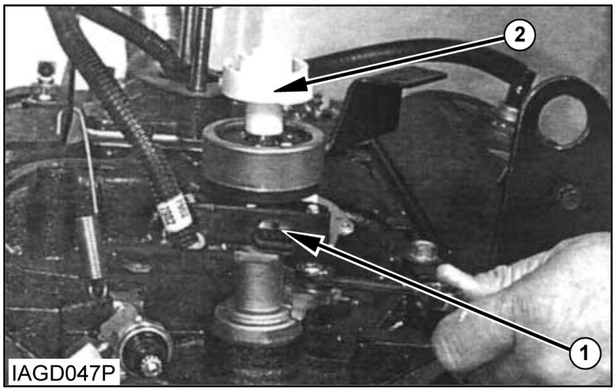
3. Remove the coil wire, spark plug wires (3) and cap (4) from the distributor.



NOTE: Scribe an alignment mark on the distributor and intake manifold to show the position of the rotor.

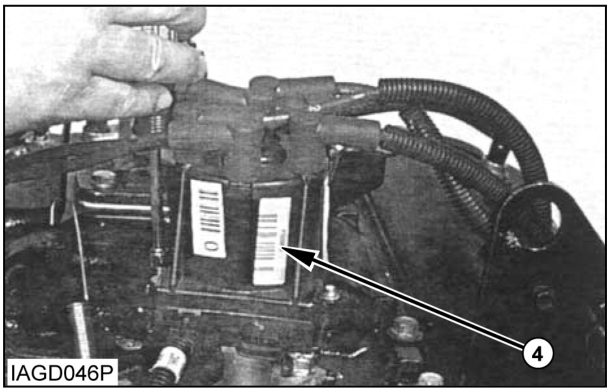
4. Remove the bolt, distributor clamp, and distributor.

Install Distributor

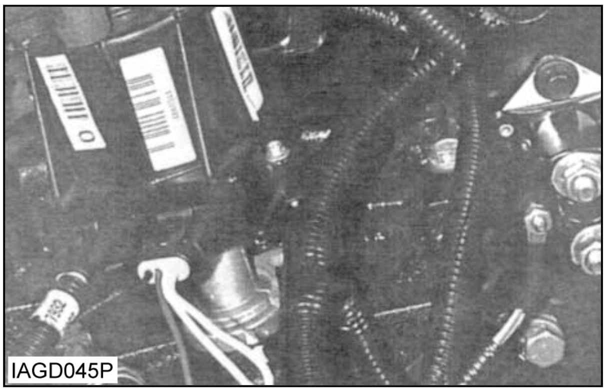


1. Install the distributor (1) in position in the intake manifold. Make sure that the rotor (2) is in alignment with the scribe mark and number one cylinder.

2. Install the distributor clamp and bolt to the distributor.



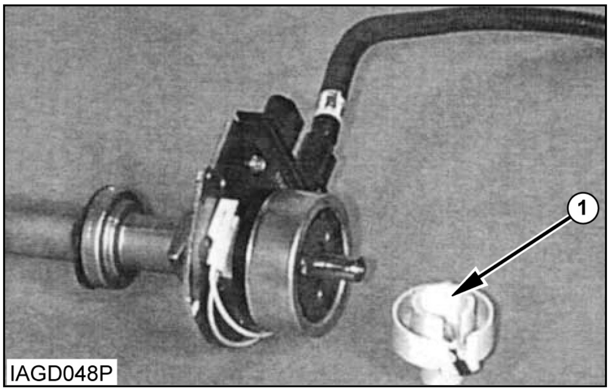
3. Install cap (4) and plug and coil wires to the distributor.



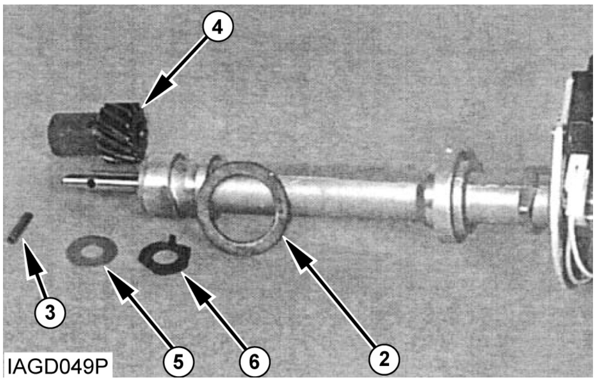
4. Connect the coil harness to the distributor and the coil wire to the coil.5.Check the ignition timing. (See Test and Adjustment)

Disassemble Distributor

Start By: Removing the distributor.



1. Remove rotor (1)

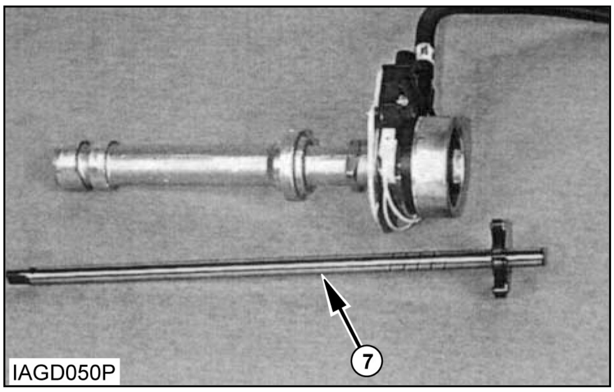


2. Remove gasket (2) from location.

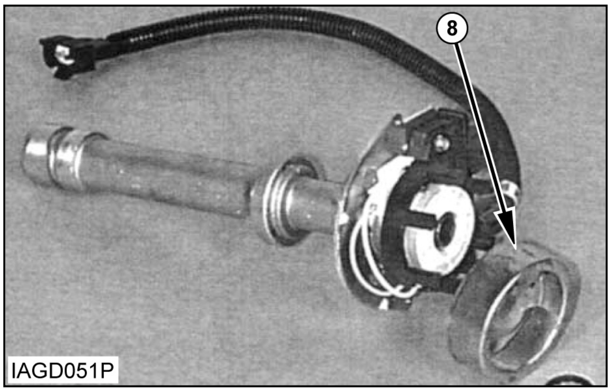
3. Drive roll pin (3) from gear (4).

4. Remove gear (4), thrustwasher (5) and tabbed thrustwasher (6).

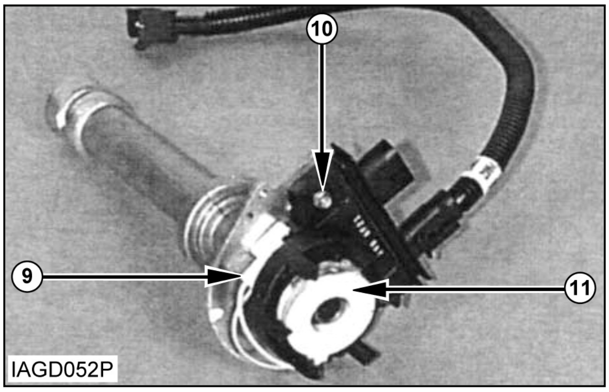
NOTE: mark gear and shaft for correct assembly.



5. Remove shaft assembly (7).



6. Pry off spring washer and remove retainer (8).



7. Unplug and remove the pickup coil (9).

8. Remove two screws (10) and remove pickup module (11).

Assemble Distributor

9. Wipe distributor base and module clean, apply silicone lubricant between module and base for heat dissipation.

10. Attach module (11) to base with two screws (10). Connect pickup coil (9) connector to module and mount coil.

11. Assemble retainer (8) and fasten with a new spring washer (7).

12. Assemble shaft, thrust washers, gear and roll pin in proper alignment.

13. Spin shaft to ensure that teeth to not touch.

14. Install rotor.

Ignition Timing Adjustment for G643 Engine

The ignition timing advance of G643 is controlled by the SECM. The initial ignition timing setting of the distributor is described in the following steps. It will be necessary to mechanically adjust the distributor to an initial setting for startup, and then adjust the final timing using the Service Tool.

1. Be sure engine is turned OFF.

2. Remove distributor cap **(Figure 34)**.

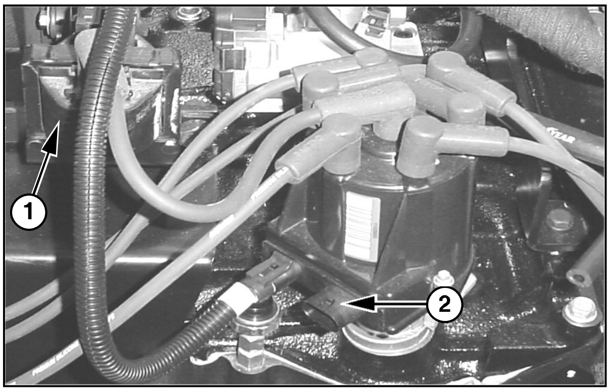
3. Disconnect the fuel lock-off connector at the lock off so that fuel cannot flow during cranking.

4. Disconnect the 4-pin connector **(Figure 35)** to the ignition module. This eliminates the +12 Vdc power on Pin D and puts the ignition to a default value not controlled by the SECM.

5. Connect standard inductive timing light **(Figure 36)** to the #1 cylinder.

6. Manually bar the engine so that the timing indicator on the crankshaft pulley lines up to 0° Top Dead Center (TDC) of the #1 cylinder **(Figure 37)**.

7. Verify that the distributor rotor is lined up with #1 cylinder on the distributor cap **(Figure 38)**.



(1) Ignition Coil. (2) Ignition Module.

Figure 34. GM Ignition Module

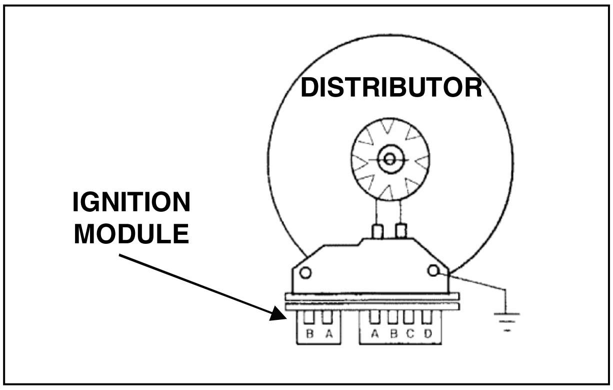


Figure 35. Four-Pin Connector to Ignition Module

Figure 36. Standard Inductive Timing Light

8. Using standard inductive timing light with no offset adjustment set the initial timing to 4° BTDC (advanced) by rotating the distributor while cranking the engine with the ignition key.

9. Tighten the distributor hold-down bolt to the specified torque value and re-connect the 4-pin ignition module connector and the fuel lock-off connector.

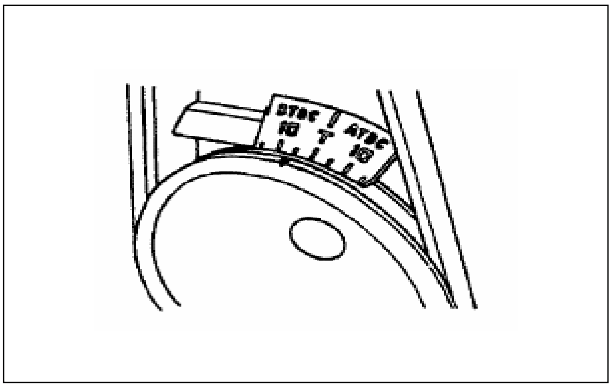


Figure 37. Engine Set at 0° Top Dead Center (TDC)

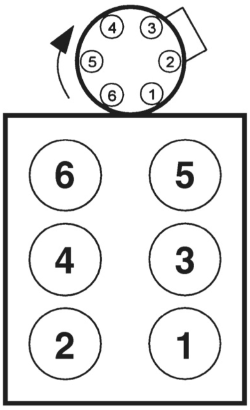


Figure 38. Topside of Engine Showing Position of Cylinders

NOTE: This completes the initial ignition timing. The final ignition adjustment can be made at engine start-up using the software Service Tool.

Final Timing Verification

To verify the mechanical timing adjustment of the distributor you will need to lock the spark using the Service Tool Test Screen and use the timing light to verify adjustment.

NOTE: Service Tool software (Moto TuneViewer) and the security Crypt Token is obtainable by certified technicians through authorized dealers.

1. Without starting the engine turn the Key switch to the ON position and open the Service Tool Display Test Screen. The Spark Control Lock parameter should be "Unlocked" as in (Figure 42). The Spark Offset should read 0.00 and "OFF" in the Units column of the display. When a value is entered in the Spark Offset, the offset value is added to the value displayed in the Spark Advance parameter.

NOTE: You must always return the Spark Offset value to 0.00 before closing the Service Tool or the offset will be applied during engine operation causing inaccurate ignition timing with the possibility of misfire or engine damage.

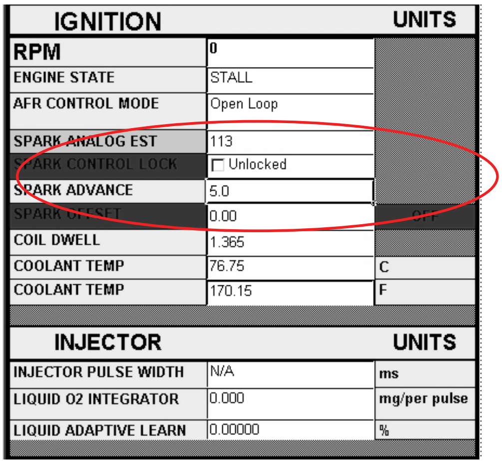


Figure 42. Spark Control Lock Parameter "Unlocked"

2. The preferred reference timing to use for verification with a timing light is 10 degrees BTDC. In Figure 42 the Spark Advance with the engine not running is 5.0° BTDC. To lock the spark at 10° BTDC a Spark Offset value of 5.0 would need to be entered (5.0 + 5.0 = 10). Enter the appropriate offset value that will equal 10 when added to your engine's spark advance. (10 – Spark Advance = Spark Offset). Once an offset value is entered the "OFF" description will change and display "WARNING" to alert you that the offset value is not set to 0.00.

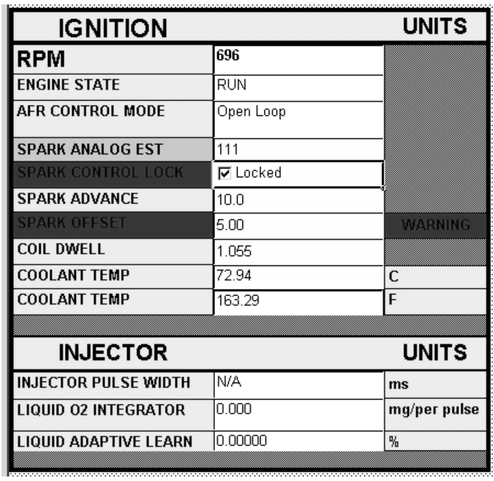


Figure 43. Spark Control Lock Parameter "Locked"

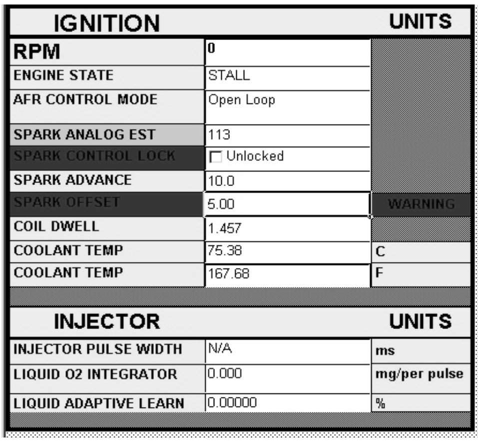
3. Select the Spark Control Lock "Unlocked" check box. The check box display will change to read "Locked" as in Figure 43. You have now locked the SECM ignition timing at a fixed value (Spark Advance + Spark Offset).

4. Start the engine, using the timing light verify the engine is running at the correct timing, in this case 10° BTDC. If it is not 10° BTDC loosen the distributor hold down bolt and slightly adjust the distributor for 10° BTDC using your timing light. Tighten the distributor hold down bolt.

5. Un-check the Spark Control Lock, it should now read “Unlocked” as in Figure 42 allowing the SECM to control spark advance.

6. Enter 0.00 in the Spark Offset, the Warning message should now read OFF as in Figure 44. The SECM is in full control of the spark advance with no offset.

7. Setting the distributor position is now complete.



IGNITION		UNITS
RPM	0	
ENGINE STATE	STALL	
AFR CONTROL MODE	Open Loop	
SPARK ANALOG EST	113	
SPARK CONTROL LOCK	☐ Unlocked	
SPARK ADVANCE	10.0	
SPARK OFFSET	5.00	WARNING
COIL DWELL	1.457	
COOLANT TEMP	75.38	C
COOLANT TEMP	167.68	F

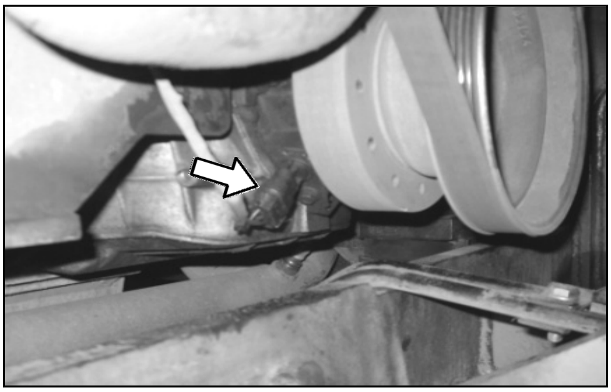
INJECTOR		UNITS
INJECTOR PULSE WIDTH	N/A	ms
LIQUID O2 INTEGRATOR	0.000	mg/per pulse
LIQUID ADAPTIVE LEARN	0.00000	%

Figure 44. SECM in Full Control of Spark Advance

Ignition Timing Adjustment for G643E Engine

On **G643** engine, crankshaft position was sensed from the distributor. Adjusting the distributor has a direct affect on ignition timing - 1 degree of the distributor rotation would produce a 2 degree change in spark timing.

G643E engine senses crank position from the crank position sensor and the target wheel. Rotating the distributor will not directly affect ignition timing, except in extreme conditions. When engine is disturbed and ignition timing is incorrect, inspect the sensors concerned with ignition timing, at first.



[Figure] Crank Position Sensor of G643E Engine

NOTE: Affective SECM input to ignition timing control

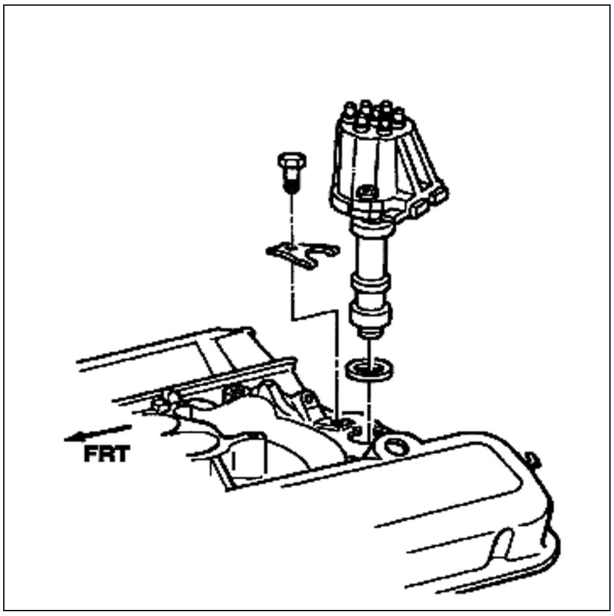
- Coolant temperature sensor
- Oxygen sensor
- Battery voltage
- MAP sensor (Engine load)
- Crankshaft position sensor
- Throttle position sensor
- Intake Air Temperature sensor

If the distributor is severely misaligned, the rotor will not properly align with the distributor cap and spark will misfire or go to the wrong cylinder. When replace the distributor, install new distributor as follows;

1. Install distributor shaft into engine, aligning marks made at time of removal (see, figure). Be sure that the shaft engages oil pump

2. Secure distributor with clamp

3. Install distributor cap



Charging System

General Description

The alternator is an electrical and mechanical components driven by a belt from engine rotation. It is used to charge the storage battery during the engine operation. The alternator is cooled by an external fan mounted behind the pulley. The fan pulls air through the holes in the back of the alternator. The air exits the front of the alternator, cooling it in the process. The valeo alternator also has an internal fan. This fan is mounted on the rotor. This fan pulls air through the holes in the back of the alternator to cool the rectifier bridge and regulator. The air exits the front of the alternator.

The alternator converts mechanical and magnetic energy to alternating current (AC) and voltage. This process is done by rotating a direct current (DC) electromagnetic field (rotor) inside a three phase stator. The alternating current and voltage (generated by the stator) are changed to direct current by a three phase, full wave rectifier system using six silicone rectifier diodes. Some alternators have three exciter diodes or a diode trio. They rectify the current needed to start the charging process. Direct current flows to the alternator output terminal.

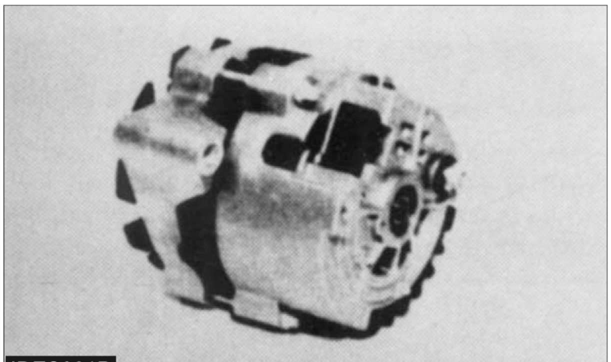
A solid state regulator is installed in or on the back of the alternator. Two brushes conduct current, through two slip rings, to the rotor field. Some alternators have a capacitor mounted on them. The capacitor protects the rectifier from high voltages. It also suppresses electrical noise through a radio, if equipped.

The alternator is connected to the battery through the ignition switch for alternator turn on. Therefore, alternator excitation occurs when the switch is turned on.

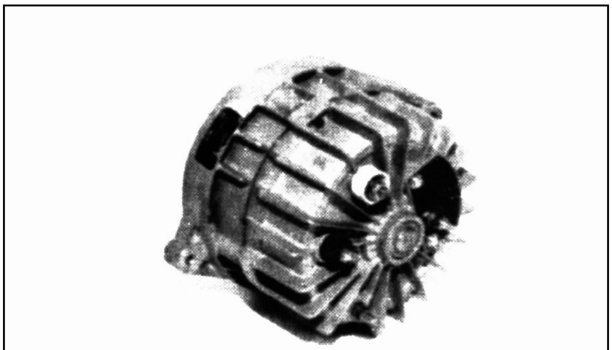
Alternators

The alternators used on these engines have three phase, full-wave, rectified output. They are the brush type. Refer to the Alternator Coverage chart for detailed systems operation information

ALTERNATOR COVERAGE	
Alternator Part Number	Manufacturer/ Series
D167411	Korea-Delphi CS121D
D187478	MICO/K1 Sealed



IDES081P



D187478

Troubleshooting

Charging system defect is almost caused by lack of pan belt tension and faulty function of wiring, connector, and voltage regulator.
One of most important thing during troubleshooting of charging system is determining the reason between overcharging and lack of charging. So, prior to inspection of alternator, check the battery for charging. Faulty alternator causes the following symptoms.

1. Faulty battery charging

1) IC regulator fault (Short circuit)

2) Field coil fault

3) Main diode fault

4) Stator coil fault

5) Brush contact fault

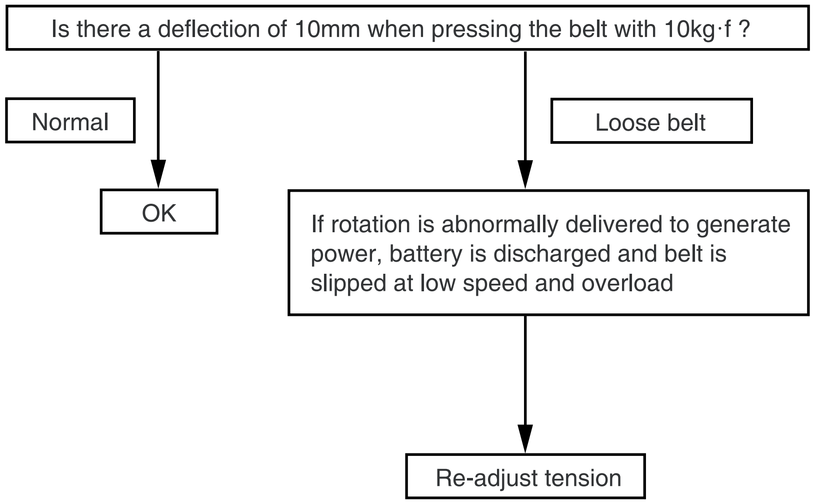
2. Overcharging : IC regulator fault(Short circuit)
Other faults such as voltage adjusting problem except above symptoms rarely happen.

Refer to the following troubleshooting table

Symptom	Possible cause	Remedy
With ignition switch ON, charging warning lamp does not illuminate	Fuse cut off	Replace
	Bulb burnt out	Replace
	Loose wiring connection	Retighten
	Bad connection of L terminal	Inspect and replace wiring
With the engine started, warning lamp is not turned off (Battery needs often charging)	Loose or worn drive belt	Correct or replace
	Fuse cut off	Replace
	Circuit breaker cut off	Reset or replace
	Faulty voltage regulator or alternator	Inspect alternator
	Faulty wiring	Repair
	Corrosion or wear of battery cable	Repair or replace
Overcharged	Faulty voltage regulator (Charging warning lamp illuminates)	Replace
	Voltage detection wring fault	Replace
Battery is discharged	Loose or worn drive belt	Correct or replace
	Loose wiring connection	Retighten
	Short circuit	Repair
	Circuit breaker cut off	Reset or replace
	Ground fault	Repair
	Faulty voltage regulator (Charging warning lamp illuminates)	Inspect alternator
	Battery out	Replace

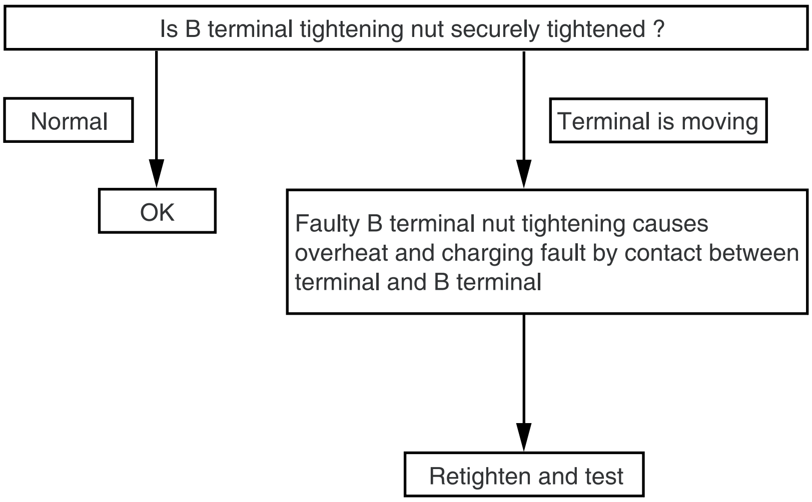
Troubleshooting Procedure

Inspection before Starting

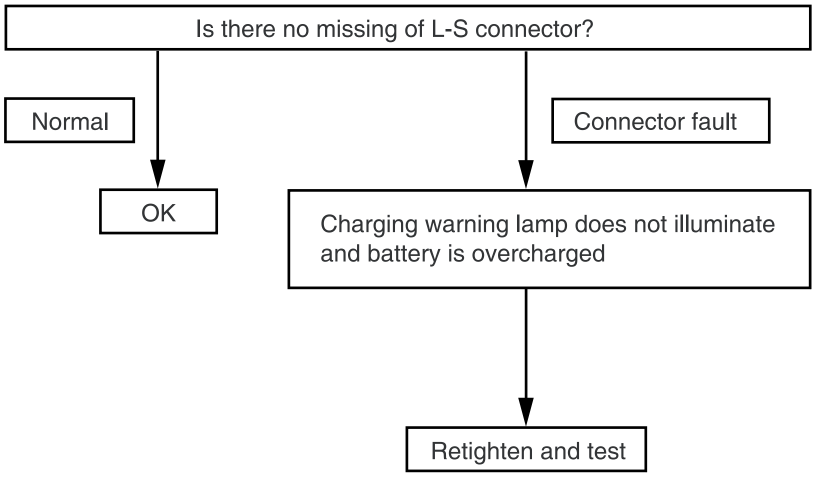


L4GC312A

1. Alternator and drive belt tension inspection.

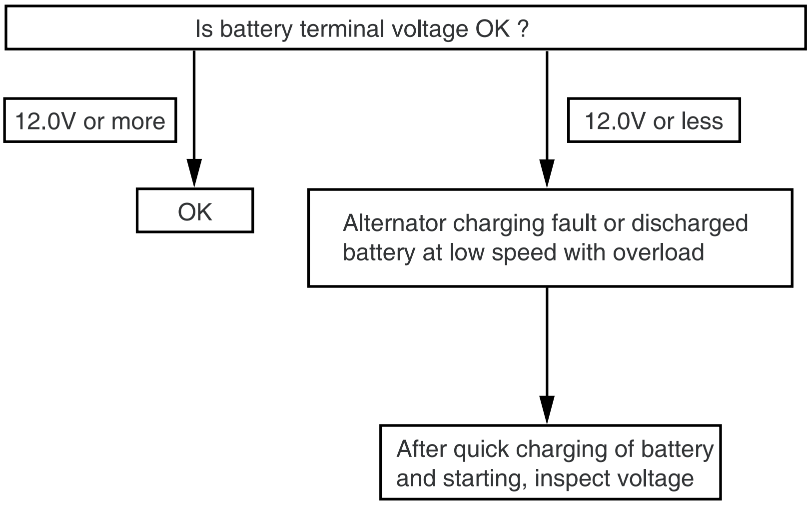


L4GC313A



L4GC314A

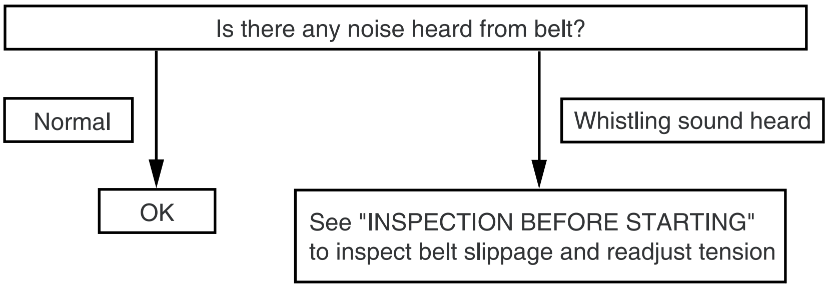
2. Alternator and outer terminal connection inspection.



L4GC315A

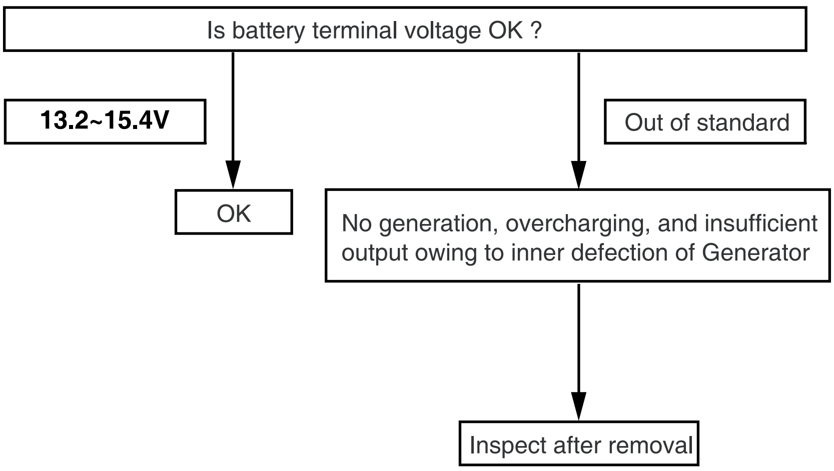
3. Battery outer terminal inspection.

Inspection after Starting



L4GC318A

1. When starting, belt slip and noise inspection

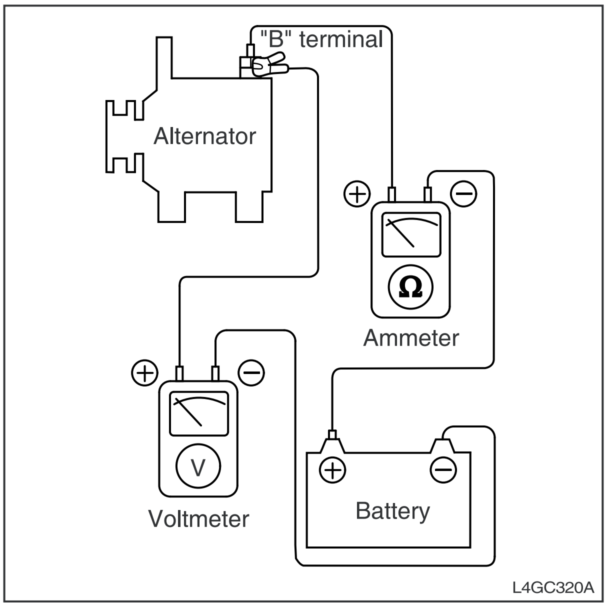


L4GC319A

2. Inspection of battery voltage at idling (At this time charge battery only)

Drop of Electric Pressure Test of Alternator Output Wire

This test is to check that wiring is correctly connected between the alternator “B“ terminal and battery (+) terminal.



Preparation

1. Turn the ignition switch OFF.

2. Disconnect the battery ground cable.

3. Disconnect the alternator output wire from the alternator “B” terminal.

4. Connect a DC ampere meter (0-100A) between the terminal and the disconnected output wire. Connect (+) lead wire to the terminal “B” and (-) lead wire to the disconnected output wire.

NOTE: In case of using a clamp type ammeter, it is possible to measure current without disconnecting the harness.

5. Connect a digital voltmeter between the alternator “B” terminal and the battery (+) terminal. Connect (+) lead wire to the terminal and (-) lead wire to the battery (+) terminal.

6. Connect the battery ground cable.

7. Be sure that the hood is opened.

Test

1. Start the engine.

2. Repeating ON and OFF of headlight and small light, adjust the engine speed until an ammeter reads 20A and at that time measure voltage.

Result

1. If voltmeter reading is within the standard, it is normal.

2. If voltmeter reading is more than the standard, mostly wiring is faulty. In this case, inspect wirings between the alternator and the battery (+) terminal as well as between the alternator “B” terminal and the fusible link.

3. Also prior to re-test, check and repair the connecting part for looseness and the harness for discoloration by overheating.

4. After test, adjust the engine speed at idle and turn the light and ignition switch OFF.

5. Disconnect the battery ground cable.

6. Disconnect the ammeter and voltmeter.

7. Connect the alternator output lead wire to the alternator “B” terminal.

8. Connect the battery ground cable.

Output Current Test

This test is to check that the alternator output current is identified with the rated current.

Preparation

1. Prior to test, inspect the following items and repair if necessary.

1) Be sure that the battery installed in the vehicle is normal. (See “Battery”)

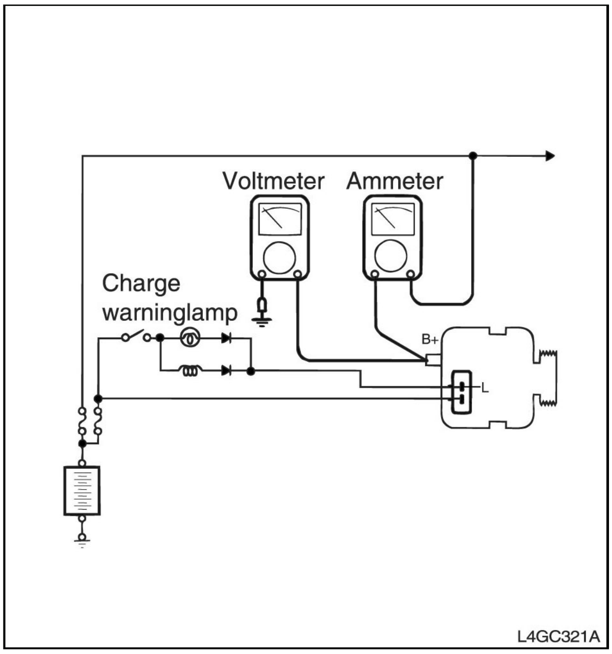
NOTE: When measuring output current, necessarily use a slightly discharged battery. Fully charged battery is not enough to use for correct test owing to insufficient load.

2) Inspect the drive belt for tension. (See “Engine body”)

2. Turn the ignition switch OFF.

3. Disconnect the battery ground cable.

4. Disconnect the alternator output wire from the alternator “B” terminal.



5. Connect a DC ampere meter (0-100V) between “B” terminal and the disconnected output wire. Connect (+) lead wire to the terminal “B” and (-) lead wire to the disconnected output wire.

NOTE: Do not use clips or equivalent owing to high current and Use bolts and nuts to tighten each connecting part securely.

6. Connect a volt meter (0-20V) between “B” terminal and the ground.
Connect (+) lead wire to the alternator “B” terminal and (-) lead wire to the proper position.

7. Connect the engine tachometer and then battery ground cable.

8. Be sure that the hood is opened.

Test

1. Be sure that voltmeter reading is identified with battery voltage.
If voltmeter reading is 0V, it means short circuit of wire between “B” terminal and the battery (-) terminal, fusible link cut off or ground fault.

2. Turn the headlight ON and start the engine.

3. With the engine running at 2,500 rpm, turn ON the high beam headlights, place the heater blower switch at ”HIGH” measure the maximum output current using a ammeter.

NOTE: This test should be done as soon as possible to measure the exact maximum current because output current drops rapidly after starting the engine.

Result

1. Ammeter reading should be as same as the load. If the reading is low even though the alternator output wire is normal, remove the alternator from the vehicle and inspect it.

Output current	As same as Elecrical load

NOTE: Output current varies according to electrical load or temperature of the alternator, so during test, lack of electrical load causes impossibility of measuring the rated output current. In this case, turn on headlight to induce the battery discharging or turn on other lights to increase the electrical load. If alternator temperature or ambient temperature is too high, it is impossible to measure the rated output current, so prior to re-test, necessarily drop the temperature.

Ambient temperature of voltage regulator(℃)	Voltage adjust(V)
-30	14.5 ~ 15.4
25	14.3 ~ 14.9
60	14.0 ~ 14.8
90	13.6 ~ 14.6

2. After test, adjust the engine speed at idle and turn the light and ignition switch OFF.

3. Disconnect the battery ground cable.

4. Disconnect the ammeter and voltmeter.

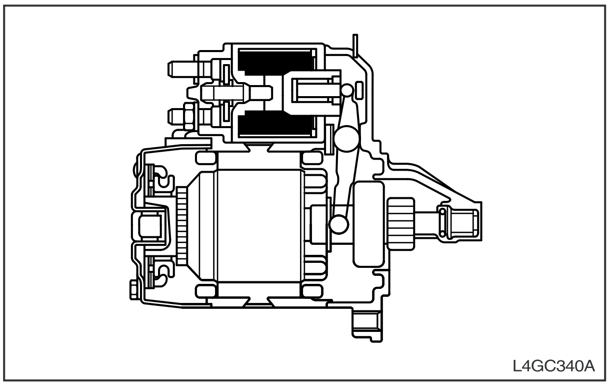
5. Connect the alternator output lead wire to the alternator “B” terminal.

6. Connect the battery ground cable.

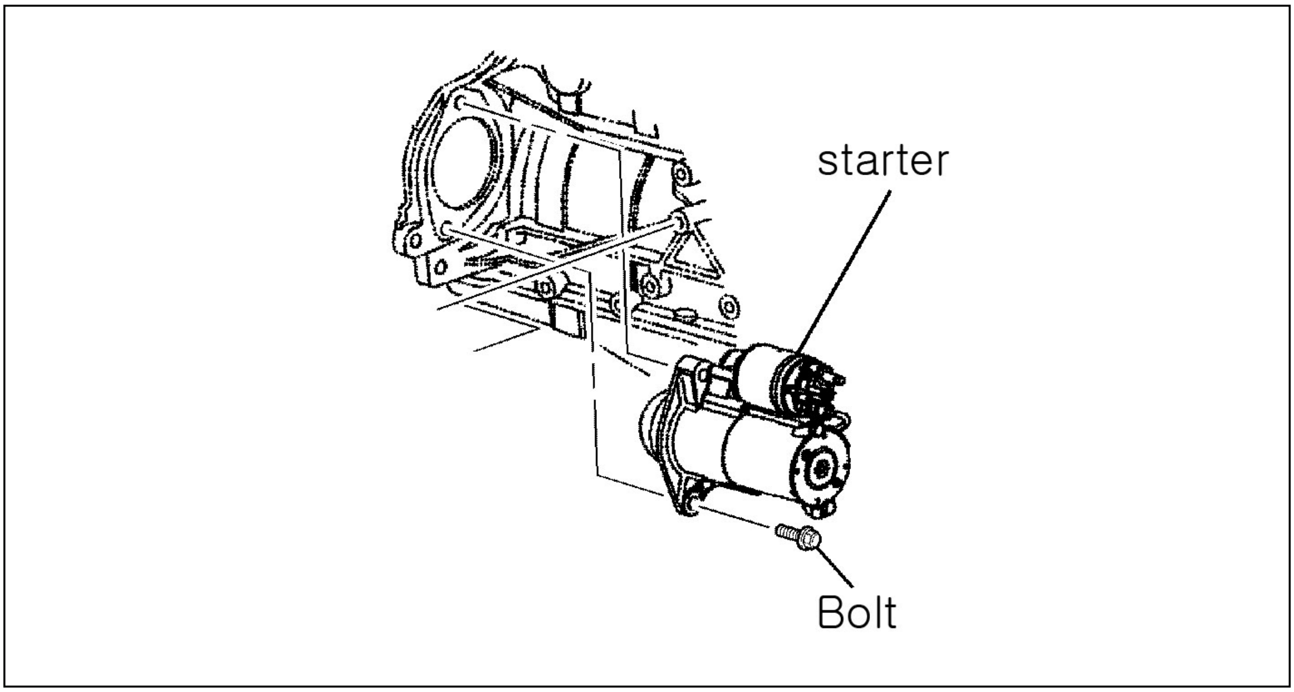
STARTING SYSTEM

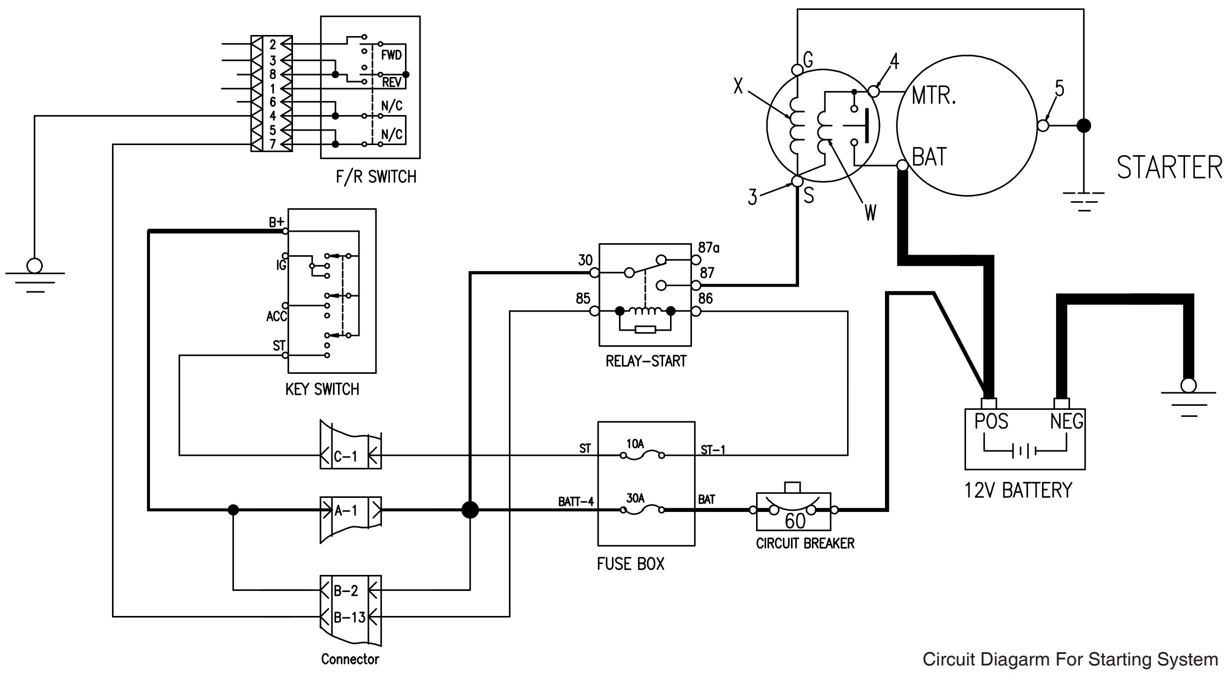
General Description

The starting motor is used to turn the engine flywheel lfast enough to make the engine run. The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to move the pinion toward the flywheel ring gear of the engine. The electrical contacts in the solenoid close the circuit between the battery and the starting motor just before the pinion engages the ring gear. This causes the starting motor to rotate. This type of motor "turn on" is a positive shift starting motor. When the engine begins to run, the overrunning clutch portion of the pinion drive prevents damage to the armature caused by excessive speeds. The clutch does this by breaking the mechanical connection. The pinion will stay meshed with the ring gear until the ignition switch is released. A return spring in the overrunning clutch returns the clutch to its rest position.



Components





Circuit Diagarm For Starting System

Diagnosis Procedure

The following simplified procedure is intended to help the serviceman determine if a starting motor needs to be removed and replaced or repaired. It is not intended to cover all possible problems and conditions, but to serve only as a guide. The most common 12 volt circuit is shown and discussed.

General Information

All starting systems are made up of four elements. They are the ignition switch, start relay, the starting motor solenoid and starting motor.

Start switches are relatively low current devices. They are rated to switch approximately 5 to 20 amps. Because the coil of a start relay [between test point 86 and 85] draws about 0.2 amp, the start switch can easily turn on the start relay and have long life.

The switch contacts of a typical start relay are rated to switch 30 amps. Because the solenoid requires 5 to 20amps the start relay can easily switch this load.

The starting motor solenoid has two functions:

1. Engages the pinion with flywheel.

2. Is a high current switch rated about 1000 amps that actually turns on the starting motor.

The starting motor solenoid has two coils. Pull-in coil (W) draws about 40 amps and hold-in coil (X) requires about 5 amps. The instant the start relay closes, both coils (W) and (X) receive power. Battery voltage is applied to the high end of both coils, at test point (3) which is the start (S) terminal. The low end of hold-in coil (X) is permanently grounded to the ground post or motor housing of the starting motor. Grounding for the low end, test point (4), of pull-in coil (W) is momentary, and takes place through the DC resistance of the starting motor. As soon as magnetic force builds in both coils, the pinion moves toward the flywheel ring gear. The pinion will stop short of engagement of the flywheel ring gear. Only then will the solenoid contacts close to power the starting motor. This temporarily removes the ground from pull-in coil (W), and puts battery voltage on both ends of it while the starting motor cranks. During this period, the pull-in coil is out of the circuit. Cranking continues until power to the solenoid is broken by releasing the ignition switch.

The result of these switches and relays is to permit a 5 amp dash-mounted switch to turn on a 500 to 1000amp motor used to crank an engine. Battery voltage (power) available during cranking varies according to the temperature of the batteries. The following chart is a guide as to what to expect from a normal system.

TYPICALSYSTEM VOLTAGE DURING CRANKING AT VARIOUS AMBIENT TEMPERATURES	
Temperature	12V System
-23 to -7 C (-10 to 20 F)	6 to 8 Volts
-7 to 10 C (20 to 50 F)	7 to 9 Volts
10 to 27 C (50 to 80 F)	8 to 10 Volts

Figure 1
The next chart shows maximum acceptable voltage loss in the high current battery circuit feeding the starting motor. These values are maximums for machines of approximately 2000 SMH and up. Newer machines would be less than those shown.

MAXIMUM ACCEPTABLE SYSTEM VOLTAGE DROPS DURING CRANKING	
Circuit	12V System
Battery(-) post to starting motor (-) terminal	0.7 Volts
Battery (+) post to solenoid (+) terminal	0.5 Volts
Solenoid Bat terminal to solenoid Mtr terminal	0.4 Volts

Figure 2
Voltages greater than those shown are most often caused by loose and/or corroded connections or defective switch contacts.

Diagnosis Procedure

TOOLS NEEDED	
Digital Multimeter or Equivalent	1
DC Clamp-On Ammeter or Equivalent	1

NOTICE

Do not operate the starting motor for more than 30seconds at a time. After 30 seconds, the cranking must be stopped for two minutes to allow the starting motor to cool. This will prevent damage to the starting motor due to excessive heat buildup.

If the starting motor cranks real slow or does not crank at all, do the following procedure:

1. Measure battery voltage at the battery posts with the multimeter while cranking or attempting to crank the engine. Make sure to measure the battery posts. Do not measure the cable post clamps.

2. Is battery voltage equal to or greater than shown in Figure 1?

- If the battery voltage is correct, go to Step 3.

- If the battery voltage is too low, Charge or replace the battery.

NOTE: Alow battery can be caused by battery condition or a shorted starting motor.

3. Measure current draw on the (+) battery cable between the battery and the starting motor solenoid with the clamp-on ammeter. The maximum current draw allowed is 350 Amp. At temperatures below27°C (80°F), the voltage will be less and the current draw will be higer. If current draw is too much, the starting motor has a problem and must be removed for repair or replacement.

NOTE: If voltage at the battery post is within approximately 2 volts of the lowest value in the applicable temperature range of Figure1 and if the large starting motor cables get hot, then the starting motor has a problem and the Ammeter test is not needed.

4. Measure starting motor voltage from test point (4) to (5) with the multimeter while cranking or attempting to crank the engine.

5. Is voltage equal to or greater than shown in Figure1?

- If the starting motor voltage is correct, the battery and starting motor cables down to the motor are within specifications. Go to Step 8.

- If the starting motor voltage is low, the voltage drop between the battery and the starting motor is too great. Go to Step 6.

6. Measure the voltage drops in the cranking circuits with the multimeter. Compare the results with maximum voltage drops allowed in Figure 2.

7. Are all the voltages within specifications ?

- If the voltage drops are correct, go to Step 8, to check the engine.

- If the voltage drops are too high, repair and/ or replace the faulty electrical component.

8. Rotate the crankshaft by hand to make sure it is not locked up. Check oil viscosity and any external loads that would affect engine rotation.

9. Is the engine locked up or hard to turn ?

- If it is, repair the engine as required. If the engine is not hard to turn, go to Step 10.

10. Does the starting motor crank?

- If it does crank, remove the starting motor for repair and/or replacement.

- If it does not crank, check for blocked engagement of the pinion and flywheel ring gear.

NOTE: Blocked engagement and open solenoid contacts will give the same electrical symptoms.

Start Relay Tests

Relay

1. Put the multimeter on the 200 ohm scale.

2. Put the multimeter lead to the 85 and 86 terminals.

3. The indication on the meter must be 82 5 ohms. If the indication is not correct, the start relay must be replaced.

4. Put the multimeter leads to the 30 and 87 terminals.

5. The indication must be "OL"(Over Load). If the indication is not correct, the start relay must be replaced.

6. Connect WH wire to 86 and BK wire to 85 terminal with the ignition switch to start position. Put the meter lead to 30 and 87 terminal.

7. The indication must be Zero ohm. If the indication is not correct the start relay must be replaced.

Troubleshooting

Starting system problem can be classified into “Start motor is not operating”, “Start motor is operating but engine is not starting” , and “There is a lot of time taken to start engine”.

When the starting system has problems, before removing the start motor, find where the problem happens. Generally if it is difficult to start, there are problems in ignition system, fuel system, and electrical system. In this case, necessarily inspect and repair step by step, or the same problem will happen.

Symptom	Possible cause	Remedy
Impossible cranking	Low battery charging voltage	Charge or replace
	Loose, corroded or worn battery cable	Repair or replace
	Inhibitor switch fault	Adjust or replace
	Circuit breaker cut off	Reset or replace
	Start motor fault	Repair
	Ignition switch fault	Replace
Slow cranking	Low battery charging voltage	Charge or replace
	Loose, corroded or worn battery cable	Repair or replace
	Start motor fault	Repair
Continuous rotating of start motor	Start motor fault	Repair
	Ignition switch fault	Replace
	Start relay fault	Replace
Start motor is rotating but engine is not cranking	Short circuit of wiring	Repair
	Worn or broken pinion gear tooth or motor fault	Repair
	Worn or broken ring gear tooth	Replace flywheel ring gear or torque converter

Starter Repair

Removal

Remove or disconnect

⚠ WARNING

Always disconnect the cable at the battery before you make repairs to the engine. Disconnect the cable at the negative terminal first. Install a tag on the battery terminals first. Install a tag on the battery terminals so that no one connects the cable on the terminal.

1. Discount battery negative cable at negative terminal.

2. Disconnect the battery positive cable at positive terminal.

3. Put labels on wires and cables prior to disconnecting to aid in correct installation.

4. Disconnect wires and cables from starter.

5. Hold starter so it won't fall. Remove capscrews that fasten the starter to the flywheel housing. Install capscrews to fasten the starter to the flywheel housing.

Installation

Install or connect

1. Place starter in position in flywheel housing. Install capcrews to fasten the starter to the flywheel housing. Tighten cap screws to 38 N•M (28 lb•ft)

2. Connect wires and cables as labeled in removal.

3. Connect the battery positive cable at positive terminal.

4. Connect battery negative cable at negative terminal.

Chapter 5. ENGINE MANAGEMENT SYSTEM (EMS)

General Information

Specifications

SECM and Sensor/Switch Inputs

Components	Q'ty		Items	Specifications
	G643E	G643		
Environmental / Electrical Specifications	None	None	Ambient Operating Temperature Operating Voltage	-20 °F to 221°F [-29 °C to 105 °C] 8-16 Vdc
Engine Control Module (SECM)	1	1	Operating Temperature Operating Voltage Operating Environment	-20 °F to 221°F [-29 °C to 105 °C] 8-16 Vdc SECM microprocessor may reset at voltages below 6.3 Vdc On-engine mounting, underhood automotive
Crankshaft Position Sensor	1	None	Type Tooth wheel	VR sensor 3X
TMAP Sensor	1	1	MAP sensor Intake Air Temp Sensor	Piezo- Resistivity type 0-5V output Thermistor type (built in MAP sensor) 2.0-3.0kohms at 20°C
LP Fuel Temperature Sensor	1	None	Type Resistance	Thermister 2.5kΩ@20℃ 243Ω@90℃
Oxygen Sensor	2	None	Type Output Voltage	Zirconia Sensor (Heated) 0 - 1V
Coolant Temperature Sensor	1	1	Type Resistance	Thermistor Type 1.0-4.0 kohms at 20°C
Acceleration Pedal Angle Sensor	1	1	Type APP1(Low idle) APP2(Low idle) APP1(Hi idle) APP2(Hi idle)	Hall IC 0.4 ± 0.1 V 4.5 ±0.1 V 3.6 ±0.15 V 1.39 ± 0.15 V
Engine Oil Pressure Switch	1	1	Actuation Pressure	0.3 +/- 0.1 kgf/cm^2
Transmission Oil Temperature Switch	1	1	Actuation Temperature	125°C
Ground speed limit device	option	option	Sensor Controller	Magnetic Pick-up Digital output

Electronic Throttle System

Components	Q'ty		Items	Specifications
	G643E	G643		
Electronic Throttle System	1	1	Minimum Electrical Resistance of Throttle Actuator	1.5 ohms

LP Fuel Components Specification

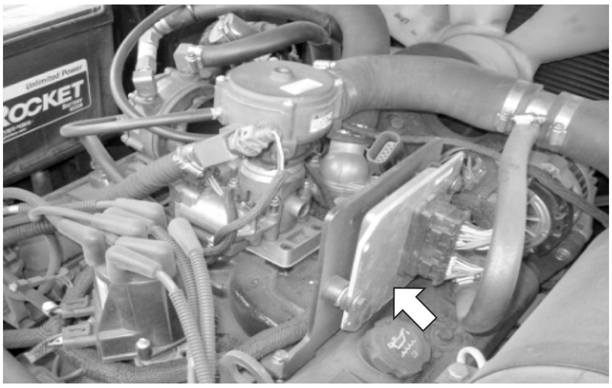
Components	Q'ty		Items	Specifications
	G643E	G643		
LP Fuel System Requirements	-	-	Operating Temperature LPG Composition Requirements	-20 °F to 221°F [-29 °C to 105 °C] HD5 / HD10 LPG. Failure to use fuel compliant with HD5 or HD10 standards will void the user warranty.
LP Fuel Filter	1	1	Fuel Filter Micron Size	40 micron
LP Fuel Lock-off	1	1	Electrical Resistance	20~25Ω
N-2007 LP Regulator For G643E	1	None	Fuel Supply Pressure Fuel Inlet Fitting Fuel Outlet Fitting Fuel Supply Temperature at Tank Outlet Primary Pressure Tap Max Flow Coolant Flow to Vaporizer Fuel Outlet Pressure Setpoints Mounting	10 psi to 250 psi (68.95 kPa to 1723.69 kPa) 1/4" NPT Two 3/4" NPT fittings with one plugged and one 1/8" NPT fitting with plug -20 °F to 120 °F [-29 °C to 49 °C] 1/8" NPT with plug 50 lbm/hr LPG > 1.0 gpm/100bhp, equipped with 140 °F (60 °C) thermostat -0.7 ± 0.2 inH2O @ 1.7 lbm/hr LPG (-1.744 ± 0.498 mbar) @ 1.7 lbm/hr LPG) -2.0 ± 0.2 inH2O @ 50 lbm/hr LPG (-4.982 ± 0.498 mbar) @ 50 lbm/hr LPG) Regulator should be installed with centerline of outlet at least 15° below horizontal to permit drainage of any liquid precipitates from LPG fuel. Diaphragm should be vertically oriented.

<table>
<tr><th rowspan="2">Components</th><th colspan="2">Q'ty</th><th rowspan="2">Items</th><th rowspan="2">Specifications</th></tr>
<tr><th>G643E</th><th>G643</th></tr>
<tr><td rowspan="8">N-2001 LP Regulator
For G643</td><td rowspan="8">None</td><td rowspan="8">1</td><td>Fuel Supply Pressure</td><td>10 psi to 250 psi (69 kPa to 1724 kPa)</td></tr>
<tr><td>Fuel Inlet Fitting</td><td>1/4" NPT</td></tr>
<tr><td>Fuel Outlet Fitting</td><td>One 3/4" NPT and one 1/8" NPT fitting with plug</td></tr>
<tr><td>Fuel Supply Temperature At Tank Outlet</td><td>-20 °F to 120 °F [-29 °C to 49 °C]</td></tr>
<tr><td>Primary Pressure Tap</td><td>1/8" NPT with plug</td></tr>
<tr><td>Max Flow</td><td>50 lbm/hr LPG</td></tr>
<tr><td>Coolant Flow to Vaporizer</td><td>>1.0 gpm/100bhp, equipped with 140 °F (60°C) thermostat</td></tr>
<tr><td>Fuel Outlet Pressure Setpoints</td><td>-0.5 ± 0.35 inH2O@1.7 lbm/hr LPG
(-1.25 ± 0.87 mbar)@1.7 lbm/hr LPG)
-1.35 ± 0.5 inH2O@32.1 lbm/hr LPG
(-3.36 ± 1.25 mbar)@32.1 lbm/hr LPG)</td></tr>
<tr><td rowspan="10">CA100 Mixer
For G643</td><td rowspan="10">1</td><td rowspan="10">None</td><td>Fuel</td><td>LPG</td></tr>
<tr><td>Fuel Inlet Fitting</td><td>1/2" NPT Fuel inlet fitted with Delphi temperature sensor</td></tr>
<tr><td>Air Intake Flange</td><td>2.25" (57.15mm) ID inlet, four #10-24 screws in
1.94" (49.28mm) square pattern</td></tr>
<tr><td>Mixer Mounting Flange</td><td>1.87" (47.49mm ID outlet, four #12-24 screws arranged in a rectangular pattern</td></tr>
<tr><td>Reference Pressure Ports</td><td>Two 1/8-NPT ports. Pressure readings must be identical within 0.25 inH2O (0.623 mbar) at all airflows.</td></tr>
<tr><td>Air Valve Vacuum (AVV) Port Size</td><td>1/4-28 UNF</td></tr>
<tr><td>Fuel Inlet Adjustments</td><td>None</td></tr>
<tr><td>Idle Air Adjustment</td><td>None</td></tr>
<tr><td>Mounting</td><td>Suitable for on-engine mounting in vertical orientation</td></tr>
</table>

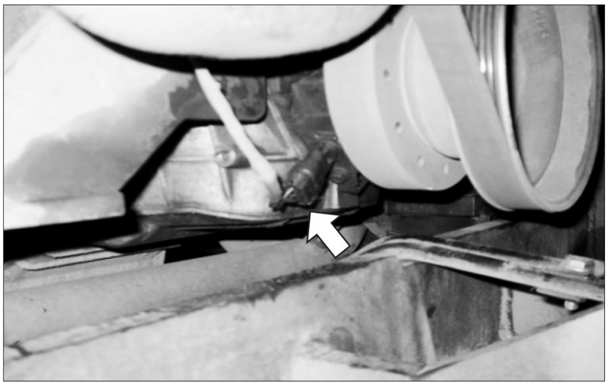
Components	Q'ty		Items	Specifications
	G643E	G643		
CA100 Mixer For G643	None	1	Fuel	LPG
			Fuel Inlet Fitting	1/2" NPT Fuel inlet fitted with Delphi temperature sensor
			Air Intake Flange	2.25" (57.15mm) ID inlet, four #10-24 screws in 1.94" (49.28mm) square pattern
			Mixer Mounting Flange	1.87" (47.49mm ID outlet, four #12-24 screws arranged in a rectangular pattern
			Reference Pressure Ports	1/4-1/8 NPT ports. Pressure readings must be identical within 0.25 inH_2O (0.623 mbar) at all airflows.
			Air Valve Vacuum (AVV) Port Size	1/4-28 UNF
			Fuel Inlet Adjustments	Power valve
			Idle Air Adjustment	Idle adjustment screw
			Mounting	Suitable for on-engine mounting in vertical orientation
Fuel Trim Valve (FTV)	2	None	Actuator Type Operating Voltage	On/off two-position valve compatible with LPG 8-16 Vdc

Component Location

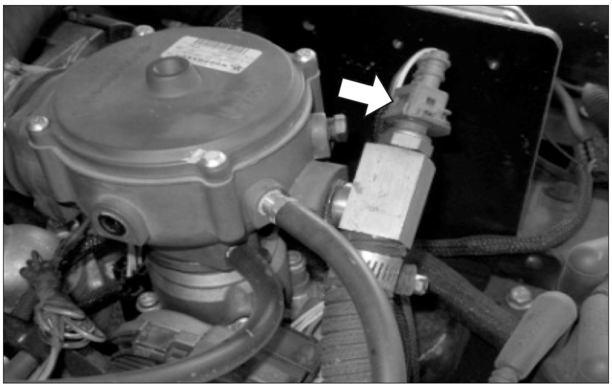
Engine Control Module (SECM48)



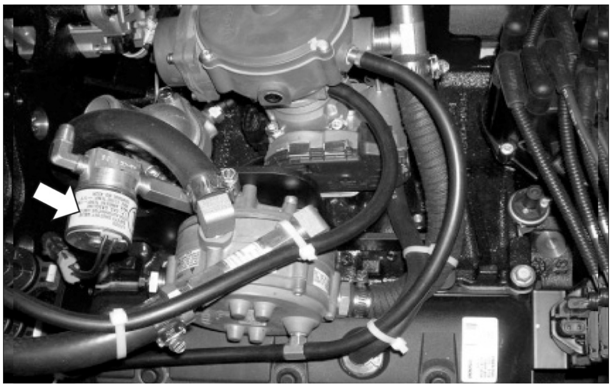
Crankshaft Position Sensor



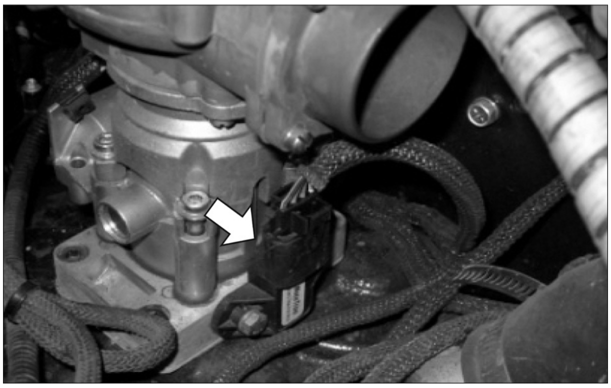
LP Fuel Temperature Sensor



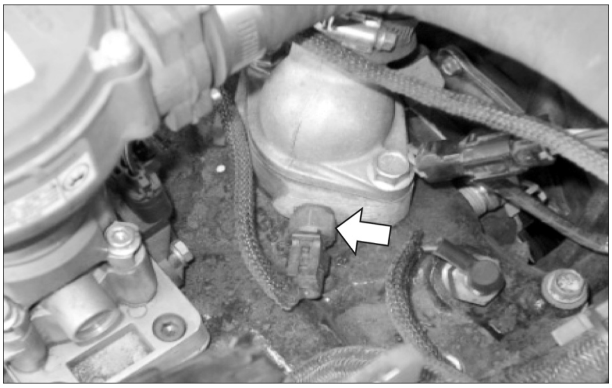
LP Fuel Lock-off



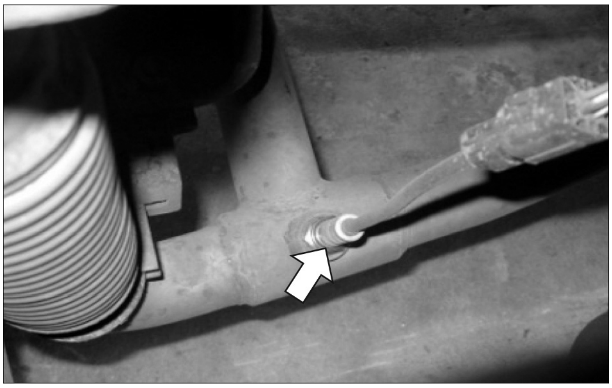
TMAP Sensor



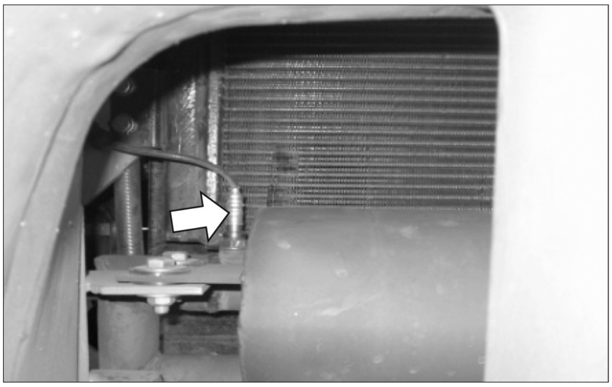
Coolant Temperature Sensor



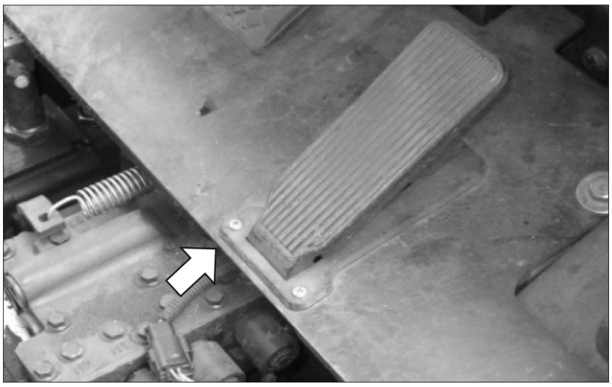
Pre-Catalyst Oxygen Sensor



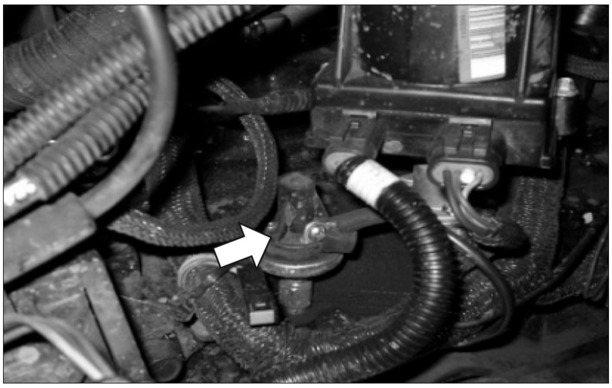
Post-Catalyst Oxygen Sensor



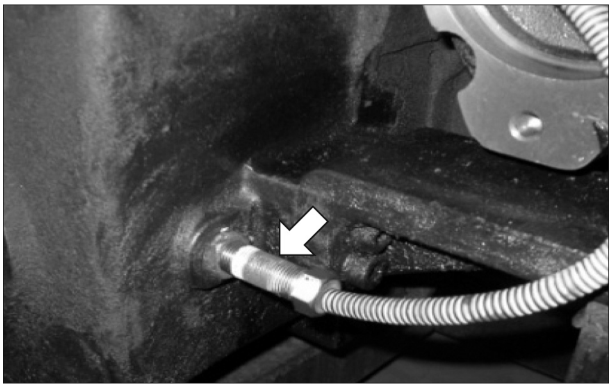
Pedal Angle Sensor



Engine Oil Pressure Switch

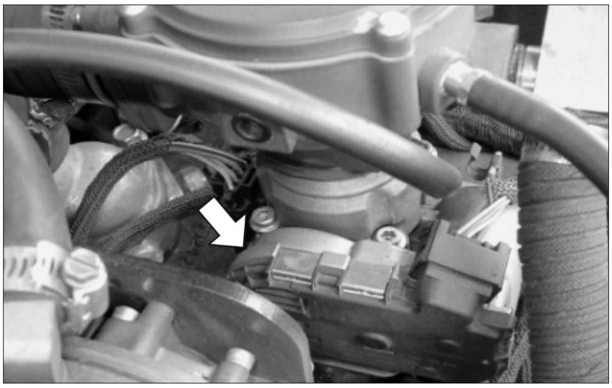


Ground Speed limit (option) – Sensor
-

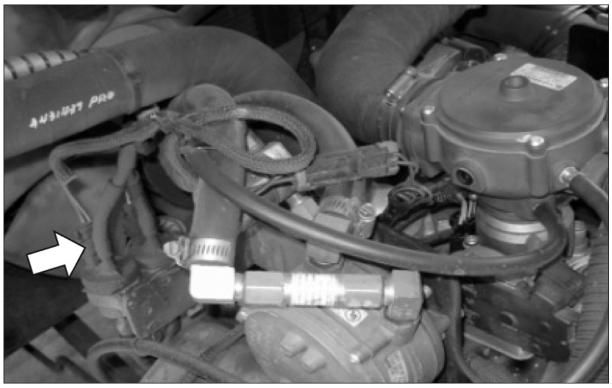


Ground speed limit (option) - Controller

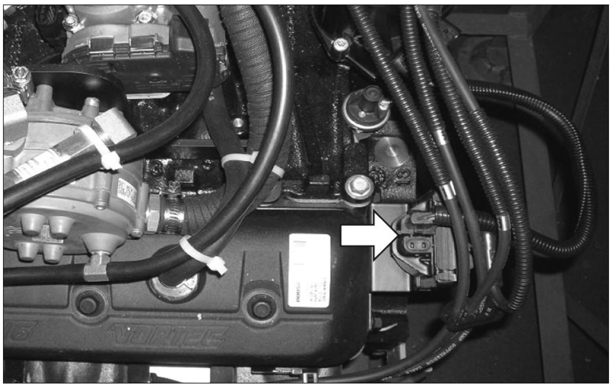
Electronic Throttle Body



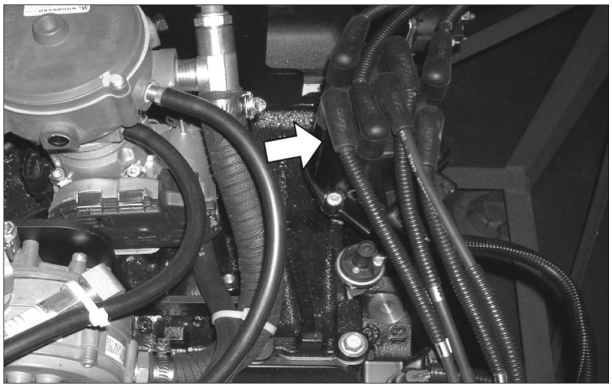
Fuel Trim Valve(FTV)



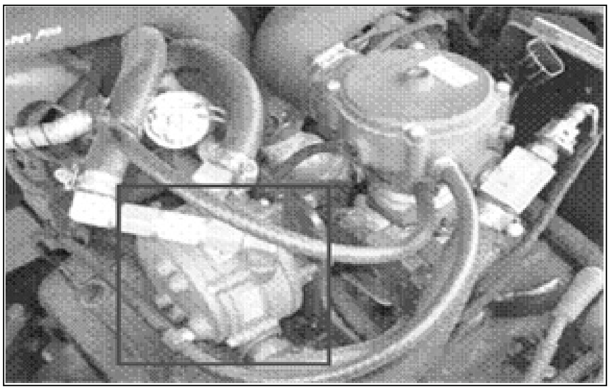
Ignition Coil



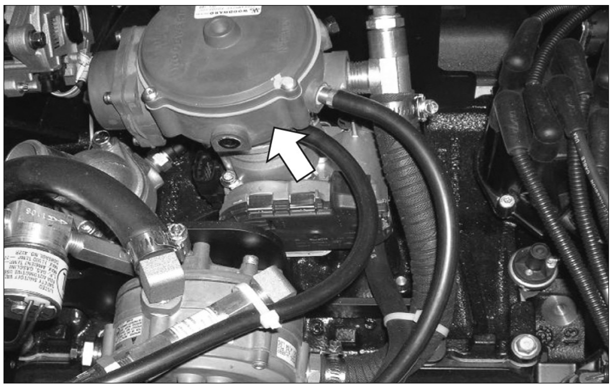
Distributor



N-2007 LP Regulator



CA100 Mixer



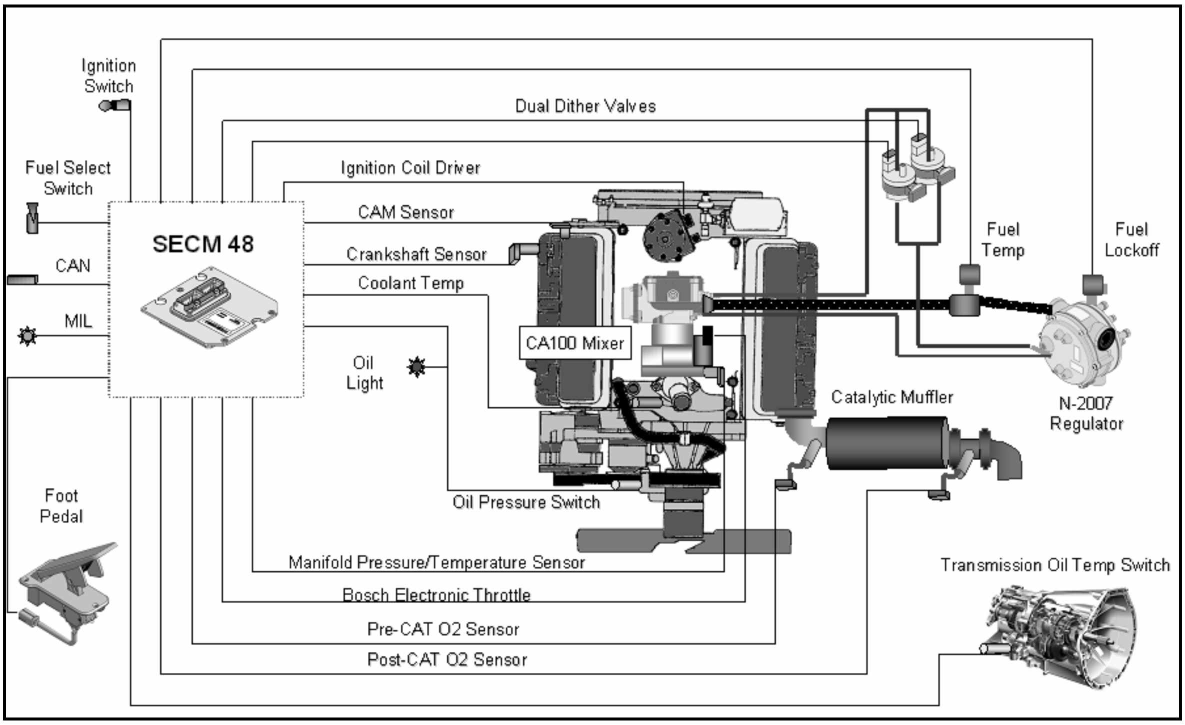
G643E EMS (Engine Management System) Overview

General Description

MI-07 control system provides a complete, fully integrated engine management system that meets or exceeds 2007 emission standards for Large Spark Ignited (LSI) engines established by the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA).

The control system is applicable to naturally aspirated engines running on LPG and/or gasoline. It provides accurate, reliable, and durable control of fuel, spark, and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

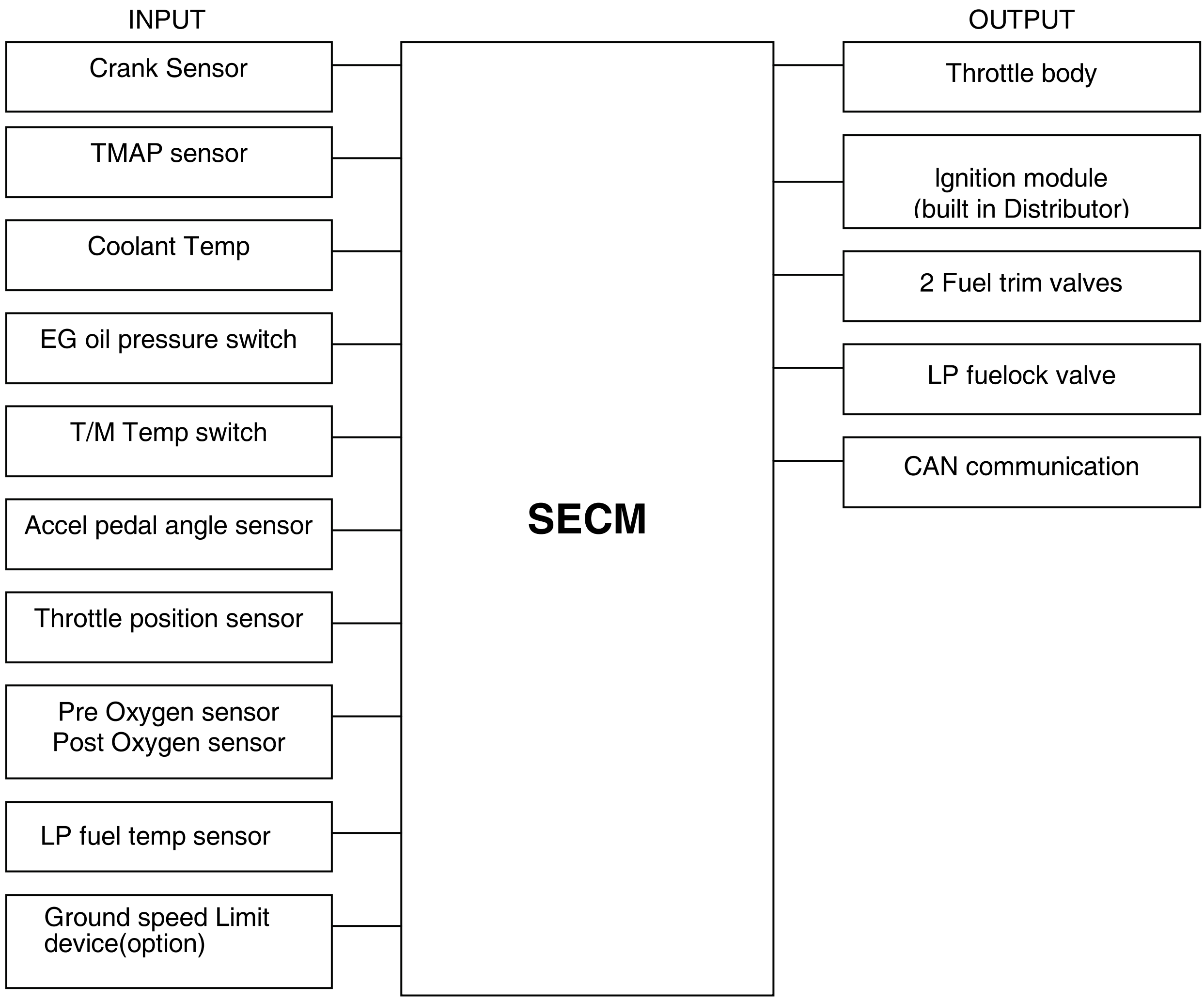
MI-07 is a closed loop system utilizing a catalytic muffler to reduce the emission level in the exhaust gas. In order to obtain maximum effect from the catalyst, an accurate control of the air fuel ratio is required. A small engine control module (SECM) uses two heated exhaust gas oxygen sensors (HEGO) in the exhaust system to monitor exhaust gas content. One HEGO is installed in front of the catalytic muffler and one is installed after the catalytic muffler.



[Figure 1] MI-07 LP Fuel System for G643E Engine

The SECM makes any necessary corrections to the air fuel ratio by controlling the inlet fuel pressure to the air/fuel mixer by modulating the dual fuel trim valves (FTV) connected to the regulator. Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air/fuel mixture. To calculate any necessary corrections to the air fuel ratio, the SECM uses a number of different sensors to gain information about the engine's performance. Engine speed is monitored by the SECM through a Variable reluctance (VR) sensor. Intake manifold air temperature and absolute pressure are monitored with a TMAP sensor. MI-07 is a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Even engine coolant temperature and adequate oil pressure are monitored by the SECM. The SECM controller has full adaptive learning capabilities, allowing it to adapt control function as operating conditions change. Factors such as ambient temperature, fuel variations, ignition component wear, clogged air filter, and other operating variables are compensated.

LP Fuel System of G643E (certified engine system)



MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

• Fuel delivery system

• Spark-ignition control system

• Air throttle

• Sensors/Switches/Speed inputs

The chart below lists the MI-07 components required for a G643 (E) engine operating on LP fuel.

Q'ty		DESCRIPTION
G643E	G643	
1	1	Engine Control Module (SECM)
None	None	Camshaft Position Sensor
1	1	Crankshaft Position Sensor
1	1	TMAP Sensor
1	None	Fuel Temperature Sensor
1	None	Transmission Oil Temperature Switch
2	None	Oxygen Sensors
1	1	Coolant Temperature Sensor
1	1	Engine Oil Pressure Switch
2	None	Fuel Trim Valve
1	1	Ignition Coil
1	1	Fuel Lock Off Solenoid
N-2007	N-2001	LP Regulator
CA-100 (Certified)	CA-100	LP Mixer
1	1	Electronic Throttle Body

Key Components

The MI-07 system functions primarily on engine components that affect engine emissions and performance. These key components include the following:

• Engine/Combustion chamber design

• Intake/Exhaust valve configuration, timing and lift

• Intake/Exhaust manifold design

• Catalytic converter and exhaust system

• Throttle body

• Air intake and air filter

• LPG mixer

• LPG pressure regulator

• Fuel trim valves

• Fuel trim orifices

• Small engine control module (SECM), firmware and calibration †

• Fuel system sensors and actuators

• Ignition system including spark plugs, cables, coils and drivers

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

• Closed-loop fuel control

• Speed-load spark control with tables for dwell, timing, and fuel type

• Speed-load throttle control with table for maximum TPS limiting

• Closed-loop fuel control with two oxygen sensors (one installed pre catalyst and one installed post catalyst). The pre-catalyst oxygen sensor includes adaptive learn to compensate for fuel or component drift. The post-catalyst oxygen sensor includes adaptive learn to compensate the pre-catalyst oxygen sensor setting for pre-catalyst oxygen sensor drift and catalyst aging. The pre-catalyst oxygen sensor function includes parameters for transport delay, O2 set point, excursion rich/lean, jump back rich/lean, and perturbation.

• LPG fuel temperature compensation

• Min/max governing

• All-speed isochronous governing

- Fixed-speed isochronous governing with three switch-selectable speeds

- Fuel enrichment and spark timing modifiers for temperature and fuel type

- Transient fuel enrichment based on rate of change of TPS

- Transient wall wetting compensation for gasoline

- Input sensor selection and calibration

- Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.

- CANBus data transfer for speed, torque, etc.

Other system features include:

Tamper-Resistance
Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics
MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL lamp. With the MIL lamp, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode
The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 rpm at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool
A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

LPG Fuel System Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system.

An LPG fuel system consists of the following components:

- Fuel filter

- Electric fuel lock-off solenoid valve

- Fuel pressure regulator/vaporizer

- Two orificed fuel trim valves

- Gas/Air mixer with fixed orifice for trim system and fuel temperature sensor

- Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer.

Dual Dither Valve

The key to meeting emissions requirements when operating in LPG is the dual dither valve hardware in the fuel system. Similar to the MI-04 system, the dual dither system modulates the fuel pressure regulator outlet pressure by providing an offset to the regulator secondary stage reference pressure. By adding a second dither valve, or fuel trim valve (FTV), to the MI-07 system, smoother, more accurate control of supply pressure is achieved, resulting in better control of air fuel ratio and emissions. This smoother control also minimizes wear on fuel system components such as the regulator diaphragm and lever by significantly reducing the pressure pulsations observed with a single FTV.

Regulator Pressure Offset

Regulator pressure offset is achieved through the use of a fixed orifice and a variable orifice in series. The inlet to the fixed orifice is connected to the mixer inlet pressure (roughly equal to ambient pressure). The outlet of the fixed orifice is connected to both the pressure regulator reference port and the inlet to the two FTVs (the variable orifice) that act in parallel. The outlets of the FTVs are connected to the mixer outlet, referred to as Air Valve Vacuum (AVV). Thus, by modulating the FTVs, the pressure regulator reference pressure can be varied between mixer inlet pressure and AVV. For a given change in the pressure regulator reference pressure, the pressure regulator outlet pressure changes by the same amount and in the same direction. The end result is that a change in FTV modulation changes the outlet pressure of the regulator/fuel inlet pressure of the mixer, and thus the AFR. A major benefit of this trim system results from the use of mixer inlet pressure and AVV as the reference pressure extremes. The pressure differential across the mixer fuel valve is related to these same two pressures, and thus so is fuel flow. Given this arrangement, the bias pressure delta scales with the fuel cone delta pressure. The result is that the trim system control authority and resolution on AFR stays relatively constant for the entire speed and load range of the engine.

SECM

The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve and the FTVs. The lock-off solenoid is energized when fueling with LPG and the engine is turning. FTV modulation frequency will be varied as a function of rpm by the SECM in order to avoid resonance phenomena in the fuel system. FTV commands will be altered by the SECM in order to maintain a stoichiometric air-fuel ratio. Commands are based primarily on feedback from the exhaust gas oxygen sensor, with an offset for fuel temperature.

MI-07 LP Fuel Filter

After exiting the fuel tank, liquid propane passes through a serviceable inline fuel filter to the electric fuel lock off. Figure 3 shows a typical inline type LP fuel filter manufactured by Century. The primary function of the fuel filter is to remove particles and sediments that have found their way into the tank. The LP fuel filter will not remove heavy end solids and paraffins that build up in LPG fuel systems as a result of vaporization.

Figure 3. Inline LP Fuel Filter

MI-07 Fuel Lock-Off (Electric)

The fuel lock-off is a safety shutoff valve, normally held closed by spring pressure, which is operated by an electric solenoid and prevents fuel flow to the regulator/ converter when the engine is not in operation. This is the first of three safety locks in the MI-07 system.

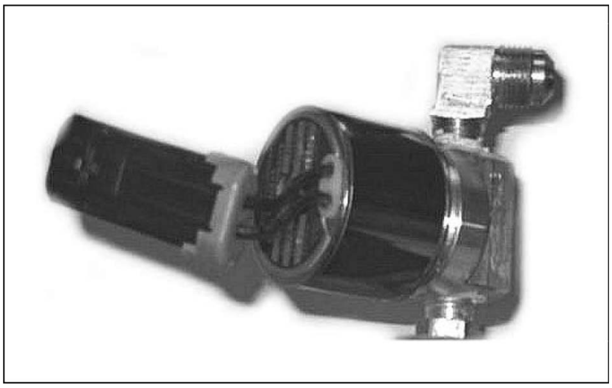


Figure 4. Electric Fuel Lock Assembly

In the MI-07 design, power is supplied to the fuel lock-off via the main power relay with the SECM controlling the lock-off ground (earth) connection. The lock-off remains in a normally closed (NC) position until the key switch is activated.
This supplies power to the lock-off and the SECM, but will not open the lock-off via the main power relay until the SECM provides the lock-off ground connection. This design gives the SECM full control of the lock-off while providing additional safety by closing the fuel lock-off in the unlikely event of a power failure, wiring failure or module failure.

When the liquid service valve in the fuel container is opened, liquid propane flows through the LP filter and through the service line to the fuel lock-off. Liquid propane enters the lock-off through the 1/4" NPT liquid inlet port and stops with the lock-off in the normally closed position. When the engine is cranked over the main power relay applies power to the lock-off and the SECM provides the lock-off ground causing current to flow through the windings of the solenoid creating a magnetic field. The strength of this magnetic field is sufficient to lift the lock-off valve off of its seat against spring pressure. When the valve is open liquid propane, at tank pressure, flows through the lock-off outlet to the pressure regulator/converter. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states: Crank, when the crankshaft position sensor detects any engine revolutions; Stall, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions; and the Run state, when the engine reaches pre-idle rpm. When an operator turns on the key switch the lock-off is opened, but if the operator fails to crank the engine the SECM will close the lock-off after 5 seconds.

N-2007 Pressure Regulator/Vaporizer

The pressure regulator/vaporizer receives liquid LPG from the fuel storage tank, drops the pressure, changes the LPG phase from liquid to vapor, and provides vapor phase LPG at a regulated outlet pressure to the mixer. To offset the refrigeration effect of the vaporization process, the regulator will be supplied with engine coolant flow sufficient to offset the latent heat of vaporization of the LPG.

A thermostat provided in the coolant supply line to maintain regulator outlet coolant temperature at or below 140oF (60°C) will minimize the deposit of fuel contaminants and heavy ends in the regulator and assure a more controlled vaporization process with reduced pressure pulsations.

A higher flow pressure regulator is required on larger engines.

Figure 5. N-2007 Regulator

The regulator is normally closed, requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the secondary (2nd stage) valve and the primary (1st stage) valve closes. Unlike most other regulator/converters, the N-2007 primary valve closes with fuel pressure rather than against pressure, extending primary seat life and adding additional safety.

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced, the liquid propane vaporizes and refrigeration occurs inside the regulator due to the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber.

N-2007 Operation

(Refer to Figure 6.)

Liquid propane, at tank pressure, enters the N-2007 through the fuel inlet port (1). Propane liquid then flows through the primary valve (2). The primary valve located at the inlet of the expansion chamber (3), is controlled by the primary diaphragm (4), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (5), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (6). The secondary valve is held closed by the secondary spring on the secondary valve lever (7). The secondary diaphragm controls the secondary lever. When the pressure in the expansion chamber reaches 1.5 psig (10.3 kPa) it causes a pressure/force imbalance across the primary diaphragm (8). This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

Since the fuel pressure has been reduced from tank pressure to 1.5 psig (10.3 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened. To open the secondary valve, a negative pressure signal must be received from the air/fuel mixer.

When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator, which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

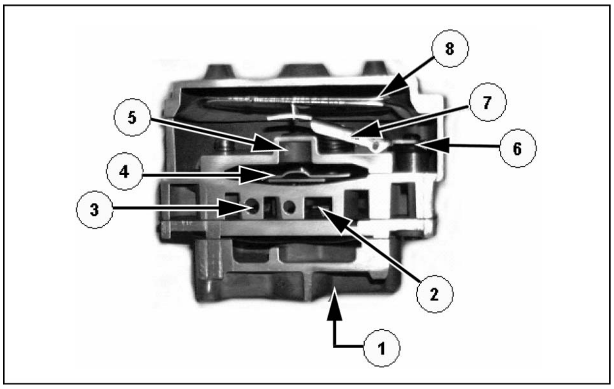


Figure 6. Parts View of N-2007 Regulator

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

CA100 Mixer

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine.

The mixer fuel inlet is fitted with a thermistor-type temperature sensor. This permits the SECM to correct fuel pressure to compensate for variations in fuel temperature. Left uncorrected, fuel temperature variations can cause significant variations in air fuel ratio.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.

Figure 7. CA100 Mixer

CA100 Mixer Operation

Vapor propane fuel is supplied to the CA100 mixer by the N-2007 pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.

Figure 8. CA100 Mixer Attached to Throttle Body

(Refer to Figure 98.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (1) and a gas discharge jet (2). In the center of the main body is the air valve assembly, which is made up of the air valve (3), the gas-metering valve (4), and air valve diaphragm (5) and air valve spring (6). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranked over it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

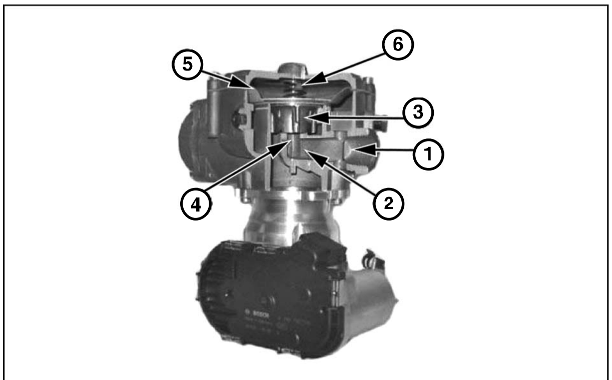


Figure 9. Parts View of CA100 Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inH2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inH2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

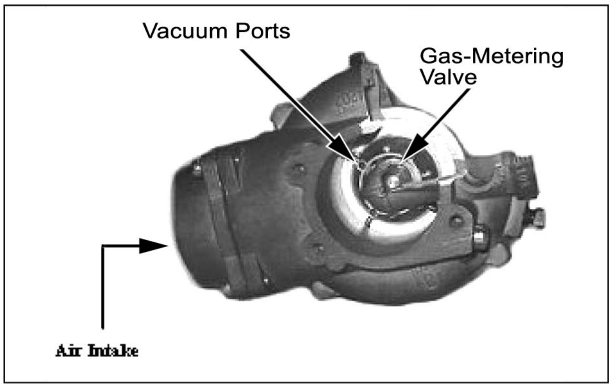


Figure 10. Bottom View of Air Valve Assembly

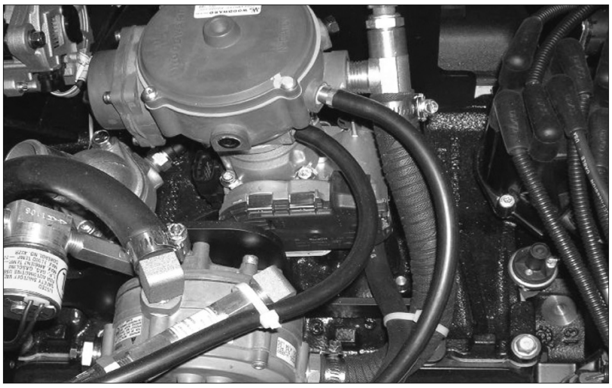


Figure 11. CA100 Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the CA100 is not used in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (Figure 12). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper proof cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter.

NOTE: Adjustments should only be performed by trained service technicians.

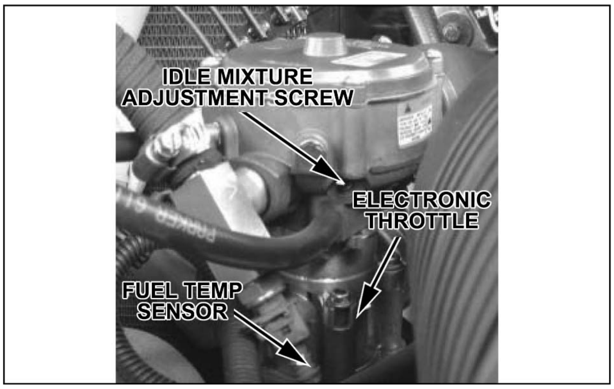


Figure 12. Idle Mixture Adjustment Screw
(with tamper proof cap removed)

Fuel Trim Valve (FTV)

The Fuel Trim Valve (FTV) is a two-way electric solenoid valve and is controlled by a pulse-width modulated (PWM) signal provided by the SECM. Two FTVs are used to bias the output fuel pressure on the LPG regulator/converter (N-2007), by metering air valve vacuum (AVV) into the atmospheric side of the N-2007 secondary regulator diaphragm. An orifice balance line connected to the air inlet side of the mixer provides atmospheric reference to the N-2007 when the FTV is closed. The SECM uses feedback voltage from the O2 sensor to determine the amount of bias needed to the regulator/converter.

In normal operation the N-2007 maintains fuel flow at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing from the N-2007 will vary depending on how far the secondary diaphragm opens the secondary valve in response to the negative pressure signal generated by the air/fuel mixer. One side of the N-2007 secondary diaphragm is referenced to FTV control pressure while the other side of the diaphragm reacts to the negative pressure signal from the mixer. If the pressure on the reference side of the N-2007 secondary diaphragm is reduced, the diaphragm will close the secondary valve until a balance condition exists across the diaphragm, reducing fuel flow and leaning the air/fuel mixture.

Branch-Tee Fitting

A branch-tee fitting is installed in the atmospheric vent port of the N-2007 with one side of the branch-tee connected to the intake side of the mixer forming the balance line and referencing atmospheric pressure. The other side of the branch-tee fitting connects to the FTV inlet (small housing side). The FTV outlet (large housing connector side) connects to the AVV port. When the FTVs are open AVV is sent to the atmospheric side of the N-2007 secondary diaphragm, which lowers the reference pressure, closing the N-2007 secondary valve and leaning the air/fuel mixture. The MI-07 system is calibrated to run rich without the FTV. By modulating (pulsing) the FTVs the SECM can control the amount of AVV applied to the N-2007 secondary diaphragm. Increasing the amount of time the FTVs remain open (modulation or duty cycle) causes the air/fuel mixture to become leaner; decreasing the modulation (duty cycle) enriches the mixture.

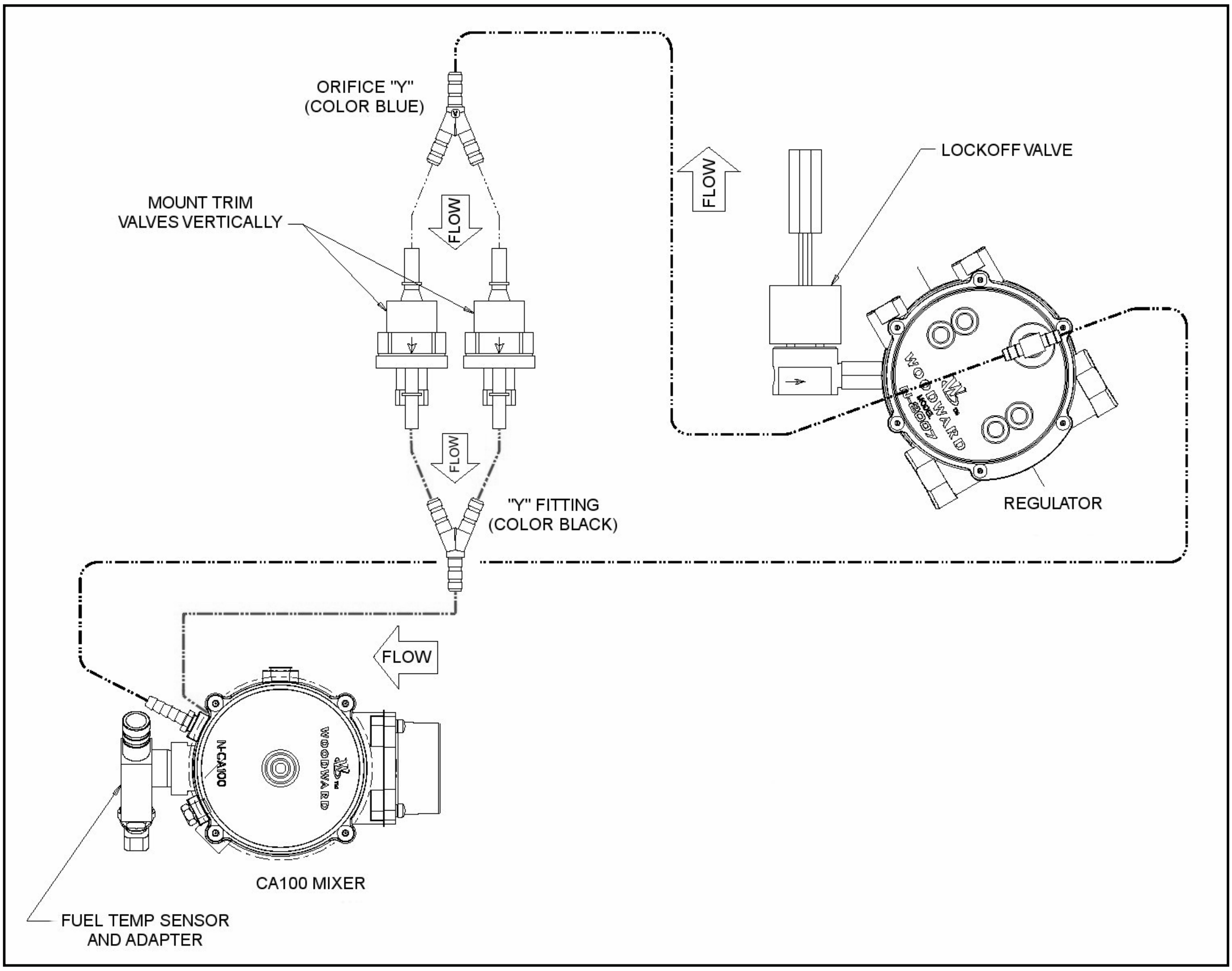


Figure 13. Fuel Trim Valves Connected to MI-07 System

Electronic Throttle System

The electronic throttle system controls engine output (speed and torque) through electronic control of mass airflow to the engine. Any DC motor-actuated or Limited Angle Torquemotor (LAT)-actuated throttle with less than 5A peak and 2A steady state can be controlled. The TPS must be directly coupled to the throttle shaft for direct shaft position measurement.

A commonly used throttle is the Bosch DV-E5. This throttle is available in a variety of bore sizes to meet specific engine needs: 32mm, 40mm, and 54mm are readily available throttle bore sizes; other sizes are possible. The Bosch throttle is a fully validated automotive component incorporating a brushed DC motor with gear reduction, dual throttle position sensors, throttle plate, and cast aluminum housing. In the event of an electrical disconnection or other related failure, the throttle plate returns to a limp-home idle position at a no-load engine speed above curb idle speed. This provides sufficient airflow for the engine to move the vehicle on level ground. Any throttle bodies used for MI-07 meet or exceed the specification for the Bosch throttle bodies.

In terms of response, the throttle is capable of fully opening and closing in less than 50 msec. Position resolution and steady state control should be 0.25% of full travel or better.

MI-07 Electronic Throttle

Conventional throttle systems rely on a mechanical linkage to control the throttle valve. To meet fluctuating engine demands a conventional system will typically include a throttle valve actuator designed to readjust the throttle opening in response to engine demand, together with an idle control actuator or idle air bypass valve.

In contrast, the MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 40mm electronic throttle body DV-E5 (Figure 14). The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver's demand, makes any adjustments needed for adaptation to the engine's current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator.

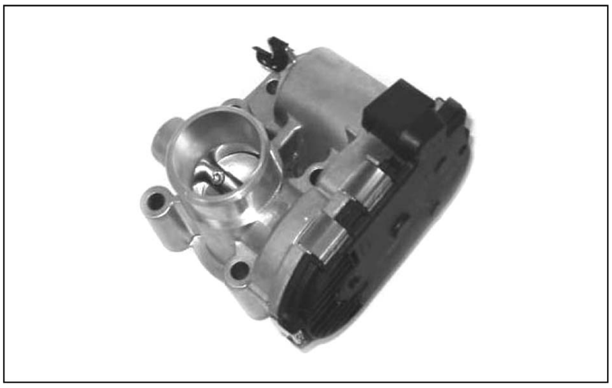


Figure 14. Bosch Electronic Throttle Body

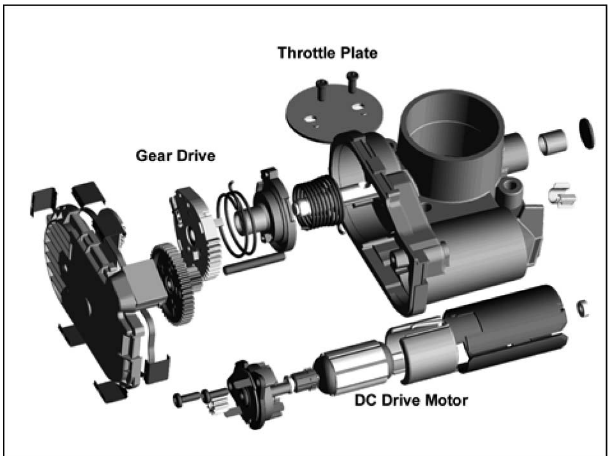
The MI-07 uses a dual TPS design (TPS1 and TPS2). The SECM continuously checks and monitors all sensors and calculations that effect throttle valve position whenever the engine is running. If any malfunctions are encountered, the SECM's initial response is to revert to redundant sensors and calculated data. If no redundant signal is available or calculated data cannot solve the malfunction, the SECM will drive the system into one of its limp-home modes or shut the engine down, storing the appropriate fault information in the SECM.

There are multiple limp-home modes available with electronic throttle control:

1. If the throttle itself is suspected of being inoperable, the SECM will remove the power to the throttle motor. When the power is removed, the throttle blade returns to its “default” position, approximately 7% open.

2. If the SECM can still control the throttle but some other part of the system is suspected of failure, the SECM will enter a “Reduced Power” mode. In this mode, the power output of the engine is limited by reducing the maximum throttle position allowed.

3. In some cases, the SECM will shut the engine down. This is accomplished by stopping ignition, turning off the fuel, and disabling the throttle.



Picture courtesy of Robert Bosch GmbH

Figure 15. Throttle Body Assembly Exploded View

Ignition System Control

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

• SECM

• Distributor with ignition module

• Ignition coil ∗

• Crankshaft position sensor ∗

• Crankshaft timing wheel ∗

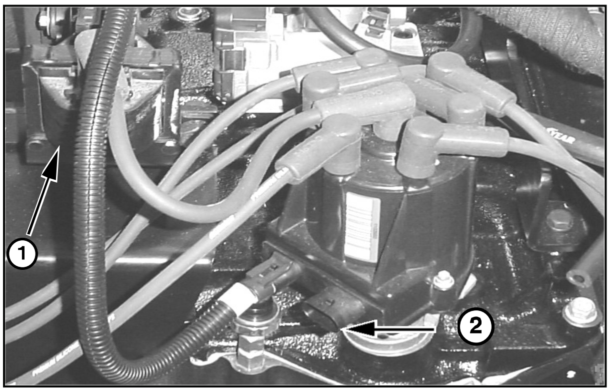
• Spark plugs ∗

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

Figure 14. GM Distributor

The MI-07 system is capable of operating with either a distributor based ignition system or a distributorless ignition system. The current application uses a distributor based ignition system. The distributor will have no internal advance mechanisms giving the SECM consistent authority over ignition timing. The spark is sent to the appropriate cylinder in the conventional way via the rotor arm and spark plug wires. The SECM uses the signal from the GM (General Motors) Delco Ignition Module to determine the engine position and RPM at any time. It uses this information together with the information from the TPS sensor and TMAP to calculate the appropriate ignition timing settings.

The General Motors (GM) distributor (Figure 14) used in the Delco EST ignition system, incorporates



a Variable Reluctance (VR) sensor, which transmits a reference signal to the GM ignition module (Figure 15) located on the distributor. A variable reluctance sensor is an electromagnetic device consisting of a permanent magnet surrounded by a winding of wire. The sensor is used in conjunction with a ferrous signal rotor on the distributor shaft. The signal rotor has six lobes, one for each cylinder. Rotation of the signal rotor near the tip of the sensor changes the magnetic flux, creating an analog voltage signal in the sensor coil.

(1) Ignition coil (2) Ignition module

Figure 15. GM Ignition Module

The rising edge of the VR signal is converted to a rising 5-volt signal by the ignition module. As the VR signal passes back through zero volts, a falling edge is created producing a square wave or digital signal, similar to the signal produced by a Hall effect sensor. This falling edge signal provides a stable engine position reference at all engine speeds for the SECM.

Exhaust System

Heated Exhaust Gas Oxygen Sensors (HEGO)

The MI-07 system utilizes two HEGO (O2) sensors. One sensor is a pre-catalyst sensor that detects the amount of oxygen in the exhaust stream and is considered the primary control point. Based upon the O2 sensor feedback, the MI-07 system supplies a stoichiometric air-fuel ratio to the catalytic converter. The catalytic converter then reduces emissions to the required levels. The second sensor is a post-catalyst sensor that detects the amount of oxygen after the catalyst. This sensor is used as a secondary control point to adjust the pre-catalyst setpoint to ensure proper catalyst conversion efficiency.

Figure 18. HEGO (O2) Sensor

Once a HEGO sensor reaches approximately 600°F (316°C), it becomes electrically active. The concentration of oxygen in the exhaust stream determines the voltage produced. If the engine is running rich, little oxygen will be present in the exhaust and voltage output will be relatively high. Conversely, in a lean situation, more oxygen will be present and a smaller electrical potential will be noticed.

In order for the sensor to become active and create an electrical signal below 600°F (316°C) a heated element is added to the sensor housing. Two wires provide the necessary 12 Vdc and ground signal for the heater element. A fourth wire provides an independent ground for the sensor. The pre-catalyst sensor heater is powered by the main power relay and is always powered. The post-catalyst sensor heater is powered from an additional relay that is controlled by the SECM. This relay is only energized when the SECM calculates that water condensation in the exhaust system and catalytic muffler prior to the sensor should be evaporated. This is to avoid thermal shock of the sensor that could prematurely fail the sensor.

The HEGO stoichiometric air-fuel ratio voltage target is approximately 500 mV and changes slightly as a function of speed and load. When the pre-catalyst HEGO sensor sends a voltage signal less than 450 mV the SECM interprets the air-fuel mixture as lean. The SECM then decreases the PWM duty cycle sent to the fuel trim valves in order to increase the fuel pressure to the mixer inlet; thus richening air-fuel mixture. The opposite is true if the SECM receives a voltage signal above 450 mV from the HEGO. The air-fuel mixture would then be interpreted as being too rich and the SECM would increase the duty cycle of the trim valves.

⚠ CAUTION

The HEGO sensors are calibrated to work with the MI-07 control system. Use of alternate senso-rs may impact performance and the ability of the system to diagnose rich and lean conditions.

Catalytic Muffler

In order to meet 2007 emission requirements a 3-way catalyst is necessary.

All exhaust gases pass through a catalyst that is mounted in the catalytic muffler. It filters the harmful gases through a dense honeycomb structure coated with precious metals such as platinum, palladium, and rhodium. Chemical reactions occur on these surfaces to convert the pollutants into less harmful gases. Catalysts store oxygen on lean mixtures (less than optimal amount of fuel) and release oxygen on rich mixtures (more than optimal amount of fuel). The primary pollutant produced on the lean swing is nitrous oxide. Oxygen is removed from nitrous oxide by the converter, resulting in nitrogen gas, a harmless emission. On the rich cycle, the primary pollutant is carbon monoxide. By adding the oxygen that was stored on the lean cycle to the carbon monoxide, carbon dioxide is produced.

Inside the catalytic muffler is a three-way catalyst as well as sound dampening and spark arresting features. The three-way catalyst section consists of a honeycomb coated with a mixture of platinum, palladium and rhodium. As engine exhaust gases flow through the converter passageways, they contact the coated surface, which initiate the catalytic process. The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce the NOx emissions. The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. Cerium is also used to promote oxygen storage and improve oxidation efficiency.

Oxidation and Reduction Process

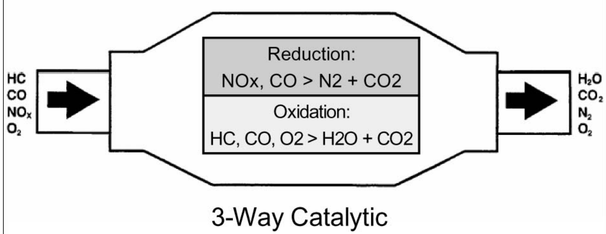
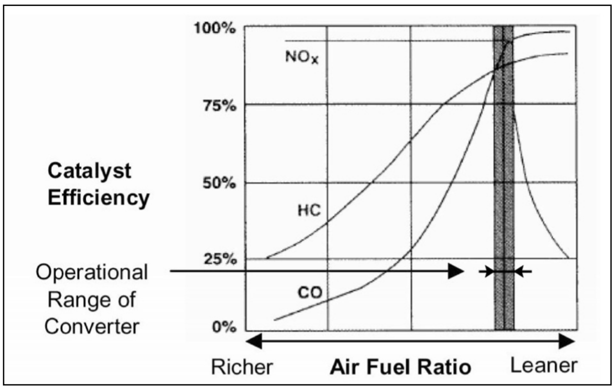


Figure 25

As exhaust and catalyst temperatures rise the following reaction occurs:

• Oxides of nitrogen (NOx) are reduced into simple nitrogen (N2) and carbon dioxide (CO2).

• Hydrocarbons (HC) and carbon monoxide (CO) are oxidized to create water (H2O) and carbon dioxide (CO2).



The MI-07 control system monitors the exhaust stream pre and post catalyst and uses this information to control the air-fuel mixture. By using the signals from the HEGOs, the SECM can increase or decrease the amount of oxygen in the exhaust by modulating the FTVs and adjusting the air-fuel ratio. This control scheme allows the SECM to make sure that the engine is running at the correct air to fuel ratio so that the catalyst can perform as required to meet the emissions certification.

SECM

General Description

The Small Engine Control Module (SECM) controller has full authority over spark, fuel and air. Utilizing a Freescale micro controller, the SECM has 48 pins of I/O and is fully waterproof and shock hardened. To optimize engine performance and drivability, the SECM uses several sensors for closed loop feedback information. These sensors are used by the SECM for closed loop control in three main categories:

• Fuel Management

• Load/Speed Management

• Ignition Management

The SECM monitors system parameters and stores any out of range conditions or malfunctions as faults in SECM memory. Engine run hours are also stored in memory. Stored fault codes can be displayed on the Malfunction Indicator Light (MIL) as flash codes or read by the MI-07 Service Tool software through a CAN (Controller Area Network) communication link.

Constant battery power (12 Vdc) is supplied through the fuse block to the SECM and the main power relays. Upon detecting a key-switch ON input, the SECM will fully power up and energize the main power relays.
The energized main power relays supply 12 Vdc power to the heated element of the oxygen sensors, fuel lock-off, fuel trim valves (FTVs), gasoline injectors, gasoline fuel pump, crank sensor, cam sensor, and the ignition coils.
The SECM supplies voltage to the electronic throttle actuator, oil pressure switch, fuel temperature sensor, and the coolant temperature sensor.
Transducer or sensor power (+ 5 Vdc) is regulated by the SECM and supplied to the manifold temperature/air pressure (TMAP) sensor, throttle position sensor (TPS), and the accelerator pedal position sensors (APP1 & APP2).

The SECM provides a transducer ground for all the sensors, and a low side driver signal controlling the fuel lock-off, MIL, gasoline injectors, gasoline fuel pump, and FTVs.

Fuel Management

During engine cranking at startup, the SECM provides a low side driver signal to the fuel lock-off, which opens the lock-off allowing liquid propane to flow to the N-2007 regulator. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states:

<u>Crank,</u> when the crankshaft position sensor detects any engine revolutions
<u>Stall</u>, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions
<u>Run</u> state, when the engine reaches pre-idle RPM.

When an operator turns on the key switch the lock-off is opened but if the operator fails to crank the engine, the SECM will close the lock-off after 5 seconds.

To maintain proper exhaust emission levels, the SECM uses a heated exhaust gas oxygen sensor (HEGO) mounted before the catalyst, to measure exhaust gas content in the LP gas system. Engine speed is monitored by the SECM through a variable reluctance (VR) sensor or Hall-Effect type sensor. Intake manifold air temperature and absolute pressure are monitored with a (TMAP) sensor.
The HEGO voltage is converted to an air/fuel ratio value. This value is then compared to a target value in the SECM. The target value is based on optimizing catalyst efficiency for a given load and speed. The SECM then calculates any corrections that need to be made to the air/fuel ratio.
The system operates in open loop fuel control until the engine has done a certain amount of work. This ensures that the engine and HEGO are sufficiently warmed up to stay in control. In open loop control, the FTV duty cycle is based on engine speed and load.
Once the HEGO reaches operating temperature the fuel management is in closed loop control for all steady state conditions, from idle through full throttle. In closed loop mode, the FTV duty cycle is based on feedback from the HEGO sensor. The system may return to open-loop operation when engine load or engine speed vary beyond a chosen threshold.

The SECM makes any necessary corrections to the air-fuel ratio by controlling the inlet fuel pressure to the air-fuel mixer Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air-fuel mixture. Control is achieved by modulating the fuel trim valves.

Speed Management

Drive-by-wire refers to the fact that the MI-07 control system has no throttle cable from the foot pedal to the throttle body. Instead, the SECM is electronically connected both to the foot pedal assembly and the throttle body.
The SECM monitors the foot pedal position and controls the throttle plate by driving a DC motor connected to the throttle. The DC motor actuates the throttle plate to correspond to the foot pedal position when the operator depresses the pedal. The SECM will override the pedal command above a maximum engine speed and below a minimum idle speed.

Figure 19. Foot Pedal

The use of electronic throttle control (ETC) ensures that the engine receives only the correct amount of throttle opening for any given situation, greatly improving idle quality and drivability.

Two throttle position sensors (TPS1 and TPS2), which are integral to the drive-by-wire (DBW) throttle assembly, provide feedback for position control by monitoring the exact position of the throttle valve. See Figure 20.

SECM self-calibration and “cross checking” compares both signals and then checks for errors.

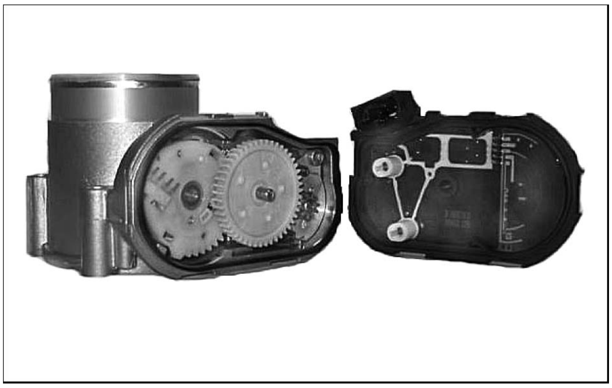


Figure 20. Throttle Position Sensor (TPS) on DV-E5 Throttle

NOTE : The DV-E5 throttle is not a serviceable assembly. If a TPS sensor fails, the assembly should be replaced.

The MI-07 system also performs minimum (min) and maximum (max) speed governing through the SECM and DBW throttle. For min governing, or idle speed control, the idle speed is fixed by the SECM. Unlike a mechanical system, the idle speed is not adjustable by the end user. The idle speed is adjusted by the SECM based on engine coolant temperature. At these low engine speeds, the SECM uses spark and throttle to maintain a constant speed regardless of load.

The MI-07 system eliminates the need for air velocity governors. This substantially increases the peak torque and power available for a given system as shown in Figure 21. When the engine speed reaches the max governing point the speed is controlled by closing the DBW throttle. Using the DBW throttle as the primary engine speed control allows for a smooth transition into and out of the governor. If excessive over speed is detected, the engine is shut down.

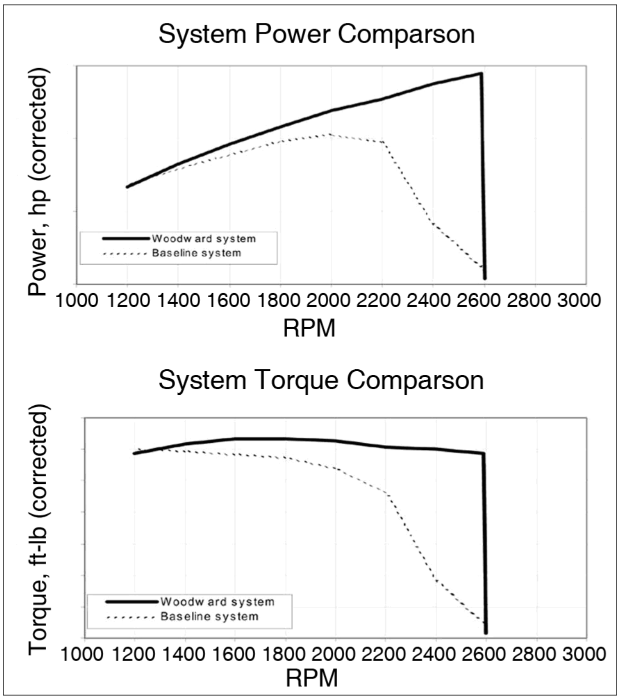


Figure 21. Peak Torque and Power Available with MI-07 System

Drive-By-Wire Signal Flow Process

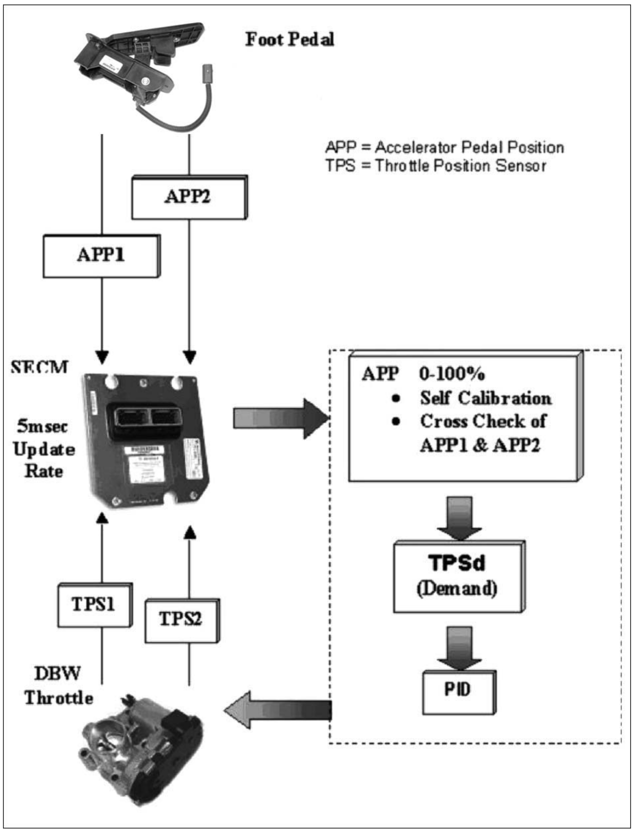


Figure 22. Drive-By-Wire Signal Flow Process

Figure 22 describes the signal flow process of the MI-07 DBW section. The foot pedal assembly uses two potentiometers to detect pedal position.

These two signals, accelerator pedal position 1 (APP1) and accelerator pedal position 2 (APP2) are sent directly to the SECM.

The SECM uses a series of algorithms to self calibrate and cross check the signals from the pedal assembly. A demand position for the throttle will then be derived and sent to the throttle as a throttle position sensor demand (TPSd). This signal will be processed through a PID (Proportional, Integral, Derivative) controller in the SECM to achieve the appropriate motor-current response then passed to the throttle. The throttle moves to the commanded position and provides a feedback signal from the throttle position sensors (TPS1 and TPS2) to the SECM.

Ignition Management

In the normal course of events, with the engine operating at the correct temperature in defined conditions, the SECM will use load and engine speed to derive the correct ignition timing. In addition to load and speed there are other circumstances under which the SECM may need to vary the ignition timing, including low engine coolant temperature, air temperature, start-up, and idle speed control.

SECM Electrical Mounting

Recommendations

In order to prevent the possibility of any SECM malfunctions due to EMI/RFI emissions, the SECM mounting and harness recommendations listed below:

- The SECM should be mounted in a location that minimizes the amount of EMI the module is exposed to by locating it as far as practical from all high tension components, such as ignition coils, distributors, spark plug wires, etc. It is recommended that the SECM be mounted at least 29.5" (749 mm) away from the distributor and ignition coil, and at least 20" (508 mm) from the nearest plug wire.

- All wiring harnesses should be routed to minimize coupling (both radiated and conducted), and be securely fastened to minimize movement and maintain proper clearance between the SECM and all ignition system components.

- The OEM must ensure that a high-quality ground connection between the SECM and battery negative (–) is provided and can be maintained for the useful life of the vehicle. This may require the use of star-type washers on all ground lug connections between the SECM and the battery and/or special preparation of all mating surfaces that complete the ground connection in order to ensure that the connection is sound.

SECM Wiring Diagrams for G643E

⚠ CAUTION—PROPER WIRING

To prevent system faults be sure to follow good wiring practices. Poor wiring may cause unexpected or intermittent failures not related to MI-07 components.

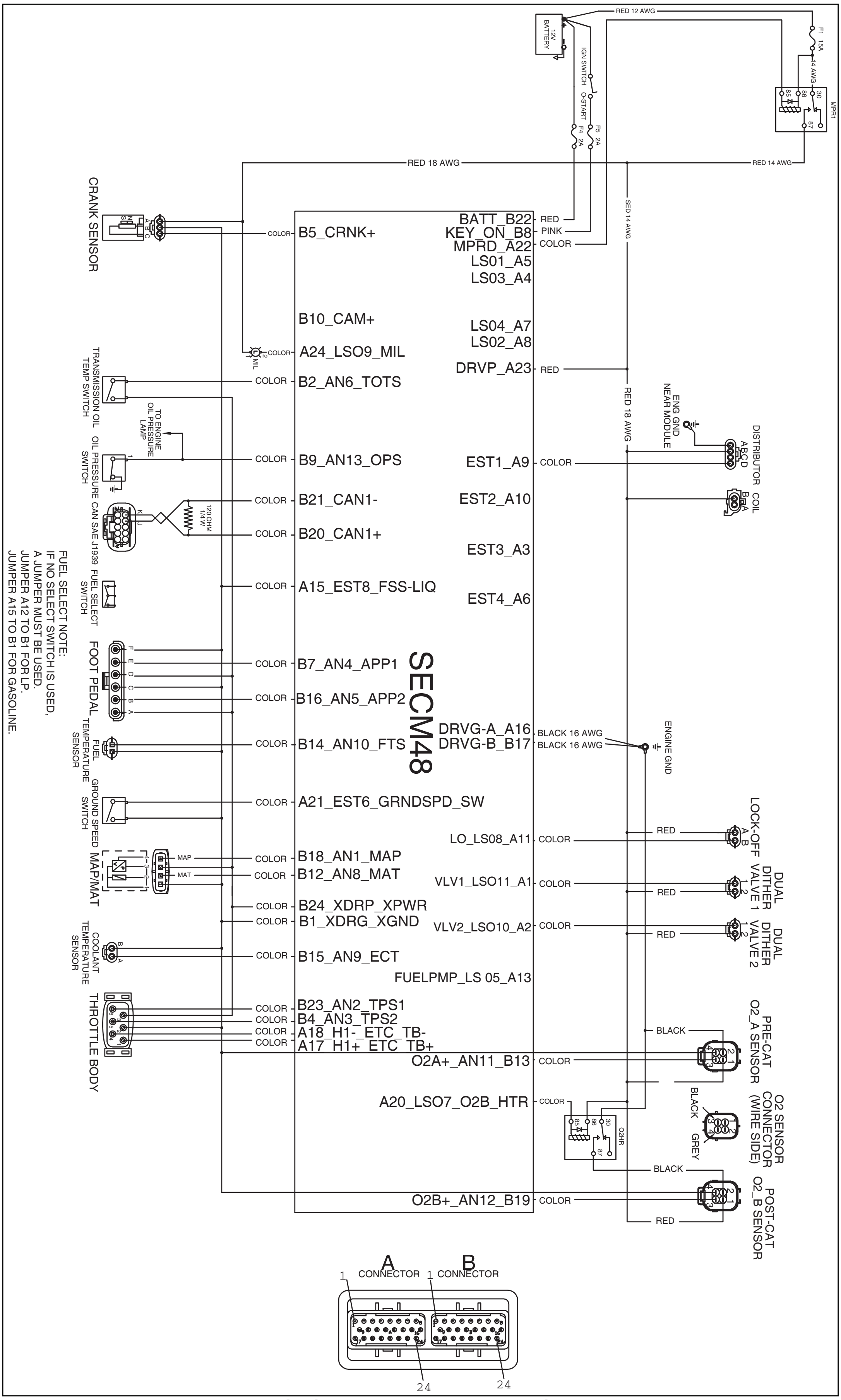


Figure21. SECM Wiring Diagram for G643E LP Fuel

G643 EMS (Engine Management System) Overview

General Description

MI-04 control system provides a complete, fully integrated engine management system for naturally aspirated engines.

It provides accurate, reliable, and durable control of spark and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

The SECM monitors the engine through a number of different sensors to ensure optimal performance.

Engine speed is monitored by the SECM through a variable reluctance (VR) sensor. Intake manifold air temperature and absolute pressure are monitored with a TMAP sensor. MI-04 is a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Even engine coolant temperature and adequate oil pressure are monitored by the SECM

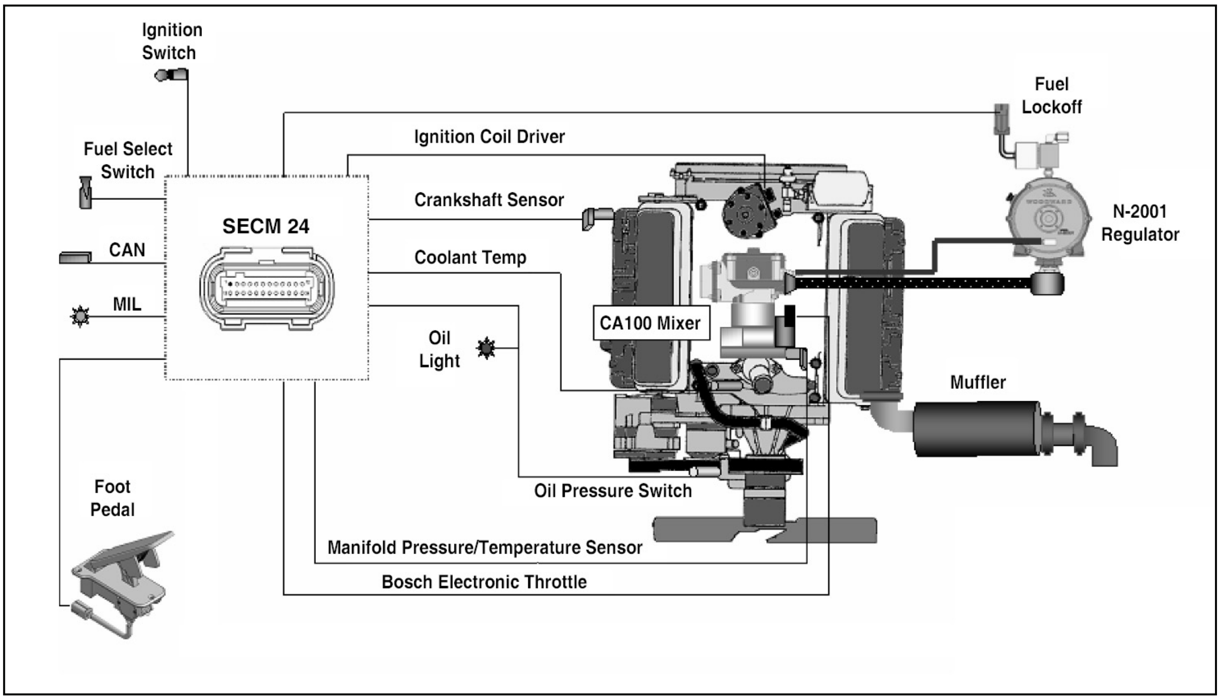
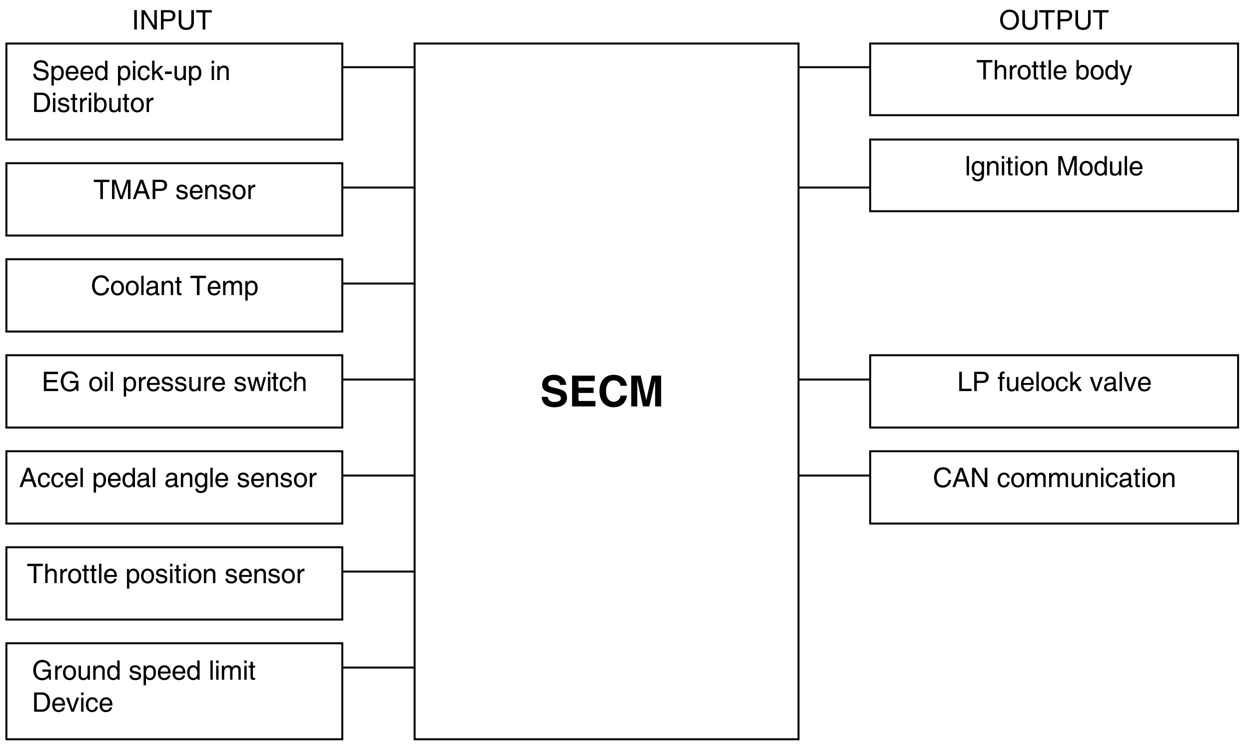


Figure 2. G643 LP System

The LPG regulator and the mixer operate as an open loop system since no mixture adjustments are made by the SECM. The mixer does have an idle mixture adjustment and a power valve adjustment. Manifold pressure from the TMAP, rpm from the crank position sensor and throttle position is used by the SECM to calculate load. Feedback from the electronic throttle is provided to the SECM by the throttle position sensors (TPS).

LP System of G643



MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

• Spark-ignition control system

• Air throttle

• Sensors/Switches/Speed inputs

Key Components

The MI-07 system functions primarily on engine components that affect engine emissions and performance. These key components include the following:

• Engine/Combustion chamber design

• Intake/Exhaust valve configuration, timing and lift

• Intake/Exhaust manifold design

• Throttle body

• Air intake and air filter

• LPG mixer

• LPG pressure regulator

• Small engine control module (SECM), firmware and calibration †

• Fuel system sensors and actuators

• Ignition system including spark plugs, cables, coils and drivers

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

- Open-loop fuel control with fuel specific controls for LPG
- Speed-load spark control with tables for dwell, timing, and fuel type
- Speed-load throttle control with table for maximum TPS limiting
- Min/max governing
- All-speed isochronous governing
- Fixed-speed isochronous governing with three switch-selectable speeds
- Spark timing modifiers for temperature and fuel type
- Input sensor selection and calibration
- Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.
- CANBus data transfer for speed, torque, etc.

Other system features include:

Tamper-Resistance

Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics

MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL lamp. With the MIL lamp, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode

The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 rpm at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool

A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

LPG Fuel System Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system.

An LPG fuel system consists of the following components:

- Fuel filter (supplied by customer)
- Electric fuel lock-off solenoid valve
- Fuel pressure regulator/vaporizer
- Gas/Air mixer
- Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer. The mixer meters fuel delivery based upon airflow into the engine.

SECM

The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve. The lock-off solenoid is energized when fueling with LPG and the engine is turning. The lock-off is de-energized when engine rpm is not detected.

MI-07 LP Fuel Filter

The LP fuel filter of G643 engine is the same as that of G643E engine. See, “G643E EMS overview”

MI-07 Fuel Lock-Off (Electric)

The LP fuel lock-off of G643 engine is the same as that of G643E engine. See, “G643E EMS overview”

N-2001 Regulator/Converter

After passing through the electric fuel lock-off, liquid propane enters the N-2001 regulator/converter (Figure 4). The N-2001 functions as a fuel vaporizer, converting liquid propane to vapor propane and as a two-stage negative pressure regulator, supplying the correct vapor propane fuel pressure to the mixer.

The regulator is normally closed requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the secondary (2nd stage) valve and the primary (1st stage) valve closes. Unlike most other regulator/converters, the N-2001 primary valve closes with fuel pressure rather than against pressure, extending primary seat life and adding additional safety.

Figure 4. N-2001 Regulator

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced the liquid propane vaporizes and refrigeration occurs inside the regulator due to the large temperature drop inside the regulator from the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber. Figure 5 shows the heat chamber and the coolant passage in the N-2001 regulator.

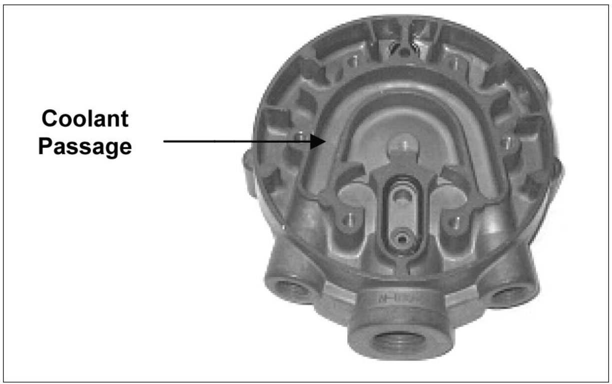


Figure 5. Heat Chamber and Coolant Passage

N-2001 Operation

Refer to Figure 6.

Liquid propane, at tank pressure, enters the N-2001 through the fuel inlet port (1). Propane liquid then flows through the primary valve (2). The primary valve located at the inlet of the expansion chamber (3), is controlled by the primary diaphragm (4), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (5), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (6). The secondary valve is held closed by the secondary spring on the secondary valve lever (7). The secondary diaphragm controls the secondary lever. When the pressure in the expansion chamber reaches 1.5 psi (10.342 kPa it causes a pressure/ force imbalance across the primary diaphragm (8). This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

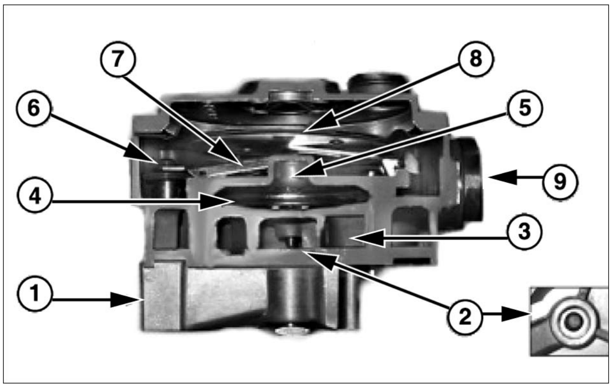


Figure 6. Parts View of N-2001 Regulator

Since the fuel pressure has been reduced from tank pressure to 1.5 psi (10.342 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened. To open the secondary valve a negative pressure signal must be received from the air/fuel mixer. When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator (9), which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

CA100 Mixer

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.

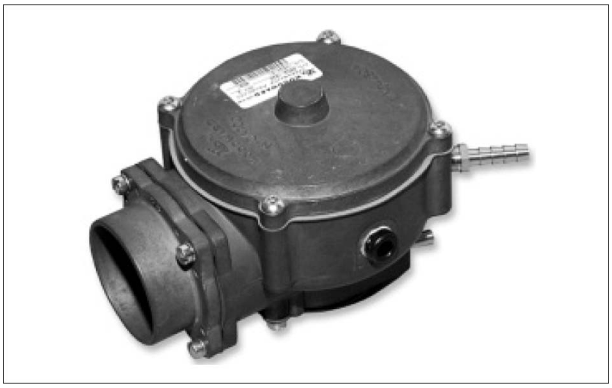


Figure 7. CA100 Mixer

CA100 Mixer Operation

Vapor propane fuel is supplied to the CA100 mixer by the N-2001 pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.

Figure 8. CA100 Mixer Attached to Throttle Body

(**Refer to Figure 98**.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (1) and a gas discharge jet (2). In the center of the main body is the air valve assembly, which is made up of the air valve (3), the gas-metering valve (4), and air valve diaphragm (5) and air valve spring (6). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranked over it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

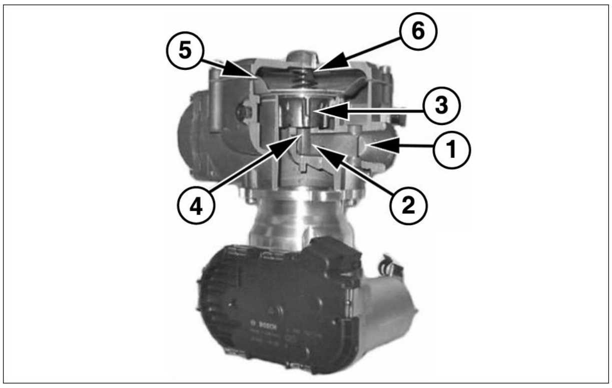


Figure 9. Parts View of CA100 Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inH2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inH2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

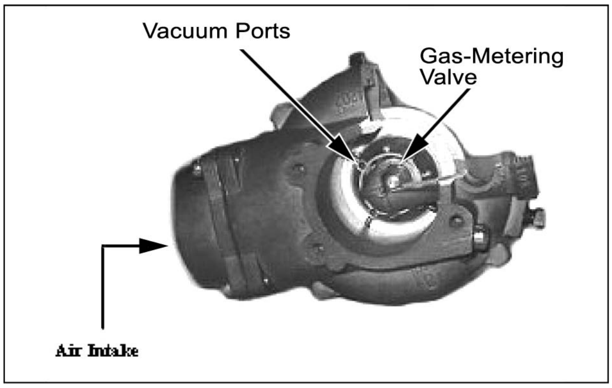


Figure 10. Bottom View of Air Valve Assembly


Figure 11. CA100 Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the CA100 is not used in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (Figure 12). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper proof cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter.

NOTE: Adjustments should only be performed by trained service technicians.

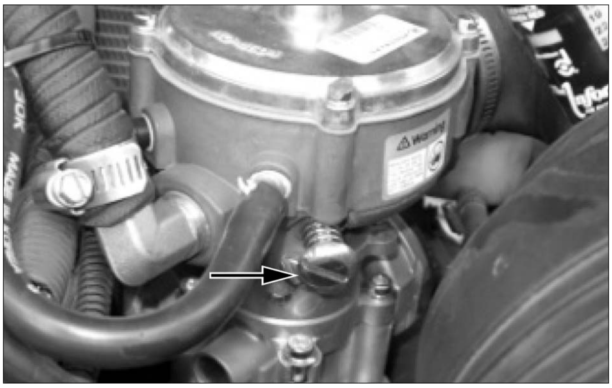


Figure 12. Idle Mixture Adjustment Screw

Electronic Throttle System

The electronic throttle system of G643 engine is the same as that of G643E engine. See, “Electro-nic throttle system of G643E EMS overview”

Ignition System

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

- SECM
- Distributer with Ignition module
- Ignition coil(s) *
- Crankshaft position sensor *
- Crankshaft timing wheel *
- Spark plugs *

(*) Customer-supplied components

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

GM Delco EST Ignition System

The MI-07 system is capable of operating with either a distributor based ignition system or a distributorless ignition system. The current application uses a distributor based ignition system. The distributor will have no internal advance mechanisms giving the SECM consistent authority over ignition timing. The spark is sent to the appropriate cylinder in the conventional way via the rotor arm and spark plug wires. The SECM uses the signal from the GM (General Motors) Delco Ignition Module to determine the engine position and RPM at any time. It uses this information together with the information from the TPS sensor and TMAP to calculate the appropriate ignition timing settings.

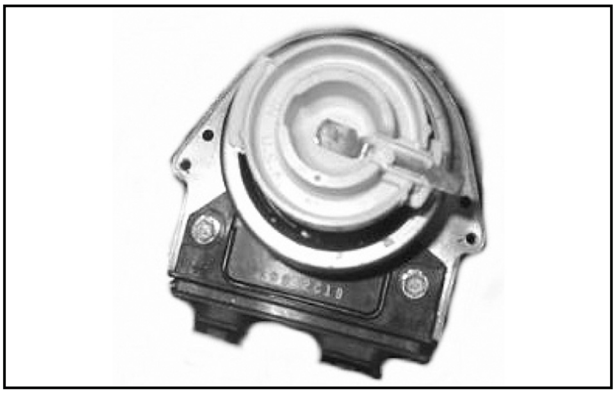
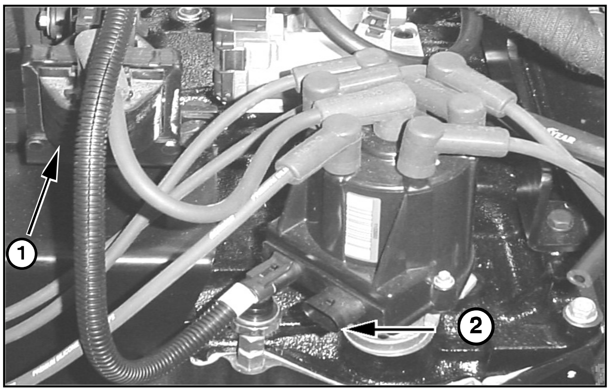


Figure 14. GM Distributor

The General Motors (GM) distributor (**Figure 14**) used in the Delco EST ignition system, incorporates a Variable Reluctance (VR) sensor, which transmits a reference signal to the GM ignition module (**Figure 15**) located on the distributor. A variable reluctance sensor is an electromagnetic device consisting of a permanent magnet surrounded by a winding of wire. The sensor is used in conjunction with a ferrous signal rotor on the distributor shaft. The signal rotor has six lobes, one for each cylinder. Rotation of the signal rotor near the tip of the sensor changes the magnetic flux, creating an analog voltage signal in the sensor coil.



(1) Ignition Coil (2) Ignition Module

Figure 15. GM Ignition Module

The rising edge of the VR signal is converted to a rising 5-volt signal by the ignition module. As the VR signal passes back through zero volts, a falling edge is created producing a square wave or digital signal, similar to the signal produced by a Hall effect sensor. This falling edge signal provides a stable engine position reference at all engine speeds for the SECM.

SECM

Small Engine Control Module (SECM) controller has full authority over spark and air. the SECM has 24 pins of I/O and is fully waterproof and shock hardened (**Figure 16**).

To optimize engine performance and drivability, the SECM uses several sensors for closed loop feedback information. These sensors are used by the SECM for closed loop control in two main categories:

- Load/Speed Management
- Ignition Management

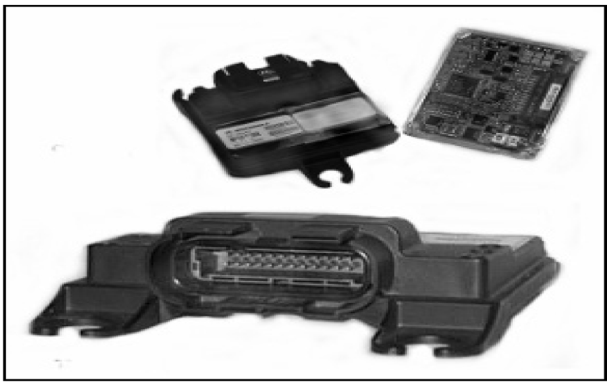


Figure 16. Small Engine Control Module (SECM)

The SECM monitors system parameters and stores any out of range conditions or malfunctions as faults in SECM memory. Engine run hours are also stored in memory. Stored fault codes can be displayed on the Malfunction Indicator Light (MIL) as flash codes or read by the Service Tool software through a CAN (Controller Area Network) communication link.

Battery power (12 Vdc) is supplied through the fuse block to the main power relay. The ignition key switch is used to energize the main power relay. A main power relay supplies 12 Vdc power to the SECM, fuel lock-off, and the Smart Coil. The SECM supplies positive voltage to the electronic throttle actuator, oil pressure switch and the coolant temperature sensor. Transducer or sensor power (+5 Vdc) is regulated by the SECM and supplied to the temperature/manifold air pressure sensor (TMAP), throttle position sensor (TPS), and the accelerator pedal position sensors (APP1 & APP2). The SECM provides a constant voltage (VCC) to the Smart Coil Driver, transducer ground for the all sensors, and a low side driver signal controlling the fuel lock-off and MIL.

SECM (Load/Speed Management)

Drive by wire refers to the fact that the MI-07 control system has no throttle cable from the foot pedal (Figure 17) to the throttle body. Instead, the SECM is electronically connected both to the foot pedal assembly and the throttle body. The SECM monitors the foot pedal position and controls the throttle plate by driving a dc motor connected to the throttle. The dc motor actuates the throttle plate to correspond to the foot pedal position when the operator depresses the pedal.

The use of electronic throttle control (ETC) ensures that the engine only receives the correct amount of throttle opening for any given situation, greatly improving idle quality and drivability.

Figure 17. Foot Pedal

A Throttle Position Sensor (TPS), (**Figure 18**) which is integral to the Drive By Wire (DBW) throttle assembly, provides feedback for position control by monitoring the exact position of the throttle valve.

NOTE: The DV-E5 is not a serviceable assembly. If the TPS sensor fails, the assembly should be replaced.

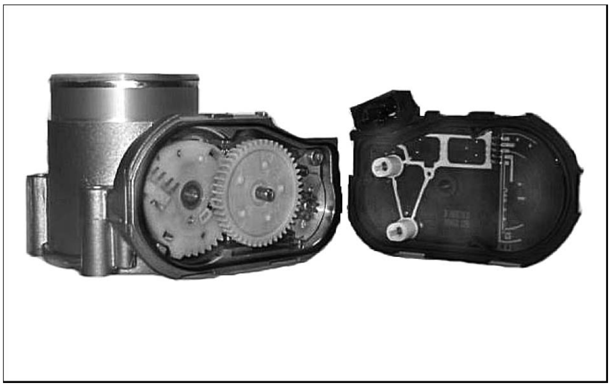


Figure 18. Throttle Position Sensor (TPS) on DV-E5 Throttle

SECM self-calibration and “cross checking” of the TPS is accomplished by comparing the TPS signal to a calculated throttle position in the SECM software (Predicted TPS). In addition to the throttle position sensor, a temperature/manifold air pressure sensor (TMAP) is used to monitor intake manifold temperature and pressure (**Figure 19**). This enables the SECM full control capabilities monitoring actual airflow in relationship to desired airflow. The TMAP sensor is a single unit incorporating both intake manifold temperature and manifold pressure measurement.

Figure 19. TMAP Sensor

The MI-07 system also performs minimum (min) and maximum (max) governing through the SECM and DBW throttle. For min governing, or idle speed control, the idle speed is fixed by the SECM. Unlike a mechanical system, the idle speed is not adjustable by the end user. The idle speed is adjusted by the SECM based on engine coolant temperature. At these low engine speeds, the SECM uses spark and throttle to maintain a constant speed regardless of load.

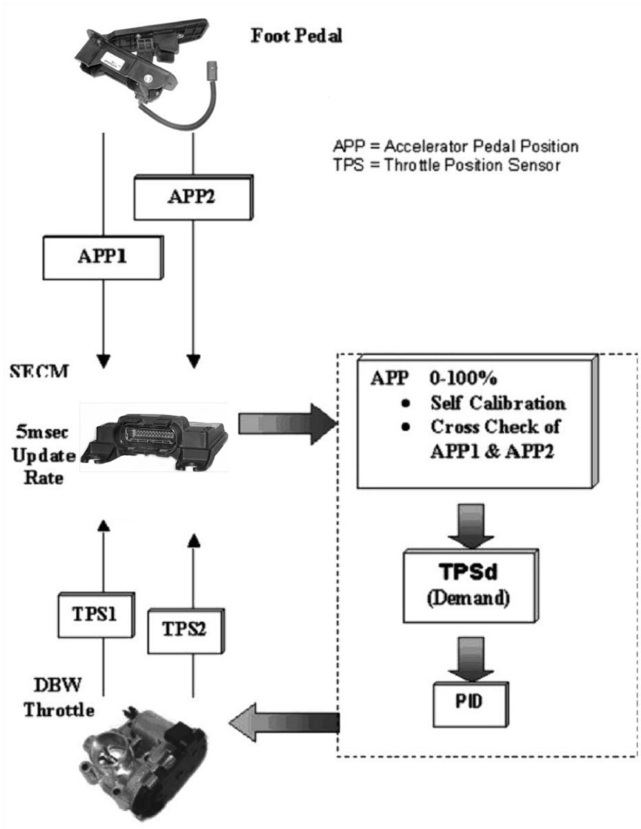


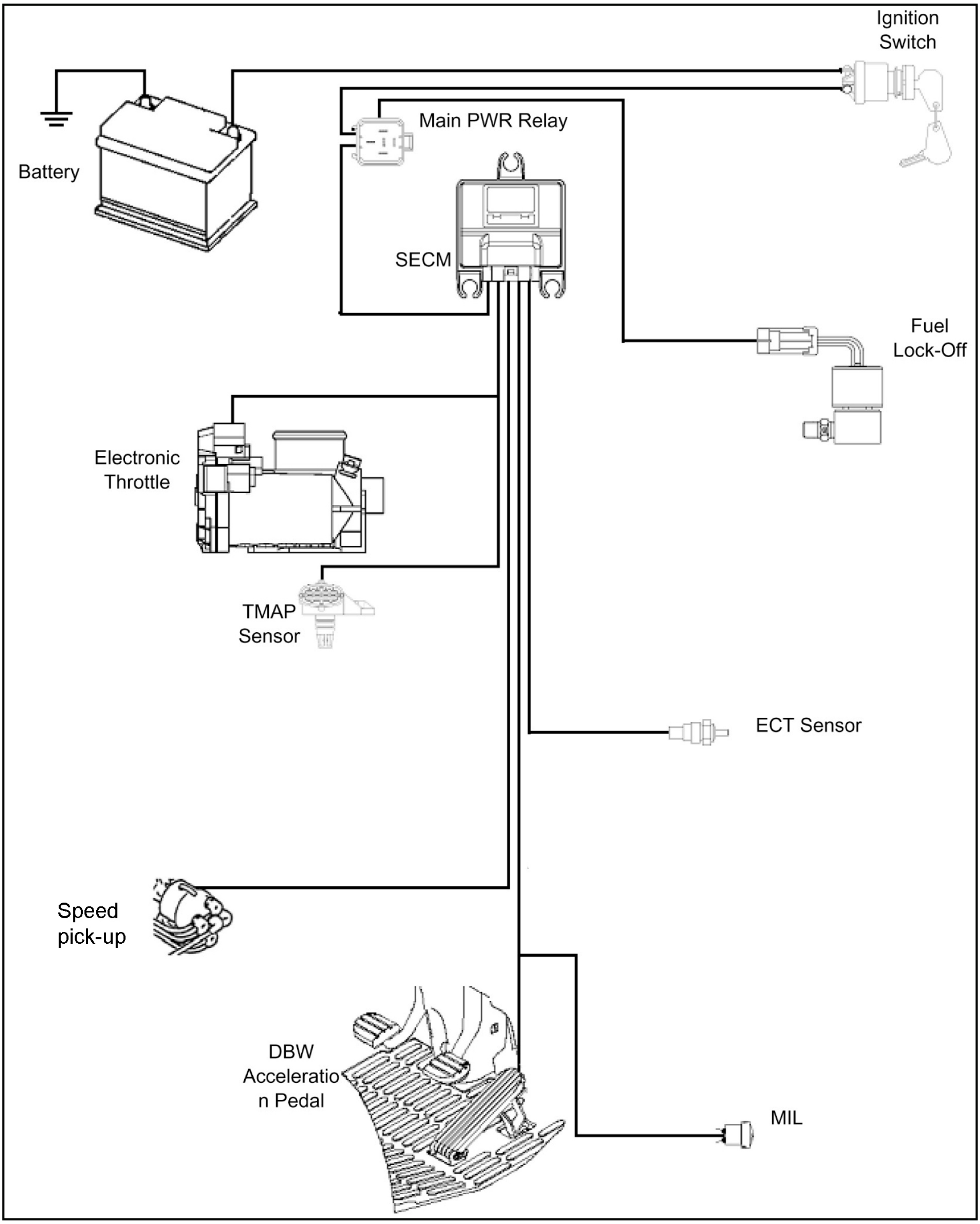
Figure 21. Drive-By-Wire Signal Flow Process

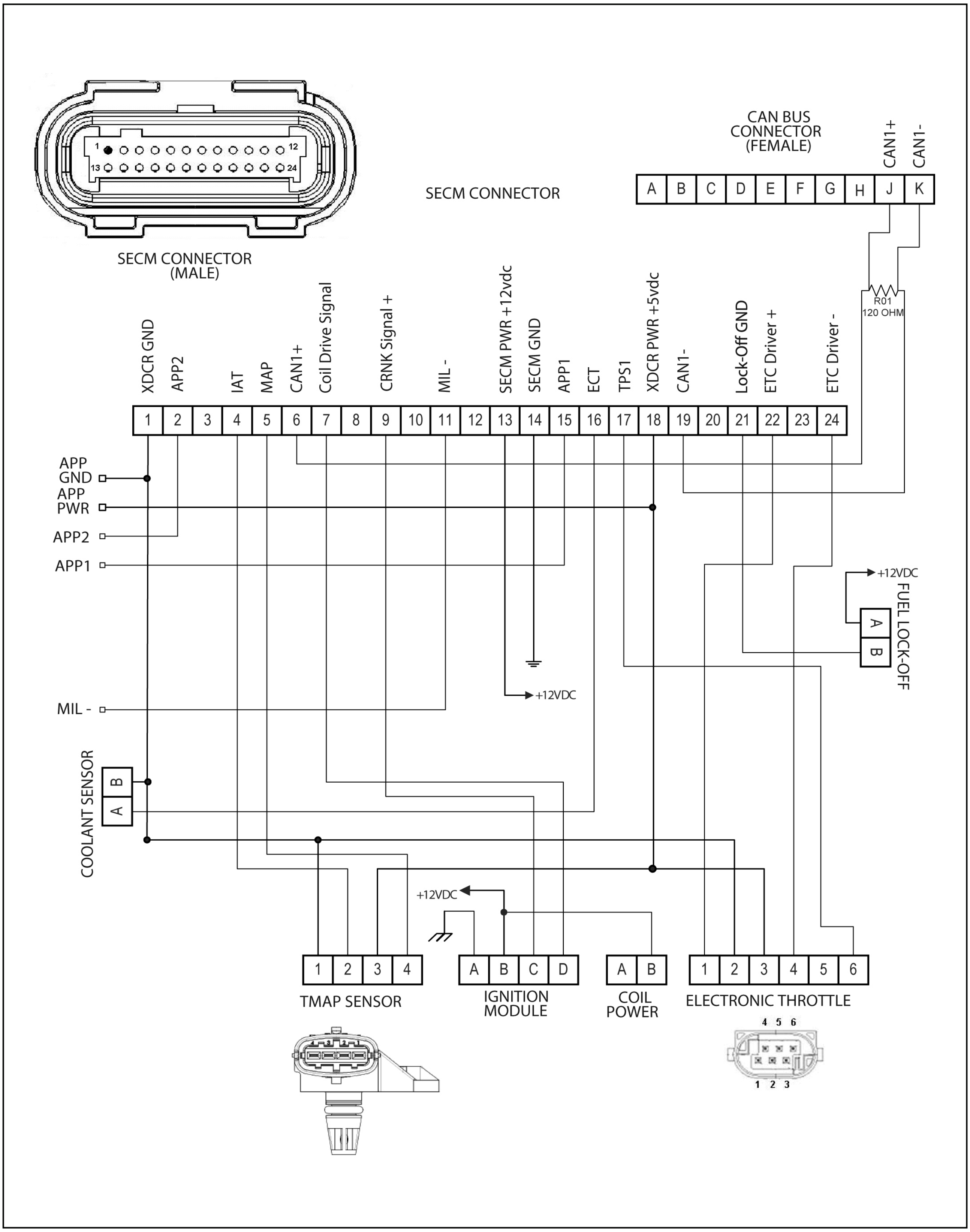
(**Figure 21**) describes the signal flow process of the MI-07 DBW section. The foot pedal assembly uses two potentiometers to detect pedal position. These two signals, accelerator pedal position 1 (APP1) and accelerator pedal position 2 (APP2) are sent directly to the SECM. The SECM uses a series of algorithms to self calibrate and cross check the signals from the pedal assembly. A demand position for the throttle will then be derived and sent to the throttle as a throttle position sensor demand (TPSd). This signal will be processed through a PID (Proportional, Integral, Derivative) controller in the SECM to achieve the appropriate motor-current response then passed to the throttle. The throttle moves to the commanded position and provides a feedback signal from the throttle position sensor (TPS) to the SECM.

MI-07 Ignition Management

In the normal course of events, with the engine operating at the correct temperature in defined conditions, the SECM will use load and engine speed to derive the correct ignition timing. In addition to load and speed there are other circumstances under which the SECM may need to vary the ignition timing, including low engine coolant temperature, air temperature, start-up, idle speed control.

SECM Wiring Diagrams for G643 LP Engine




SECM CONNECTOR (MALE)
SECM CONNECTOR
CAN BUS CONNECTOR (FEMALE)
CAN1+
CAN1-
R01
120 OHM
XDCR GND
APP2
IAT
MAP
CAN1+
Coil Drive Signal
CRNK Signal +
MIL -
SECM PWR +12vdc
SECM GND
APP1
ECT
TPS1
XDCR PWR +5vdc
CAN1-
Lock-Off GND
ETC Driver +
ETC Driver -
APP GND
APP PWR
APP2
APP1
MIL -
+12VDC
FUEL LOCK-OFF
COOLANT SENSOR
TMAP SENSOR
IGNITION MODULE
COIL POWER
ELECTRONIC THROTTLE

EMS Inspection and Repair

Engine Control Module [G643E]

The 48-pin Small Engine Control Module (SECM) and sensors provide the computational power, algorithm logic, sensor inputs and control outputs to control the system. The SECM receives signals from the sensors, digitizes these signals, and then, through algorithms and calibration MAPs, computes the desired output response to effect control of fuel, spark and air to the engine. The SECM also provides a variety of other functions and features. These include system monitoring and diagnostics to aid in maintaining efficient system operation and auxiliary control.

SECM/sensor inputs and control output specifications are specific to the application, but include a selection of the following:

Analog Inputs

The 48-pin SECM is equipped with sufficient analog inputs for the following sensors.

- Manifold Absolute Pressure (MAP) 1bar MAP, 0 to 5 V
- Manifold Air Temperature (MAT)
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kohm to 85 ohm sensor range
- Throttle Position Sensor 1&2 (TPS1 & TPS2) 0 to 5 V
- Foot Pedal Position 1&2 (FPP1 & FPP2) 0 to 5 V
- Coolant Temperature Sensor (CTS)
  -40°F to 266°F (-40ºC to 130ºC) range,
  48K ohm to 85 ohm sensor range
- Fuel Temperature Sensor (FTS)
  -40°F to 266°F (-40ºC to 130ºC) range,
  48K ohm to 57 ohm sensor range
- HEGO (3) 0 to 1 V
- Auxiliary Analog Input (2) 0 to 5 V
- Battery Voltage (Vbatt) (1) 8-18 V

With the exception of battery voltage, all inputs are 0-5 Vdc, ground referenced. Resolution should be 0.1% or better. Accuracy should be 2% or better.

Frequency/Position Inputs

- Crankshaft position

  Variable reluctance (2-wire, 200 Vpp max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors Permits speed resolution of 0.25 rpm and crankshaft position resolution of 0.5º

- Camshaft position

  Variable reluctance (2-wire, 200 Vpp max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors.

Digital Inputs

- Oil pressure switch
  Normally open, internal pull-up resistor provided to detect external switch to ground
- Transmission oil temperature switch
  Normally open, internal pull-up resistor provided to detect external switch to ground
- Fuel select switch
  Three-position switch for bi-fuel applications to detect gasoline mode, LPG mode, and fuel off (center switch position)
- Ground speed select switch
  Permits selecting two different maximum engine speeds
- Vswitched
  Switched battery voltage

Outputs

- Saturated injector drivers (4)
  10A peak, 45 V max, 1 injector per channel capable of continuous on-time
  Driver circuit designed for minimum turn-on/turn-off delay
  Minimum pulse width resolution of 1 usec

- FTV drivers (2)
  10A peak, 45V max. To drive an on/off fuel trim valve with a minimum impedance of 5 ohms Capable of continuous on-time
  Drive circuit designed for minimum turn-on /turn-off delay
  FTVs will be pulse width modulated between 8 and 40 Hz with a minimum pulse width resolution of 50 usec

- Fuel lock-off solenoid valve
  Low side switch, 10A peak, 4A continuous 45 V max

- Gasoline fuel pump drive
  Low side switch, 10A, 4A continuous 45 V max

- Electronic Spark Timing (EST) (4)
  TTL compatible outputs Software configured for coil-on-plug ignition system

- Throttle control (1)
  H-Bridge, 5A peak, 2.5A continuous at 2500 Hz PWM includes current feedback for diagnostic purposes.

- MIL (malfunction indicator lamp)
  Low side switch, sufficient to drive a 7W incandescent lamp continuously

- CANBus
  CAN 2.0b serial communication for J1939 communications, programming and diagnostics.
  Requires proper termination resistance per CAN 2.0b.

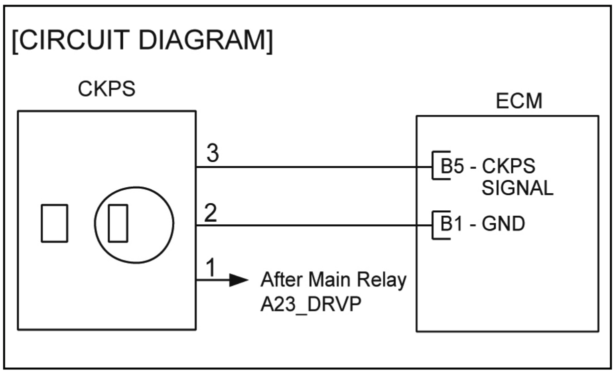
Crank Shaft Position Sensor [G643E]

Component Location

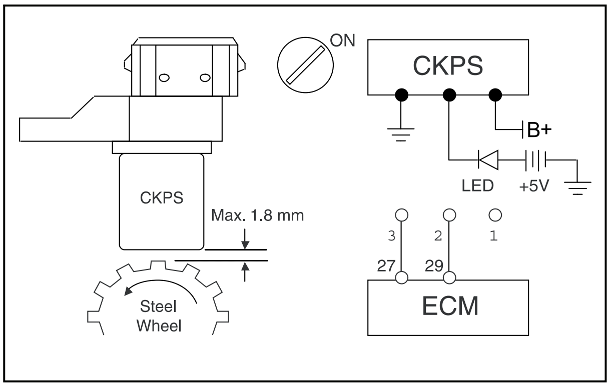
Description

The Crankshaft Position Sensor (CKPS) is a hall effect type sensor that generates voltage using a sensor and a target wheel mounted on the crankshaft;
During one crankshaft rotation there are the rectangular signals. The ECM calculates engine RPM by using the sensor' signal and controls the the ignition timing.

Schematic Diagram for G643E



Sensor Inspection



1. Turn ignition switch to OFF position and then disconnect CKPS connector.

2. Remove the CKPS from the engine.

3. Turn ignition switch to ON position.

4. Apply battery voltage to the terminal 1 and ground terminal 1 and ground terminal 3 of CKPS as shown in the figure.

5. Install a LED between +5V power and CKPS terminal 2, and then set a steel wheel (or anything made of steel ; hammer, wrench, bolt and nut etc.) at the CKPS's tip.

6. Rotate the steel wheel slowly and check if the LED flashes light.

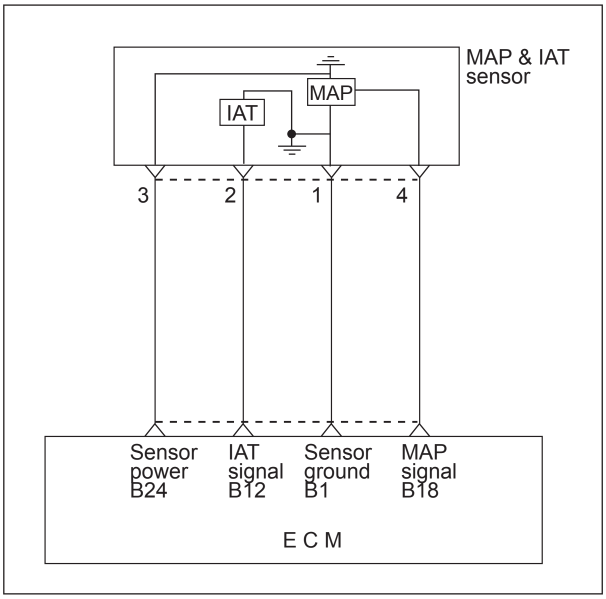
• If the LED blinks, the CKPS works normally

MAP (Manifold Absolute Pressure) Sensor [G643E and G643]

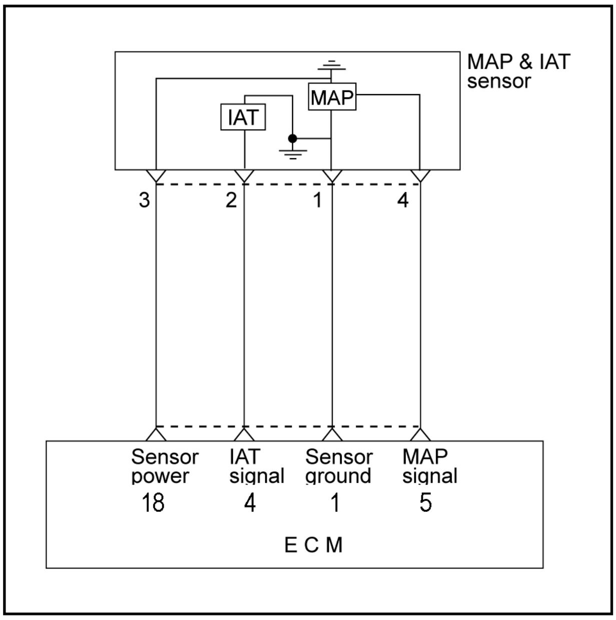
MAP sensor

The manifold absolute pressure (MAP) sensor is a pressure sensitive variable resistor. It measures changes in the intake manifold pressure which result from engine load and speed changes, and converts this to a voltage output. The MAP sensor is also used to measure barometric pressure at start up, and under certain conditions, allows the ECM to automatically adjust for different altitudes. The ECM supplies 5 volts to the MAP sensor and monitors the ECM supplies 5 volts to the MAP sensor and monitors the voltage on a signal line. The sensor provides a path to voltage on a signal line. The sensor provides a path to ground through its variable resistor. The MAP sensor in put affects fuel delivery and ignition timing controls in the ECM.

Circuit Diagram (G643E)



Circuit Diagram (G643)



Sensor Inspection

1. Measure the voltage between terminals 1 and 4 of the MAP sensor connectors.
Terminal 4 : MAP sensor ground
Terminal 1 : MAP sensor output

Engine state	Test specification
Ignition SW. ON	4~5V
At idle	0.5~2.0V

2. If the voltage deviates from the standard value, replace the MAP sensor assembly.

Removal

1. Disconnect the negative battery cable.

2. Disconnect the electrical connector from the MAP/MAT sensor.

3. Remove the two screws retaining the MAP/MAT sensor to the intake manifold.

4. Remove MAP/MAT sensor.

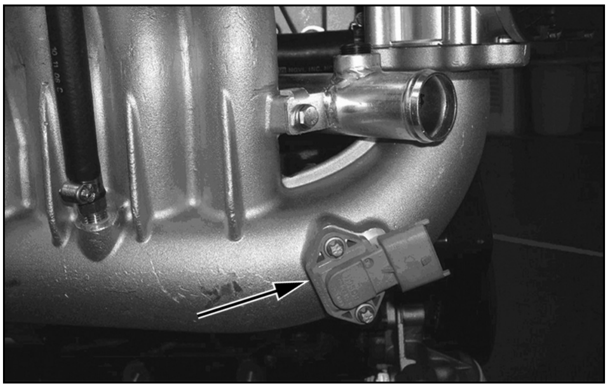
Installation

1. Place the MAP/MAT Sensor in position on the intake manifold and install the two retaining screws. Tighten retaining screws to 6 N•m (53 lbf• ft)

2. Connect the electrical connector to the MAP/MAT sensor. Verify that the connector clicks/locks into place.

3. Connect the negative battery cable.

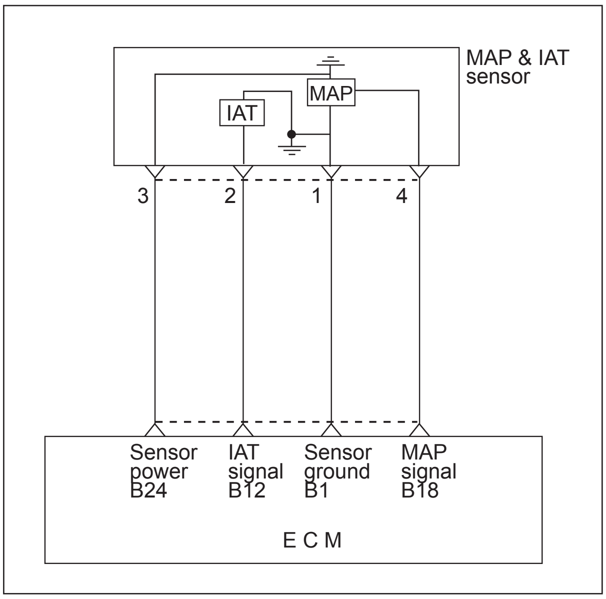
IAT (Intake Air Temperature) Sensor [G643E and G643]



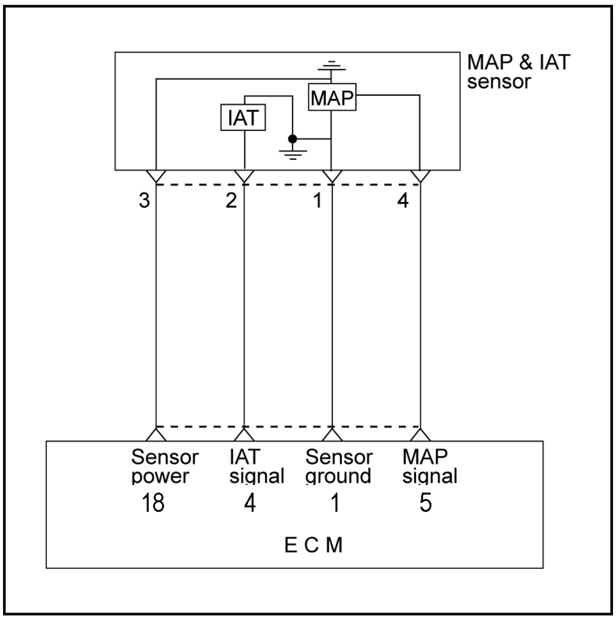
MAP sensor

The intake air temperature sensor (IAT Sensor), built in to the MAT sensor, is a resistor-based sensor detect the intake air temperature. According to the intake air temperature information frim the sensor, the ECM will control the necessary amount of fuel injection.

Circuit Diagram (G643E)



Circuit Diagram (G643)



Sensor Inspection

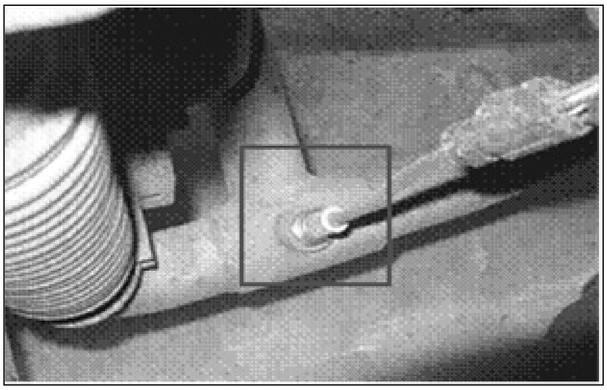
1. Using a multimeter, measure the IAT sensor resistance between terminals 3 and 4.

IG.SW.ON	Temperature ℃ (°F)	Resistance(kΩ)
	0 (32)	4.5 ~ 7.5
	20 (68)	2.0 ~ 3.0
	40 (104)	0.7 ~ 1.6
	80 (176)	0.2 ~ 0.4

2. If the resistance deviates from the standard value, replace the intake air temperature sensor assembly.

OxygenSensor (Pre-Catalyst) [G643E]

Component Location



Pre - Catalyst Oxygen Sensor

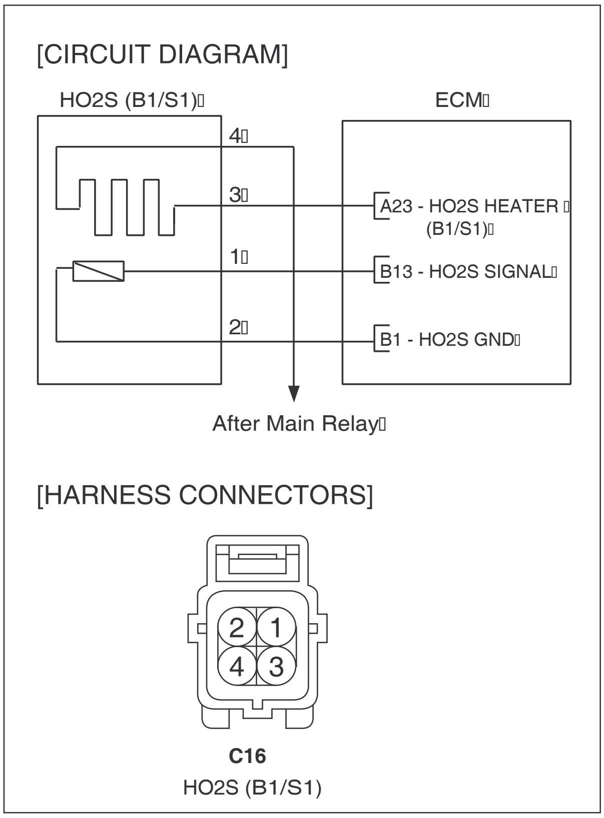
Description

The heated oxygen sensor is mounted on the front side of Catalytic Muffler, which detects the oxygen concentration in the exhaust gas. The heated oxygen sensor produces a voltage that varies between 0V and 1V. When the air/fuel ratio is lean, the oxygen concentration in the exhaust gas increases and the front HO2S outputs a low voltage (approximately0~0.1V). When the air/fuel ratio is rich, the oxygen concentration in the exhaust gas decreases and the front HO2S outputs a high voltage (approximately0.8~1V). The ECM constantly monitors the HO2S and increases or decreases the fuel injection duration by using the HO2S signal, which is called closed-loop fuel control operation.

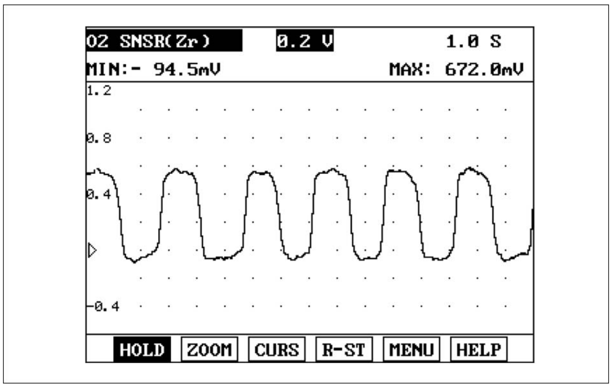
Specification

Temperature		Front HO2S Heater Resis-tance(Ω)	Temperature		Front HO2S Heater Resistance (Ω)
(℃)	(°F)		(℃)	(°F)	
20	68	9.2	400	752	17.7
100	212	10.7	500	932	19.2
200	392	13.1	600	1,112	20.7
300	572	14.6	700	1,292	22.5

Schematic Diagram (G643E)



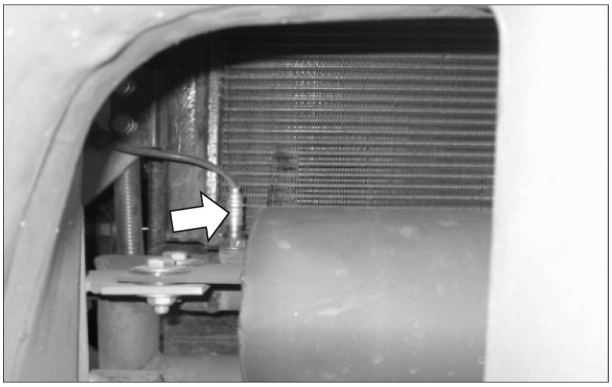
Signal Wave Form



If you release the accelerator pedal suddenly after engine running about 2600 rpm, fuel supply will stop for short period and the O2 sensor service data will display values 200mV or lower. When you suddenly press on the accelerator pedal down, the voltage will reach 0.6 ~ 1.0 V. When you let the engine idle again, the voltage will fluctuate between 200 mV or lower and 0.6 ~ 1.0 V. In this case, the O2sensor can be determined as good.

Oxygen Sensor (Post-Catalyst) ［G643E］

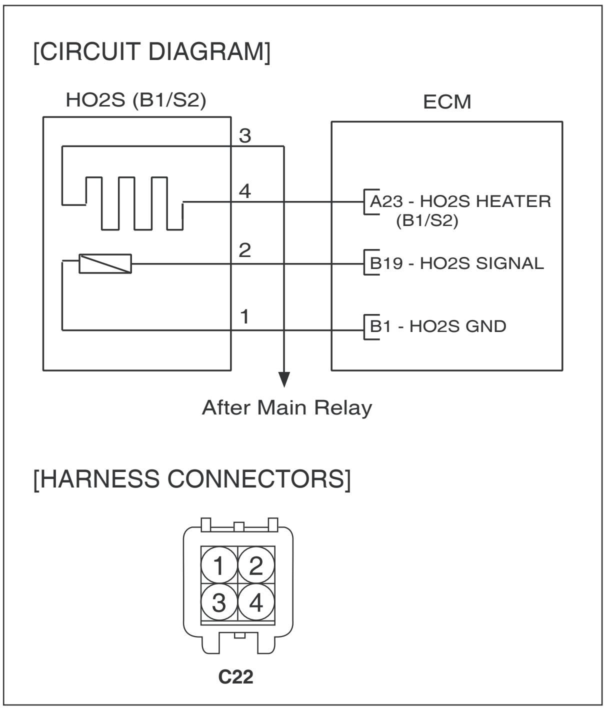
Component Location



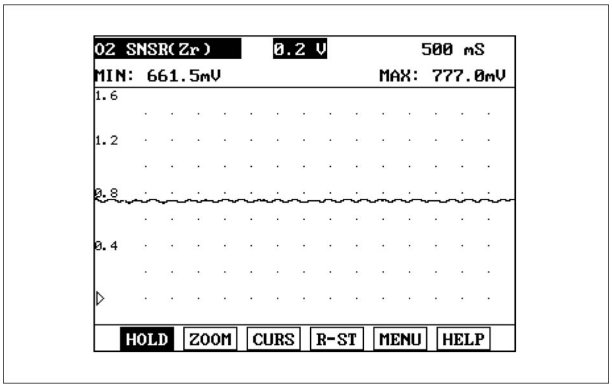
Description

The rear heated oxygen sensor is mounted on the rear side of the Catalytic Muffler, which detects the catalyst efficiency. The rear heated oxygen sensor (HO2S) produces a voltage between 0V and 1V. This rear heated oxygen sensor is used to estimate the oxygen storage capability. If a catalyst has good conversion properties, the oxygen fluctuations are smoothed by the oxygen storage capacity of the catalyst. If the conversion provided by the catalyst is low due to aging, poisoning or misfiring, then the oxygen fluctuations are similar to signals from the front oxygen sensor.

Schematic Diagram (G643E)



Signal Wave Form



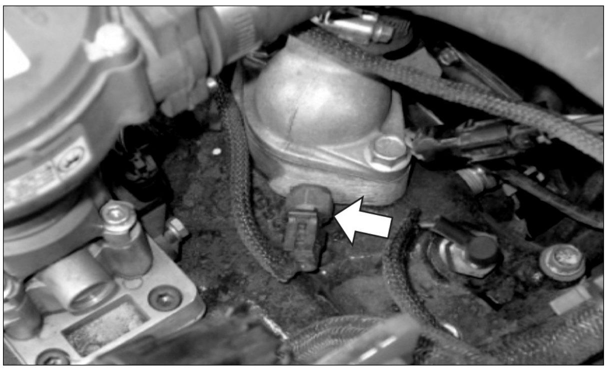
The amplitude of the signal output of the rear HO2S is small compared to the front HO2S because the rear HO2S detects emission gas purified by the catalytic converter. This illustration is the normal signal waveform of the rear HO2S at idle.

Specification

Temperature		Rear HO2S Heater Resis-tance(Ω)	Temperature		Rear HO2S Heater Resistanc e(Ω)
(℃)	(°F)		(℃)	(°F)	
20	68	9.2	400	752	17.7
10	212	10.7	500	932	19.2
200	392	13.1	600	1,112	20.7
300	572	14..6	700	1,272	22.5

ECT (Engine Coolant Temperature) Sensor [G643E and G643]

Component Location

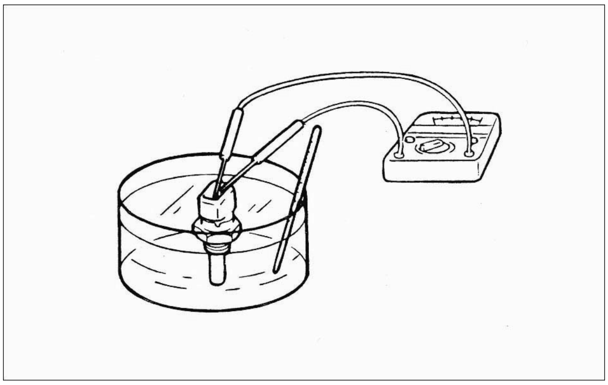


ECT Senser

Description

The Engine Coolant Temperature Sensor (ECTS) is located in the engine coolant passage of the cylinder head for detecting the engine coolant temperature. The ECTS uses a thermister whose resistance changes with the temperature. The electrical resistance of the ECTS decreases as the temperature increases, and increases as the temperature decreases. The reference 5 V in the ECM is supplied to the ECTS via a resistor in the ECM. That is, the resistor in the ECM and the thermistor in the ECTS are connected in series. When the resistance value of the thermistor in the ECTS changes according to the engine coolant temperature, the output voltage also changes.

Sensor Inspection



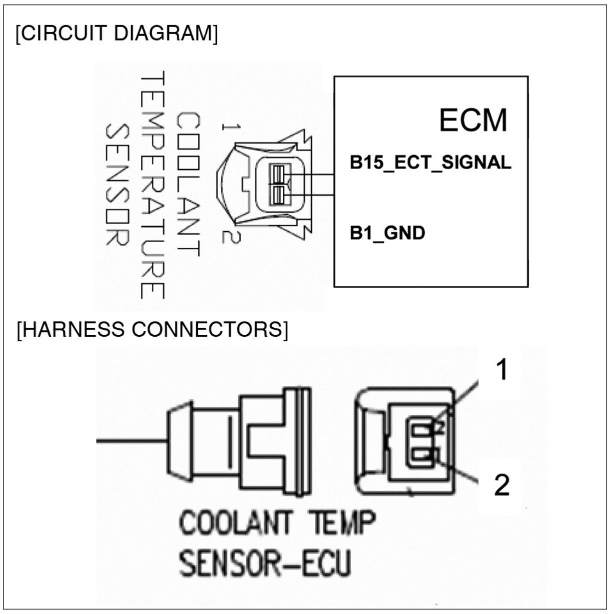
1. Remove the engine coolant temperature sensor from the intake intake manifold.

2. With the temperature sensing portion of the engine coolant temperature sensor immersed in hot water, check resistance.

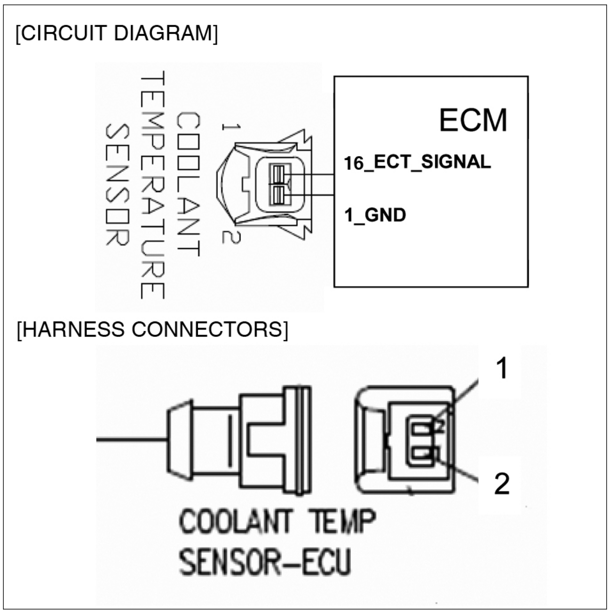
Temperature ℃ (°F)	ECTS Resistance(kΩ)
20(68)	2.31~2.59

3. If the resistance deviates from the standard value greatly, replace the sensor.

Schematic Diagram (G643E)



Schematic Diagram (G643)



Installation

1. Install engine coolant temperature sensor and tighten it to specified torque.

Tightning torque

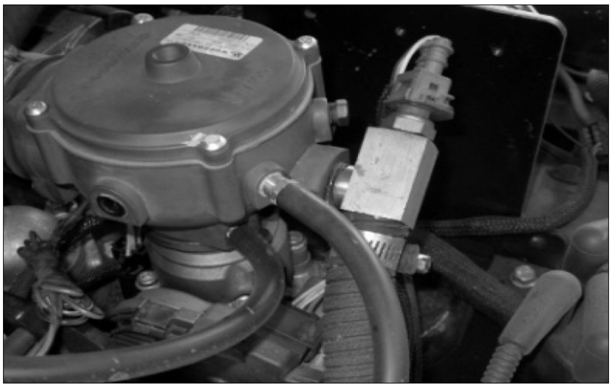
Engine coolant temperature sensor "
15~20Nm (150~200 kg·cm, 11~15 lb·ft)

---

2. Connect the harness connector securely.

LP Fuel Temperature Sensor [G643E]

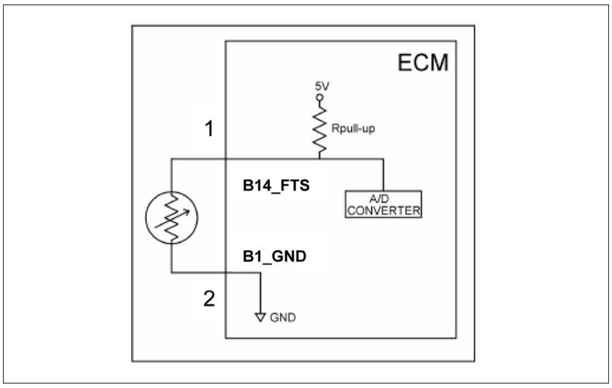
Location



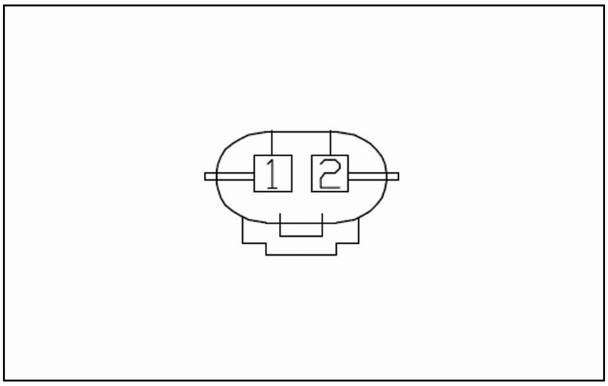
Description

The LP Fuel Temperature Sensor (FTS) is located in the LP fuel passage of the LP mixer for detecting the LP fuel temperature. The FTS uses a thermistor whose resistance changes with the temperature. The electrical resistance of the FTS decrease as the temperature increase, and increase as the temperature decrease. The reference 5V in the ECM is supplied to the FTS by way of a resister in the ECM. That is, the resistor in the ECM and the thermistor in the FTS are connected in series. When the resistance value of the thermistor in the FTS changes according to the LP fuel temperature, the output voltage also change.

Circuit Diagram [G643E]



[Harness Connectors]



Inspection

1. Remove the LP fuel temperature sensor from the adapter connected to LP mixer.

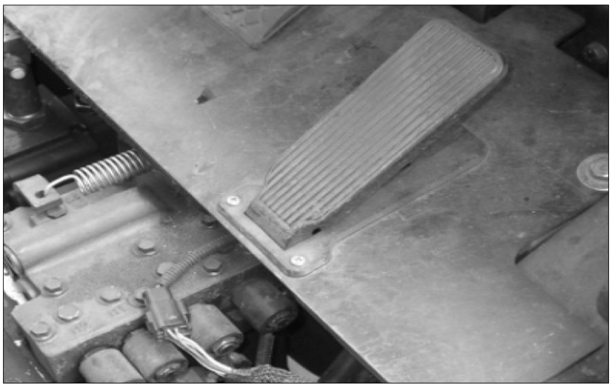
2. With the temperature sensing portion of the LP engine fuel temperature immersed in hot water, check resistance.

Temperature °C (°F)	FTS Resistance (Ohms)
-20(-4)	15462
0(32)	5896
20(68)	2498
40(104)	1175
60(140)	596
80(176)	323

3. If the resistance deviates from the standard value greatly, replace the sensor.

Angle Sensor-Accelerator [G643E and G643]

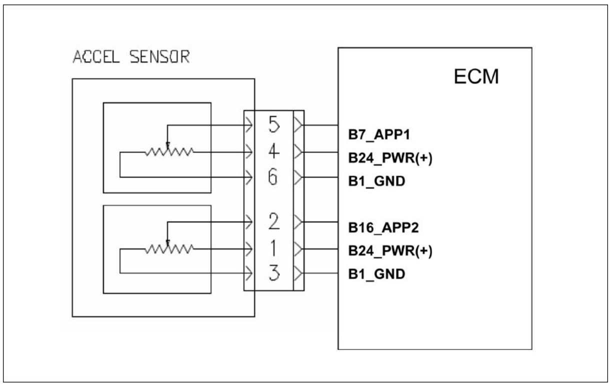
Location



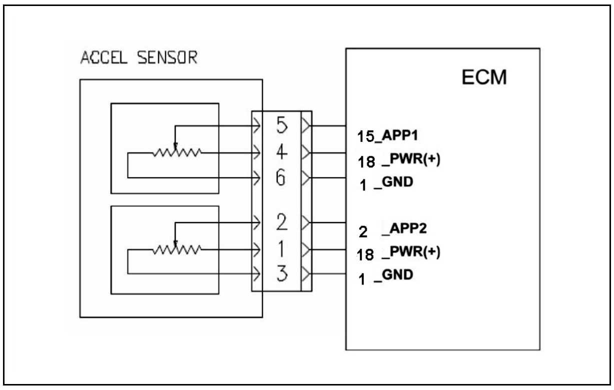
Description

Angle Sensor-Accelerator is located in the accelerator pedal assembly. The engine speed management deals with a Drive-by-wire system. Drive-by-wire refers to the fact that the MI-07 control system has no throttle cable from the foot pedal to the throttle body. Instead, the ECM is electronically connected both to the foot pedal assembly and the throttle body. The SECM monitors the foot pedal position and controls the throttle plate by driving a DC motor connected to the throttle. The DC motor actuates the throttle plate to correspond to the foot pedal position when the operator depresses the pedal. The SECM will override the pedal command above a maximum engine speed and below a minimum idle speed. The foot pedal assembly uses two potentiometers to detect pedal position. These two signals, accelerator pedal position 1 (APP1) and accelerator pedal position 2 (APP2) are sent directly to the SECM. The SECM uses a series of algorithms to self calibrate and cross check the signals from the pedal assembly.

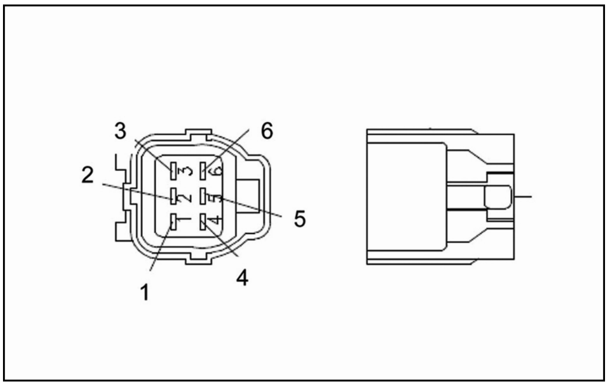
Circuit Diagram [G643E]



Circuit Diagram (G643)



[Harness Connectors]



Inspection

1. Disconnect the Accelerator Pedal's connector from the main engine harness.

2. Inspect the electrical conditions with a follow basic specification.

   Signal output is on condition that input voltage is .... 5V±0.5%
   Rated current :...................................... 20 mA
   Power : .... 100 mW
   Wire width :... 20AWG
   - At start point : Signal 'A'................... 0.4V±0.1V
     Signal 'B'................... 4.5V±0.1V
   - At end point(Push for end) :
     Signal 'A'............... 3.60V±0.15V
     Signal 'B'............... 1.39V±0.15V

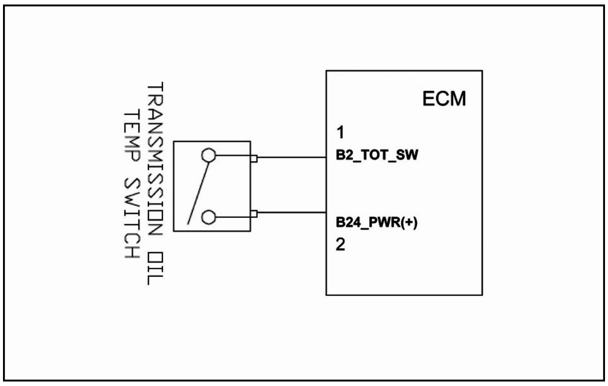
3. If the result value is out of the specification, replace the Accelerator Pedal.

Transmission Oil Temperature Switch [G643E]

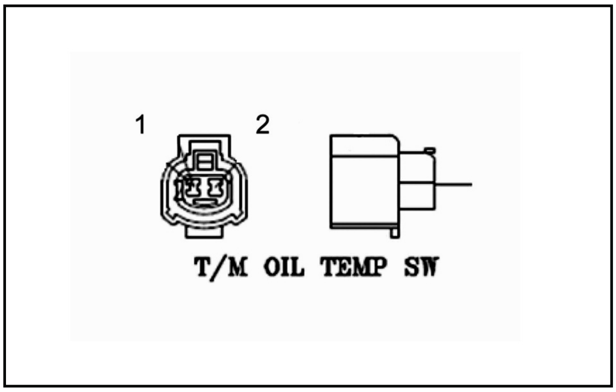
Description

Transmission Oil Temperature Switch is located in the adapter on transmission (T/M) for operating by the transmission (T/M) oil temperature change. This switch is normally open, and then it is closed as the T/M oil temperature Increases to the 125±3°C. Actually if the switch is closed by high T/M oil temperature, the ECM makes engine shutdown with fault set. If the T/M oil temperature decreases to the 118°C, the switch is open again and the engine also can run. This function can protect the engine of Tier-3 and Non cert folk lift trucks from damage as overheating.

Circuit Diagram ［G643E］



[Harness Connectors]



Inspection

1. Remove the Transmission Oil Temperature Switch from the transmission.

2. Use an ohmmeter to check the continuity between the 1 terminal and the 2 terminal. If there is continuity, replace the Transmission Oil Temperature Switch.

3. The Transmission Oil Temperature Switch is the 'ON/OFF' switch. So during the normal status the switch circuit should be open.

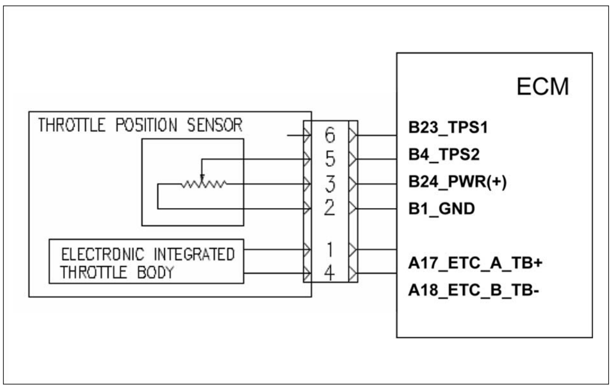
Electronic Throttle Body [G643E and G643]

Location

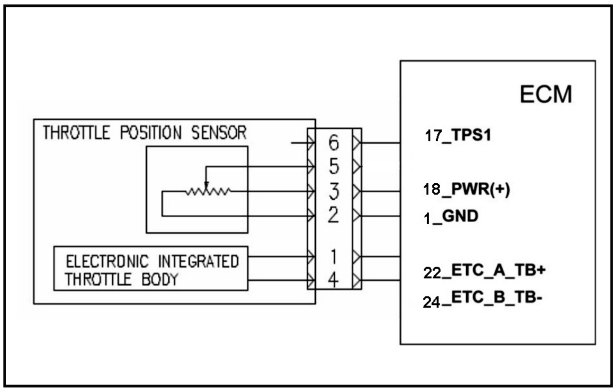
Description

The MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 32mm electronic throttle body DV-E5. The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver's demand, makes any adjustments needed for adaptation to the engine's current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator.

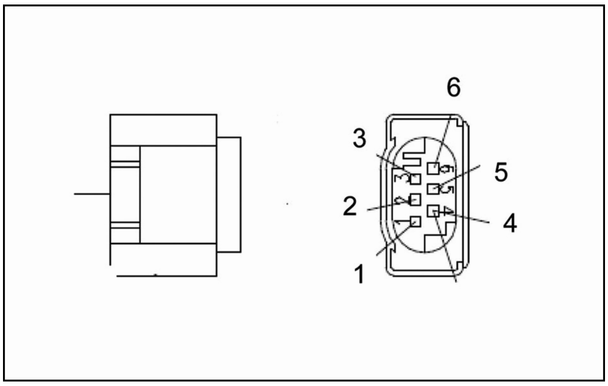
Circuit Diagram [G643E]



Circuit Diagram [G643]



[Harness Connectors]



Inspection

1. Check for loose, dirty or damaged connectors and wires on the harness

2. Check the throttle assembly motor housing for coking, cracks, and missing cover-retaining clips

3. Check the resistance of TPS sensor. (refer as blow chart)

SENSOR	POINT TO POINT	EXPECTED RANGE
TPS (Throttle Position Sensor)	TPS PIN 2(GND) TO PIN 6(TPS1 SIGNAL)	1.25KΩ +/- 30%
	TPS PIN 3(PWR) TO PIN 6(TPS1 SIGNAL)	1.25KΩ +/- 30%
	TPS PIN 1(+DRIVER) TO PIN 4(-DRIVER)	~3.0KΩ +/- 30%

Chapter 6. LPG FUEL DELIVERY SYSTEM

G643E LP System Inspection and Repair

Removal and Installation

⚠ WARNING - PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/ converter or mixer.

Hose Connections

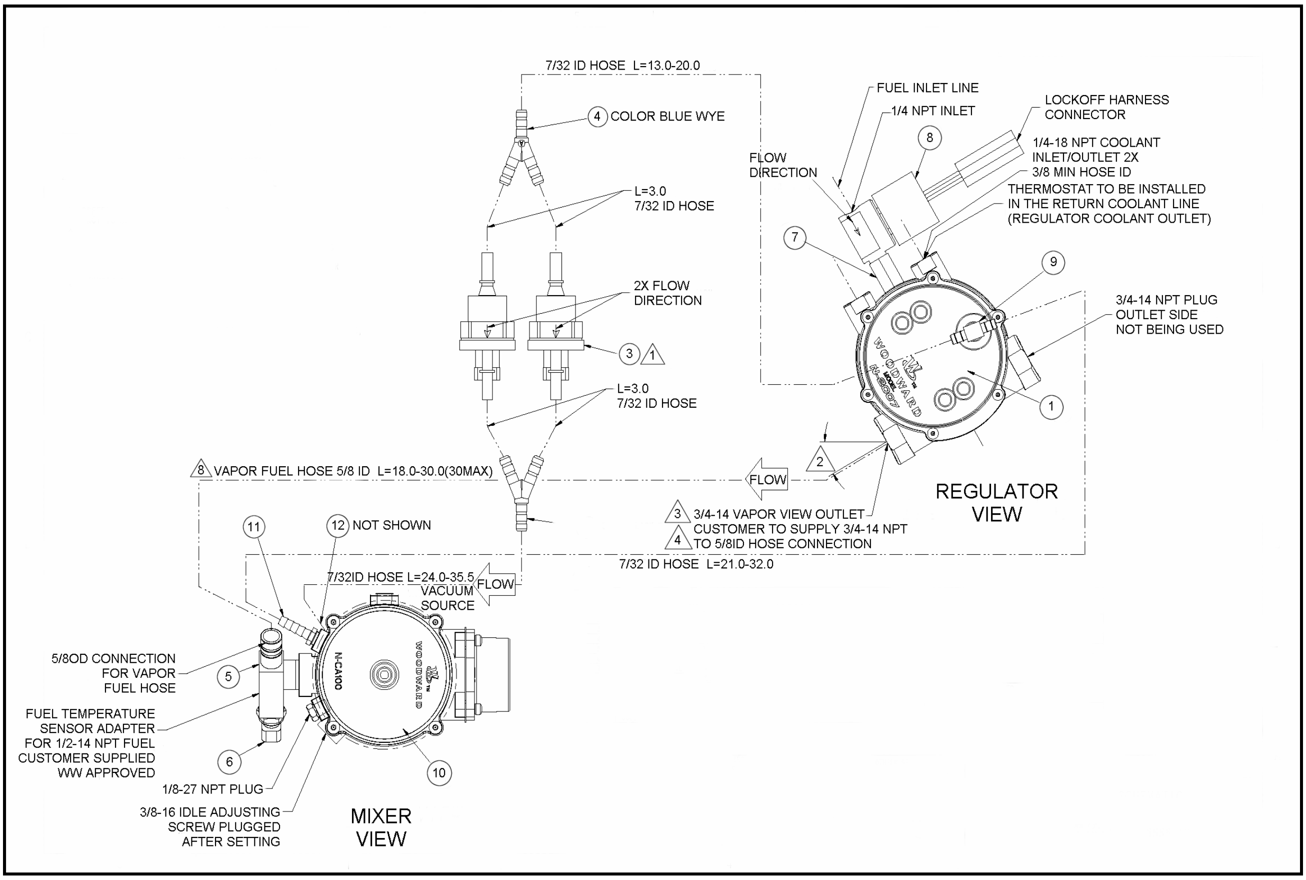
Proper operation of the closed loop control greatly depends on the correct vacuum hose routing and fuel line lengths. Refer to the connection diagrams below for proper routing and maximum hose lengths when reinstalling system components.

NOTE: Preferred mounting of regulator is off engine.

Hose Specifications

Vacuum hose to comply to SAE 1403 Type I or SAE J30 R7 R8 / EPDM textile reinforced / -40° F to +257° F (-40° C +125° C / Inside Diameter: 7/32" (5.56mm)

Certified System Connections



DWG NO 5555-1201

Figure 26. Hose Connections for Certified Systems

DIAGRAM NOTES

△1 Trim valves must be positioned vertically with flow arrows in position shown

△2 Fuel outlet must be min 15° below horizontal position

△3 Only one 90° fitting permissible on vapor fuel line between mixer and regulator (As shown the temp sensor adaptor is considered the one 90° fitting.)

△4 Vapor fuel fittings (regulator and mixer) must have minimum ID of 0.46" (11.68mm)

△8 Vapor hose length to be as short as possible and have no restrictions for best regulator performance

(1) N-2007 Regulator

(2) Plastic WYE Fitting (black color) for 7/32" (5.56mm) ID Tube Hose

(3) Valve (TEV Bosch Canister)

(4) Plastic WYE Fitting (blue color) for 7/32" (5.56mm) ID Tube Hose

(5) Adapter (temperature sensor)

(6) Sensor (coolant, temperature)

(7) Nipple (.625 hex 4mp, 2.5L steel)

(8) Solenoid (AFS Lock Off Valve)

(9) Brass Tee Fitting. 1/4 Tube x 1/8 NPTF x 1/4 Tube

(10) CA100 Mixer

(11) 1/4" (6.35mm) hose barb to 1/8" (3.2mm) male pipe, 125HBL, .062 flow ID

(12) 1/4-28 UNF x 1/4" (6.35mm) hose barb

Removal and Installation of N-2007 LP Regulator

Follow the procedures below for removal and reinstallation of the N-2007 regulator in certified systems.

N-2007 Removal Steps

Refer to **Figure 28.**

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in “OFF” position.

4. Remove the fuel inlet line (1) from the lock-off, the two vacuum lines (2) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (3).

5. Remove the four rear-mounting bolts that hold the regulator to the support bracket. This will allow easier access to the remaining hose clamps.

6. Remove the two cooling lines (4) and a thermostat (7) from the regulator.

NOTE: Either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.

7. Remove the fuel vapor outlet hose (5) from the regulator.

8. Remove the nipple extension (6) with the lock-off from the regulator.

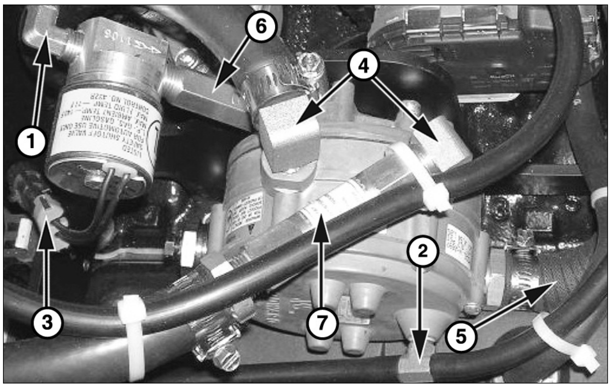


Figure 28. N-2007 Regulator in Certified System

N-2007 Installation Steps

Refer to **Figure 28.**

1. Install the nipple extension (6) with the lock-off to the regulator.

2. Install the fuel vapor outlet hose (5) to the regulator.

3. Install the two cooling lines (4) and a thermostat (7) to the regulator.

4. Install the four rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 60-70 lbf•in (6.78-7.91 N·m).

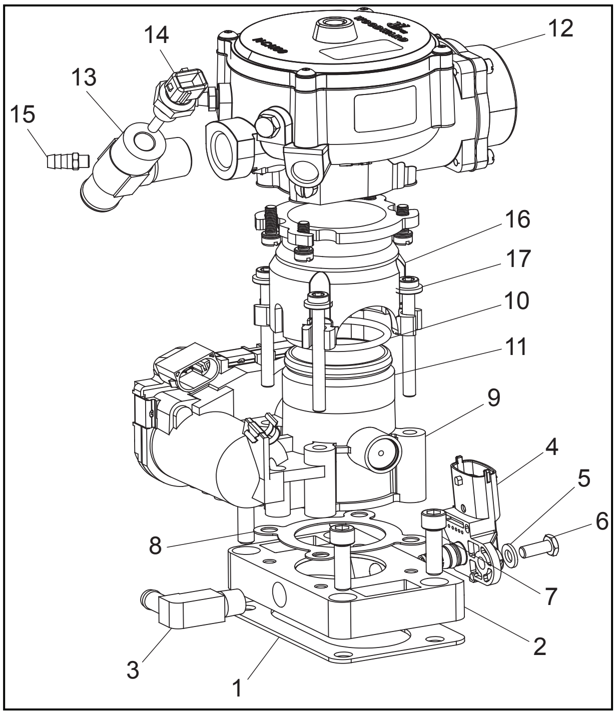
5. Install the fuel inlet line (1) to the lock-off, the two vacuum lines (2) to the branch-tee fitting in the regulator vent and re-connect the lock-off connector (3).

6. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of CA100 Mixer for G643E

Follow the procedures below for removal and reinstallation of the CA100 mixer.

CA100 Certified Mixer Removal Steps



1. Gasket	2. Adapter	3. Fitting
4. Tmap	5. Washer	6. Bolt
7. Bolt	8. Gasket-ITB	9. ITB
10. O-Ring	11. O-Ring	12. Mixer
13. Adapter	14. Fuel Temp Sensor	15. Fitting
16. Apollo Adapter	17. Bolt	

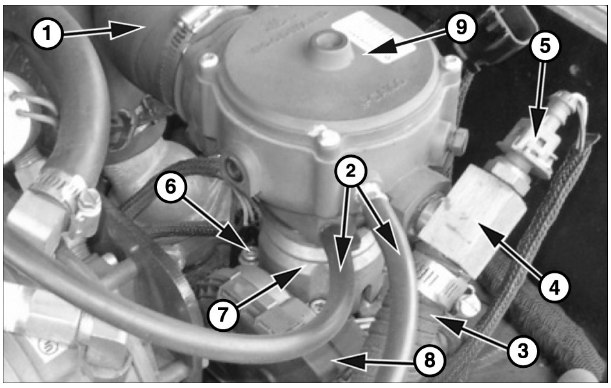


Figure 30. CA100 Mixer in Certified System

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in "OFF" position.

4. Remove the air cleaner hose (1).

5. Mark the two vacuum lines (2) to the mixer for identification, as they must be reinstalled correctly for proper operation. Remove the two vacuum lines (2).

6. Remove vapor fuel inlet line (3) from the fuel temperature sensor fitting (4).

7. Disconnect the fuel temperature sensor connector (5).

8. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector. (See Figure 31 for location of connector)

9. Loosen the four bolts (6) that secure the mixer/adapter/throttle body assembly to the intake manifold.

10. Remove the mixer (9), the adapter (7), and the throttle body (8) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.

11. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.

12. Remove the four mounting screws that attach the throttle body adapter to the mixer.

13. Remove the fuel temperature sensor (not shown) from the tee (4).

14. Remove the fuel temperature sensor fitting from the mixer. Take note of the fitting's orientation on the mixer, as it must be reinstalled correctly for proper fit.

15. Remove the short vacuum port barb from the mixer. (See **Figure 32** for location of port barb on mixer.)

NOTE: A plastic O-ring spacer and an O-ring are inside the mixer/adapter assembly. Be careful not to lose these items when removing the assembly from the throttle (Figure 31).

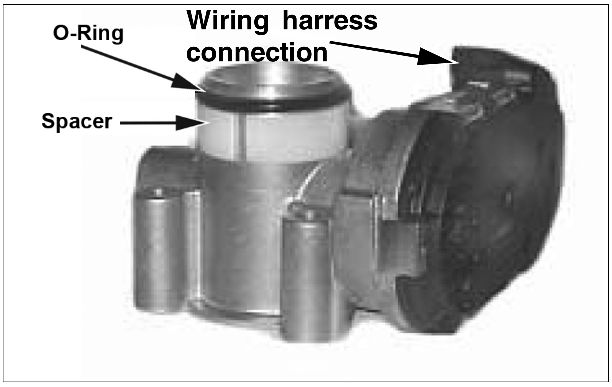


Figure 31. O-Ring and Spacer Within Mixer Adapter Assembly

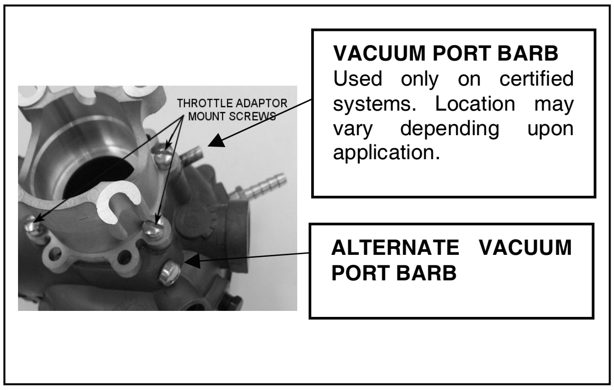


Figure 32. Throttle Adapter Mount Screws

CA100 Certified Mixer Installation Steps

Refer to **Figure 30.**

1. Install the vacuum port barb onto the mixer (9).

2. Install the fuel temperature sensor fitting (4) onto the mixer.

3. Install the fuel temperature sensor into the fitting.

4. Ins tall the four mounting screws that attach the throttle adapter (7) to the mixer. See Figure 32. Torque bolts to 30-40 lbf·in (3.39-4.52 N·m).

5. Position the mixer/adapter assembly onto the throttle body (8), then drop in the four mounting bolts (6) and gently push down on the assembly until it rests on the throttle body. Be careful not to pinch the O-ring. (See Figure 31.)

6. Attach the mixer/throttle body assembly to the intake manifold, making sure gasket is in place. Tighten the four mounting bolts.

7. Connect the wiring harness to the throttle body. (See Figure 31 for location of connector.) Connect the fuel temperature sensor connector (5) to the sensor.

8. Install the vapor fuel inlet line (3) to the fuel temperature sensor fitting.

9. Install the two vacuum lines (2) to the mixer using the previous marks for identification. Vacuum lines must be installed correctly for proper operation.

10. Install the air cleaner hose (1).

Tests and Adjustments

⚠ WARNING—PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator converter or mixer.

N-2007 Regulator Service Testing

For checking the N-2007 regulator/converter operation, the following tests can be performed (See Chapter 5 for removal/installation of the N-2007 regulator). To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump

2. Regulator vapor outlet test fitting 3/4” NPT x 1/4” hose barb

3. Union Tee 1/4” NPT with three 1/4” NPT x 1/4” hose barb

4. Vacuum hose

5. 0-3” WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge and the regulator vapor outlet to the Union Tee fitting (Figure 34). Make sure there is no leakage at any of the fittings.

2. Using the vacuum pump slowly apply enough vacuum to measure above -2” WC on the gauge. This vacuum signal opens the secondary valve in the N-2007 regulator/converter.

3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-0.5 +/- 0.35 “ WC) of the secondary spring, the needle should stop moving.

4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

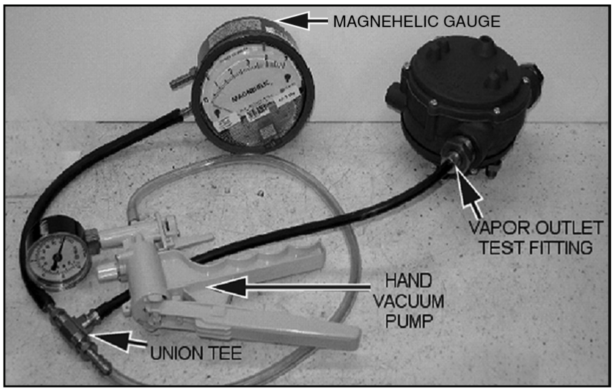


Figure 34. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Shop air pressure regulator adjusted to 100 psi

2. Shop air hose fitting (1/4” NPT to air hose)

3. Air hose

4. Test gauge fitting (1/16” NPT x 1/4” hose barb)

5. Vacuum hose or vinyl tubing

6. 0-60” WC Magnehelic gauge (inches of water column)

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16” NPT hose barb fitting (Figure 35).

2. Connect a compressed air line (shop air ~100psi) to the liquid propane fuel inlet of the N-2007 regulator (Figure 35).

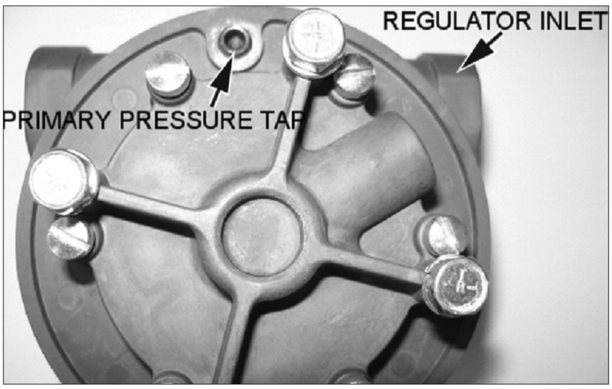


Figure 35. Primary Stage Test Connection

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (Figure 36) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from reading maximum pressure due to the large velocity of compressed air entering the primary chamber.

4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60” of water column on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

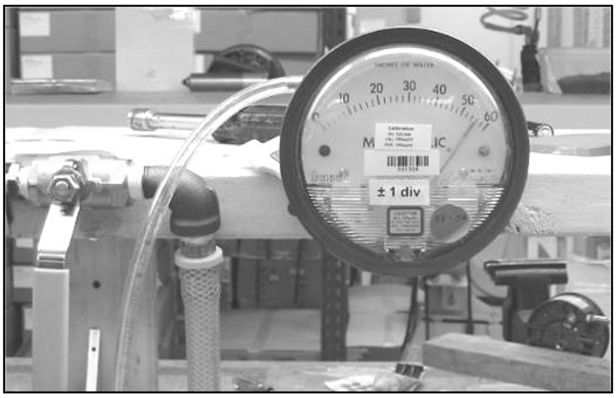


Figure 36. Magnehelic Gauge Connection to Hose Barb

5. If the pressure reading begins to increase, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator should be replaced.

6. If the pressure begins to decrease, the secondary seat is probably not making an adequate seal and is leaking. The regulator should be replaced.

7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the N-2007 regulator.

NOTE : The N-2007 primary stage pressure can also be tested at idle on a running engine. The N-2007 primary pressure should be between 40 inH20 (99.6mbar) and 55 inH20 (137 mbar) at 750 rpm, idle.

⚠ CAUTION

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across CA100 mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4” (6.35mm) NPT with three 1/4” (6.35mm) NPT x 1/4” (6.35mm) hose barbs

2. Vacuum hose

3. 0-20” H_2O differential pressure Magnehelic gauge

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (Figure 37).

2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (Figure 37).

3. With the engine fully warmed up and running at idle (750 rpm) place the transmission in Neutral. The AVV should be between 5” and 8” H_2O of pressure vacuum.

4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.

5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

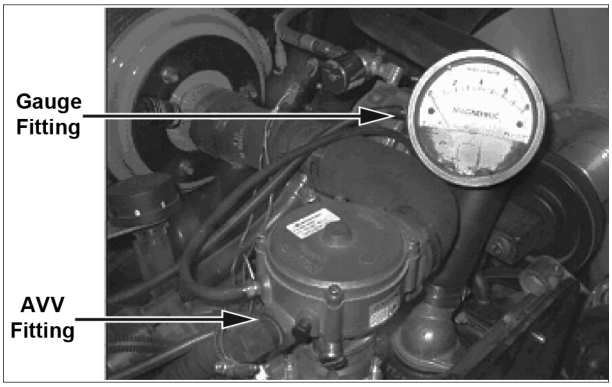


Figure 37. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM see, chapter 4. Ignition system for the detail information.

Idle Mixture Adjustment

The CA100 mixer requires adjustment of the idle mixture screw to assure optimal emissions and performance. This adjustment accounts for minor part-to-part variations in the fuel system and assures stable performance of the engine at idle. Once adjusted, the idle mixture screw is sealed with a tamper proof cap, after which it need not be adjusted for the life of the vehicle.

Therefore, the only situations in which the idle mixture screw needs to be adjusted are when the engine is initially fitted with a fuel system at the factory and following the field replacement of the mixer. Under these situations, follow the procedures below for adjustment of the idle mixture screw.

Factory Test Preparation:

1. Install the MI-07 fuel system, wiring harness and SECM-48 control module on the engine.

2. All coolant hoses should be attached, filled with coolant and bled to remove any air.

3. Attach LPG fuel lines.

4. Attach wiring harness to battery power.

5. Attach exhaust system.

6. If present, set fuel select switch to LPG fuel.

When operated at the factory, it is critical to simulate the airflow found on a forklift at idle as nearly as possible in order to achieve the proper air valve lift in the mixer. It may be necessary to place a load on the engine to achieve the required airflow without overspeeding the engine. Means of achieving this load include:

a) Place an electrical load on the alternator. The alternator should be able to briefly hold loads of approximately 1.2 kW.

b) Attach the engine to a dynamometer.

Attach the Mototune Service Tool to the wiring harness and add parameter MAFPort to the display screen.

Factory Adjustment Procedure:

NOTE : Be sure engine is fully warm (ECT>167°F [75°C]) before performing the idle mixture adjustment.

1. Operating the engine on LPG fuel, start the engine and permit the engine to warm up until the coolant temperature (ECT on Mototune display) is approximately 167°F (75 oC).

2. Set APP input to minimum.

3. Adjust the load until engine speed reaches 750 rpm.

4. Mototune display parameter LP Fuel Control must display “Closed Loop.”

5. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.

6. To adjust the idle mixture screw, use a 5mm hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counter-clockwise) should decrease the duty cycle.

7. Adjust the idle mixture screw on the mixer until a reading of 40-45% is reached for the FTV Duty Cycle in Closed Loop Idle (Figure 35).

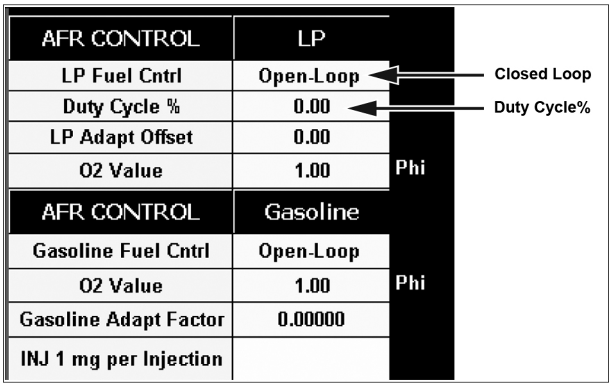


Figure 41. FTV Duty Cycle Percentage Displayed on Service Tool

8. Use the accelerator pedal to increase RPM above idle momentarily (rev the engine) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (40-45%). Place your thumb over the adjustment port for a more accurate reading by preventing air from leaking past the mixture adjustment screw, which may cause the duty cycle to decrease.

9. Use the Mototune Service Tool to lock the FTV duty cycle. Set display parameter DitherValveDC_ovr = locked (displayed in screen tab Manual Override 1 under AFR Trim Vales, select “locked” under box labeled Lock DC%).

10. Use the Mototune Service Tool to monitor throttle position (TPS1) and Exhaust gas oxygen equivalence ratio (“O2 Value” in Figure 1). While monitoring O2, slowly increase the pedal input (APP) to achieve a TPS1 value of 15%.

11. Use the Mototune Service Tool to unlock the FTV duty cycle. Set display parameter DitherValveDC_ovr = unlocked (displayed in screen tab Manual Override 1 under AFR Trim Vales, select “unlocked” under box labeled Lock DC%).

12. If at any time in step 10, O2 was greater than 1.2 go to step 13. If 02 remained below 1.2, proceed to Step 15.

13. Adjust the idle mixture screw on the mixer until a reading of 50-55% is reached for the FTV Duty Cycle in Closed Loop Idle (Figure 35).

14. Use the accelerator pedal to increase RPM above idle momentarily (rev the engine) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (50-55%). Place your thumb over the adjustment port for a more accurate reading by preventing air from leaking past the mixture adjustment screw, which may cause the duty cycle to decrease.

NOTE : If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.

15. Turn the ignition key to the OFF position to shut down the engine.

16. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (Figure 36).

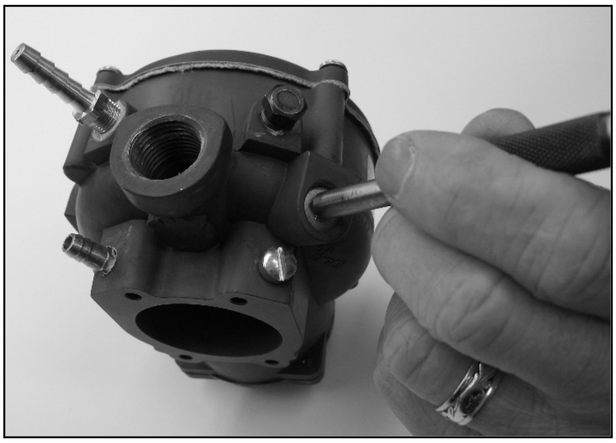
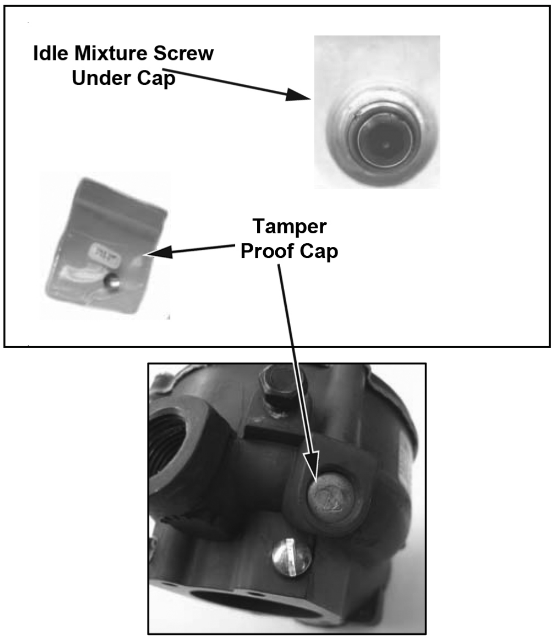


Figure 42. Installing Tamper Proof Cap



Field Adjustment Procedure:

The idle mixture adjustment should only be necessary on a new mixer that does not have the tamper proof cap installed. The method for making the idle mixture adjustment to a running engine is to use the Service Tool software by connecting a laptop computer to the SECM. If you do not have the Service Tool a multimeter capable of measuring duty cycle, such as a Fluke 87 III, can be used. If using a multimeter, connect the meter positive lead to between battery positive and the meter negative to the FTV signal wire. For the Fluke 87, press the “RANGE” button until 4 or 40 appears in the lower right-hand corner of the display. Press the “Hz” button twice so that the percent sign (%) appears on the right-hand side of the display. The multimeter will then read the duty cycle percentage the same as the Service Tool shown in Figure 41.

1. After installing a new mixer, operate the engine Bon LPG fuel. Start the engine and permit it to warm up until the coolant temperature (ECT on Mototune display) is approximately 167°F (75°C).

2. Place the transmission in Neutral.

3. Mototune display parameter LP Fuel Control must display “Closed Loop”.

4. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.

5. To adjust the idle mixture screw, use a hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counterclockwise) should decrease the duty cycle.

6. Adjust the idle mixture screw on the mixer until a reading of 45-55% is reached for the FTV Duty Cycle in Closed Loop Idle (Figure 41). If engine idle performance is unstable screw the idle screw in slightly to see if stability is obtained, but in no case should duty cycle exceed 60%.

7. Use the accelerator pedal to increase rpm above idle momentarily (rev the engine) then release the pedal to return to idle rpm. The duty cycle setting should remain within the adjustment range (45-55%). Place your thumb over the adjustment port for a more accurate reading by preventing air from leaking past the mixture adjustment screw, which may cause the duty cycle to decrease.

8. If the FTV duty cycle reading is above 55% adjust the idle adjustment screw outward and re-check the duty cycle reading. Continue to do this until the FTV duty cycle reading is within the optimum range (45-55%). DO NOT adjust the screw so far outward that the tamper proof cap cannot be installed. A duty cycle measurement at Closed Loop Idle of 40-60% is acceptable if the optimum range of 45-55% cannot be reached through adjustment. If the FTV duty cycle cannot be adjusted below 60%, the mixer is faulty and should be replaced.

NOTE : If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.

9. Turn the ignition key to the OFF position to shut down the engine.

10. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (Figure 42).

Parts Description

CA100 Mixer for G643E Engine

Parts List of CA100 Mixer (Certified)

REF NO	DESCRIPTION	QTY
1	Torx Screws (T-25) #10-24 x 5/8”	4
2	Lockwashers (T-210) #10 SST	4
3	Mixer Cover	1
4	Mixer Spring	1
5	Diaphragm	1
6	Air Valve Assembly	1
7	Gas Valve Cone (part of air valve assembly)	1
8	Mixer Body	1
9	Expansion Plug Cap Ø 1/2” x 1/16” thick (Ø 12.7mm x 27mm)	1
10	Fuel Inlet	1
11	Air Horn Gasket	1
12	Air Horn Adapter 2-1/16” (52.37mm)	1
13	Fillister Head Screws SEMS Lockwasher 10-24 UNC x 5/8”	4
14	Throttle Body Gasket	1
15	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	4

Exploded View of CA100 Mixer (Certified)

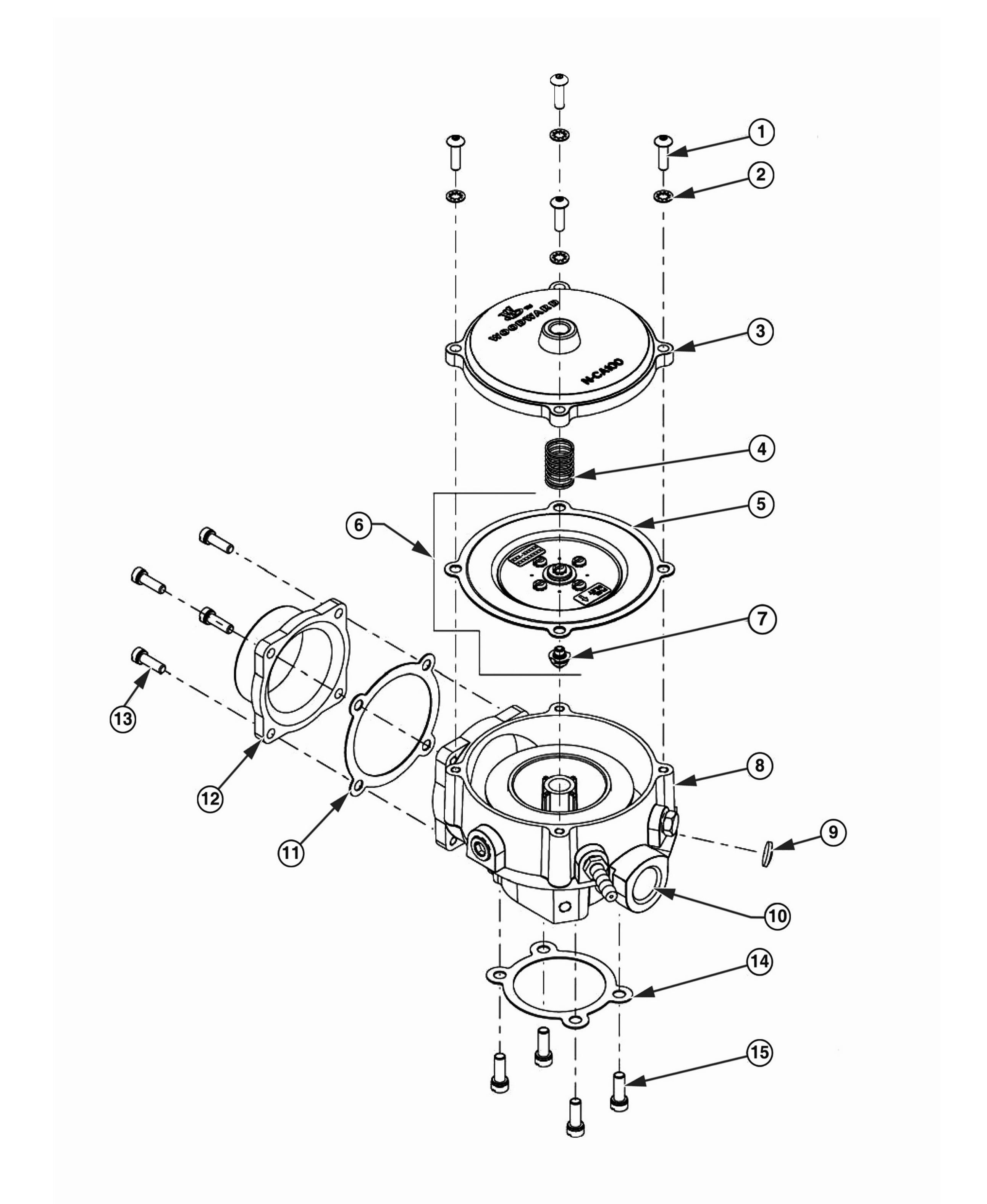


Figure 44. CA100 Certified Mixer Exploded View

N-2007 Regulator for G643E Engine

Parts List of N-2007 Regulator (Certified)

REF NO	DESCRIPTION	QTY
1	N-2007 Body	1
2	Diaphragm, Primary Assembly	1
3	Springs, Primary Assembly	2
4	Cover, Primary Assembly	1
5	Spring, Secondary Seat, Red	1
6	Dowel Pin Ø 0.094” x 1” L (Ø 2.39mm x 25.4mm L) Hardened Steel	1
7	Diaphragm, Secondary Assembly	1
8	Lever, Secondary	1
9	Seat, Secondary	1
10	Valve Primary	1
11	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	6
12	Pan Head Screw SEMS Ext. Tooth Lockwasher #12-24 x 1/4”	1
13	Body Gasket	1
14	Back Plate	1
15	O-ring, Size 107 GLT Viton®	1
16	Bottom Plate Gasket	1
17	Plate Cover	1
18	Fillister Head Screws SEMS Split Lockwasher #12-24 x 1-3/8”	6
19	Hex Head Screws SEMS Split Lockwasher 1/4-20 x 5/8”	4
20	Plug, Socket Head Pipe (T-086)	1
21	Cover, Secondary Diaphragm	1
22	Lockwasher, Int. Tooth (T-210) #8 SST	6
23	Torx Screws (T-15) #8-32 x 5/8”	6

Exploded View of N-2007 Regulator (Certified)

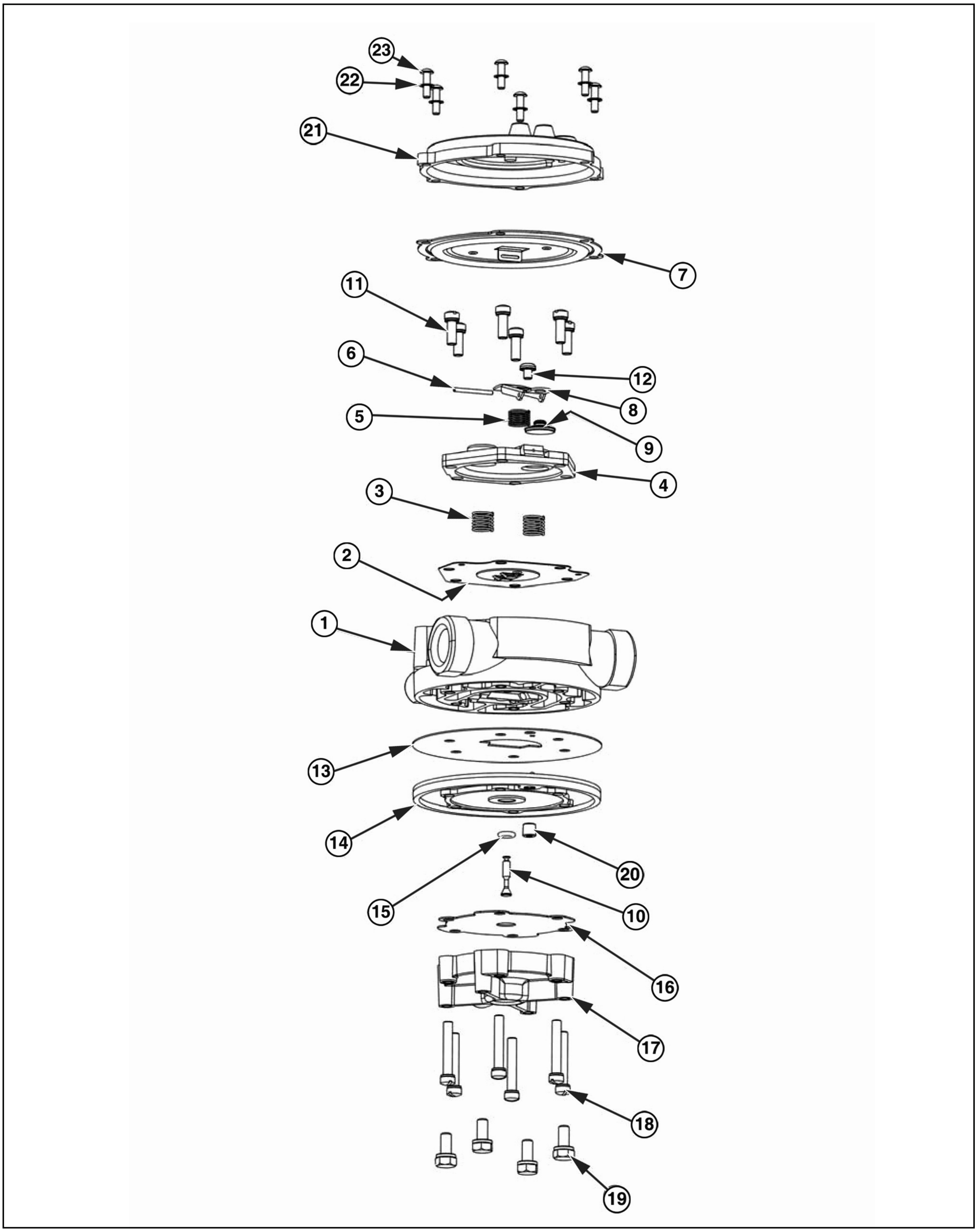


Figure 46. N-2007 Certified Regulator Exploded View

G643 LPG System Inspection and Repair

Removal and Installation

⚠ WARNING – PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator / converter or mixer.

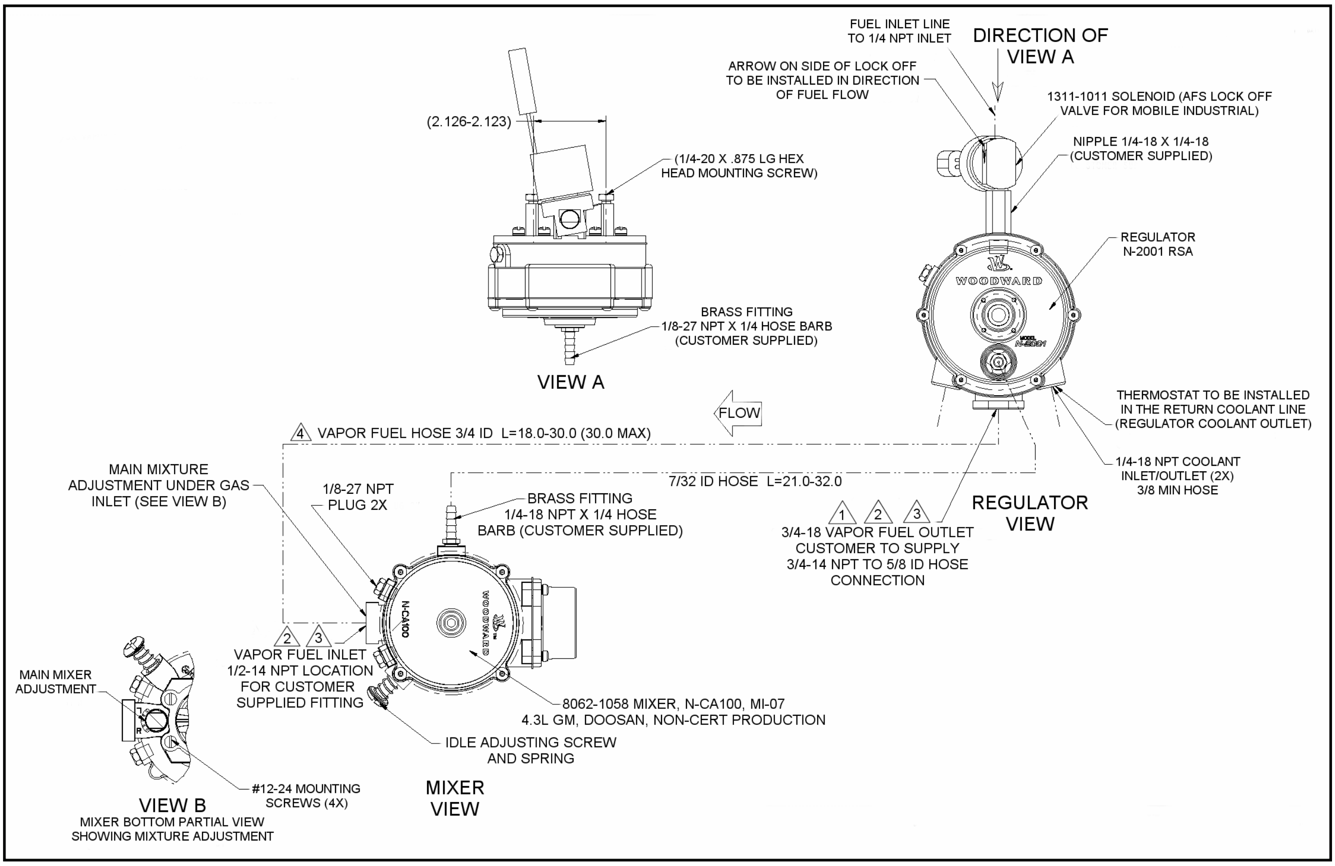
Hose Connections

Proper operation of the closed loop control greatly depends on the correct vacuum hose routing and fuel line lengths. Refer to the connection diagram below for proper routing and maximum hose lengths when reinstalling system components.

NOTE: Preferred mounting of regulator is off engine.

Hose Specifications

Vacuum hose to comply to SAE 1403 Type I or SAE J30 R7 R8 / EPDM textile reinforced / -40˚ F to +257˚ F (-40˚ C +125˚ C / Inside Diameter: 7/32" (5.56mm)



DWG NO 5555-1236

Figure 25. Hose Connections for G643 Engines

DIAGRAM NOTES

1 Fuel outlet must be positioned vertically in the down position

2 Only one 90 fitting permissible on vapor fuel line between mixer and regulator

3 Vapor fuel fittings (regulator and mixer) must have minimum ID of 0.59" (14.99mm)

5 Vapor hose length to be as short as possible and have no restrictions for best regulator performance

Removal and Installation of N-2001 LP Regulator/Converter

Follow the procedures below for removal and reinstallation of the N-2001 regulator.

N-2001 Removal Steps

Refer to Figure 29.

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Remove the fuel inlet line (1) from the lock-off, the vacuum lines (2) the regulator and disconnect the lock-off connector (3).

4. Remove the two rear-mounting bolts that hold the regulator to the support bracket. This will permit easier access to the remaining hose clamps.

5. Remove the two cooling lines (4) from the regulator.

NOTE: It will be necessary to either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.

6. Remove the fuel vapor outlet hose (5) from the regulator.

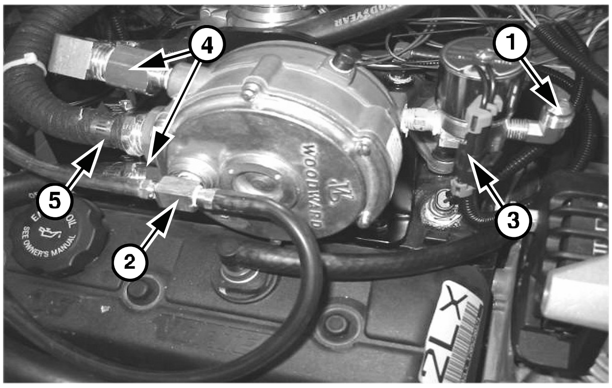


Figure 29. N-2001 Regulator in Non-Certified System

N-2001 Installation Steps

Refer to Figure 29.

1. Install the fuel vapor outlet hose (5) onto the regulator.

2. Install the two cooling lines (4) onto the regulator.

3. Install the two rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 50-60 lbf-in (5.65-6.78 N-m)

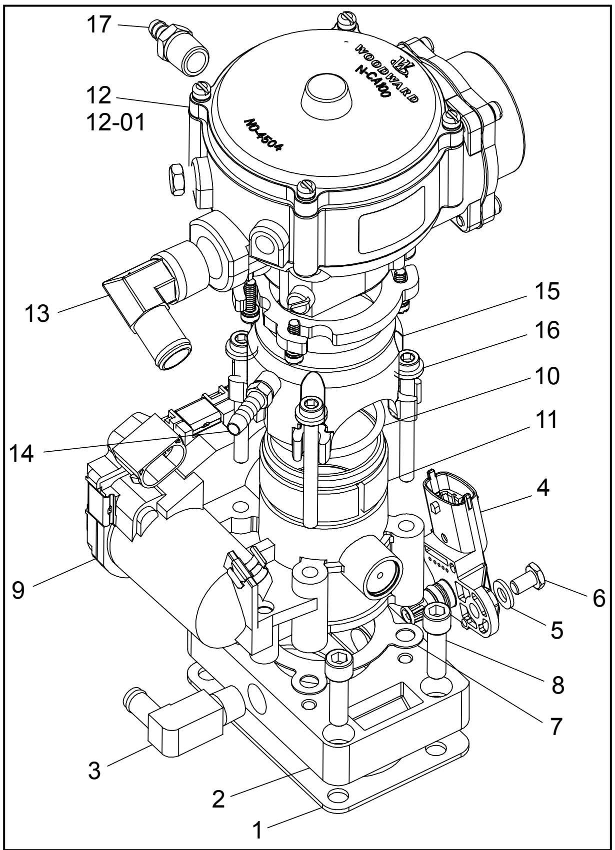
4. Install the fuel inlet line (1) onto the lock-off, the vacuum line (2) onto the regulator and connect the lock-off connector (3).

5. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of CA100 Mixer for G643

Follow the procedures below for removal and reinstallation of the CA100 mixer in non-certified systems.

CA100 Mixer Removal Steps



(1) Gasket-Adapter Plate MTG.
(2) Adapter-Intake Manifold
(3) Fitting
(4) TMAP sensor
(5) Washer-Tamp MTG
(6) Bolt-Tamp MTG
(7) Gasket-ITB
(8) Bolt-Adapter
(9) ITB
(10) O-Ring
(11) O-Ring Spacer
(12) Mixer
(13) Fitting
(14) Fitting- Vacuum Small
(15) Apollo Adapter
(16) Bolt
(17) Fitting

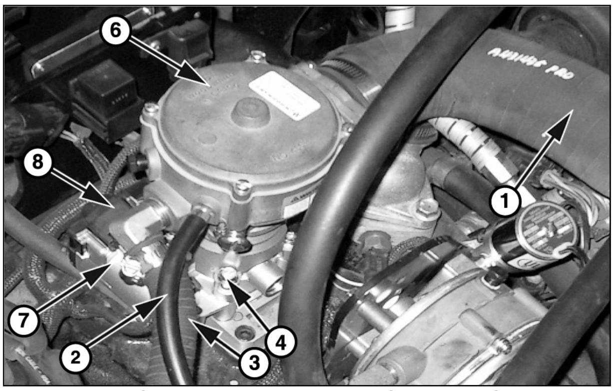


Figure 33. CA100 Mixer in Non-Certified System

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in “OFF” position.

4. Remove the air cleaner hose (1).

5. Remove the vacuum line (2).

6. Remove vapor fuel inlet line (3) from the mixer (6).

7. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector (8).

8. Loosen the four bolts (4) that secure the mixer/adapter/throttle body assembly to the intake manifold.

9. Remove the mixer (6) and the throttle body (7) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.

10. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.

11. Remove the four mounting screws that attach the throttle adapter to the mixer.

12. Remove the vapor fuel inlet fitting from the mixer.

CA100 Mixer Installation Steps

1. Install the vapor fuel inlet fitting onto the mixer.

2. Install the four mounting screws that attach the throttle adapter (5) to the mixer. (See **Figure 32**). Torque bolts to 30-40 lbf-in (3.39-4.52 N-m).

3. Position the mixer/adapter assembly onto the throttle body (7), then drop in the four mounting bolts (4) and gently push down on the assembly until it rests on the throttle body. Be careful not to pinch the O-ring. (See Figure 31.)

4. Attach the mixer/throttle body assembly to the intake manifold, making sure gasket is in place. Tighten the four mounting bolts.

5. Connect the wiring harness (8) to the throttle body.

6. Install the vapor fuel inlet line (3) to the mixer.

7. Install the vacuum line (2) to the mixer.

8. Install the air cleaner hose (1).

NOTE : A plastic O-ring spacer and an O-ring are inside the mixer/adapter assembly. Be careful not to lose these items when removing the assembly from the throttle (Figure 31).

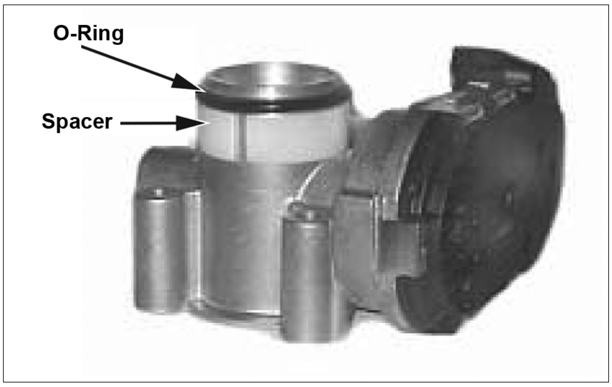


Figure 31. O-Ring and Spacer Within Mixer Adapter Assembly

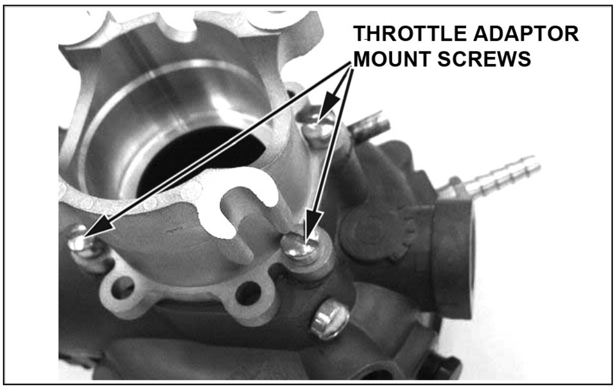


Figure 32. Throttle Adapter Mount Screws

Tests and Adjustments

⚠ WARNING – PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

N-2001 Regulator Service Testing

For checking the N-2001 regulator/converter operation, the following tests can be performed. To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump

2. Regulator vapor outlet test fitting 3/4” NPT x 1/4” hose barb

3. Union Tee 1/4” NPT with three 1/4” NPT x 1/4” hose barb

4. Vacuum hose

5. 0-3” WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge and the regulator vapor outlet to the Union Tee fitting (Figure 30). Make sure there is no leakage at any of the fittings.

2. Using the vacuum pump slowly apply enough vacuum to measure above -2” WC on the gauge. This vacuum signal opens the secondary valve in the N-2001 regulator/converter.

3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-1.2 “ WC) of the secondary spring, the needle should stop moving.

4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

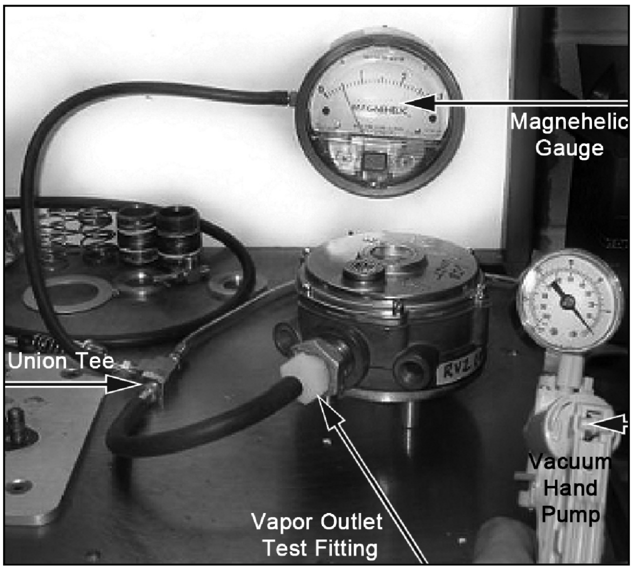


Figure 30. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Hand vacuum pump

2. Regulator fuel inlet test fitting 1/4 NPT standard air coupling)

3. Test gauge fitting (1/4” NPT X 1/4” hose b)

4. Vacuum hose or vinyl tubing

5. 0-60” WC Magnehelic gauge (inches of water column)

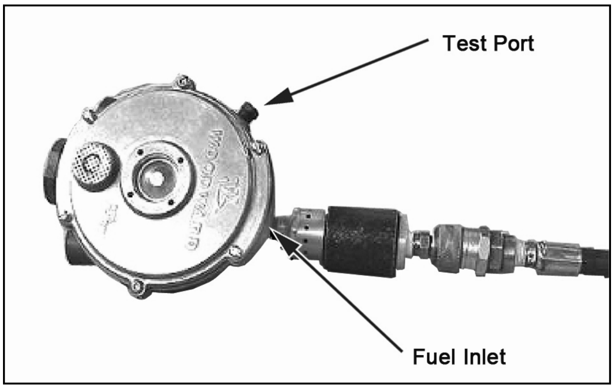


Figure 31. Primary Stage Test Connection

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16” NPT hose barb fitting (Figure 31).

2. Connect a compressed air line (shop air ~100 psi) to the liquid propane fuel inlet of the N-2001 regulator (Figure 31).

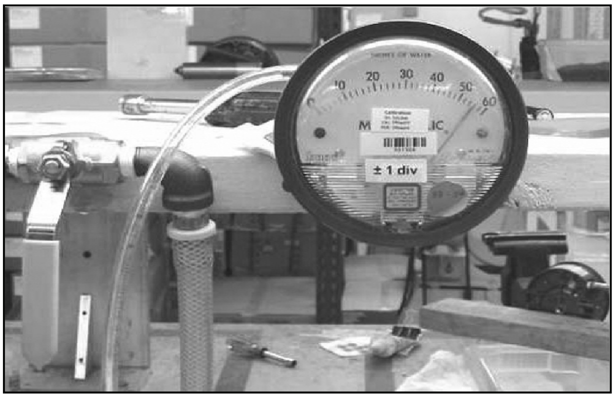


Figure 32. Magnehelic Gauge Connection to Hose Barb

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (Figure 32) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from reading maximum pressure due to the large velocity of compressed air entering the primary chamber.

4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60” WC on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

5. If the pressure reading begins to increase, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator should be replaced.

6. If the pressure begins to decrease, the secondary seat is probably not making an adequate seal and is leaking. The regulator should be replaced.

7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the N-2001 regulator.

NOTE : The N-2001 primary stage pressure can also be tested at idle on a running engine. The N-2001 primary pressure should be between 40 inH20 (99.635 mbar) and 55 inH20 (136.999 mbar) at 750 rpm, idle.

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across CA100 mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4” (6.35mm) NPT with three 1/4” (6.35mm) NPT x 1/4” (6.35mm) hose barbs
2. Vacuum hose
3. 0-20” H2O differential pressure Magnehelic gauge

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (Figure 37).

2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (Figure 37).

3. With the engine fully warmed up and running at idle (750 rpm) place the transmission in Neutral. The AVV should be between 5” and 8” H2O of pressure vacuum.

4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.

5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

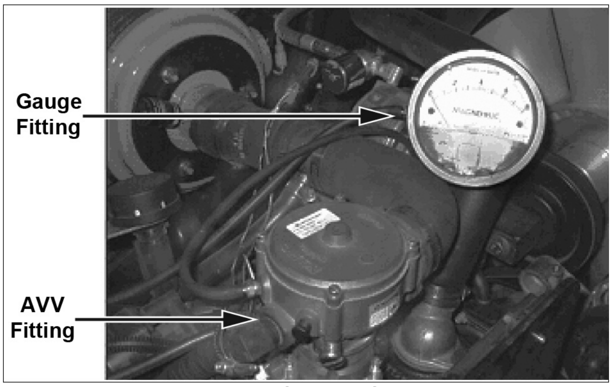


Figure 37. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM.
The initial ignition timing setting of the distribytor is described in chapter 4 Ignition System.

Idle Mixture Adjustment

NOTE : Be sure engine is fully warm (ECT>167°F [75°C]) before performing the idle mixture adjustment.

G643 LP Fuel Systems with O2 Sensor

Idle Adjustment

1. Install mixer and a UEGO or HEGO sensor. (A UEGO sensor should be used when desired phi settings are not at stoichiometric.)

2. After the mixer is installed, start and warm up the engine to normal operating temperature (ECT>167°F [75°C]). Also ensure that the vehicle drive train and hydraulic systems are at normal operating temperatures per vehicle manufacturer recommendations.

3. Allow the engine to reach steady state at idle.

4. While monitoring the output of the UEGO or HEGO sensor adjust the idle screw using a standard screwdriver until the desired phi reading is achieved (phi = 1.00 to 1.01 is optimal). To make the mixture richer, turn the screw clockwise; to make the mixture leaner, turn the screw counter-clockwise.

5. Rev the engine to take it off of idle and let it return to idle.

6. Once the engine has reached steady state at idle, verify the phi reading. Adjust further as needed.

Power Valve Adjustment

1. The power valve should only be adjusted after the idle screw has been adjusted properly. The engine and vehicle drive train and hydraulics should also be at normal operating temperatures.

2. Apply a load to the engine while the engine is operating above idle speed. Torque converter stall is the preferred operating mode for this test. If a torque converter speed test cannot be performed, the engine can be run at another speed (max governor), but a load must be applied by using hydraulics.

NOTE : While adjusting the power valve, do not hold engine at load point for longer than 5-10 seconds. Holding for a longer period of time will cause the fuel temperature to drop, which could adversely affect the power valve setting.

3. Monitor the output of the UEGO or HEGO sensor while the engine is at the higher speed with the load applied (phi = 1.00 to 1.05 is optimal).

4. If the phi reading is not at the desired level, bring the engine back to idle and adjust the power valve.

5. Bring the engine back to the higher speed with a load applied and verify the power valve setting. Adjust further as needed.

6. Once the power valve is set, bring the engine back to idle and verify the idle screw setting.

G643 LP Fuel Systems Without O2 Sensor

Idle Adjustment

1. After the mixer is installed, start and warm up the engine to normal operating temperature (ECT>167°F [75°C]). Also ensure that the vehicle drive train and hydraulic systems are at normal operating temperatures per vehicle manufacturer recommendations.

2. Allow the engine to reach steady state at idle.

3. With the idle screw completely tightened clockwise, use a standard screwdriver to adjust the idle screw counterclockwise until a minimum average MAP value has been reached. The MAP value is displayed on the Service Tool screen.

Power Valve Adjustment

1. The power valve should only be adjusted after the idle screw has been adjusted properly. The engine and vehicle drive train and hydraulics should also be at normal operating temperatures.

2. Apply a load to the engine while the engine is operating above idle speed. Torque converter stall is the preferred operating mode for this test. If a torque converter speed test cannot be performed, the engine can be run at another speed (max governor), but a load must be applied by using hydraulics.
The power valve should be adjusted to obtain maximum torque converter stall speed.

NOTE : While adjusting the power valve, do not hold engine at load point for longer than 5-10 seconds. Holding for a longer period of time will cause the fuel temperature to drop, which could adversely affect the power valve setting.

3. Once the power valve is set, bring the engine back to idle and verify the idle screw setting.

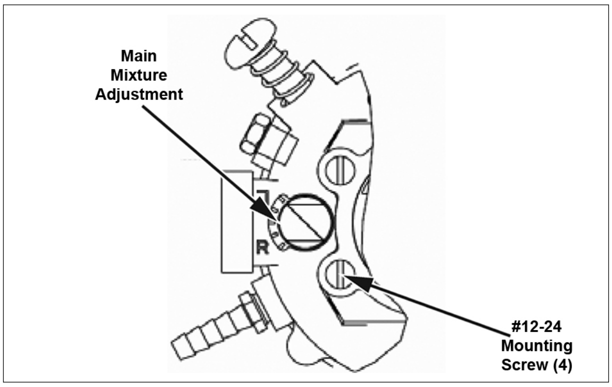


Figure 43. Main Mixture Adjustment on Bottom of Mixer (partial view)

Parts Description

CA100 Mixer for G643 Engine

Refer to **Figure 45** exploded view on facing page.

REF NO.	DESCRIPTION	QTY
1	Screws 10-24 x 5/8” T-25 Button Head SEMS	4
2	Mixer Cover	1
3	Mixer Spring	1
4	Diaphragm	1
5	Gas Valve Cone (part of air valve assembly)	1
6	Mixer	1
7	Throttle Body Gasket	1
8	Screws 12-24 x 5/8” Fillister Head SEMS	8
9	Air Horn Adapter	1
10	Air Horn Gasket	1

Parts List for CA100 Mixer

Exploded View

CA100 Mixer

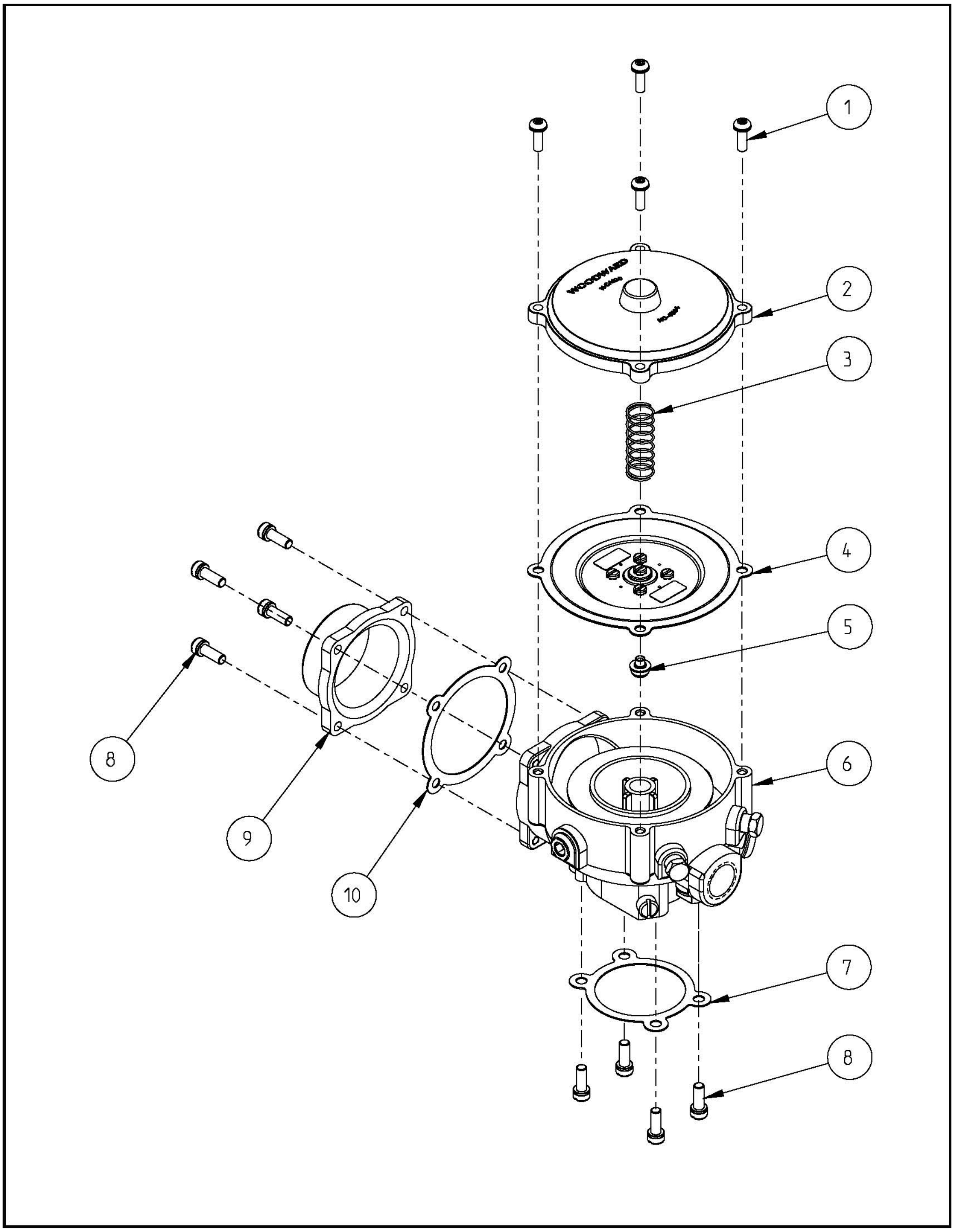
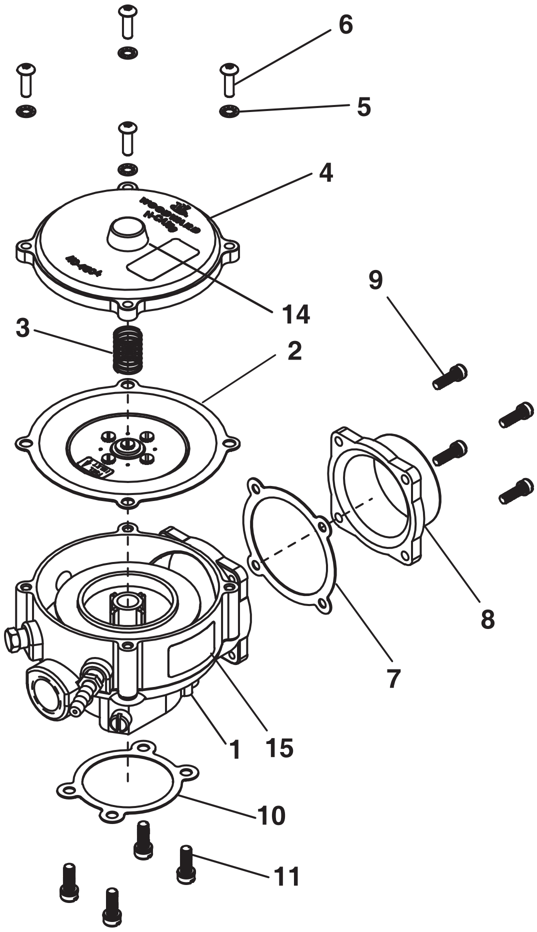


Figure 44. CA100 Non-Certified Mixer Exploded View

CA100 Disassembly and Service



(1) BODY (2) VALVE (3) SPRING (4) COVER
(5) WASHER (6) SCREW (7) GASKET (8) ADAPTER
(9) SCREW (10)GASKET (11) SCREW

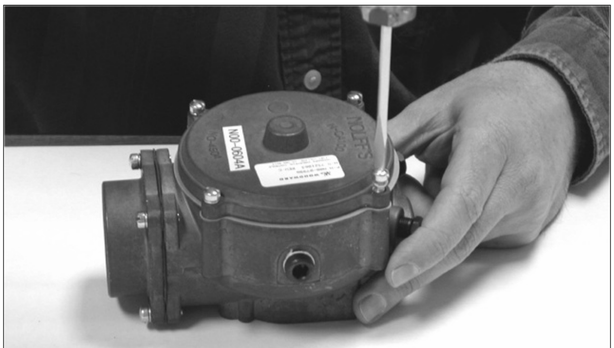


Figure M4

1. With the mixer/adapter assembly removed from the engine, and the throttle adapter removed from the mixer, remove the four cover retaining screws from the top of the mixer (Figure M4).

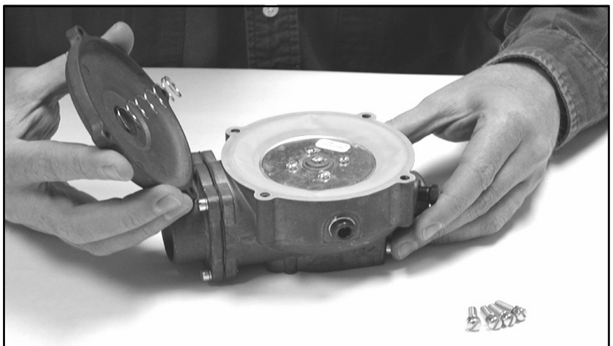


Figure M5

2. Gently remove the diaphragm cover from the top of the mixer. Take care not to loose the air-valve spring shown in (Figure M5).

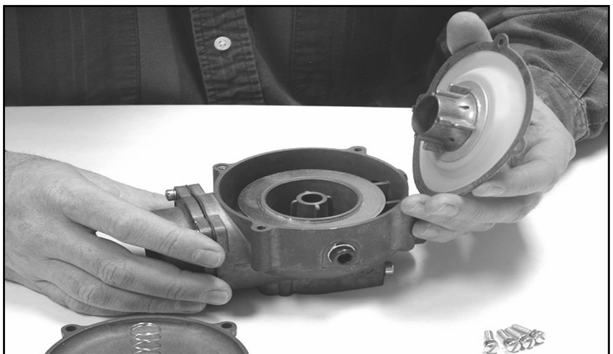


Figure M6

3. Remove the air-valve assembly from the mixer as shown in (Figure M6).

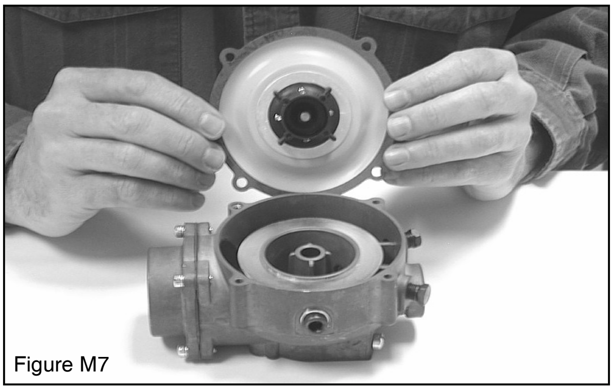


Figure M7

4. Clean the heavy end deposits from the mixer body with solvent. Be sure the mixer body is completely dry before installing the new air-valve assembly. Replace the air-valve assembly as shown (Figure M7).

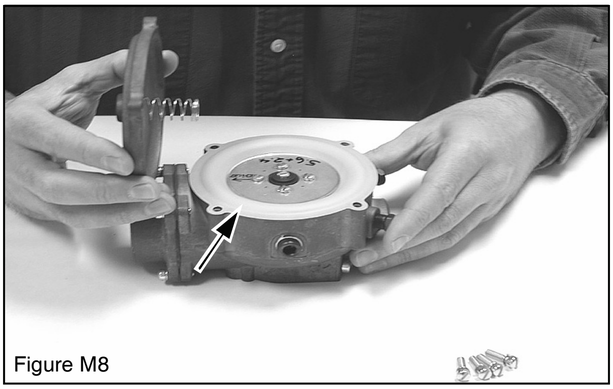


Figure M8

5. Place the alignment mark on top of the air valve assembly toward the fuel inlet of the mixer; this places the small notches in the fuel metering valve (fuel cone) inline with the fuel inlet and the large notches of the fuel metering valve “cone”, perpendicular to the fuel inlet of the mixer. Now reinstall the air-valve spring and diaphragm cover (Figure M8).

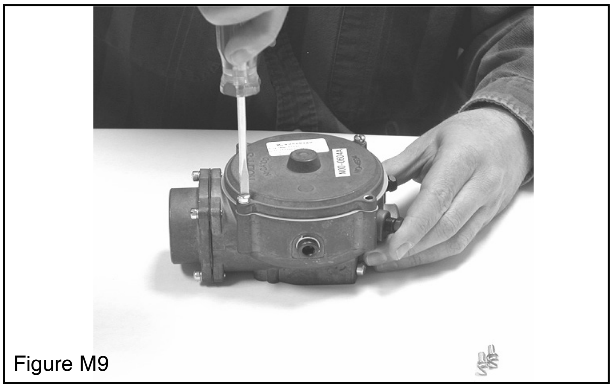


Figure M9

6. Tighten the cover fastners and reinstall the mixer on the engine (Figure M9).

CA100 Disassembled Service

1. Clean the air valve assembly with soap and warm water to remove heavy-end deposits. Inspect the fuel metering valve and sealing ring for wear. Replace worn components as necessary.

Replace all gaskets before assembly.

Clean the mixer body (casting) with a parts cleaning solvent. Be sure to remove all seals and gaskets before cleaning the casting with solvent. Make sure all parts are completely dry before re-assembly.

NOTE
For re-assembly of the CA100 reverse the disassembly steps.

WARNING
DO NOT spray car carburetor cleaner or solvent into the mixer while installed on the engine. These chemicals may damage the oxygen sensor and cause pre-mature failure of the catalytic muffler.

N-2001 Regulator for G643 Engine

Refer to Figure 47 exploded view on facing page.

Parts List
N-2001-RSA Regulator

REF NO.	DESCRIPTION	QTY
1	Cover Screws 8-32 x 5/8” SEMS	4
2	Torx Screws (T-15) 8-32 x 5/8” Tamper Resistant	2
3	Lockwasher #8 Internal Tooth	2
4	Secondary Cover	1
5	Secondary Diaphragm Assembly	1
6	Pan Head Screw 10-24 x 1/4” w/Star Washer	1
7	Secondary Lever	1
8	Secondary Valve	1
9	Secondary Lever Fulcrum Pin	1
10	Red Secondary Spring	1
11	Pilot Valve Lever	1
12	Pilot Valve Lever Fulcrum Pin	1
13	Internal Hex Head Set Screw 8-32 x 1/4”	1
14	Cover Screws 12-24 x 5/8” SEMS	6
15	Primary Diaphragm Cover	1
16	Primary Regulator Springs	2
17	Primary Diaphragm Assembly	1
18	1/8 NPT Hex Pipe Plug Fitting	1
19	Body Assembly	1
20	Body Seal O-ring	1
21	Body Gasket	1
22	Regulator Back Plate	1
23	Primary Seal O-Ring	1
24	Primary Regulator Valve	1
25	Cover Screws 12-24 x 5/8” SEMS	6
26	Inlet Seal O-Ring	1
27	Inlet Plug	1
28	Hex Head Screws 1/4-20 UNC-2A x 5/8” SEMS	2

Exploded View
N-2001-RSA Regulator

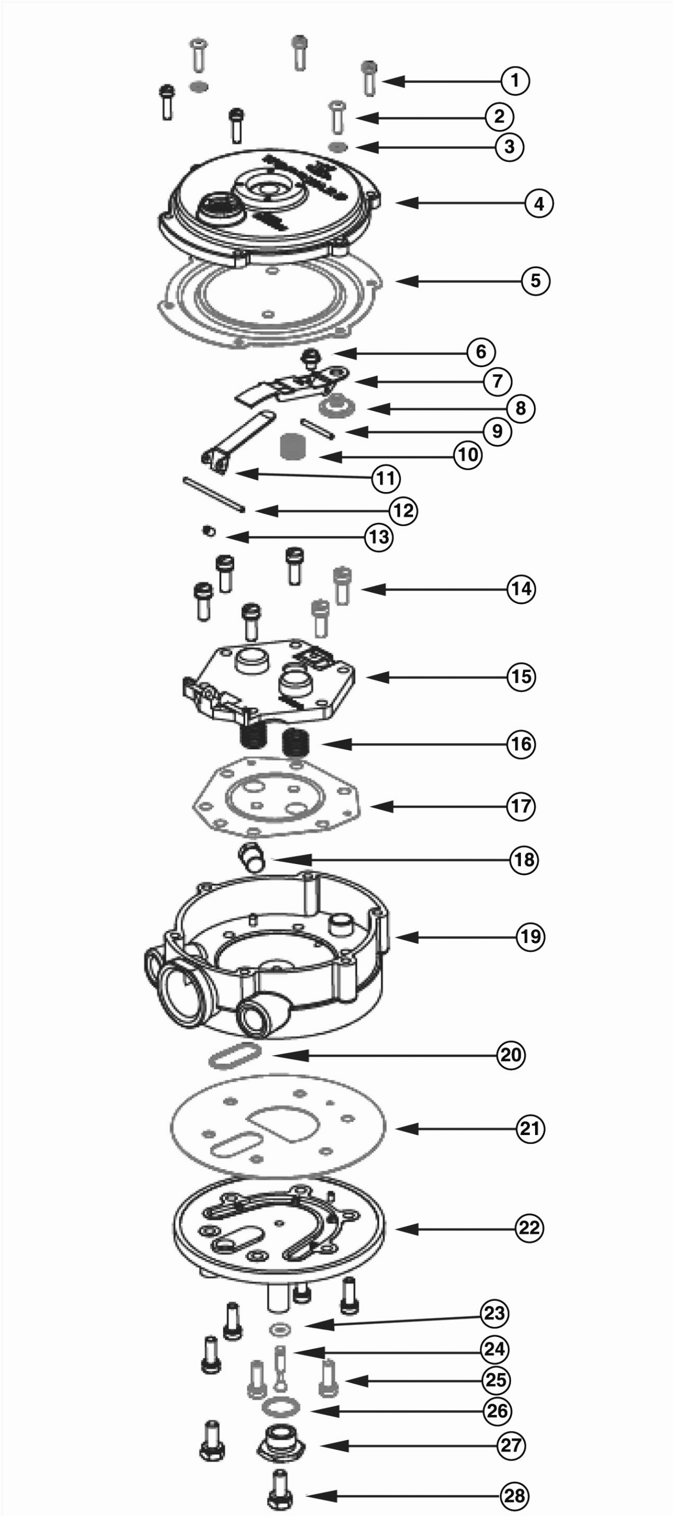


Figure 47. N-2001 Regulator Exploded View

N2001 Regulator Disassembly Steps:

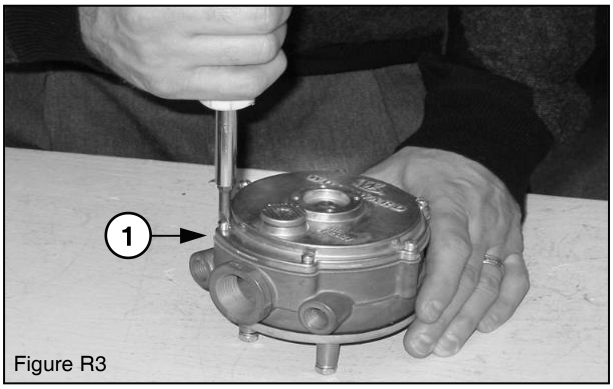


Figure R3

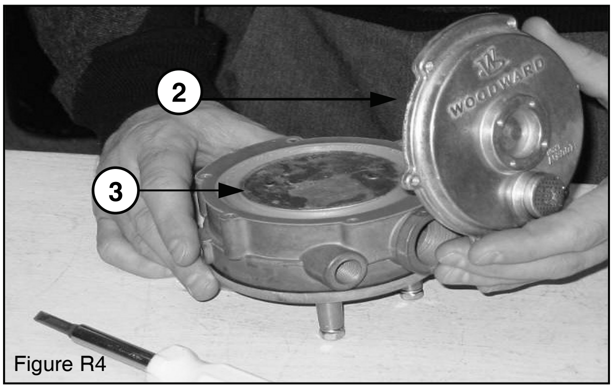


Figure R4

1. Remove the six secondary cover screws (1), the secondary cover (2) and the secondary diaphragm (3).

2. Remove the six primary diaphragm cover screws (4) and the primary cover assembly (5).

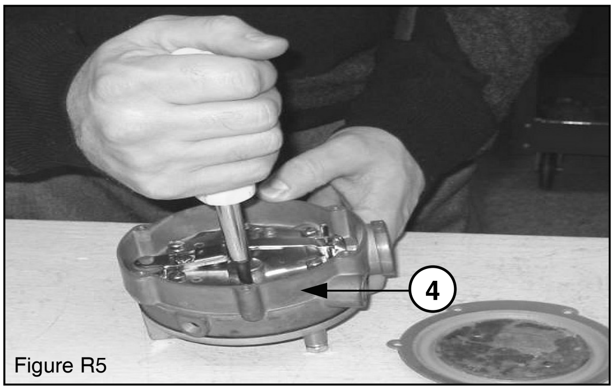


Figure R5

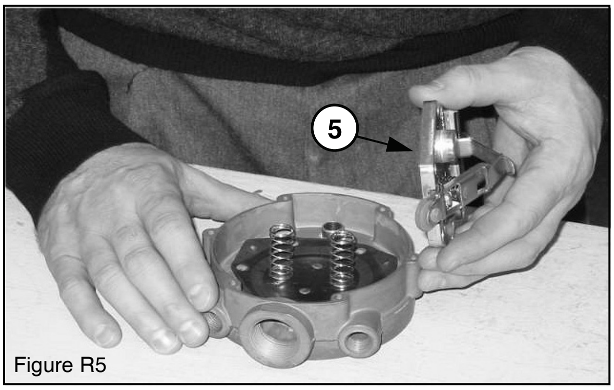


Figure R5

Remove the six primary diaphragm cover screws (4) and the primary cover assembly (5).

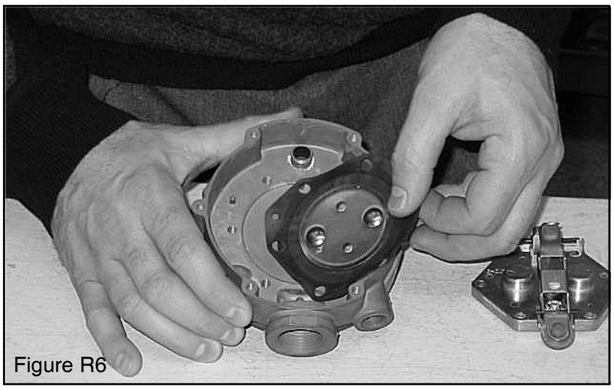


Figure R6

Remove the primary diaphragm by sliding the diaphragm to one side, releasing the primary valve pin (Figure R6).

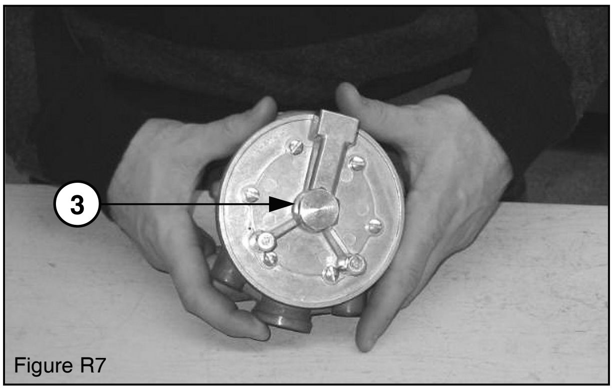


Figure R7

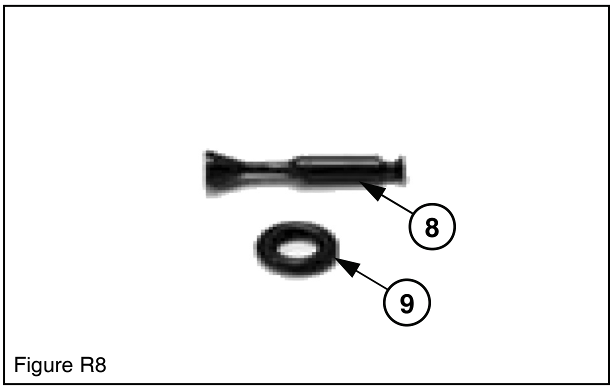


Figure R8

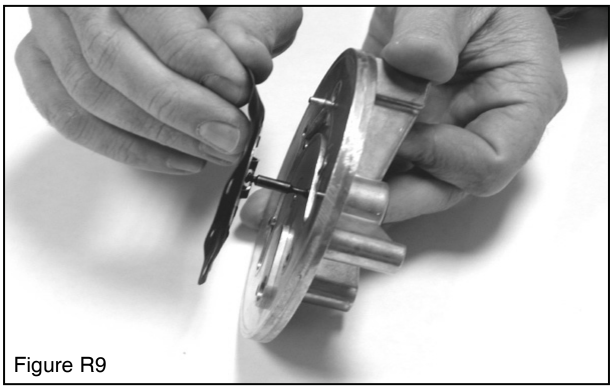
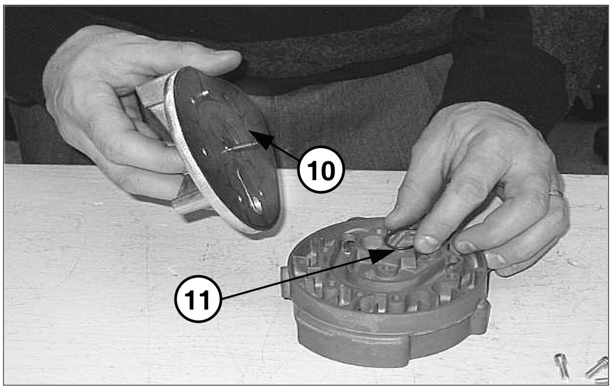


Figure R9

Turn the regulator body over with the rear fuel inlet plate facing up. Remove the primary valve access plug (7), the primary valve (8) and the primary valve o-ring seal (9). **The primary valve goes through the inlet plate, then through the body assembly and is retained by the primary diaphragm (Figure R9).**



6. Remove the body gasket (10), body o-ring seal (11) and the fuel inlet plate, exposing the fuel inlet expansion chamber and the coolant passage.

NOTE
For re-assembly of the N2001 regulator/converter, reverse the steps for disassembly. Tighten all fasteners to recommended torque values and test the regulator before installing in the vehicle. Torque primary cover screws to (40-50 inch lbs.), secondary cover screws to (15-18 inch lbs.).

N2001 Disassembled Service

1. Clean the primary and secondary valves with soap and warm water to remove heavy-end deposits. Inspect the valve seats and o-rings for wear. Replace worn components as necessary.

2. Clean the primary and secondary diaphragms with soap and warm water. Inspect for wear, tears or pinholes and deformations that may cause leaks or poor performance of the regulator/converter.

3. Replace the body gasket of the coolant chamber and body o-ring seal when servicing the N2001 to avoid coolant leaks from the fuel expansion chamber to the coolant passage.

4. Clean the regulator body (casting) with a parts cleaning solvent. Be sure to remove all seals and gaskets before cleaning the casting with solvent.

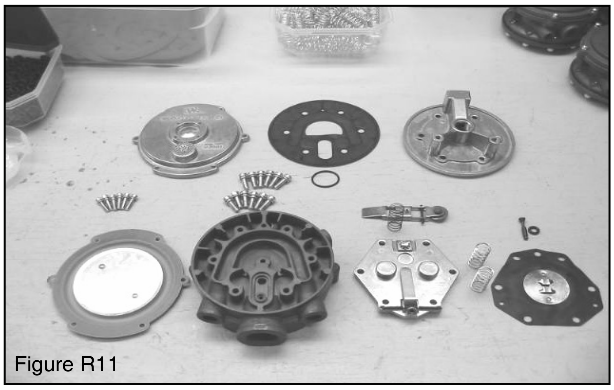


Figure R11

5. Make sure all parts (Figure R11) are completely dry before re-assembly.

Chapter 7. BASIC TROUBLESHOOTING

Preliminary Checks

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) and are covered in Chapter 9, Advanced Diagnostics. However, items such as fuel level, plugged fuel lines, clogged fuel filters, and malfunctioning pressure regulators may not set a fault code and usually can be corrected with the basic troubleshooting steps described on the following pages.

If engine or drivability problems are encountered with your MI-07 system, perform the checks in this section before referring to Advanced Diagnostics.

NOTE: Locating a problem in a propane engine is done exactly the same as with a gasoline engine. Consider all parts of the ignition and mechanical systems as well as the fuel system.

Before Starting

1. Determine that the SECM and MIL light are operating. Verify operation by keying on engine and checking for flash of MIL light. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

2. Determine that there are no diagnostic codes stored, or there is a diagnostic code but no MIL light.

Visual/Physical check

Several of the procedures call for a "Careful Visual/Physical Check" which should include:

- SECM grounds for being clean and tight
- Vacuum hoses for splits, kinks, and proper connection.
- Air leaks at throttle body mounting and intake manifold
- Exhaust system leaks
- Ignition wires for cracking, hardness, proper routing, and carbon tracking
- Wiring for pinches and cuts

Also check:

- Connections to determine that none are loose, cracked, or missing
- Fuel level in vehicle is sufficient
- Fuel is not leaking
- Battery voltage is greater than 11.5 volts
- Steering, brakes, and hydraulics are in proper condition and vehicle is safe to operate

NOTE: The Visual/Physical check is very important, as it can often correct a problem without further troubleshooting and save valuable time.

Basic Troubleshooting Guide

Customer Problem Analysis Sheet

1. Forklift Information

(I) VIN:
(II) Production Date:
(III) Hour meter Reading: (hrs)

2. Symptoms

☐ Unable to start	☐ Engine does not turn over ☐Incomplete combustion ☐ Initial combustion does not occur
☐ Difficult to start	☐ Engine turns over slowly ☐ Other_________________
☐ Poor idling	☐ Rough idling ☐ Incorrect idling ☐Unstable idling (High: ______ rpm, Low: ______ rpm) ☐ Other__________________________________
☐ Engine stall	☐ Soon after starting ☐ After accelerator pedal depressed ☐After accelerator pedal released ☐ Shifting from N to D-range ☐ Other____
☐ Others	☐ Poor driving (Surge) ☐ Knocking ☐ Poor fuel economy ☐ Back fire ☐ After fire ☐ Other____________________________

3. Environment

Problem frequency	☐ Constant ☐ Sometimes (_________________) ☐ Once only ☐ Other____
Weather	☐ Fine ☐ Cloudy ☐ Rainy ☐ Snowy ☐ Other__________________
Outdoor temperature	Approx._____ ℃/°F
Place	☐ Suburbs ☐ Inner City ☐ Uphill ☐ Downhill ☐ Rough road ☐ Other___________________________________
Engine temperature	☐ Cold ☐ Warming up ☐ After warming up ☐ Any temperature
Engine operation	☐ Starting ☐ Just after starting (____min) ☐ Idling ☐ Racing ☐ Driving ☐ Constant speed ☐ Acceleration ☐ Deceleration ☐ Other_____________________________

4. MIL/DTC

MIL (Malfunction Indicator Lamp)	☐ Remains ON ☐ Sometimes lights up ☐ Does not light
DTC	☐ Normal ☐ DTC(____)

Basic Inspection Procedure

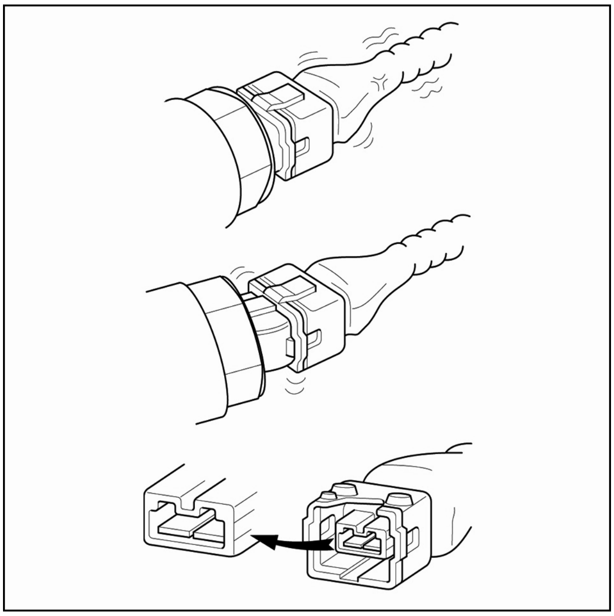
Measuring Condition Of Electronic Parts Resistance

The measured resistance at high temperature after vehicle running may be high or low. So all resistance must be measured at ambient temperature (20℃, 68 ℉), unless there is any notice.

NOTE: The measured resistance in except for ambient temperature (20℃, 68℉) is reference value.

Intermittent Problem Inspection Procedure

Sometimes the most difficult case in troubleshooting is when a problem symptom occurs but does not occur again during testing. An example would be if a problem appears only when the vehicle is cold but has not appeared when warm. In this case, technician should thoroughly make out a "CUSTOMER PROBLEM ANALYSIS SHEET" and recreate (simulate) the environment and condition which occurred when the vehicle was having the issue.



1. Clear Diagnostic Trouble Code (DTC).

2. Inspect connector connection, and check terminal for poor connections, loose wires, bent, broken or corroded pins, and then verify that the connectors are always securely fastened.

3. Slightly shake the connector and wiring harness vertically and horizontally.

4. Repair or replace the component that has a problem.

5. Verify that the problem has disappeared with the road test.

• SIMULATING VIBRATION

1) Sensors and Actuators
: Slightly vibrate sensors, actuators or relays with finger.

⚠ WARNING

Strong vibration may break sensors, actuators or relays.

2) Connectors and Harness
: Lightly shake the connector and wiring harness vertically and then horizontally.

• Simulating Heat

1) Heat components suspected of causing the malfunction with a hair dryer or other heat sourre.

⚠ WARNING

DO NOT heat components to the point where they may be damaged.
DO NOT heat the ECM directly.

• Simulating Water Sprinkling

1) Sprinkle water onto vehicle to simulate a rainy day or a high humidity condition.

⚠ WARNING

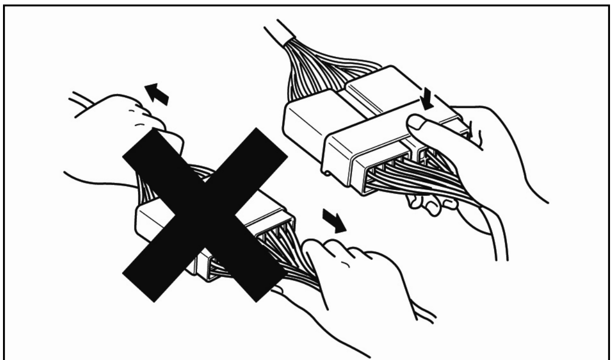
DO NOT sprinkle water directly into the engine compartment or electronic components.

• Simulatingelectricalload

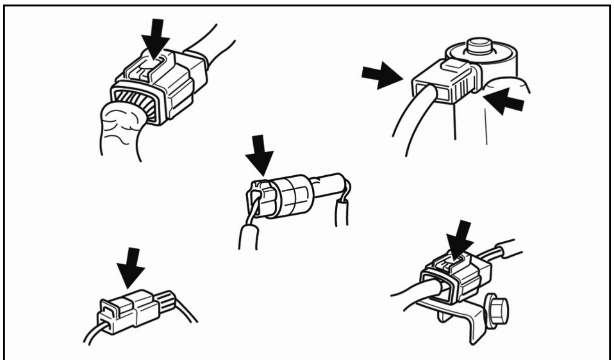
1) Turn on all electrical systems to simulate excessive electrical loads (Radios, fans, lights, etc.).

Connector Inspection Procedure

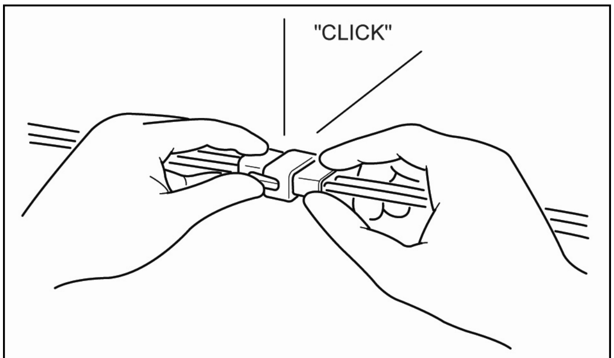
Handling of Connector


BFGE015F

1. Never pull on the wiring harness when disconnecting connectors.

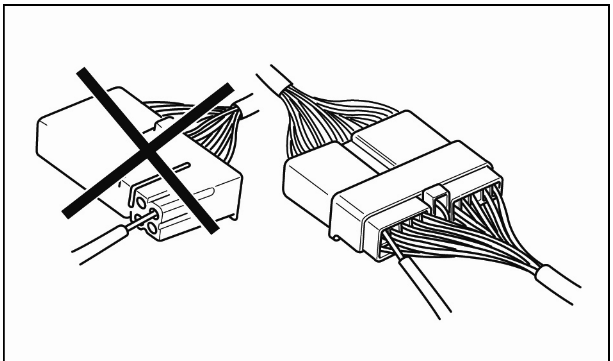

BFGE015G

2. When removing the connector with a lock, press or pull locking lever.

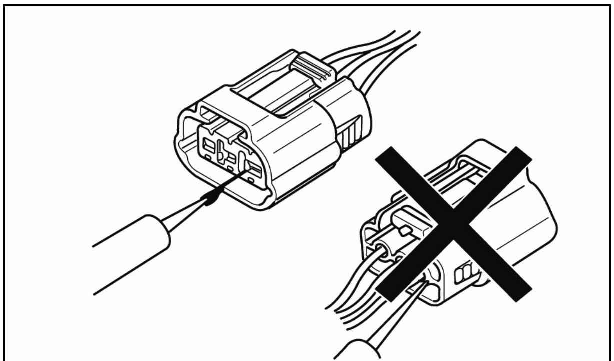


BFGE015H

3. Listen for a click when locking connectors. This sound indicates that they are securely locked.


BFGE015I

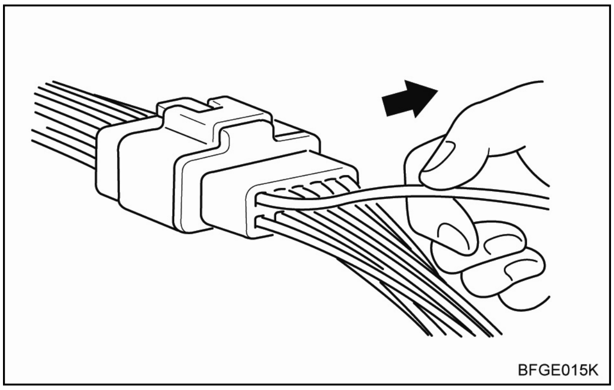
4. When a tester is used to check for continuity, or to measure voltage, always insert tester probe from wire harness side.


BFGE015J

5. Check waterproof connector terminals from the connector side. Waterproof connectors cannot be accessed from harness side.

NOTE: Use a fine wire to prevent damage to the terminal. Do not damage the terminal when inserting the tater lead.

Checking Point for Connector



1. While the connector is connected:
Hold the connector, check connecting condition and locking efficiency.

2. When the connector is disconnected:
Check missed terminal, crimped terminal or broken core wire by slightly pulling the wire harness. Visually check for rust, contamination, deformation and bend.

3. Check terminal tightening condition:
Insert a spare male terminal into a female terminal and then check terminal tightening conditions.

4. Pull lightly on individual wires to ensure that each wire is secured in the terminal.

Repair Method of Connector Terminal

1. Clean the contact points using air gun and/or shop rag.

NOTE: Never uses and paper when polishing the contact points, otherwise the contact point may be damaged.

2. In case of abnormal contact pressure, replace the female terminal.

Wire Harness Inspection Procedure

1. Before removing the wire harness, check the wire harness position and crimping in order to restore it correctly.

2. Check whether the wire harness is twisted, pulled or loosened.

3. Check whether the temperature of the wire harness is abnormally high.

4. Check whether the wire harness is rotating, moving or vibrating against the sharp edge of a part.

5. Check the connection between the wire harness and any installed part.

6. If the covering of wire harness is damaged; secure, repair or replace the harness.

Electrical Circuit Inspection Procedure

• Check Open Circuit

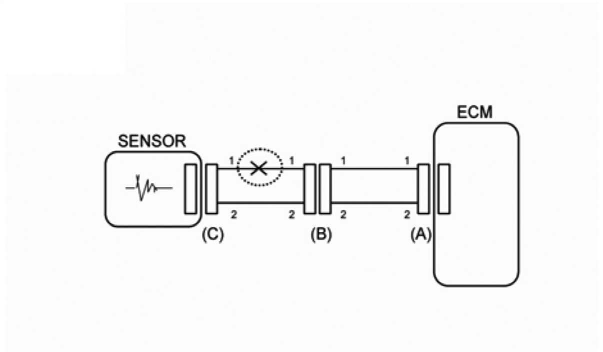


Figure 1

1. Procedures for Open Circuit

- Continuity Check
- Voltage Check

If an open circuit occurs (as seen in [FIG.1]), it can be found by performing Step 2 (Continuity Check) or Step 3 (Voltage Check Method) as shown below.

2. Continuity Check Method

NOTE: When measuring for resistance, lightly shake the wire harness above and below or from side to side.

Specification (Resistance)
1Ω or less → Normal Circuit
1MΩ or Higher → Open Circuit

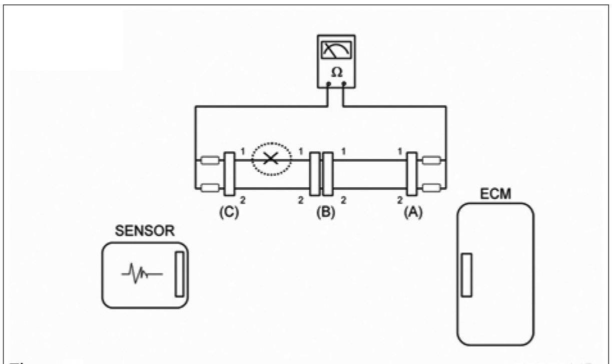


Figure 2

a. Disconnect connectors (A), (C) and measure resistance between connector (A) and (C) as shown in [FIG.2].

In [FIG.2.] the measured resistance of line1and 2 is higher than 1MΩ and below 1Ω respectively. Specifically the open circuit is line 1(Line 2 is normal). To find exact break point, check sub line of line 1as described in next step.

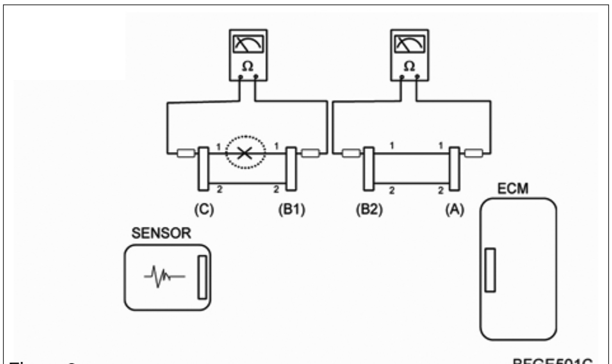


Figure 3

b. Disconnect connector (B), and measure for resis tance between connector (C) and (B1) and between (B2) and (A) as shown in [FIG.3]. In this case the measured resistance between connector (C) and (B1) is higher than 1MΩ and the open circuit is between terminal 1 of connector (C) and terminal 1 of connector (B1).

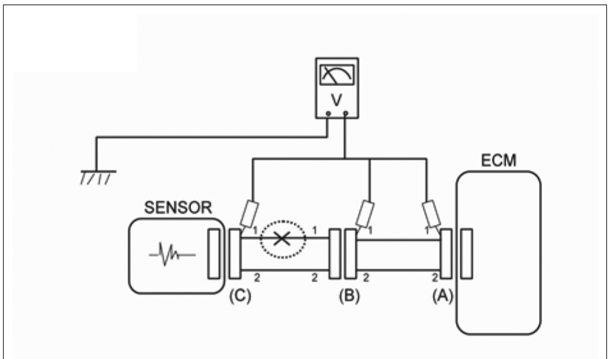


Figure 3

3. Voltage Check Method

a. With each connector still connected, measure the voltage between the chassis ground and terminal1 of each connectors (A), (B) and (C) as shown in [FIG.4].

The measured voltage of each connector is 5V, 5V and 0V respectively. So the open circuit is between connector (C) and (B).

• Check Short Circuit

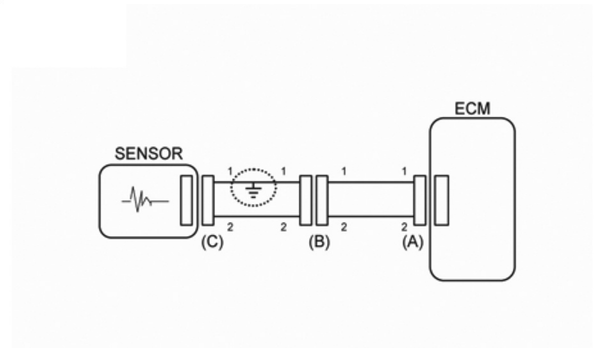


Figure 5 BFGE501E

1. Test Method for Short to Ground Circuit

• Continuity Check with Chassis Ground

If short to ground circuit occurs as shown in [FIG.5], the broken point can be found by performing below Step 2 (Continuity Check Method with Chassis Ground) as shown below.

2. Continuity Check Method (with Chassis Ground)

NOTE: Lightly shake the wire harness above and below, or from side to side when measuring the resistance.

Specification (Resistance)
1Ω or less → Short to Ground Circuit
1MΩ or Higher → Normal Circuit

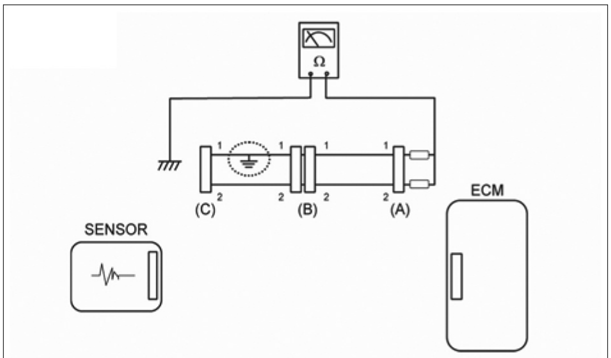


Figure 6 BFGE501F

a. Disconnect connectors (A), (C) and measure for resistance between connector (A) and Chassis Ground as shown in [FIG.6].

The measured resistance of line 1 and 2 in this example is below 1Ω and higher than 1MΩ respectively. Specifically the short to ground circuit is line 1 (Line 2is normal). To find exact broken point, check the sub line of line1 as described in the following step.

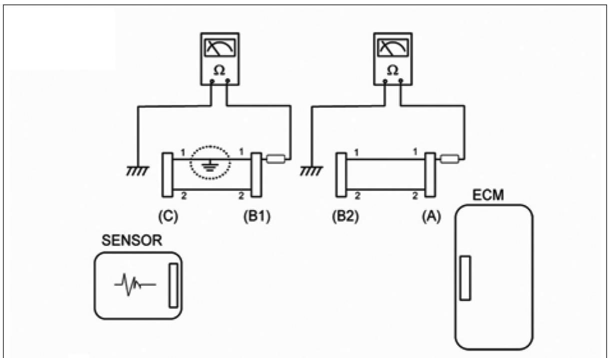


Figure 7 BFGE501G

b. Disconnect connector (B), and measure the resistance between connector (A) and chassis ground, and between (B1) and chassis ground as shown in [FIG.7].

The measured resistance between connector (B1) and chassis groundis1Ω or less. The short to ground circuit is between terminal 1 of connector (C) and terminal 1 of connector (B1).

Basic Troubleshooting

Intermittents

An intermittent fault is the most difficult to troubleshoot since the MIL flashes on at random, causing uncertainty in the number of flashes or the conditions present at the time of the fault. Also, the problem may or may not fully turn “ON” the MIL light or store a code.

Therefore, the fault must be present or able to be recreated in order to locate the problem. If a fault is intermittent, use of diagnostic code charts may result in the unnecessary replacement of good components.

Corrective Action

Most intermittent problems are caused by faulty electrical connections or wiring. Perform careful visual/physical check for:

- Poor mating of the connector halves or terminal not fully seated in the connector body (backed out)
- Improperly formed or damaged terminal. All connector terminals in problem circuit should be carefully reformed or replaced to insure proper contact tension
- Loose connections or broken wires
- Poor terminal to wire connection crimp

If a visual/physical check does not find the cause of the problem, perform the following:

(1) Drive the vehicle with a voltmeter or “Service” tool connected to a suspected circuit. Check if circuit is active and signal is reasonable.

(2) Using the “Service” tool, monitor the input signal to the SECM to help detect intermittent conditions.

(3) An abnormal voltage, or “Service” reading, when the problem occurs, indicates the problem may be in that circuit.

(4) If the wiring and connectors check OK, and a diagnostic code was stored for a circuit having a sensor, check sensor.

An intermittent “Service Engine Soon” light with no stored diagnostic code may be caused by:

- Ignition coil shortage to ground and arcing at spark plug wires or plugs
- MIL light wire to ECM shorted to ground
- SECM grounds (refer to SECM wiring diagrams).

Check for improper installation of electrical options such as lights, 2-way radios, accessories, etc.

EST wires should be routed away from spark plug wires, distributor wires, distributor housing, coil and generator. Wires from SECM to ignition should have a good connection.

Surges and/or Stumbles

Engine power varies under steady throttle or cruise. Feels like the vehicle speeds up and slows down with no change in the acceleration pedal.

Preliminary Checks
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver understands vehicle operation as explained in the operator manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Oxygen sensor malfunction	The fuel management should maintain a stoichiometric air-fuel ratio under all steady state operating conditions following engine warmup. Failure of the Pre-catalyst O2 sensor should cause an O2 sensor fault that can be diagnosed with the MIL lamp or Service Tool.
Fuel system malfunction	NOTE: To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring pre-catalyst O2 adapts*, dither valve duty cycle, or mechanical injector pulse width will help identify problem. Check fuel supply while condition exists. Check in-line fuel filter. Replace if dirty or plugged. Check fuel pressure.
Ignition system malfunction	Check for proper ignition voltage output using spark tester. Check spark plugs. • Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. • Repair or replace as necessary. • Check condition of distributor cap, rotor and spark plug wires (where applicable). Check ignition timing. Refer to application manual for specs.
Component malfunction	Check vacuum lines for kinks or leaks. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Exhaust backpressure	Check condition of exhaust system. Check backpressure before catalyst. It should be less than 3.5 psig (24.13 kPa).

(*) Refer to Table 1 for description of gaseous and liquid O2 adapts.

Related MIL Faults:
Pre-catalyst O2 sensor errors / O2 control errors
Dither valve DC faults / EST faults / ETC faults

Engine Cranking but Will Not Start / Difficult to Start

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

Preliminary Checks
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver is using correct method to start engine as explained in operator's manual. Use "clear flood" mode during cranking by fully depressing the pedal and cranking the engine. If engine does not start, continue troubleshooting.

PROBABLE CAUSE	CORRECTIVE ACTION
CORRECTIVE ACTION	Verify "selected" fuel with Service Tool. Make sure fuel select switch is in proper position.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Liquid valve closed	Slowly open liquid valve.
Propane excess flow valve closed	Reset excess flow valve in LPG tank. Close liquid valve. Wait for a "click" sound; slowly open liquid valve.
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve. • Leak test.
Clogged fuel filter	Repair/replace as required. See Chapter 2 Fuel Filter replacement.
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Fuel lock-off malfunction	Repair/replace fuel lock-off. See Chapter 5 Fuel Lock-off.
Pressure regulator/converter malfunction	Test regulator/converter operation and pressure. See Chapter 6 LPG Fuel Delivery System.
Incorrect air/fuel or ignition/spark control	See Chapter 8 Advanced Diagnostics.
No crankshaft position sensor signal	Verify the crankshaft position signal is present See Chapter 8 Advanced Diagnostics.

Engine Cranking but Will Not Start / Difficult to Start (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
SECM / control system malfunction	Check Coolant Temperature Sensor using the Service Tool; compare coolant temperature with ambient temperature on cold engine. If coolant temperature reading is 5° greater than or less than ambient air temperature on a cold engine, check resistance in coolant sensor circuit or sensor itself. Compare CTS resistance value to "Diagnostic Aids" chart at end of this section. Verify that there is no code for ETC spring check fault. Check for 0% APP during cranking. Cycle key ON and OFF and listen for throttle check (movement) on key OFF. Check for oil pressure switch faults. Check for sensor "sticking" faults. Check TPS for stuck binding or a high TPS voltage with the throttle closed.
Fuel system malfunction	Check fuel lock off (propane) or fuel pump relay gasoline operation: actuator should turn "ON" for 2 seconds when ignition is turned "ON". Check fuel pressure. Check for contaminated fuel. Check both gasoline injector and lock off fuses (visually inspect). Check propane tank valve & pickup. A faulty in-tank fuel pump check valve will allow the fuel in the lines to drain back to the tank after engine is stopped. To check for this condition, perform fuel system diagnosis. Check FTV system for proper operation.
Ignition system malfunction	Check for proper ignition voltage output with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check for: • Moisture in distributor cap* • Bare or shorted wires • Worn distributor shaft/rotor* • Loose ignition coil ground • Pickup coil resistance and connections (*) Where present

Related MIL Faults:
ETC spring check / ETC faults / EST faults / TPS conflict
APP faults / Encoder error / MAP faults
Injector faults / Oil pressure faults

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration

Engine delivers less than expected power. Little or no increase in speed when accelerator pedal is pushed down part way. Momentary lack of response as the accelerator is pushed down. Can occur at all vehicle speeds. Usually most severe when first trying to make vehicle move, as from a stop. May cause engine to stall.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Drive vehicle; verify problem exists. Remove air filter and check for dirt or other means of plugging. Replace if needed.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for restricted fuel filter. Check fuel supply. Check for LPG vapor from LPG liquid outlet valve on tank. Check for contaminated fuel. Check for clogged fuel filter and repair or replace as required. See Chapter 4 Fuel Filter replacement Check for plugged fuel line and remove any obstruction from the fuel line: • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve and leak test. Check for faulty vapor connection between pressure regulator/converter and mixer: • Verify that there are no holes in hose. • Observe that clamps are tight. • Look for kinked, pinched and/or collapsed hose. Monitor pre-catalyst O2 with Service Tool. Check for proper pressure regulator operation. See Chapter 6 Test and Adjustments. Check for proper air/fuel mixer operation.
Ignition system malfunction	Check spark advance for excessive retarded ignition timing. Use Service Tool. Check secondary voltage using an oscilloscope or a spark tester to check for a weak coil. Check spark plug condition. Check poor spark plug primary and secondary wire condition.

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Component malfunction	Check SECM grounds for cleanliness and secure connection. See SECM wiring diagrams. Check alternator output voltage. Repair if less than 9 volts or more than 16 volts. Check for clogged air filter and clean or replace as required. Check exhaust system for possible restriction. Refer to Chart T-1 on later pages. Inspect exhaust system for damaged or collapsed pipes. • Inspect muffler for heat distress or possible internal failure. • Check for possible plugged catalytic converter by comparing exhaust system backpressure on each side at engine. Check backpressure by removing Pre-catalyst O2 sensor and measuring backpressure with a gauge.
Engine mechanical	See Chapter 3 Engine Mechanical System. Check engine valve timing and compression Check engine for correct or worn camshaft.

Related MIL Faults:
EST faults
ETC faults
ETC spring check
TPS faults
APP faults
Encoder error
Delayed Shutdown faults

Detonation / Spark Knock

A mild to severe ping, usually worse under acceleration. The engine makes sharp metallic knocks that change with throttle opening (similar to the sound of hail striking a metal roof).

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for proper fuel level: • Check for LPG vapor from LPG liquid outlet valve on tank. • Fill fuel container. Do not exceed 80% of liquid capacity. Check fuel pressure. To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring with the Service tool will help identify problem.
Cooling system malfunction	Check for obvious overheating problems: • Low engine coolant • Loose water pump belt • Restricted air flow to radiator, or restricted water flow through radiator • Inoperative electric cooling fan • Correct coolant solution should be a mix of anti-freeze coolant (or equivalent) and water • High coolant temperature
Ignition system malfunction	Check ignition timing. Check spark module wiring.
Exhaust system malfunction	Check exhaust backpressure. Check for debris clogging the catalyst. Check that pre-catalyst O2 sensor is functioning.
Engine mechanical	Check for excessive oil in the combustion chamber and/or blow by from excessive PCV flow. Check combustion chambers for excessive carbon build up. Check combustion chamber pressure by performing a compression test. Check for incorrect basic engine parts such as cam, heads, pistons, etc.

Related MIL Faults:
EST faults
Encoder error
High coolant temperature faults

Backfire

Fuel ignites in intake manifold or in exhaust system, making loud popping noise.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Simulate condition by reviewing operation procedure practiced by vehicle operator.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Perform fuel system diagnosis check: • Check for fuel leaks • Check for MIL faults • Check for damaged components
Ignition system malfunction	Check proper ignition coil output voltage with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check spark plug wires for crossfire; also inspect distributor cap, spark plug wires, and proper routing of plug wires. Check ignition timing.
Engine mechanical	Check compression: look for sticking or leaking valves. Check intake and exhaust manifold for casting flash and gasket misalignment. Refer to Chapter 3 Engine Mechanical System.

Related MIL Faults: EST faults / ETC faults / Encoder error
Pre-catalyst O2 sensor faults

Dieseling, Run-on

Engine continues to run after key is turned "OFF," but runs very roughly. If engine runs smoothly, check ignition switch and adjustment.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for fuel leaks or leaking injector.
Ignition switching	Make sure power to system is shut off when key is in OFF position.
Fuel lock off valve	Make sure lock off valve is closing properly.
Ignition system malfunction	Check spark advance at idle.

Related MIL Faults: EST faults / ETC faults / Pre-catalyst O2 sensor faults

Rough, Unstable, Incorrect Idle, or Stalling

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

PRELIMINARY CHECKS
Perform the visual checks as described at start of "Basic Troubleshooting" chapter. Check for vacuum leaks. Check that SECM grounds are clean and tight. See SECM wiring diagram

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Monitor oxygen feedback to help identify the cause of the problem. If the system is running lean or if the system is running rich evaluate further i.e. dither valve duty cycle and injector pulse width. Check for incorrect minimum idle speed that may be caused by foreign material accumulation in the throttle bore, on the throttle valve, or on the throttle shaft. Check that the injectors are clean and functioning. Check for liquid fuel in propane pressure regulator hose. If fuel is present, replace regulator assembly. The pre-catalyst oxygen (O2) sensor should respond quickly to different throttle positions. If it does not, then check the pre-catalyst O2 sensor for contamination. If the pre-catalyst O2 sensor is aged or contaminated, the SECM will not deliver correct amount of fuel, resulting in a drivability problem.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Ignition system malfunction	Check ignition system; wires, plugs, rotor, etc.
LPG pressure regulator malfunction	Test regulator operation and pressure. See Chapter 6 Tests and Adjustments
Air/fuel mixer malfunction	Check mixer.
Component malfunction	Check throttle for sticking or binding. Check PCV valve for proper operation by placing finger over inlet hole in valve end several times. Valve should snap back. If not, replace valve. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Engine mechanical	Perform a cylinder compression check. See Chapter 3 Engine Mechanical System.

Rough, Unstable, Incorrect Idle, or Stalling (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Excess flow valve closed	Reset excess flow valve. • Close liquid valve. • Wait for a "click" sound. Slowly open liquid valve.
Clogged fuel filter	Repair/replace as required See Chapter 2 Fuel Filter Replacement
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve & leak test.
Fuel lock-off malfunction	Repair/replace fuel lock-off. See Chapter 2 Fuel Lock-Off.
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection. • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Pressure regulator freezes	Check level in cooling system: • Must be full, check coolant strength • -35°F (-37°C) minimum Check coolant hoses. • Watch for kinks and/or pinched hoses. • Verify one pressure hose and one return hose. Test regulator. See Chapter 6
Vacuum leak	Check for vacuum leaks. • Between mixer and throttle body • Between throttle body and intake manifold • Between intake manifold and cylinder head

Related MIL Faults:
EST faults
ETC Sticking fault
Pre-catalyst adapts error

Cuts Out, Misses

Steady pulsation or jerking that follows engine speed, usually more pronounced as engine load increases, sometimes above 1500 rpm. The exhaust has a steady spitting sound at idle or low speed.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check fuel system specifically for plugged fuel filter, low pressure. Check for contaminated fuel. Check lock off intermittent connection. Check dither valve operation.
Ignition system malfunction	Check for spark on the suspected cylinder(s) using a shop oscilloscope or spark tester or equivalent. If no spark, check for intermittent operation or miss. If there is a spark, remove spark plug(s) in these cylinders and check for cracks, wear, improper gap, burned electrodes, heavy deposits. Check spark plug wires by connecting ohmmeter to ends of each wire in question. If meter reads over 30,000 ohms, replace wire(s). Visually inspect distributor cap, rotor, and wires for moisture, dust, cracks, burns, etc. Spray cap and plug wires with fine water mist to check for shorts. Check engine ground wire for looseness or corrosion.
Component malfunction	Check for electromagnetic interference (EMI). A missing condition can be caused by EMI on the reference circuit. EMI can usually be detected by monitoring engine rpm with Service Tool. A sudden increase in rpm with little change in actual engine rpm indicates EMI is present. If problem exists, check routing of secondary wires and check distributor ground circuit. Check intake and exhaust manifolds for casting flash or gasket leaks.
Engine mechanical	Perform compression check on questionable cylinders. If compression is low, repair as necessary. Check base engine. Remove rocker covers and check for bent pushrods, worn rocker arms, broken valve springs, worn camshaft lobes, and valve timing. Repair as necessary.

Related MIL Faults:
EST faults
ETC Sticking fault

Poor Fuel Economy / Excessive Fuel Consumption / LPG Exhaust Smell

Fuel economy, as measured during normal operation, is noticeably lower than expected. Also, economy is noticeably lower than what it has been in the past. Propane fuel smell near vehicle sets off carbon monoxide sensors.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Verify operator complaint: identify operating conditions. Check operator's driving habits: Are tires at correct pressure? Are excessively heavy loads being carried? Is acceleration too much, too often? Check air cleaner element (filter) for being dirty or plugged. Visually (physically) check vacuum hoses for splits, kinks, and proper connections as shown on application manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for faulty gasoline pressure regulator. Check for leaking injector. Check that dither valve duty cycle is < 15%. Check for too high propane pressure at mixer (> 1" positive pressure). Monitor Pre-catalyst O2 sensor with Service Tool.
Cooling system malfunction	Check engine coolant level. Check engine thermostat for faulty part (always open) or for wrong heat range.
Ignition system malfunction	Check ignition timing. Refer to application manual. Check for weak ignition and/or spark control. Check spark plugs. Remove spark plugs and check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary.
Component malfunction	Check for exhaust system restriction or leaks. Check induction system and crankcase for air leaks. Check for clogged air filter; clean or replace as required. Check FTV for housing cracks or obstructions; repair or replace as required. Check for vacuum leak. Check system vacuum hoses from regulator to FTV and mixer. Repair or replace as required.
Air/fuel mixer malfunction	Check mixer.
Pressure regulator malfunction / fuel pressure too high	Test regulator operation and pressure. See Chapter 6 Tests and Adjustments.
Engine mechanical	Check compression. Refer to Chapter 3 Engine Mechanical System.

Related MIL Faults:
Pre-catalyst O2 sensor faults / Low side driver / Dither valve duty cycle
EST faults / Fuel adapt faults / Low coolant temperature

High Idle Speed

Engine idles above the range of 750-1100 rpm.

PRELIMINARY CHECKS
Perform the visual checks as described at start of “ Basic Troubleshooting” chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Incorrect idle speed control	Check all hoses and gaskets for cracking, kinks, or leaks. Verify that there are no vacuum leaks. See Chapter 8 Advanced Diagnostics & Chapter 6 Tests and Adjustments
Throttle sticking	Replace throttle. See Fault Code 461: ETC_Sticking
Foot pedal sticking or incorrect pedal signal	Check pedal return spring travel for binding. Check APP function with Service Tool. Verify smooth change of APP reading with pedal movement. See Chapter 8 Advanced Diagnostics.
Engine mechanical	Check for vacuum hose leak. Check for PCV malfunction. Check for defective intake gasket.

Related MIL Faults:
ETC Sticking fault
Idle adapt out of range
MAP Sticking fault
MAP high value

Excessive Exhaust Emissions or Odors

Vehicle has high CO emissions.
NOTE: Excessive odors do not necessarily indicate excessive emissions.

PRELIMINARY CHECKS
Verify that no stored codes exist. If emission test shows excessive CO and HC, check items that cause vehicle to run rich. If emission test shows excessive NOx, check items that cause vehicle to run lean or too hot.

PROBABLE CAUSE	CORRECTIVE ACTION
Cooling system malfunction	If the Service tool indicates a very high coolant temperature and the system is running lean: • Check engine coolant level. • Check engine thermostat for faulty part (always open) or for wrong heat range. • Check fan operation
Fuel system malfunction	If the system is running rich, refer to "Diagnostic Aids" chart on the next page. If the system is running lean, refer to "Diagnostic Aids" chart on the next page. Check for properly installed fuel system components. Check fuel pressure.
Ignition system malfunction	Check ignition timing. Refer to application manual. Check spark plugs, plug wires, and ignition components.
Component malfunction	Check for vacuum leaks. Check for contamination for catalytic converter (look for the removal of fuel filler neck restrictor). Check for carbon build-up. Remove carbon with quality engine cleaner. Follow instructions on label. Check for plugged PCV valve. Check for stuck or blocked PCV hose. Check for fuel in the crankcase.

Related MIL Faults:
Low side driver
Fuel adapt faults
EST faults

Diagnostic Aids for Rich / Lean Operation

SERVICE TOOL ITEM	RICH	LEAN
Pre-catalyst O2 A/ D counts	Consistently > 250	Consistently < 170
Pre-catalyst O2 sensor switching between high and low	Always high ADC	Always low ADC
Trim valve duty cycle	> 90%	< 10%
Malfunction codes	• Pre-catalyst O2 sensor failed rich • Pre-catalyst O2 sensor high • Fuel adapts	• Pre-catalyst O2 sensor failed rich • Pre-catalyst O2 sensor high • Fuel adapts
Closed loop operation	Stuck in open loop	Stuck in open loop

(*) The duty cycle injector pulse width criteria for lean or rich operation apply only if the O2 sensor is functioning properly. If the sensor is not operating properly the criteria may be reversed.

Rich Operation

LP (Trim valve duty cycle>90%)

- Inspect hoses from AVV port (port on bottom of mixer) to trim valves and regulator for leaks or blockages, replace as necessary.
- Inspect in-line orifices for blockages (in wye), replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec
- Inspect fuel cone for damage, replace mixer assembly as necessary

Lean Operation

LP (Trim valve duty cycle<10%)

- Check for vacuum leaks, replace hoses, o-rings, and gaskets as necessary
- Check balance line for blockage, replace as necessary
- Check vapor hose for restrictions, replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec

Chart T-1 Restricted Exhaust System Check

Proper diagnosis for a restricted exhaust system is essential before replacement of any components. The following procedures may be used for diagnosis, depending upon engine or tool used.

Check Atpre - Catalystoxygen (O2) Sensor

1. Carefully remove pre-catalyst oxygen (O2) sensor.

2. Install exhaust backpressure tester or equivalent in place of O2 sensor using Snap-On P/N EEVPV311A kit and YA8661 adapter or Mac tool (see illustration).

3. After completing test described below, be sure to coat threads of O2 sensor with anti-seize compound prior to re-installation.

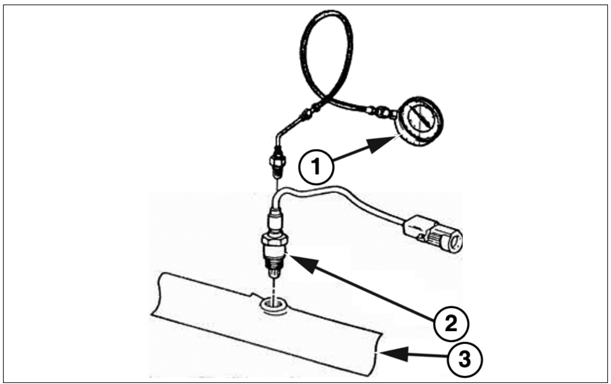


Illustration Notes

1. Backpressure gage

2. Pre-catalyst Oxygen (O2) sensor

3. Exhaust manifold

Diagnosis:

1. With the engine idling at normal operating temperature, observe the exhaust system backpressure reading on the gage. Reading should not exceed 1.25 psig (8.61 kPa).

2. Increase engine speed to 2000 rpm and observe gage. Reading should not exceed 3 psig (20.68 kPa).

3. If the backpressure at either speed exceeds specification, a restricted exhaust system is indicated.

4. Inspect the entire exhaust system for a collapsed pipe, heat distress, or possible internal damage, split welds, or cracked pipe.

5. If there are no obvious reasons for the excessive backpressure, the catalytic converter is restricted and should be replaced using current recommended procedures.

Chapter 8. ADVANCED DIAGNOSTICS

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) as Diagnostic Fault Codes (DFC) or flash codes, and viewed in detail with the use of the Service Tool software. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

Reading Diagnostic Fault Codes

G643E Engines

All fault codes are three-digit codes. When the fault codes are retrieved (displayed) the MIL will flash for each digit with a short pause (0.5 seconds) between digits and a long pause (1.2 seconds) between fault codes. A code 12 is displayed at the end of the code list.

EXAMPLE: A code 461 (ETCSticking) has been detected and the engine has shut down and the MIL has remained ON. When the codes are displayed the MIL will flash four times (4), pause, then flash six times (6), pause, then flash one time (1) This identifies a four sixty one (461), which is the ETCSticking fault. If any additional faults were stored, the SECM would again have a long pause, then display the next fault by flashing each digit. Since no other faults were stored there will be a long pause then one flash (1), pause, then two flashes (2). This identifies a twelve, signifying the end of the fault list. This list will then repeat.

G643 Engines

All fault codes are two digit codes. When the fault codes are retrieved (displayed) the MIL will flash for each digit with a short pause (.5 seconds) between digits and a long pause (1.2 seconds) between fault codes. A code 12 is displayed at the beginning of the code list.

EXAMPLE: A code 26 has been detected (ETCSticking) and the engine has shutdown and the MIL has remained **ON.** When the codes are displayed the MIL will flash one time (1), pause, then flash two times (2). This identifies a twelve (12), which is the beginning of the fault list. It will then pause for 1.2 seconds (long pause) and flash two times (2), pause, then flash six times (6). This identifies a twenty-six (26), which is the ETCSticking fault. If any additional faults were stored the SECM would again have a long pause, then display the next fault by flashing each digit. Since no other faults were stored there will be a long pause then one flash (1), pause, then two flashes (2). This identifies a twelve meaning the fault list will begin again.

Displaying Fault Codes (DFC) from SECM Memory

To enter code display mode you must turn OFF the ignition key. Now turn ON the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal three (3) times within five (5) seconds to enable the display codes feature of the SECM. Simply turn the key OFF to exit display mode. The code list will continue to repeat until the key is turned OFF.

Clearing Fault (DFC) Codes

To clear the stored fault codes from SECM memory you must complete the reset fault pedal maneuver.

⚠ CAUTION

Once the fault list is cleared it cannot be restored.

First turn OFF the ignition key. Now turn ON the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal ten (10) times within five (5) seconds to clear the fault code list of the SECM. Simply turn the key OFF to exit the reset mode. The code list is now clear and the SECM will begin storing new fault codes as they occur.

Software released after level MI07SEQ062V05_***.mfu allows fault codes to be cleared while displaying the fault codes. You must fully cycle the foot pedal ten (10) times within five (5) seconds to clear the fault code list of the SECM. The fault code list will continue to display until the end of the list is reached.

Fault Action Descriptions

Each fault detected by the SECM is stored in memory (FIFO) and has a specific action or result that takes place. Listed below are the descriptions of each fault action.

Engine Shutdown: The most severe action is an Engine Shutdown. The MIL will light and the engine will immediately shutdown, stopping spark, closing the fuel lock-off closing, and turning off the fuel pump and fuel injectors.

Delayed Engine Shutdown: Some faults, such as low oil pressure, will cause the MIL to illuminate for 30 seconds and then shut down the engine.

Cut Throttle: The throttle moves to its default position. The engine will run at idle but will not accelerate.

Cut Fuel: Fuel flow will be turned off.

Turn on MIL: The MIL will light by an active low signal provided by the SECM, indicating a fault condition. May illuminate with no other action or may be combined with other actions, depending on which fault is active.

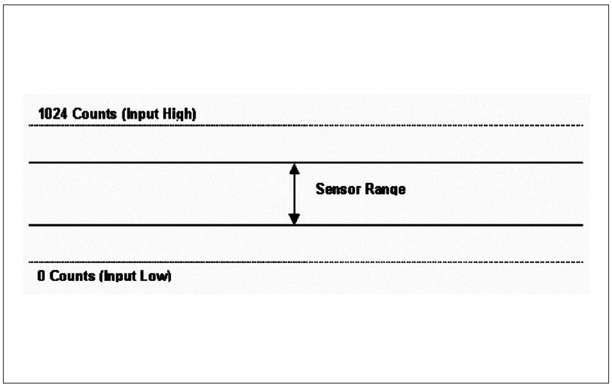
Soft Rev Limit / Medium Rev Limit / Hard Rev Limit: System will follow various sequences to bring engine speed back to acceptable levels.

Level4 Power Limit / Level3 Power Limit / Level2 Power Limit / Level1 Power Limit: The maximum engine power output will be limited to one of four possible levels. The engine power is calculated from measured engine parameters (e.g. MAP, rpm, fuel flow, etc).

Disable Gas O2 Control: In LPG mode, closed loop correction of air fuel ratio based on the Pre-catalyst O2 sensor is disabled.

Fault List Definitions

All the analog sensors in the MI-07 system have input sensor range faults. These are the coolant temperature sensor, fuel temperature sensor, throttle position sensors, pedal position sensors, manifold pressure sensor, HEGO sensors, and intake air temperature sensor. Signals to these sensors are converted into digital counts by the SECM. A low/high range sensor fault is normally set when the converted digital counts reach the minimum of 0 or the maximum of 1024 (1024 = 5.0 Vdc with ~ 204 counts per volt).



Additionally, the SECM includes software to learn the actual range of the pedal position and throttle position sensors in order to take full advantage of the sensor range. Faults are set if the learned values are outside of the normal expected range of the sensor (e.g. APP1AdaptLoMin).

Appendix

LPG And LPG Fuel Tanks

LPG Fuel Supply

Liquefied petroleum gas (LPG) consists mainly of propane, propylene, butane, and butylenes in various mixtures. LPG is produced as a by-product of natural gas processing or it can be obtained from crude oil as part of the oil refining process. LPG, like gasoline, is a compound of hydrogen and carbon, commonly called hydrocarbons.

In its natural state, propane is colorless and odorless; an odorant (ethyl mercaptan) is added to the fuel so its presence can be detected. There are currently three grades of propane available in the United States. A propane grade designation of HD5 (not exceeding 5% propylene), is used for internal combustion engines while much higher levels of propylene (HD10) are used as commercial grade propane along with a commercial propane /butane mixture.

APPROXIMATE COMPOSITION OF HD5 PROPANE BY VOLUME

Propane (C3H8)	Propy lene	Butane (C4H10)	Iso-Butane	Methane (CH4)	TOTAL
90.0% min.	5% max.	2.0%	1.5%	1.5%	100%

An advantage of LPG is the ability to safely store and transport the product in the liquid state. In the liquid state propane is approximately 270 times as dense as it is in a gaseous form. By pressurizing a container of LPG we can effectively raise the boiling point above –44 deg. C / -42 deg. C, keeping the propane in liquid form. The point at which the liquid becomes a gas (boiling point) depends on the amount of pressure applied to the container.

This process operates similarly to an engine coolant system where water is kept from boiling by pressurizing the system and adding a mixture of glycol. For example water at normal atmospheric pressure will boil at 212 deg. F / 100 deg. C. If an engines operating temperature is approximately 230 deg. F / 110 deg. C, then the water in an open un-pressurized cooling system would simply boil off into steam, eventually leaving the cooling system empty and over heating the engine. If we install a 10 PSIG cap on the radiator, pressurizing the cooling system to 10 PSIG, the boiling point of the water increases to 242 deg. F / 117 deg. C, which will cause the water to remain in liquid state at the engines operating temperature.

The same principle is applied to LPG in a container, commonly referred to as an LPG tank or cylinder. Typically an LPG tank is not filled over 80% capacity allowing for a 20% vapor expansion space. Outside air temperature effect's an LPG tank and must be considered when using an LPG system. (Figure 2) shows the relationship between pressure and temperature in a LPG tank at a steady state condition.

LPG Tank Pressure VS Temperature

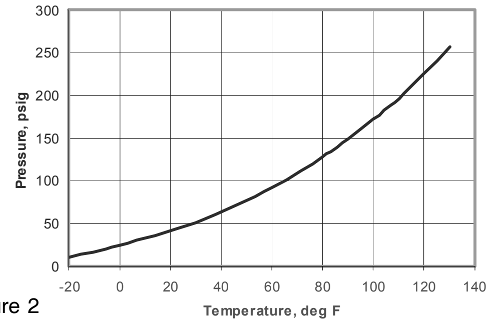


Figure 2

With 128 PSIG vapor pressure acting against the liquid propane the boiling point has been raised to slightly more than 80 deg. F / 27 deg. C.

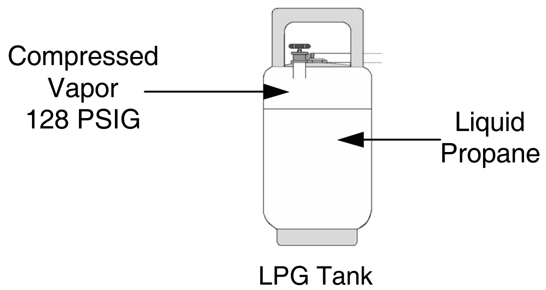


Figure 3

NOTE: Vapor pressure inside an LPG tank depends on the ambient air temperature outside the tank, not the amount of liquid inside the tank. A tank that is ¾ full of liquid propane at 80 deg. F will contain the same vapor pressure as a tank that is only ¼ full of liquid propane.

LPG's relative ease of vaporization makes it an excellent fuel for low-rpm engines on start-and-stop operations. The more readily a fuel vaporizes the more complete combustion will be.
Because propane has a low boiling point (-44F), and is a low carbon fuel, engine life can be extended due to less cylinder wall wash down and little, if any, carbon build up.

LPG Fuel Tanks

The two styles of LPG storage containers available for industrial use and lift truck applications are portable universal cylinders and permanently mounted tanks. Portable universal cylinders are used primarily for off-highway vehicles and are constructed in accordance with the DOT-TC (United States Department of Transport – Transport Canada). The cylinders are referred to as universal because they can be mounted in either a vertical or horizontal position (Figure 4).

Figure 4

NOTE: A 375-psig, relief valve is used on a DOT forklift tank. The relief valve must be replaced with a new valve after the first 12 years and every 10 years thereafter.

The tank must be discarded if the collar is damaged to the point that it can no longer protect the valves. It must also be replaced if the foot ring is bent to the point where the tank will not stand or is easily knocked over.

Installing LPG Fuel Tanks

When installing a tank on a lift truck, the tank must be within the outline of the vehicle to prevent damage to the valves when maneuvering in tight spaces. Horizontal tanks must be installed on the saddle that contains an alignment pin, which matches the hole in the collar of the tank. When the pin is in the hole, the liquid withdrawal tube is positioned to the bottom of the tank. A common problem is that often these guide-pins are broken off, allowing the tank to be mounted in any position. This creates two problems. 1). When the liquid withdrawal tube is exposed to the vapor space, it may give a false indication that the tank is empty, when it actually is not. 2). The safety relief valve may be immersed in liquid fuel. If for any reason the valve has to vent, venting liquid can cause a serious safety problem,

⚠ CAUTION

When empty, the tank is exchanged with a pre-filled replacement tank. When exchanging a tank, safety glasses and gloves should be worn.

LPG Fuel Tank Components

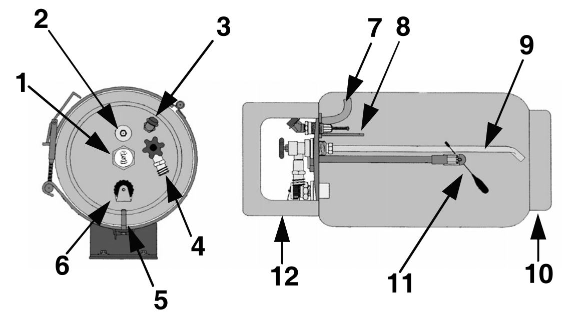


Figure 5

(1) Fuel Gauge (2) 80% Stop Bleeder
(3) Pressure Relief Valve
(4) Service Valve (Tank end male coupling) (5) Filler Valve
(6) Alignment Pin
(7) Vapor Withdrawal Tube (Only used with Vapor Withdrawal)
(8) 80% Limiter Tube (9) Liquid Withdrawal Tube
(10) Foot Ring (11) Fuel Level Float (12) Collar

Fuel Gauge

In figure 5 a visual fuel gauge is used to show the fuel level in the tank. A mechanical float mechanism detects the liquid propane level. A magnet on the end of the float shaft moves a magnetic pointer in the fuel gauge. Some units have an electronic sending unit using a variable resistor, installed in place of a gauge for remote monitoring of the fuel level. The gauge may be changed with fuel in the tank. **DO NOT REMOVE THE FOUR LARGE FLANGE BOLTS THAT RETAIN THE FLOAT ASSEMBLY, WITH FUEL IN THE TANK!**

⚠ CAUTION

It is not a legal practice to fill the tank through the liquid contents gauge.

In some applications a fixed tube fuel indicator is used in place of a float mechanism. A fixed tube indicator does not use a gauge and only indicates when the LPG tank is 80% full. The fixed tube indicator is simply a normally closed valve that is opened during refueling by the fueling attendant. When opened during refueling and the tanks LPG level is below 80%, a small amount of vapor will exit the valve. When the LPG tank level reaches 80% liquid propane will begin exiting the valve in the form of a white mist (Always wear the appropriate protective apparel when refueling LPG cylinders). In order for this type of gauge to be accurate, the tank must be positioned properly. When full (80% LPG) the valve is closed by turning the knurled knob clockwise. Typically a warning label surrounds the fixed tube gauge which reads **STOP FILLING WHEN LIQUID APPEARS.**

Service Valve

The service valve is a manually operated valve using a small hand wheel to open and close the fuel supply to the service line (fuel supply line). The service valve installs directly into the tank and has two main categories, liquid and vapor service valves. Liquid service valves used on portable LPG tanks use a 3/8” (3/8” NPT) male pipe thread on the service valve outlet for attachment of a quick disconnect coupler.

An excess flow valve is built into the inlet side of the service valve as a safety device in case of an accidental opening of the service line or damage to the service valve itself. The excess flow valve shuts off the flow of liquid propane if the flow rate of the liquid propane exceeds the maximum flow rate specified by the manufacturer.

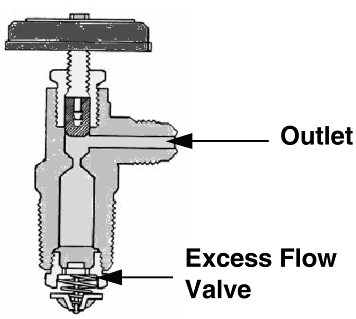


Figure 6

⚠ CAUTION

When the tank is in use the service valve should be completely open. If the valve is partly open, the vehicle may not be getting enough fuel to operate efficiently.

In addition to possibly starving the engine for fuel, a partly open valve may restrict the flow enough to prevent the excess flow valve from closing in the event of a ruptured fuel line.

Most liquid service valves have an internal hydrostatic relief valve and are usually labeled **"LIQUID WITH INTERNAL RELIEF"**. The hydrostatic relief valve protects the fuel service line between the tank and the lock off from over pressurization. The internal hydrostatic relief valve has a minimum opening pressure of 375 PSIG and a maximum pressure of 500 PSIG. These type of relief valves have an advantage over external relief valves because the propane is returned to the tank in the event of an over pressurization instead of venting the propane to atmosphere.

Quick Disconnect Coupling

The liquid withdrawal or service valve on a DOT tank has male threads and accepts the female portion of a quick disconnect coupling (Figure 8). The female portion is adapted to the liquid hose going to the fuel system. Both halves are equipped with 100% shutoffs, which open when coupled together to allow fuel flow. The coupler has two seals. One is an o-ring and the other is a flat washer. The o-ring prevents leakage from the shaft on the other coupling and the flat washer seals when the coupler is fully connected.

NOTE: The flat seal and / or the o-ring will sometimes pop off when disconnecting and slide up the shaft of the mating connector, causing the valve not to open when fully mated. The extra washer or o-ring must be removed from the shaft and the coupling reconnected.

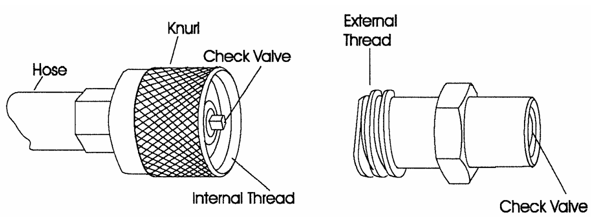


Figure 8

Filler Valve

The liquid filler valve (Figure 9) has a male thread to receive a fuel nozzle and typically has a plastic or brass screw on cap that is retained with a small chain or plastic band to keep debris out of the filler valve. The filler valve is a one-way flow device that uses two check valves to allow fuel to enter the tank but prevent it from exiting. Both check valves are backpressure type check valves, designed so that backpressure from the tank assists the check valves own spring pressure to close the valve. The first valve uses a neoprene on metal seal and the second valve uses a metal on metal seal.

A weakness ring is machined into the filler valve just above the check valves and will allow the filler valve to shear off in case of an accident. The valve will break or shear off above the check valves so that the tank will be sealed and no liquid propane can escape.

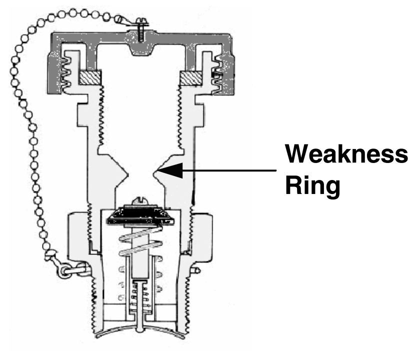


Figure 9

Regulatory Compliance

EPA / CARB Emissions Certification

When properly applied and calibrated, 's MI-07 control system is capable of meeting EPA 2007 LSI emission standards (40 CFR Part 1048.101) when operating properly with an approved three-way catalyst. The emission standards, including appropriate deterioration factors over the useful life of the system, are as follows:

HC+NOx: 2.0 g/hp-hr [2.7 g/kW-hr]
CO: 3.3 g/hp-hr [4.4 g/kW-hr]

Evaporative emissions comply with 40 CFR Part 1048.105. These standards apply only to volatile liquid fuels such as gasoline. Note that the engine crankcase must be closed.

North American Compliance

The N-2007 regulator is UL listed per Category ITPV LP-Gas Accessories, Automotive Type.

The N-2007 regulator and CA100 mixer have tamper-resistant features approved by CARB.

Special Conditions for Safe Use

Field wiring must be suitable for at least 248°F (120°C).

SECM-48 inputs are classified as permanently connected IEC measurement Category I. To avoid the danger of electric shock, do not use inputs to make measurements within measurement categories II, III, or IV.

SECM-48 input power must be supplied from a power supply/battery charger certified to IEC standard with a SELV (Safety Extra Low Voltage) classified output.

SECM-48 inputs and outputs may only be connected to other circuits certified as SELV (Safety Extra Low Voltage).

⚠ WARNING—EXPLOSION HAZARD

Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.

Substitution of components may impair suitability for Class I, Division 2, or Zone 2 applications.

Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).

2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.

3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.

Abbreviations

ACFM	Actual cubic feet per minute at the specified suction conditions
AFR	Air fuel ratio
BHP	Brake horsepower
Bi-Fuel	Able to operate on either of two fuels
CTS	Coolant temperature sensor
CNG	Compressed natural gas
Dual Fuel	Able to run simultaneously on two fuels, e.g. diesel and natural gas. Often this term is incorrectly used to describe bi-fuel operation. Spark-ignited engines are typically bi-fuel while compression ignition engines are dual-fuel.
ECM	Engine control module
FPP	Foot pedal position
FPV	Fuel primer valve
FTS	Fuel temperature sensor
FTV	Fuel trim valve
GPM	Gallons per minute of flow
HEGO	Heated exhaust gas oxygen (sensor)
LAT	Limited-angle torque motor
LPG	Liquified petroleum gas
MAP	Manifold absolute pressure
MAT	Manifold air temperature
MIL	Malfunction indicator lamp
MOR	Manufacturer of record for emissions certification on the engine
OEM	Original equipment manufacturer
PHI	Relative fuel-air ratio or percent of stoichiometric fuel (actual fuel-air ratio / stoichiometric fuel-air ratio)
RPM	Revolutions per minute
SECM	Small engine control module
TMAP	Temperature and manifold absolute pressure
TPS	Throttle position sensor
VDC	Voltage of direct current type
VE	Volumetric efficiency
WOT	Wide open throttle