SERVICE REPAIR

MANUAL

Hyster A267 (S50CT) Forklift Service Repair Manual

HYSTER

DIAGNOSTIC TROUBLESHOOTING MANUAL

S50CT [A267];
H2.0-2.5CT (H50CT) [A274];
S50CT [B267];
H2.0-2.5CT (H50CT) [B274]

HYSTER

PART NO. 4023070 9000 SRM 1434

SAFETY PRECAUTIONS
TROUBLESHOOTING PROCEDURES

- The Service Manuals are updated on a regular basis, but may not reflect recent design changes to the product. Updated technical service information may be available from your local authorized Hyster® dealer. Service Manuals provide general guidelines for maintenance and service and are intended for use by trained and experienced technicians. Failure to properly maintain equipment or to follow instructions contained in the Service Manual could result in damage to the products, personal injury, property damage or death.
- When lifting parts or assemblies, make sure all slings, chains, or cables are correctly fastened, and that the load being lifted is balanced. Make sure the crane, cables, and chains have the capacity to support the weight of the load.
- Do not lift heavy parts by hand, use a lifting mechanism.
- Wear safety glasses.
- DISCONNECT THE BATTERY CONNECTOR before doing any maintenance or repair on electric lift trucks. Disconnect the battery ground cable on internal combustion lift trucks.
- Always use correct blocks to prevent the unit from rolling or falling. See HOW TO PUT THE LIFT TRUCK ON BLOCKS in the **Operating Manual** or the **Periodic Maintenance** section.
- Keep the unit clean and the working area clean and orderly.
- Use the correct tools for the job.
- Keep the tools clean and in good condition.
- Always use **HYSTER APPROVED** parts when making repairs. Replacement parts must meet or exceed the specifications of the original equipment manufacturer.
- Make sure all nuts, bolts, snap rings, and other fastening devices are removed before using force to remove parts.
- Always fasten a DO NOT OPERATE tag to the controls of the unit when making repairs, or if the unit needs repairs.
- Be sure to follow the **WARNING** and **CAUTION** notes in the instructions.
- Gasoline, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG), and Diesel fuel are flammable. Be sure to follow the necessary safety precautions when handling these fuels and when working on these fuel systems.
- Batteries generate flammable gas when they are being charged. Keep fire and sparks away from the area. Make sure the area is well ventilated.

NOTE: The following symbols and words indicate safety information in this manual:

WARNING

Indicates a condition that can cause immediate death or injury!

CAUTION

Indicates a condition that can cause property damage!

On the lift truck, the WARNING symbol and word are on orange background. The CAUTION symbol and word are on yellow background.

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This section is for the following models:

(S50CT) [A267];
H2.0-2.5CT (H50CT) [A274];
(S50CT) [B267];
H2.0-2.5CT (H50CT) [B274]

How To Use This Troubleshooting Manual

GENERAL INSTRUCTIONS AND SAFETY INFORMATION

WARNING

DO NOT add to or modify the lift truck. Any modification that affects the safe operation of the truck cannot be undertaken without written authorization of the Hyster company.

Any change to the lift truck, the tires, or its equipment can change the lifting capacity. The lift truck must be rated as equipped and the nameplate must show the new rating capacity.

WARNING

The technician must be aware of, and follow, all general safety precautions that are published in the Operating Manual and that are posted as Safety Decals on and in the lift truck.

Before starting, the technician should be familiar with certain policies, requirements, and instructions used in the troubleshooting procedures. Using the troubleshooting procedures correctly helps the technician to perform the procedure safely and prevents damage to the machine and support equipment.

HOW TO USE DIAGNOSTIC TROUBLESHOOTING MANUAL

Manual Layout:

Sections: The manual is divided into eight sections, each representing a major system, functional area, or specific operation on the lift truck.

- 9010 – Operational Diagnostic Procedures
- 9020 – Engine
- 9030 – Electrical System
- 9040 – Powertrain
- 9050 – Hydraulic Systems
- 9060 – Operator's Station
- 9070 – Front End (Mast) and Chassis
- 9080 – Supplementary Data

Groups: The sections of the manual are further subdivided into groups, where applicable, that identify specific functions, operating criteria, or maintenance tasks.

- 01 – Introduction to the Troubleshooting Manual
- 03 – General Maintenance/Diagnostic Data
- 05 – Operational Checkout
- 10 – Principles of Operation
- 20 – Diagnostic Trouble Codes
- 30 – Observed Symptoms
- 40 – Test and Adjustments

For Diagnostic Trouble Code listings, see Electrical System, General Maintenance and Diagnostic Data, Diagnostic Trouble Codes, Page 9030-03-6.

NOTE: Not all groups will appear in all sections.

Supplementary Data: The supplementary data section of the manual includes information and data that apply to many sections or groups and is stored here for access by all users of the manual. This data includes, but is not limited to:

- Abbreviations and Acronyms
- Special Tools List
- Fault Mode Indication Reference Table
- Supplier Specification Data

GENERAL INSTRUCTIONS

1. Become familiar with the content, layout, and access provisions of data in this manual. This will improve your efficiency and decrease the time required to resolve the problems.
2. Use all sections of the manual for relevant information on the subject system.
3. Once you begin a troubleshooting procedure, do not skip steps.
4. If you reach the end of a procedure without resolving the problem and you are not directed to another procedure contact Resident Service Engineering through the Contact Management System.
5. Do not limit yourself, remember to apply your own experience and knowledge to assist in resolving the problems, but do not compromise safety in doing so.
6. Most of the cross-reference data in the manual will be electronically linked for rapid and easy access. Use the links wherever the cursor highlights an item as a linkable option.

As an example of this linking option:

Assume that during a procedure or test, it is necessary to refer to a different section of manual, in this case, the Light Circuit Check in the Operational Checkout part of this manual.

The instruction would read, "refer to, or see" followed by text identifying what the reference is (for hard-copy, paper manual use). When the cursor is placed over the text, it will then indicate that it is active, and left-clicking will direct the system to take you directly to that reference.

Try it using the process below:

See Operational Diagnostic Procedures, Operational Checkout, Page 9010-05-2.
When you have reviewed the reference document or manual, and need to return to the troubleshooting procedure, the "BACK" button will permit you to do this.

"THE QUALITY KEEPERS"

HYSTER APPROVED PARTS

SECTION 9010

OPERATIONAL DIAGNOSTIC PROCEDURES

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Group 05

Operational Checkout

Operational Checkout Procedures

These procedures are designed so technicians can make a quick check of the operation of the machine while sitting in operator's seat.

WARNING

Be sure to read the warnings prior to performing the checkout procedures.

WARNING

Before operating the lift truck, FASTEN YOUR SEAT BELT.

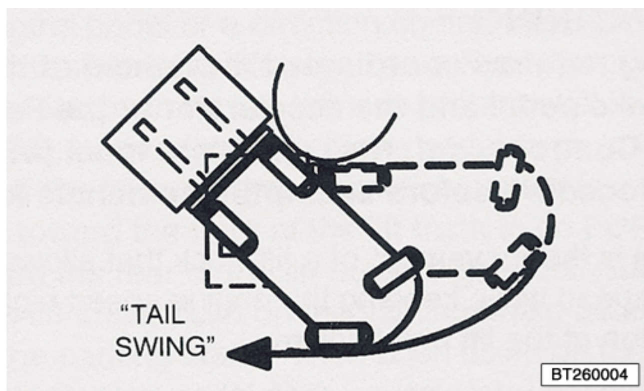
There are a number of operations, if not performed carefully, that can cause the lift truck to tip. If you have not read the WARNING page in front of the Operating Manual, do so NOW. As you study the following information about how to properly operate a lift truck, remember the Warnings.

WARNING

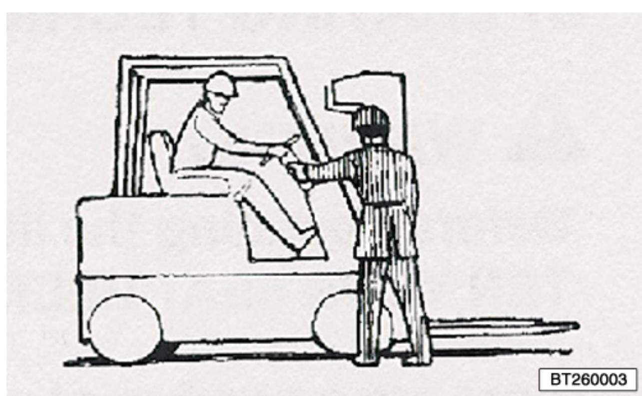
Mast parts are heavy and can move. Distances between parts are small. Serious injury or death can result if part of the body is hit by parts of the mast or the carriage.

- **Never put any part of the body into or under the mast or carriage unless all parts are completely lowered or a safety chain is installed. Also make sure the power is OFF and the key is removed. Fasten a DO NOT OPERATE tag in the operator's compartment.**
- **Be careful of the forks. When the mast is raised, the forks can be at a height that may cause an injury.**
- **DO NOT climb on the mast or lift truck at any time. Use a ladder or personnel lift to work on the mast.**
- **DO NOT use blocks to support the mast weldments nor to restrain their movement.**
- **Mast repairs require disassembly and removal of parts and can require removal of the mast or carriage. Follow the repair procedures in the correct Service Manual for the mast.**

Adequate space is required to do the driving checks. Some checks require the lift truck and other major components to be at operating temperature.



Before performing the operational checkout, complete the INSPECTION BEFORE OPERATION in the **Operating Manual**.



Before starting operational checkout, talk to the operator and check Diagnostic Trouble Codes (DTC) using the Display Panel (DP). See Troubleshooting Guidelines and Procedures. All DTCs must be corrected or cleared before starting this checkout.

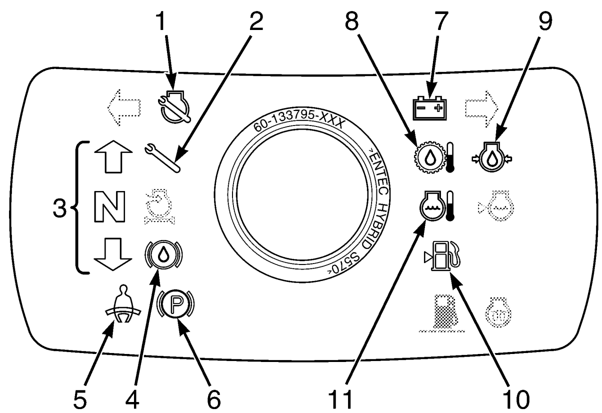
No special tools or gauges are needed. Always start sequence from left to right. Before doing check, read each check completely.

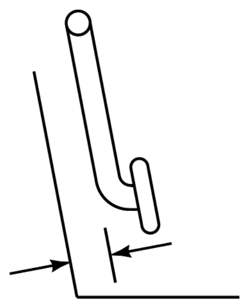
At the end of each check, a question is asked:

- If the answer indicates the check is OK, you will be instructed to go to next check.
- If the answer indicates that the check is not OK, you will be given a required SRM repair or be linked to the test to perform.

When a problem is found, stop operational checkout and correct it before going to the next check. Repeat check after repair to confirm repair was successful before proceeding with the remaining checks.

CHECK	PROCEDURE	ACTION
DTC Check	1. Turn key to **ON** position. 2. Check display for any DTCs. Depress the UP/DOWN arrows simultaneously for 2 seconds. ***Are any DTCs displayed?***	**YES:** Refer to Electrical System, General Maintenance and Diagnostic Data, Diagnostic Trouble Codes, Page 9030-03-6. **NO:** DTCs are OK. Go to next check.
Horn Circuit Check	Press horn button. ***Does horn sound?***	**YES:** Horn is OK. Go to next check. **NO:** Refer to Electrical System, General Maintenance and Diagnostic Data, Diagnostic Trouble Codes, Page 9030-03-6.
Light Circuit Check	1. Turn key switch to **ON** position. 2. Turn front and rear work lights **ON**. ***Do lights turn on?***	**YES:** Lights are OK. Go to next check. **NO:** Check fuse. If OK, check bulbs, see Device Operational Failure (Lights, Back-Up Alarm, Starter).

Indicator Light Power Check	 BT081216 1. Engine Malfunction Indictor Light-(MIL) 2. System Malfunction Indicator 3. Direction and Transmission Lights 4. Brake Fluid Level Malfunction 5. Fasten Seat Belt Malfunction 6. Parking Brake Malfunction 7. Alternator Malfunction 8. Transmission Oil Temperature Malfunction 9. Engine Oil Pressure Malfunction 10. Fuel Level 11. Engine Coolant Temperature Malfunction Turn key switch to **ON** position and at key on, all lights do a "Bulb" check. ***Do the following bulbs turn ON?*** • ***Direction Indicator, Fasten Seat Belt, Park Brake, Alternator, and Engine Oil Pressure.*** **NOTE:** Fasten seat belt light will turn off after 10 seconds. *Continue:*	**YES:** Display power is OK. Continue with this procedure. **NO:** Check fuse F8 in Power Distribution Module (PDM). If fuse is OK, go to Observed Symptoms, Vehicle Does Not Power On, Page 9030-30-9. If any one light does not turn on, replace DSC.
Cold Start Check	**NOTE:** Engine must be cold to properly check the cold start circuit. • Turn key switch to **ON** position or press power ON/OFF button. ***Does cold start indicator illuminate?***	**YES:** Go to next check. **NO:** Continue with this procedure.

Engine Malfunction Indicator Check	1. Start engine and increase to governed speed for 5 seconds. 2. Decrease engine to low idle. 3. Check DSC for engine warning indicator lights. ***Are any engine warning lights ON?***	**YES:** Repair engine malfunction. Go to Electrical System, General Maintenance and Diagnostic Data, Diagnostic Trouble Codes, Page 9030-03-6. **NO:** Engine indicators are OK. Resume operation.
Brake Pedal Check	 BT260022 1. With engine running at slow idle, release park brake. 2. Depress and hold brake pedal with approximately 45.4 kg (100 lb) force. 3. Measure pedal distance from floor plate as shown in the illustration (this is taken from bottom of brake pedal bracket to floor plate). ***Does brake pedal remain at least 25 mm (1 in.) off floor plate?***	**YES:** Brake adjustment is OK. Go to next check. **NO:** Adjust brakes. See **Brake System** 1800SRM1135.
Backup Alarm Check (If equipped)	1. With engine running, apply service brake. 2. Release park brake. 3. Shift transmission to reverse. ***Does backup alarm sound?***	**YES:** Back up alarm is OK. Go to next check. **NO:** Check wiring connections first. If connections are OK, go to Device Operational Failure (Lights, Back-Up Alarm, Starter).

Brake and Inching Pedal Check	1. With engine running, fully depress inching pedal. 2. Release park brake. 3. Shift to forward and increase engine to governed speed. **NOTE:** There is not an exact operating procedure for the inching function, except it must disengage the transmission. Inching can be set to operator's preference to fit the lift truck application in the DSC. ***Does engine increase smoothly to governed speed?***	**YES:** Inching function is OK. Go to next check. **NO:** See Observed Symptoms, Inching Operation Is Not Smooth or Chatters, Page 9040-30-1.
Park Brake Sensor Check	1. With engine running, release park brake. 2. Slowly apply park brake and note when park brake light comes ON. ***Does light come on before park brake reaches first click of engagement?***	**YES:** Park brake sensor is OK. Go to next check. **NO:** Adjust park brake sensor. See **Brake System** 1800SRM1135.

<table>
<tr>
<td>Park Brake Check</td>
<td>

BT260002
WARNING
Ensure load is secured so it will not move when mast is tilted fully forward.

Stop lift truck in an uphill direction with rated load on 15% grade or less, and apply park brake.
Stop engine and note if machine remains static.
Start engine and remove rated load.
Position lift truck with No Load in a downhill direction, on 15% grade or less, and apply park brake.
Stop engine and note if machine remains static.

Does machine remain static on grade in both directions?
</td>
<td>YES: Park brake is OK. Go to next check.
NO: Adjust park brake. See Brake System 1800SRM1135.</td>
</tr>
</table>

Engine Power Check	1. Ensure lift truck transmission and engine are at operating temperature, fully warmed transmission temperature 66 °C (150 °F). **WARNING** **Ensure load is secured so it will not move when mast is tilted fully forward.** 2. Put capacity secured load on forks. 3. Position forks against an immovable object, like a loading dock. 4. Scroll the DSC to display engine rpm. 5. Shift to forward and operate engine at governed speed. Record the highest rpm achieved with transmission engaged after 10 seconds, then disengage transmission for 10 second and release accelerator pedal. Repeat test three times to get highest stall speeding reading. ***Does engine stall speed meet stall speed specifications? For lift truck stall speed specifications, refer to Table 9040-40-5.*** **NOTE:** If engine speed is low, check if air filter restriction. A plugged air filter will lower stall speeds.	**YES:** Engine power is OK. Go to next check. **NO:** Check if air filter has any restriction.
Engine Speed Check	1. Scroll DSC to display engine rpm. 2. Run engine at low idle. Record engine rpm. 3. Run engine at governed speed. Record engine rpm. ***Does engine rpm match below specifications?*** • ***Low Idle - refer to Operating Manual for your lift truck.*** • ***Governed Speed - refer to Operating Manual for your lift truck.***	**YES:** Engine speed is OK. Go to next check. **NO:** Adjust throttle pedal. See **Frame** 0100SRM1423.

Brake and Axle Drag Check	**NOTE:** Move truck to level surface before performing the following steps. 1. Raise lift truck until drive tires are off ground. Support lift truck using suitable shop standard. (See "How to Raise Drive Tire" procedure in **Operating Manual**.) 2. Stop engine and release park brake. 3. Back off park brake adjustment on handle. 4. Check brakes for dragging. ***Are the brakes dragging?***	**YES:** Repair brakes. See **Brake System** 1800SRM1135. **NO:** Brakes are OK. Continue with this procedure.
Hydraulic Pump Flow Check	**WARNING** **Ensure load is secured so it will not move when mast is tilted fully forward.** 1. Put secured capacity load on forks. 2. With engine running at slow idle, raise forks approximately 1 m (3 ft) off floor. ***Does load raise at low idle speed?***	**YES:** Hydraulic pump output is OK. Go to next check. **NO:** If load raises only at increased governed speed, pump flow is low. Go to Hydraulic Pump Flow Test.
Lift Drift Check	Ensure the following before starting procedure: • Truck operating on flat surface. • Hydraulic oil at operating temperature. **WARNING** **Ensure load is secured so it will not move when mast is tilted fully forward.** • Secured capacity load on forks. 1. Install angle meter on mast and position mast at approximately 90° angle to ground. 2. Raise mast until approximately 75 mm (3 in.) of main lift cylinder rods are exposed on mast. Record this measurement. 3. Stop engine. 4. After 5 minutes, measure mast main lift cylinder drop. ***Does main lift cylinder rod retract more than 50 mm (2 in.)?***	**YES:** Go to Lift Cylinder Leakage Test to isolate if problem is in cylinder or control valve. **NO:** Main cylinder drift is OK. Continue with this procedure.

Tilt Function Drift Check	Ensure the following before starting procedure: • Truck operating on flat surface. • Hydraulic oil at operating temperature. **WARNING** **Ensure load is secured so it will not move when mast is tilted fully forward.** • Secured capacity load on forks. 1. Raise mast approximately 300 mm (12 in.) off floor. 2. Install angle meter on mast and position mast at approximately 90° angle to ground. 3. Stop engine. 4. After 5 minutes, measure mast angle and compare to original reading. ***Does mast tilt drift more than 2 degrees in 5 minutes?***	**YES:** Go to Tilt Cylinder Leakage Test to confirm if cylinder or control valve is leaking. **NO:** Tilt drift is OK. Go to next check.
Mast Cushion Check	Ensure the following before starting procedure: • Truck operating on flat surface. • Adequate overhead clearance to raise forks to maximum height. **WARNING** **Ensure load is secured so it will not move when mast is tilted fully forward.** • Secured capacity load on forks. 1. Operate engine at low idle and raise forks to maximum height of main lift cylinders. 2. Lower forks as fast as possible and observe cylinder rod as main lift cylinders reach bottom of stroke. ***Does fork speed slow and does a hissing sound come from cylinder at bottom of stroke?***	**YES:** Cushion valve is OK. Go to next check. **NO:** Inspect and clean cushion valve. See **Cylinder Repair (Mast S/N A551, A555, A559, A661, A662, A663, A66, B507, B508, B509, B551, B555, B559, B562, B563, B564, B661, B662, B663, C515, C551, C555, C559, D507, D508, D509, D515, D562, D563, D564, E509, and E564)** 2100SRM1139.

Lift/Tilt Mast Adjustment Check	Ensure the following before starting procedure: • Truck operating on flat surface. • Adequate overhead clearance to raise forks to maximum height. • No load on forks. 1. Operate engine at governed speed and raise forks to maximum height ***Does the top sections of mast kick to one side at maximum height?***	**YES:** Shim lift cylinders. See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431. **NO:** Mast cylinder is adjusted OK. Continue with this procedure.
Tilt Racking Check	Actuate mast back tilt function until hydraulic valve goes over relief. ***Do both sides of mast stop evenly?***	**YES:** Tilt stops are adjusted OK. Go to next check. **NO:** Adjust tilt stops. See Mast Adjustment, See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431.
Chain and Header Hose Adjustment Check	Ensure the following before starting procedure: • Truck operating on flat surface. • Hydraulic oil at operating temperature. • No load on forks. 1. Install angle meter on mast and position mast at approximately 90° angle to ground. 2. Raise and lower forks through two complete lift cycles. 3. Lower forks to lowest position. **NOTE:** The correct fork height adjustment is approximately 6 mm (0.25 in.) off floor. ***Does the heel of forks touch the floor?***	**YES:** Adjust lift chains. See Lift Chains Adjustment. See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431. **NO:** Chains are adjusted OK. Continue with this procedure.
Mast Mounting Check	1. Move mast to lowered position and stop engine. 2. Inspect the mounting hardware at axle. 3. Push the top of mast by hand while off the lift truck and note any movement of lift truck. **NOTE:** If the mast mounting is loose, mast will move without moving truck frame. ***Is the mast mounting loose?***	**YES:** Inspect and repair mast mounting. See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431. **NO:** Mast mounting is OK. Go to next check.

Mast Channel Check	**NOTE:** This is a visual check of the mast to determine if parts are worn or out of adjustment. 1. Raise mast to full height without load and stop engine. 2. Inspect outer and inner channels for wear pattern and gouging. 3. Move forks to lowered position. 4. Inspect the inner channel wear pattern for wear or gouging. ***Do channels show signs of excess wear?***	**YES:** Repair mast channels. See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431. **NO:** Mast wear is OK. Continue with this procedure.
Carriage Adjustment Check	1. Stop engine and lower forks to approximately 50 mm (2 in.) off ground. 2. Rock the carriage frame side to side. ***Does carriage move more than 0.5 mm (0.020 in.) at tightest point?***	**YES:** Adjust or repair carriage bearings. See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431. **NO:** Carriage adjustment is OK. Go to next check.
Chain Sheave Check	1. Stop engine and lower forks. 2. Inspect wear pattern on chain sheaves. ***Does sheave show a wear pattern without side wear?***	**YES:** Chain sheaves are OK. Go to next check. **NO:** Replace chain sheaves. See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431.
Carriage Adjustment Check (Standard and Integral Side Shift)	1. Lower forks and stop engine. 2. Inspect wear on carriage stop. ***Does carriage stop show a wear pattern on it?***	**YES:** Chains are out of adjustment. See **Mast Repair (S/N A698, A699, B551)** 4000SRM1431. **NO:** Checks complete.

NOTES

SECTION 9020

ENGINE

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Group 40 - Tests and Adjustments

Group 10
Principles of Operation

Engine Basics

GENERAL TERMINOLOGY

NOTE: Engine Basics may not be applicable to your lift truck configuration. For specific engine Principles of Operation, see Engine Identification.

There are basically 3 requirements for engine combustion. They are: Fuel-Air, Compression, and Ignition source.

Fuel-Air is a combination of a combustible material such as petroleum and oxygen. The fuel in a Spark Ignited engine must be vaporized prior to reaching the combustion chamber. Fuel and air are typically mixed prior to the combustion chamber.

Compression takes place within the cylinder of an engine. Compression of the fuel air mixture is accomplished by the piston and increases the energy output of the ignited fuel.

Ignition Source for Combustion converts the compressed fuel air mixture to mechanical energy.

COMBUSTION THEORY

The German physicist who developed the four-stroke engine in the 19th century was Nikolaus August Otto. The four-stroke engine, even today, is sometimes referred to as the Otto' Engine.

A four-stroke engine is comprised, basically, of one or more cylinders in which a piston moves up and down. The piston is attached to a crankshaft by connecting rods so that when the piston moves, the crank' of the crankshaft causes it to rotate. This is how up and down movement is converted to circular motion.

Two valves are located near the top of the cylinder. The intake valve opens to admit the combustible mixture into the cylinder and the exhaust valve opens to expel the exhaust gases out.

The valves are spring-loaded closed and they are opened by the action of the camshaft. The camshaft is driven by a timing gear (or in some cases by a belt or a chain) attached to the crankshaft.

The camshaft gear is twice the diameter of the crankshaft gear, so that the camshaft rotates at exactly half the speed of the crankshaft. The lobes or cams of the camshaft are arranged so that they open the valves at the correct time during the engine's operational sequence.

The physical arrangement of the valves and camshaft depends on the design of the engine. The valves of an overhead valve engine are located above the combustion chamber. The stem of each valve extends upward and rides against a rocker arm.

Each trip that the piston takes from one end of the cylinder to the other is called a stroke. Four complete strokes of the piston completes one cycle; the cylinder is then ready to begin another cycle. As previously stated, the crankshaft completes two revolutions during one cycle.

Each stroke of the piston is given a name according to what happens within the cylinder during that interval. They are intake, compression, power, and exhaust.

Intake Stroke. The first stroke is the Intake Stroke. The intake stroke is the interval during which the combustible mixture is drawn into the cylinder. The stroke begins with the piston at the top of the cylinder and the intake valve begins to open. The exhaust valve is closed. As the piston moves downward, a partial vacuum is produced within the cylinder. The intake valve opens a passage through the intake manifold to the carburetor, or throttle body, where fuel and air are mixed in the intake manifold. The fuel-charged air, called the fuel-air mixture, is drawn into the cylinder by the partial vacuum created. As the piston approaches the bottom of the cylinder, the intake valve closes, completely containing the fuel-air mixture within the cylinder.

Compression Stroke. The next stroke is the Compression Stroke. Now that the cylinder is charged with a fuel-air mixture and both valves are closed, the piston begins to travel back to the top of the cylinder. The piston squeezes or compresses the fuel-air mixture into a very small space. The temperature, as well as, the pressure of the mixture is greatly increased. By compressing the fuel-air, the expansion force produced when it is ignited is significantly increased.

A common engine measurement is its Compression Ratio.' Compression ratio is the relationship between the greatest available volume of the cylinder when the piston is at the bottom of the stroke, and the smallest available volume, when the piston is at the top of the stroke. (For example, if an engine has a compression ratio of 8 to 1, the air-fuel mixture is compressed into a space 1/8th its original volume.) At the end of the compression stroke, the crankshaft has made one complete revolution.

Power Stroke. The third stroke is the Power Stroke. With both valves closed, the piston approaches the top of the cylinder and compresses the air-fuel mixture into the smallest space possible. Near the point of the greatest compression, a high-voltage electrical spark jumps across the gap of the spark plug; that is, the spark fires.' The spark ignites the fuel-air mixture and the combustion that results causes a rapid expansion of gases. The expanding gases exert equally against the walls of the cylinder and the top of the piston. Since the piston is the only moveable element, it is forced down the cylinder like a projectile fired from a gun. The descending piston drives the crankshaft another half-turn as it travels to the bottom of the cylinder. The power stroke is the only stroke that performs work.

Exhaust Stroke. The fourth stroke is the Exhaust Stroke. As the piston approaches the bottom of the cylinder at the end of the power stroke, the exhaust valve opens. As the piston travels upward, it acts like a pump to force the exhaust gases past the open exhaust valve to the exhaust system and into the atmosphere. When the piston is near the top of the cylinder, the exhaust valve closes and the intake valve opens so the four strokes can be repeated over and over again.

There are two more topics to discuss; Power Overlap and Valve Timing.

Power Overlap. A flywheel is bolted to the crankshaft to keep the crankshaft coasting' and to help smooth out the power output of the engine by absorbing power during the power stroke and releasing it during the other 3 strokes. Remember, the impulse energy from each cylinder's power stroke is only transmitted to the crankshaft for about 1/3 of one revolution yet it takes 2 complete revolutions of the crankshaft to complete a cycle.

In a multiple cylinder engine, there are more power impulses. An engine must have at least six cylinders to provide a continuous force to the crankshaft. If more than one cylinder fires during each third of crankshaft rotation, this condition is termed Power Overlap.' As power overlap is increased by the number of engine cylinders, the mass of the flywheel can be reduced. The camshaft revolves at half the crankshaft speed. Anything driven by the camshaft, (for example, the fuel pump, distributor, etc.…), are turning at half-engine speed while items driven by the crankshaft, like the rods, pistons, flywheel, etc., are turning at engine speed.

Valve Timing. When discussing valve timing, the first things to define are the terms "top dead center" referred to often as TDC and "bottom dead center," referred to as BDC. These two terms refer to the upper and lower most limits of piston travel within the cylinder, respectively. In actual engine operation, the intake valve opens "before top dead center" and closes after "bottom dead center" of the intake stroke. Also the exhaust valve opens before "bottom dead center" and closes after "top dead center" of the exhaust stroke.

During a portion of an engine cycle, both the intake and exhaust valves are open. This is Valve Overlap.' Valve overlap provides three benefits.

1. Keeping the intake valve open longer allows a greater charge of fuel-air mixture into the cylinder.
2. Keeping the exhaust valve open during the initial portion of the intake stroke allows the incoming fuel-air mixture to help force the exhaust gases out of the cylinder, and the flow of the fuel-air mixture past the exhaust valve helps to cool the engine.
3. The combination of better engine cooling, more complete purging of the exhaust, and greater volume of fuel-air mixture that results from valve overlap increases the power output of the engine.

ENGINE COMPONENTS – CYLINDER BLOCK

The cylinder block is made from cast iron or cast aluminum. The block is usually cast as one piece. It contains the bearings that support the crankshaft and the cylinders within which each piston moves. It is typically liquid cooled through a water jacket. Components of the block include the crankshaft, piston and rod assemblies, bearings and seals, and the timing set. The camshaft is in the block unless it is an overhead cam engine.

The crankshaft converts the reciprocating motion of the pistons and rods into rotating motion. The crankshaft is located near the bottom of the block assembly. Because it is mounted in bearings, the crankshaft can rotate freely within the block.

The piston and rod assembly absorbs the power released when the fuel-air mixture is ignited. The piston is usually made of aluminum alloy and is machined so that it fits the cylinder properly when it reaches operating temperature.

A piston usually contains three rings. The bottom ring controls oil flow to the cylinder wall, the other two rings seal the combustion chamber during engine operation. The connecting rod assembly, usually made from forged steel, connects the piston to the crankshaft and transmits the energy created by the burning of the fuel-air mixture, to the crankshaft. The small' end of the connecting rod is connected to the piston by a piston pin or wrist pin. The lower end, or large end, of the connecting rod contains the rod bearing. This bearing allows the rod to be fastened to the crankshaft while still allowing it to rotate.

CAMSHAFT AND TIMING SET

The camshaft operates the engine's intake and exhaust valves. These valves channel the fuel-air mixture into the cylinders and remove the exhaust products from the cylinder. The camshaft is often responsible for other functions. For example, in a diesel engine, the camshaft operates the fuel, oil and vacuum pumps.

Either a chain, belt or gears drive the camshaft at one-half the speed of the crankshaft. The chain and its sprockets, the gears, or the belt and its sprockets are referred to as the timing set'. A timing set includes all the components used to drive the camshaft.

CYLINDER HEAD ASSEMBLY

Cylinder heads are made from cast iron or cast aluminum. An engine has one or two cylinder heads, depending on how many cylinders of the engine. The cylinder heads are located on top of the cylinder block. The cylinder heads have one intake valve and one exhaust valve for each cylinder. In spark ignited engines, the heads contain some of the ignition system parts. In many engines, a large portion of the valve train is located in the cylinder head. Many of the cooling system components may also be located in and around the cylinder head, such as the outlet housing, thermostat, and water jacket.

VALVE TRAIN ASSEMBLY

The valve train assembly is responsible for transmitting the valve signals from the camshaft to the engine valves. In some engine designs, the entire valve train is located in the block assembly. In other designs, the entire valve train is located in the cylinder head. Some of the components included in the valve train are: valve lifters (tappets), push rods, rocker arms, rocker shafts or stud valves and valve keepers, valve seats, valve springs, and other attachment parts.

MANIFOLDS

There are two types of manifolds connected to an engine: an intake manifold to take air into the cylinders and an exhaust manifold to discharge the exhaust gas. The purpose of the intake manifold is to distribute the air or fuel-air mixture uniformly to each of the engine cylinders.

To maximize volumetric efficiency, some engines have tuned intake manifolds, in which the port cross-sectional area and length are adjusted to a size that fills the cylinders most efficiently. A leaking intake system may allow unfiltered air to reach the cylinders. A leak can cause detonation, misfire, and exhaust-emission problems during engine operation and evaporative hydrocarbon emissions when the engine is not operating. Leakage of air into the fuel-air mixture unbalances the engine by producing lean mixtures and upsetting the calibration of the fuel metering system.

Many exhaust manifolds are made from cast iron or nodular iron. Some manifolds are made from stainless steel or heavy gauge steel. The exhaust manifold contains an exhaust port for each exhaust port in the cylinder head, and a flat machined surface on the manifold fits against a matching surface on the exhaust port area of the cylinder head. Some manifolds have a gasket between the manifold and the cylinder head.

The engine exhaust manifold is a casting or assembly of passages through which the products of combustion leave the exhaust-valve ports in the cylinder head or cylinder block and enter the exhaust piping system. The purpose of the exhaust manifold is to collect and carry the exhaust gases away from the cylinders with a minimum of back pressure.

The entire exhaust system, including the exhaust manifold, catalytic converter, muffler, and piping affects the efficiency of combustive gas evacuation from the engine cylinders. Exhaust back pressure, when present; represents a direct loss of engine power. Exhaust manifolds operate at high temperatures and may be subject to erosive or corrosive attack.

The exhaust pipe is connected from the exhaust manifold to the catalytic converter or muffler. On V-type engines, the exhaust pipe is connected to each manifold flange and these two pipes are connected into a single pipe under the rear of the engine. This single pipe is then attached to a catalytic converter, if included in the exhaust system. Most exhaust pipes are made from stainless steel or aluminized steel. Some pipes are double walled.

A catalytic converter reduces the levels of carbon monoxide (CO), nitrogen oxides (NOx), and hydrocarbons (HC) (unburned fuel from the exhaust gases). Many lift trucks include a catalytic converter in the exhaust system. The catalytic converter will be discussed further within this section.

The muffler directs exhaust gases through a series of tubes, baffles, and chambers to reduce noise. The tail pipe dispenses water vapor and exhaust gases into the atmosphere. Another common component in the exhaust system is the oxygen (O_2) sensor. The sensor constantly makes comparisons between the oxygen content inside the exhaust manifold and the air outside the engine. If a rich or lean air/fuel mixture is sensed in the exhaust, the sensor provides a signal to the engine control unit (ECU). The ECU will then make an adjustment to the fuel-air mixture. If equipped, an additional (O_2) sensor is after (Post) the catalytic converter. The Post (O_2) sensor is used to determine the efficiency of the catalytic converter.

AIR CLEANER/FILTER

The air cleaner/filter is common to all LPG engine systems. The air cleaner utilizes a cyclone-type dust separator, forcing dust to circulate around the blades. Dust, separated from the fresh air by the centrifugal force, accumulates in the dust pan. A special paper filter element is used to trap dust not separated by the cyclone action.

CARBURETION

The goal of a carburetor is to mix just the right amount of fuel with air so that the engine runs properly. If there is not enough fuel mixed with the air, the engine "runs lean" and either will not run or potentially damages the engine. If there is too much fuel mixed with the air, the engine "runs rich" and either will not run (it floods), runs very smoky, runs poorly (bogs down, stalls easily), or at the very least wastes fuel. The carburetor is in charge of getting the mixture just right prior to combustion.

ELECTRONIC FUEL INJECTION (EFI)

The function of an Electronic Fuel Injection (EFI) system is to deliver the correct amount of fuel to the engine under all operating conditions. Engine conditions including speed, manifold pressure, engine coolant temperature, and throttle position are used to determine the engine mode of operation and the required fuel metering.

Port fuel injection delivers metered fuel directly prior to the intake valve. There is one port injector for each cylinder of the engine.

The benefits of an injected fuel system over a standard carbureted system are:

- Better fuel atomization.
- More control of fuel delivery.
- Better fuel efficiency.
- Increased engine performance.
- Improved emission control.

Electronic adjustment of fuel delivery is based on engine temperature, engine load, and atmospheric pressure.

POSITIVE CRANKCASE VENTILATION (PCV)

The Positive Crankcase Ventilation (PCV) system is designed to remove harmful vapors from the engine and to prevent those vapors from being expelled into the atmosphere. The PCV system does this by using manifold vacuum to draw vapors from the crankcase into the intake manifold. This vapor is then carried with the fuel-air mixture into the combustion chambers where it is burned. The flow or circulation within this system is controlled by the PCV Valve. The PCV valve is effective as both a crankcase ventilation system and as a pollution control device.

The closed PCV system draws fresh air from the air filter housing. The oil filler cap in this system is NOT vented. Consequently, excessive vapor will be carried to the intake manifold. The closed system prevents vapor, whether normal or excessive, from reaching the open atmosphere.

The most critical part in the PCV system is the flow control valve, commonly referred to as the PCV Valve. The purpose of this valve is to meter the flow of the vapor from the crankcase to the intake manifold. This is necessary in order to provide for proper ventilation for the crankcase, while not upsetting the fuel-air mixture for combustion.

Blow-by gases and vapor should be removed at about the same rate they enter the crankcase. Since blow-by is minimal at idle and increases during high speed operation, the PCV valve must control the flow of vapor accordingly. The valve is operated by manifold vacuum which increases or decreases as engine speeds change. At low or idle engine speeds, manifold vacuum is high. This pulls the plunger inside the valve to a position which reduces vapor flow to a minimum. This low rate is adequate for ventilation purposes and does not upset the fuel-air mixture ratio.

At high speeds, manifold vacuum is decreased. The plunger is only drawn about halfway within the valve and allows maximum vapor flow. Since the engine needs more fuel-air mixture at higher speeds, the introduction of more vapor does not affect performance. A neglected PCV system can fail to function and result in maintenance troubles. If the crankcase is not adequately ventilated, the engine oil can be contaminated and heavy sludge accumulations will begin to form. Water and acids can become trapped within the crankcase and cause rust or corrosion of internal engine parts.

Engine Electrical

INTRODUCTION

The Engine Electrical System includes the battery, starting, charging, ignition system, and instrumentation systems.

BATTERY CONSTRUCTION

The battery stores energy for the complete truck electrical system. On demand, the battery produces a flow of direct current for the devices connected to its terminals. After a period of use, the battery becomes discharged and no longer produces a flow of current. It can, however, be recharged by making an outside direct current flow through it in the opposite way from that which the current normally flows.

The battery is made up of a number of individual cells in a case. Each cell within the battery contains a group of positive and negative plates. There is always one more negative than positive plate within each cell group. Separators are between plates to prevent the plates from physically contacting each other and allow a free flow of electrolyte around each plate. The plates hold the active materials in flat grids. Charged negative plates contain spongy lead (Pb). Charged positive plates contain lead peroxide (Pb 02). Plate groups of opposite polarity are interlaced so the negative and positive plates alternate. Negative plate groups normally have one more plate than positive groups. This keeps negative plates exposed on both sides of the interlaced group.

The main battery terminals are the positive (+) and negative (−) posts. The positive (+) terminal is larger to prevent the danger of connecting the battery in reverse polarity. Reversing the polarity may damage some components and wiring in the system. A red cable is connected to the positive (+) battery terminal and a black cable is connected to the negative (−) terminal. The negative (−) cable is typically connected to the frame or engine block. The positive post cable is connected to the starter solenoid.

WARNING

Whenever disconnecting or reconnecting a battery, always disconnect the negative post cable first and connect it last. If you don't do this, dangerous sparking could occur. You should never connect the battery with the key switch in the ON position or the engine running. Never lay metal tools or any other objects across the battery which could potentially cause a short circuit.

A standard battery has one vent cap for each cell. The caps serve two purposes: First, they close the opening in the cell cover through which the electrolyte level is checked and water added, and second, they provide a vent for the escape of gases formed when the battery is charging. Each cell within the battery has a potential voltage of approximately 2 volts. A 12-volt battery will have six cells connected in series.

CONVENTIONAL STANDARD BATTERY

A conventional standard battery, when new, contains fully-charged elements and is filled with electrolyte at the factory. It will not maintain its charged condition during storage and must be recharged periodically. A standard battery requires periodic measurement and adjustment of the electrolyte levels. Access the electrolyte within each cell through the battery vent caps. The electrolyte level should be checked daily. The electrolyte should be 6.35 to 12.7 mm (1/4 to 1/2 in.) above the plate separators, so that the tops of the battery plates are covered. The battery should be filled with distilled water and never overfilled. Do not add electrolyte to the battery unless it has been lost by spillage.

Always wait until after checking battery specific gravity before adding distilled water to the battery. This will ensure a true reading. If the electrolyte level is too low to check specific gravity, add distilled water, operate in circuit for a few minutes to mix the distilled water and electrolyte, then check the specific gravity. Specific gravity testing procedures are covered later.

Standard batteries that are stored for long periods of time without recharging form lead sulfate crystals on the wires of the positive plates and could cause permanent damage. In some instances, if the sulfation is not too severe, a slow charge rate for a longer than normal period could restore the battery to normal operating condition.

MAINTENANCE-FREE BATTERY

A Maintenance-Free battery operates similarly to a conventional standard battery. The use of lead-calcium plates instead of lead-antimony in their construction increases the ability of the battery to accept an overcharge, thus greatly reducing bubbling and gassing of the electrolyte. Less fluid is lost, eliminating the need to add water. Venting of gases from a maintenance-free battery is done through a vent.' Most maintenance-free batteries do not have typical vent caps.' These batteries are ready for service when they leave the factory. They have a very low rate of discharge and thus, have a longer shelf life than a conventional standard battery.

BATTERY CHARGING

WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

The amount of electrical current a battery can produce is limited by the amount of chemical reaction which can take place within it. When the chemical reaction in the battery has ended, either through defect or long use, it can no longer produce a flow of electrical current. In most instances, if the battery is not defective, it can be recharged.

The battery charge is maintained by the truck charging system. If a component in the charging system fails or if a truck system is drawing current while the truck is not running, the battery charge may be depleted. In these circumstances, external charging of the battery may be required. Batteries are charged by reversing their flow of current. Batteries can be recharged in two ways, either Fast Charging or Slow Charging.

A battery that is in satisfactory condition but requires recharging will accept a large amount of charging current without undesirable effects. This type of battery may be charged quickly at a high rate with a battery fast charger.' The reaction of the battery itself to fast charging will indicate the amount of charging current it can accept without damage. NEVER allow the battery electrolyte to heat above 49°C (120°F).

A battery that becomes sulfated will not accept a high rate of charging current without possible damage. Its sulfated condition provides increased resistance to current flow within the battery. Flow of high current through this kind of resistance creates heat. Damage that may occur includes plate warping, boiling of the electrolyte, and possible damage of the separators. Also, the cell caps, covers, and battery case may be damaged or distorted. A battery that has become sulfated must be charged over a long period of time at a low rate of charge.

BATTERY FAST CHARGING

WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

To fast charge the battery, perform the following steps:

1. Disconnect the truck negative (−) and then positive (+) lead. Check, and if necessary, fill the cells with distilled water to the level recommended.
2. Connect the battery to the charger following manufacturer's recommendations. Set the charger to 15-30 amps for a 12-volt battery.
3. Start the charger at a slow or low charging rate.
4. Increase the charging rate one selection' at a time.
5. Observe the charger ammeter after one minute at each selection for a 10-amp' charging rate. If necessary, select boost.
6. After the battery has charged for 3 minutes, monitor the electrolyte and look for signs of excessive gassing.
7. Reduce the charging rate until the electrolyte produces comparatively few bubbles, but basing has not stopped entirely.

The maximum charging time at the boost selection is 10 minutes for a conventional battery and 20 minutes for a maintenance-free battery. Cold temperatures can increase the time required to charge the battery. Check the charger instructions for additional details. If the battery is not accepting the required 10-ampere charging rate by the specified time, replace the battery.

The charging rate for conventional batteries may require 2 to 4 hours. The charging rate for maintenance-free batteries may require 4 to 8 hours. Once the battery is charged, check the electrolyte specific gravity after the battery has cooled for 30 minutes. The specific gravity should be between 1.230 and 1.265.

BATTERY SLOW CHARGING

WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

To slow charge the battery, perform the following steps:

1. Disconnect the truck negative (−) and then positive (+) lead. Check, and if necessary, fill the cells with distilled water to the level recommended.
2. Charge the battery at a low rate (7% of the battery amp-hour rating or less) for an extended period of time until the battery is fully charged.
3. Take three consecutive hydrometer readings an hour apart, until it shows no rise in the specific gravity. The battery is now considered fully charged.

The normal slow-charging period is from 12 to 24 hours. If the battery's specific gravity has not reached the normal full-charge range (1.225 to 1.280) within 48 hours of slow charging, replace the battery. Badly sulfated batteries, however, could take between 60 to 100 hours to recharge completely.

STARTING SYSTEM PRINCIPLES OF OPERATION

The starting circuit converts electrical energy from the battery into mechanical energy at the starter motor to crank the engine.

The basic components of a starting system are:

- **Battery** - supplies energy for the circuit.
- **Starter Switch** - activates the circuit.
- **Solenoid-Operated Motor Switch** - engages the starter motor drive.
- **Starter Motor** - drives the flywheel to crank the engine.

When the starter switch is activated by the operator, a small amount of electrical energy flows from the battery to the starter solenoid and back to the battery through the ground circuit. As the starter solenoid gets this power from the battery, it moves the solenoid plunger against spring pressure, and engages the pinion gear with the flywheel ring gear. The plunger also closes the switch inside the solenoid between the battery and the starting motor, completing the circuit, and allowing a large amount of electrical energy to flow into the starting motor. The starter takes the electrical energy from the battery and converts it into rotary mechanical energy to crank the engine.

STARTING SYSTEM COMPONENTS - IGNITION SWITCH

The ignition switch is activated by the vehicle operator. It typically has three positions: **OFF**, **START**, and **RUN**. In the **OFF** position all truck circuits are de-energized. In the **START** position, system circuitry is activated to allow the starter to rotate and ignition systems to be energized. In the **RUN** position, the starter system is de-energized but the truck auxiliary systems and ignition remain powered.

STARTING SYSTEM COMPONENTS - STARTER SOLENOID

The primary purpose of the starter solenoid is to engage the starter pinion gear. The starter solenoid is a magnetic switch, but in addition to closing a circuit, the solenoid provides a mechanical means of shifting the starter motor pinion. The solenoid switch can be either contained within the starter motor unit or a separate component.

A typical solenoid switch has two coils of wire wound in the same direction. The pull-in' winding is made up of heavy wire connected to the motor terminal of the solenoid and through the motor to ground. The hold-in' winding has an equal number of turns of fine wire with one end connected to ground. These coils are energized directly from the battery through the start' position of the ignition switch. They work together to pull-in and hold-in the pinion gear positioning plunger against spring pressure, engaging the pinion gear with the flywheel.

When the ignition switch is released to the run position, the pull-in and hold-in windings within the starter solenoid are energized in opposing directions. This causes the magnetic field controlling the plunger to collapse. Spring tension then acts on the plunger, moving it and disengaging the pinion gear from the flywheel.

STARTING SYSTEM COMPONENTS - FLYWHEEL AND RING GEAR

The flywheel is connected to the engine crankshaft. During engine starting, the starter, through the starter pinion gear, rotates the flywheel and the crankshaft. A ring gear is installed around the outer edge of the flywheel. This ring gear is engaged by the starter pinion gear during the engine start cranking process.

STARTING SYSTEM COMPONENTS - STARTER MOTOR AND DRIVE

The starter motor does the actual job of cranking the engine. It is a special electrical motor designed to operate for short intervals under great overload. It also produces very high horsepower for its size. The starter motor is a series-wound, direct-current electric motor designed to provide high power for a short time using current from a storage battery. Most starting motors have two, four, or six field poles with windings; a wound armature with a commutator; and two, four, or six brushes. The basic parts of a starter motor are the solenoid, a field frame assembly, an armature, and a drive mechanism.

After electrical power is transmitted from the battery through a switch to the starting motor, some type of connection is needed to put this energy to work. The last link in the starting circuit is the starting motor drive. The drive makes it possible to use the mechanical energy produced by the starter motor. The starter motor armature revolves at a relatively high speed. Since the speed required to start the engine is comparatively slow, the starter motor is equipped with a small drive pinion which meshes with the teeth of the flywheel ring gear.

The gear ratio between the drive pinion and the flywheel are typically in the range of 20 to 1. This permits the starter motor to develop high armature speeds and considerable power while turning the engine over at a lower speed. After combustion has occurred and the engine speeds up to idle, the starter must be disengaged to prevent damage as the flywheel RPM increases. A starter drive on the end of the armature shaft meshes the drive pinion with the ring gear on the flywheel, and prevents the starter motor from overspeeding after the engine is started.

There are two basic ways in which starter drives are engaged. They are either Inertia Drives or Electromagnetic Drives. On an inertia drive, the pinion gear is weighted on one side to aid in its initial rotating motion. An inertia drive starter does not contain a starter solenoid. When not rotating, the inertia drive is out of mesh and separated from the flywheel ring gear. The drive relies upon inertia of a counterweight pinion and acceleration of the armature to move the pinion into mesh with the flywheel. As the starter armature shaft accelerates rapidly, the pinion gear, due to inertia created by the counterweight, runs forward on a revolving screw sleeve until it meets and meshes with the flywheel. When the engine starts, the flywheel rotates faster than the starter shaft, causing the pinion to turn in the opposite direction on the screw and it spins itself out of mesh.

Electromagnetic drives are shifted in or out of mesh by the magnetic field of a switch. The Overrunning Clutch, Dyer Drive, and Sprag Clutch Drive are all electromagnetic type drives.

- **Overrunning Clutch Type Drive** - uses a shift lever to actuate the drive pinion. The pinion, together with the overrunning clutch mechanism, is moved endwise along the armature shaft and into, or out of, mesh with the flywheel.
- **Dyer Drive** - is a special drive mechanism that provides positive meshing of the drive pinion with the flywheel, before the cranking of the starter motor armature begins. This action eliminates the clashing of pinion teeth with flywheel teeth, as well as, the possibility of broken or burred teeth on either gear.

- **Sprag Clutch Drive** - is constructed and operated similar to the overrunning clutch drive, except that a series of sprags replace the rollers between the shell and sleeve. The sprag clutch drive is used primarily on larger starting motors to carry the high torque required to turn over high-compression engines.

CHARGING SYSTEM - GENERAL

AC charging circuits have an alternator and a regulator. Most regulators are internal to the alternator. The alternator is really an AC generator. The generator produces AC current and then rectifies it to DC current through the use of diodes. Alternators are generally more compact than generators of equal output, and supply a higher current output at low engine speeds.

CHARGING SYSTEM - REGULATOR

The regulator in an AC generation circuit limits the alternator voltage to a safe, preset value. Transistorized models are used in many charging circuits.

CHARGING SYSTEM - THEORY

All charging circuits operate in three stages:

- **Starting** – the battery supplies all load current.
- **Peak Operation** – the battery helps the generator supply current.
- **Normal Operation** – the generator supplies all current and recharges the battery.

In a typical charging circuit, the battery starts the circuit when it supplies the spark to start the engine. The engine then drives the generator or alternator, which produces current to take over the operation of the ignition, lights, and truck accessory loads within the electrical system. It is important to remember that once the engine is started, the generator or alternator is the work horse' which gives current to the ignition and accessory circuits.

Most lift trucks incorporate an AC charging circuit, comprised of an alternator and voltage regulator. The alternator is the heart of the charging circuit. Basically, like a generator, the alternator converts mechanical energy into electrical energy. The initial energy produced is alternating current. The AC current is electronically converted to direct current using diodes.

As the engine operates, the alternator is rotated by a belt. A voltage is produced within the alternator by moving a charged field across a stationary conductor, thereby inducing voltage. With each revolution alternating current is produced. The alternator is either ON or OFF. It generates maximum current when it is ON and no current when it is OFF. The regulator switches the alternator between ON and OFF to get the average current needed to charge the battery. Alternator output is directly changed by engine speed and rotor field current.

A diode is an electrical device that will allow current to flow through itself in only one direction. When a diode is connected to an alternating current, it only allows the alternating current to flow through it in one direction, thereby rectifying it to direct current. The diode provides what is termed half wave' rectification of the alternating current. If the circuit only has one diode, the DC generation would be very limited. A diode bridge within the alternator is designed to extract maximum DC current from the produced alternating current.

Direct current from the diodes of the diode bridge flows to the alternator output terminal, sometimes called the BAT terminal. A capacitor between the BAT terminal and the electrical ground removes any remaining alternating current from the produced direct current. The capacitor also protects the diodes from high voltages.

The voltage regulator controls the alternator to charge the battery. The voltage is set by the manufacturer and is not adjustable. Battery voltage decreases as the starting circuit and other circuits use power from it. When the ignition switch is in the start position, the voltage regulator is energized. The regulator senses battery voltage and increases alternator output to charge the battery during various operating states of the electrical system.

Engine Fuel System/Exhaust and Emissions

INTRODUCTION

This section discusses LPG Fuel Systems, Exhaust and Emissions.

LPG FUEL PROPERTIES

LPG fuel is a distillate of crude oil, just like gasoline. LPG stands for Liquefied Petroleum' Gas. There are four grades of LPG fuel: HD5, HD10 (California), commercial propane, and commercial propane/butane mix. HD5 is for use in internal combustion engines. HD5 is a blend of mainly propane and butane. LPG is colorless and odorless in its natural form. For safety reasons, ethyl mercaptan is added, which has a distinct odor. LPG is heavier than oxygen. If there is a leak or accidental spill, the gas will settle in low lying areas, such as floor drains or maintenance pits.

LPG FUEL TANK

All types of LPG fuel systems include an LPG fuel tank. The tank is externally mounted on the truck. Most tanks are mounted above the counterweight in a bracket assembly. There are three types of tanks. A horizontal mount, a vertical mount and a universal mount. The universal mount is most widely utilized. The easiest way to determine which type of tank is installed on your truck is by looking at the orientation of the tank relief valve. If the valve is oriented at 90 to the tank, it is a horizontal mount only tank. If the relief valve extends straight out of the tank, it is a vertical mount only tank. If the valve is oriented at 45 it is a universal tank, which can be used in either a horizontal or vertical position. There are several components installed in the LPG tank. The tank shutoff valve is used to contain the LPG within the tank. It is installed in the liquid' port of the bottle. On all LPG fuel systems, the LPG is delivered in the liquid' state to the filter/lockoff. Personnel should always ensure tank that is being installed on the truck is using the liquid' port. The vapor port is not used on forklift fuel systems.

WARNING

The shutoff valve should be closed prior to disconnecting or connecting the quick disconnect fitting. It should also be closed when the truck is not being used.

The quick disconnect fitting is used to connect the truck fuel line to the tank shutoff valve. Always ensure fitting is completely hand tightened prior to opening the shutoff valve. Always ensure shutoff valve is closed prior to removing the quick disconnect. The fuel gauge indicates the fuel level within the tank. When the fuel level is at "FULL" the tank is actually only 80 percent full of LPG in its liquid state. The other 20 percent of the tank volume is used to allow for expansion of the fuel due to changes in the ambient temperature. The vapor port is used in LPG fuel systems which require the fuel to be delivered in vapor' form. This is not used on lift truck LPG fuel systems. There is typically either a cap or plug installed in this port. The liquid level indicator must be opened while the tank is being filled. Vapor is expelled from the indicator when the bottle has reached the 80 percent full point. At this point, the bottle filling operation must be halted. Filling the bottle to 80 percent allows the appropriate expansion volume within the bottle. The tank relief valve is installed in the tank to allow for pressure relief if the bottle is overfilled or if exposed to high temperatures.

WARNING

An alignment pin on the tank mount bracket and the alignment pin hole are used together to ensure the tank is properly installed on the truck.

If the tank is installed in a position other than its aligned' position, the pickup tube within the tank will not be in the proper orientation to ensure all the fuel in the tank is accessible. The tank is typically secured to the bracket using tank straps.

IMPCO SPECTRUM SERIES III FUEL SYSTEM

The IMPCO Spectrum Series III fuel system is manufactured by IMPCO Technologies, Inc. for use on class four and five cushion and pneumatic trucks which have the Mazda 2.0 and 2.2 liter engines. The system is termed closed-loop' because of a closed control' loop which senses the oxygen content in the exhaust and adjusts the fuel mixture to maintain an ideal ratio of air to fuel during all operating conditions.

The air-fuel ratio is the amount (in pounds) of air needed to burn a pound of fuel. The ratio is considered ideal when all of the oxygen and fuel will be used. The ideal ratio for LPG fueled systems is approximately 15.6 to 1. Additional components in the Spectrum Series III fuel system are two oxygen (O_2) sensors, an Engine Control Unit (ECU) and an Electronic Pressure Regulator (EPR).

FILTER, LOCK-OFF VALVE AND ELECTRONIC PRESSURE REGULATOR (EPR)

When the fuel tank is connected and the tank shutoff valve is opened, fuel under pressure and in its liquid state flows through an inline filter, the lock-off valve, then into the EPR. The inline filter has a replaceable element which removes contamination from the fuel prior to it entering the lock-off valve and EPR. The lock-off valve is managed by the Engine Control Module (ECU). The lock-off valve stops the flow of fuel to the EPR when the engine is not operating. High pressure liquid fuel is supplied to the EPR. The EPR is a combination vaporizer and pressure regulating device which is managed by the ECU. The EPR's regulator section reduces the fuel pressure and causes the liquid fuel to vaporize. Engine coolant is circulated through the EPR's vaporizer section to warm it and assist in the vaporization process. The EPR functions as a negative pressure two-stage regulator that is normally closed with the ability to supply additional fuel when commanded by the ECU.

Carburetor

The air valve carburetor is an air-fuel metering device and is completely self-contained. The carburetor is an air valve design, utilizing a relatively constant pressure drop to draw fuel into the carburetor from cranking to full load. The purpose of the carburetor is to mix the regulated fuel from the EPR with the proper amount of air for all engine operating conditions. The carburetor receives fuel through a fuel hose from the EPR. The EPR provides the proper amount of fuel to the carburetor for all engine operating conditions. There are no adjustments on this carburetor.

Oxygen (O2) Sensors

This system is a closed-loop type because of a closed control' loop which senses the oxygen content in the exhaust gases and adjusts the air-fuel mixture to maintain an ideal ratio of air to fuel during all operating conditions. The air-fuel ratio is the amount (in pounds) of air needed to burn a pound of fuel. The ratio is considered ideal when all of the oxygen and fuel will be used. The ideal air-fuel ratio for LPG fueled systems is approximately 15.6 to 1. There are two oxygen sensors in this fuel system. The pre-catalyst oxygen sensor is located upstream of the catalytic converter and the post-catalyst oxygen sensor is located downstream of the catalytic converter. Both oxygen sensors send signals to the ECU. The oxygen sensor signals are the primary inputs used by the ECU to maintain the ideal air-fuel ratio. By monitoring output from the sensor upstream and the sensor downstream of the catalytic converter, the ECU can determine the performance of the catalytic converter.

ENGINE CONTROL UNIT (ECU)

The ECU is a microprocessor which receives data from sensors fitted to the engine and fuel system and then outputs various signals to control the engine operation. It also performs diagnostic functions on the fuel system and notifies the operator of malfunctions by turning on a Malfunction Indicator Lamp (MIL). The ECU receives inputs from various engine sensors, such as engine coolant temperature, intake air temperature, manifold absolute pressure, cam position, oxygen sensors, and throttle position sensors. The ECU analyzes input sensor voltages and then controls fuel delivery and spark timing for various engine operating parameters.

CATALYTIC CONVERTER

The Three-Way Catalytic Converter uses a catalyst to convert HC (unburned fuel), CO, and NOx (created when the heat in the engine forces nitrogen in the air to combine with oxygen) into harmless compounds. The converter is often called a three-way catalytic converter because it helps in reducing these three regulated emissions. In the converter, the catalyst is coated onto a ceramic honeycomb that is housed in a muffler-like package attached to the exhaust pipe. The catalyst helps to convert carbon monoxide into carbon dioxide. It converts the hydrocarbons into carbon dioxide and water. It also converts the nitrogen oxides back into nitrogen and oxygen.

Engine Management

INTRODUCTION

The function and operation of the Ignition System and Electronic Throttle Control System are discussed here.

IGNITION SYSTEM

The Mazda engine uses a Distributor-less Ignition System (DIS). There are four individual ignition coils (one per cylinder). The ECU uses engine sensor information (engine speed, cam position, temperatures, etc.) to manage each ignition coil individually. The purpose of the ignition system is to create the spark, which ignites fuel, which in turn powers the engine. The ignition system includes the following components:

- Battery
- Ignition Coils (one coil per cylinder)
- Spark Plugs and Wires
- Engine Control Unit (ECU)
- Cam Position Sensor

The initial voltage source for the ignition system is the battery. The key switch turns on the ignition system when it cranks the engine. The ECU senses the engine speed and rotation angle from the cam position sensor and determines the proper cylinder and the proper time to command a spark. The ECU then sends a “trigger” command to the proper ignition coil (the ECU controls each of the four ignition coils individually). The ECU’s “trigger” command causes the ignition coil to open and close the primary circuit, causing the coil to produce a high voltage surge. This causes the spark plug, to which it the coil is connected, to produce a spark. The spark plug ignites the air-fuel mixture within each cylinder of the engine.

COMPONENTS - IGNITION COILS

The Mazda engine uses four individual ignition coils. Each ignition coil is assigned to an individual cylinder. Each ignition coil assembly contains the primary coil windings, secondary coil windings and the ignition coil driver circuitry. The ignition coil’s driver circuit receives a “trigger” signal from the ECU which tell it to send electrical energy from the primary coil windings to the secondary coil windings which produces the high voltage pulse necessary for a spark.

COMPONENTS - CAM POSITION SENSOR

The Cam Position sensor is a powered sensor that combines two sensors in one package. It outputs a camshaft position signal and a simulated crankshaft position signal. These signals are used by the ECU to determine the camshaft’s rotation angle relative to Top Dead Center position of the #1 cylinder. The camshaft position signal is used by the ECU to synchronize the fuel and ignition systems. The simulated crankshaft position signal is used by the ECU to calculate engine speed and synchronize the fuel and ignition systems.

BASE IGNITION TIMING

The base ignition timing should always be checked after ignition system servicing or maintenance on the Mazda engine. The base timing can be checked using a ignition timing light and referencing timing marks on the front crankshaft pulley. Refer to the maintenance service manual for proper base ignition timing check/adjust procedures.

COMPONENTS - IGNITION WIRES

The ignition wires carry high voltage from the distributor cap to the spark plugs. The wire is insulated and waterproof. There is typically a booted terminal end which engages the distributor cap and a boot connector end which engages the spark plug.

COMPONENTS - SPARK PLUGS

The spark plug ignites the air-fuel mixture in the engine cylinder. There is usually no current flow in an open circuit, however, if the opening in the circuit is small and a strong enough voltage is present, the circuit can still be completed. The strong voltage is able to force the current to jump' the gap, thus completing the circuit. This is the operating principle of a spark plug. Although the spark plug has no moving parts, each of its parts is designed for a specific purpose. For this reason, many types of plugs are available. The design of the cylinder head and the type of fuel used in the engine are determining factors in the type of plug used in a specific engine application. The spark plug electrodes are usually made of a metal alloy to withstand constant burning and erosion. The gap between the two electrodes is the prime factor in plug operation. This gap must be set to exact engine specifications. Generally, if the gap is too narrow, the spark will be weak and fouling, causing misfiring. If the gap is too wide, excessive loads will strain the coil at high speeds, resulting in misfiring. Always refer to the maintenance service manual for specific plug gap settings. The spark plugs are typically resistor' type plugs, having a resistor between the terminal and center electrodes. The resistor is used to avoid the static interference generated by the ignition circuit. Refer to the Parts Manual for the proper plug type and design for the specific engine installed in your unit.

FAULTY OR FOULED SPARK PLUGS

The first sign of a spark plug failure is engine misfire. Faulty plugs are not the only cause of engine misfire, nor are plugs usually the original cause, but when the engine misfires, check the condition of the plugs. A normal plug will have brown to grayish-tan deposits and a slight wear on the electrodes. This indicates good adjustment of the engine. Two main failures of the spark plug are plug fouling and eroded plugs. Fouling around the electrodes and tip can result from a lack of heat to burn off the deposits at the firing point. Eroded plugs are caused by too much heat at the firing point. An oil-fouled plug contains wet, oily deposits. This may mean that oil is getting into the combustion area. This can be caused by something as simple as overfilling the engine crankcase. Broken or poorly seated piston rings can also cause this condition. A carbon fouled plug has a dry, fluffy, black deposit on the electrodes. This type of fouling can be caused by too rich' of an air-fuel mixture or a clogged air cleaner. Reduced voltage from faulty ignition components can also cause this condition. A deposit fouled plug has a red, brown, yellow, and white powdery deposit on the electrodes, which is usually the by-product of combustion and comes from fuel and lubricating oil additives. These powdery deposits are usually harmless, however, they can cause intermittent misfire at high speeds or with heavy loads.

ELECTRICAL THROTTLE CONTROL SYSTEM

The Mazda engine has an electronic throttle body which is managed by the ECU. The electronic throttle body's main components are: throttle plate, drive motor and throttle position sensors. The electronic throttle body is mounted between the carburetor and the intake manifold. The ECU manages the electronic throttle body through "closed loop" control. The ECU commands the drive motor to actuate the throttle plate through a gear train and the position sensors provide feedback to the ECU. The ECU manages the electronic throttle body for all operating conditions (starting, low idle, maximum governed speed, intermediate speed control, etc.).

Engine Identification

To identify the type of engine used in your lift truc refer to Figure 9020-10-1 and Figure 9020-10-2.

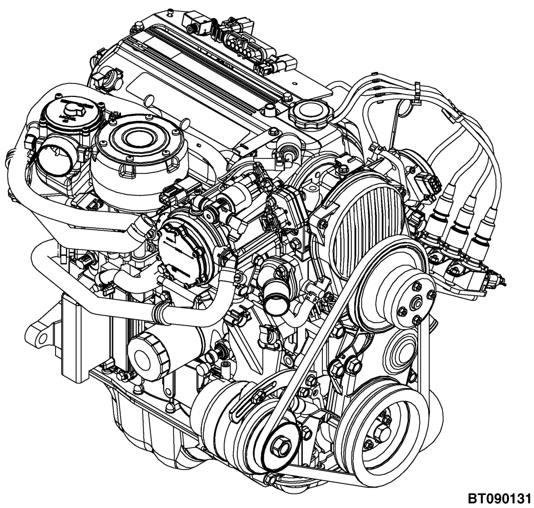


Figure 9020-10-1. Mazda LPG Engine

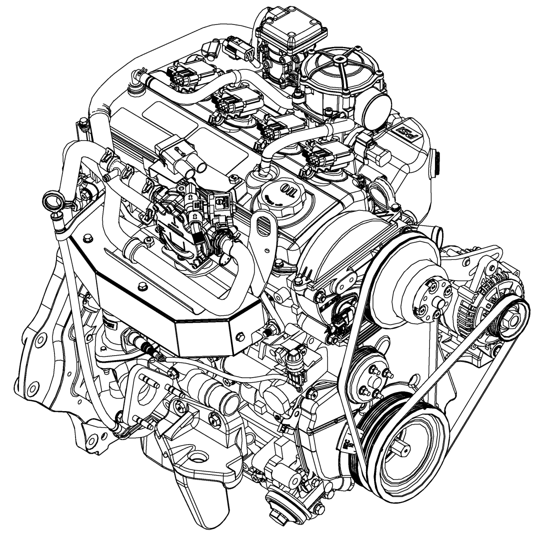


Figure 9020-10-3. PSI 2.4L LPG Engine

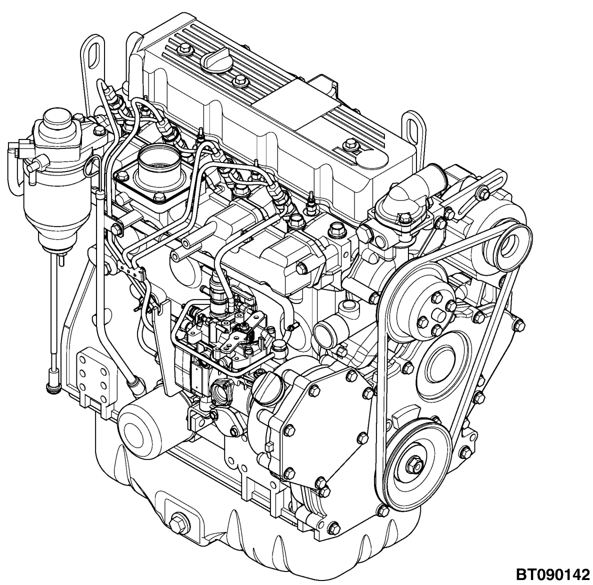


Figure 9020-10-2. Yanmar Diesel Engine

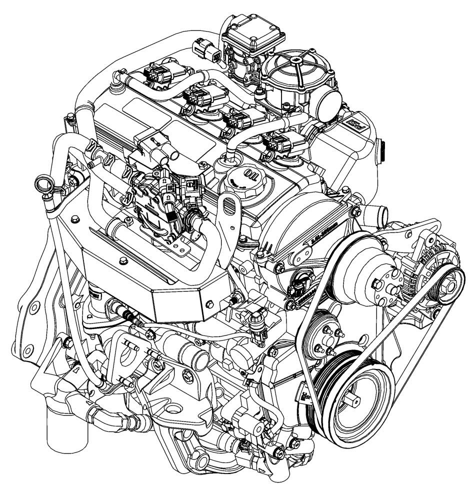


Figure 9020-10-4. PSI 2.0L LPG Engine

Cooling System

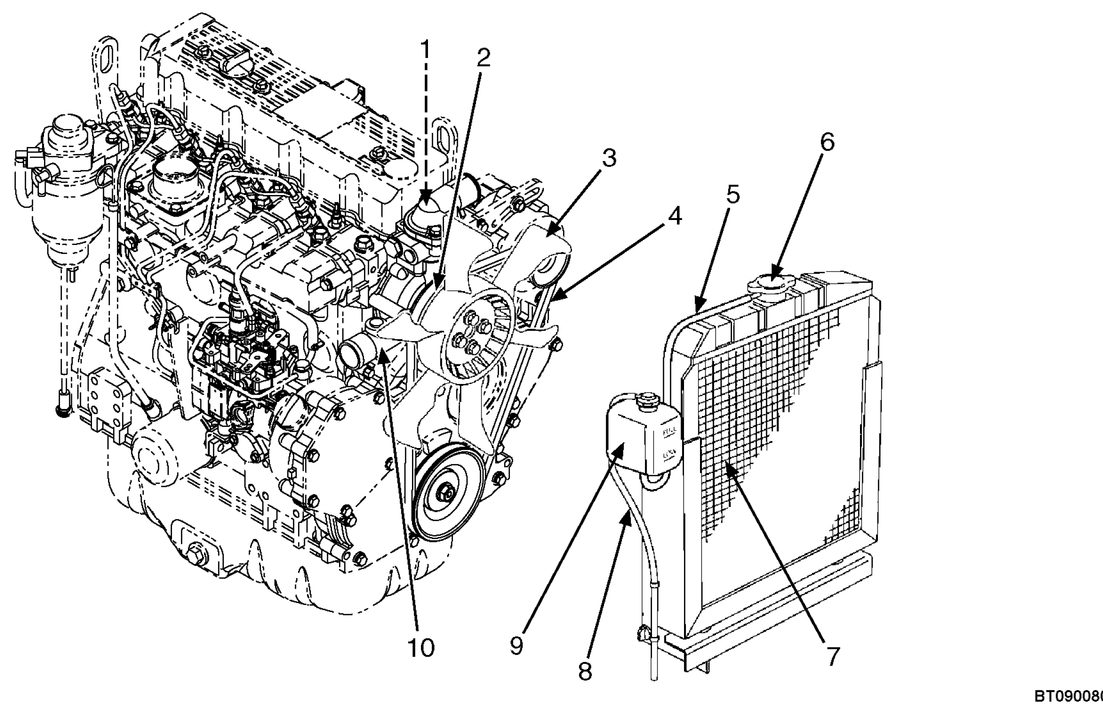
DESCRIPTION

The purpose of the cooling system is to control the operating temperature of the engine and transmission. A centrifugal engine coolant pump circulates coolant through passages in the engine block and radiator. A coolant-temperature sensor is installed in the coolant outlet fitting on the engine. As the coolant flows through the radiator, the fan moves air through the radiator to cool the system.

The cooling system has the following parts: radiator, coolant level sensor, coolant pump, thermostat, fan assembly, and fan belt.

RADIATOR

The radiator is the heat exchanger for the cooling system. The fan causes air to flow through the radiator and reduces the temperature of the coolant. The auxiliary coolant reservoir is connected to the radiator by a hose. As the engine gets hot, the coolant expands. During expansion, coolant moves from the radiator to the reservoir. When the engine stops, the coolant becomes cool and contracts. Coolant in the reservoir then flows back into the radiator. In this way, the radiator is kept full with coolant during normal operation. The radiator is also an oil cooler. Oil from the transmission flows through a second set of coils in the radiator tank to help reduce transmission oil temperature. See Figure 9020-10-5.



1. THERMOSTAT
2. FAN PULLEY
3. FAN
4. FAN BELT
5. HOSE
6. RADIATOR CAP
7. RADIATOR
8. HOSE
9. OVERFLOW BOTTLE
10. ENGINE COOLANT PUMP

Figure 9020-10-5. Typical Radiator and Fan Setup - Yanmar Diesel Engine Shown

Combination Cooler/Standard Radiator

The combination cooler is a unit that consists of two heat exchangers that are packaged together in a common framework. The combination cooler offers greater heat transfer capability for both the engine coolant and transmission fluid, since each fluid is cooled completely independent of the other. For both heat exchangers, the heat is transferred from the fluid to the air that is flowing through the cooler cores. This is not the case for a standard radiator with in-tank oil cooler. With this design, the heat from the transmission fluid is transferred into the engine coolant. This transfer of heat occurs after the engine coolant has already passed through the radiator core.

RADIATOR CAP

The radiator cap is a pressure-vent type that lets the pressure in the cooling system increase to 103 kPa (15 psi). The pressure in the system prevents vapor from forming in the coolant flowing to the engine coolant pump. This action maintains the efficiency of the engine coolant pump and performance of the cooling system. The increase in pressure also raises the boiling point of the coolant mixture to approximately 129°C (264°F) at sea level.

The radiator cap has a pressure valve and a vacuum valve. The pressure valve is held against its seat by a spring. The pressure valve opens when the pressure in the cooling system exceeds 103 kPa (15 psi). The vacuum valve is held against its seat by another spring. The vacuum valve opens to relieve the vacuum created when the coolant temperature decreases. This vacuum can cause the radiator top hose to collapse.

THERMOSTAT

The thermostat is a device that controls coolant flow by opening and closing to regulate coolant temperature. See Figure 9020-10-6.

The thermostat uses a wax pellet to control its operation. The wax pellet expands when it is heated and contracts when it is cold. When heated, the wax pellet pushes on the piston, causing the valve in the thermostat to open. As the wax pellet cools, it contracts and lets a spring close the valve. When the engine is first started and the coolant is cold, the thermostat remains closed. During this time, the coolant circulates through the engine, letting it warm quickly. As the engine becomes warm, the thermostat opens, letting coolant circulate through the radiator.

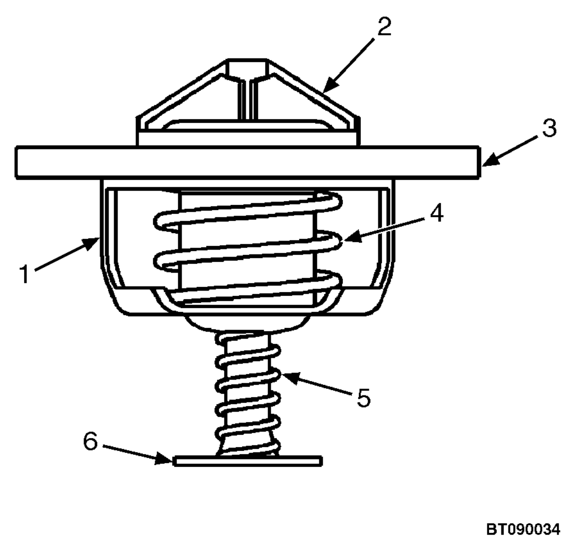
The opening and closing of the thermostat helps keep the coolant within the operating limits of the system. The same thermostat is used for summer and winter seasons. Do not operate the engine without a thermostat. The engine will take longer to warm up and can run improperly.

ENGINE COOLANT PUMP

The centrifugal-type engine coolant pump is installed at the front of the engine block. The inlet for the pump is connected to the bottom of the radiator by a hose. From the pump, coolant passes through the passages in the engine block to the top of the radiator.

FAN

The fan is used to provide airflow through the radiator at all engine speeds. The fan is a pusher type and is installed on a separate hub. The cooling fan is driven by a V-belt which is powered by the crankshaft V-pulley.



1. FRAME
2. FLANGE
3. RUBBER SEAL
4. SPRING
5. SPRING
6. SEAL

Figure 9020-10-6. Typical Thermostat

Mazda (LPG) Engine Controls

(IMPCO SPECTRUM SERIES III LPG FUEL SYSTEM)

Description

The key components of the Mazda LPG engine control system are the LPG fuel tank, Electronic Pressure Regulator (EPR), Carburetor, Electronic Throttle Assembly (ETA), Throttle Position Sensors (TPS), Heated Exhaust Gas Oxygen (HEGO) Sensors, Engine Coolant Temp (ECT) Sensor, Manifold Air Pressure (MAP) Sensor, Intake Air Temp (IAT) Sensor, Fuel Temp (FT) Sensor, Camshaft Position Sensor (CPS), Accelerator Pedal Position (APP) Sensor, Engine Control Unit (ECU) and a Three-Way Catalytic Converter.

Principles of Operation

The system operation is summarized as follows:

Propane is stored in the tank in a liquid form. With the tank valve open, liquid propane flows from the fuel storage tank through an inline liquid fuel filter and the fuel lock-off valve. Opening the fuel lock-off valve allows liquid fuel to flow into the Electronic Pressure Regulator (EPR). The liquid fuel is vaporized in the EPR's primary chamber by reducing it's pressure. Engine coolant is circulated inside the vaporizer to aid in fuel vaporization. The vaporized fuel pressure is further reduced when it enters the regulator's secondary chamber. The Engine Control Unit sends fuel pressure commands to the EPR so that it can maintain the proper fuel pressure based on the engine's operating conditions. The EPR regulates the fuel pressure in the secondary chamber by modulating the diaphragm that opens the valve to the secondary chamber with an electromagnetic actuator. Fuel is then supplied to the carburetor through a supply hose.

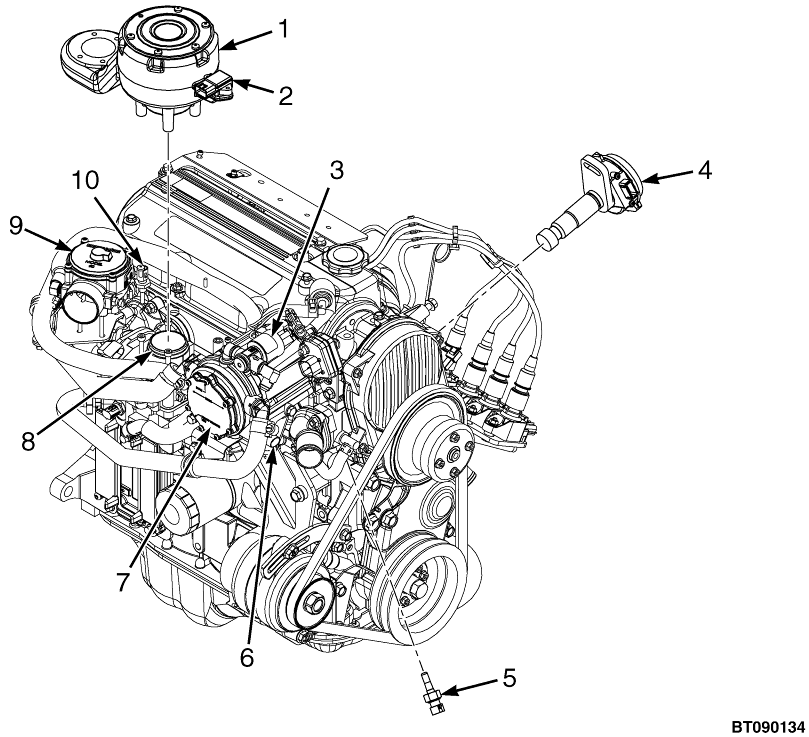
The ECU sends commands to the EPR to regulate the secondary fuel pressure based mainly on inputs from the cam position sensor which provides engine RPM, heated exhaust gas oxygen (HEGO) sensors, MAP sensor, intake air temperature (IAT) sensor, engine coolant temperature (ECT) sensor, and throttle position sensors (TPS). Also, the ECU controls the ignition timing to reduce emissions, minimize fuel consumption, and increase engine power. See Figure 9020-10-7.

After combustion, the exhaust gases pass over the pre-catalyst oxygen (O2) sensor and through a three-way catalytic converter. The three-way catalytic converter aids with reaction of the spent exhaust gases to reduce tail pipe emissions of CO, HC, and NOx. After the exhaust gases exit the catalytic converter they pass over the post-catalyst oxygen sensor. It is used to monitor the three-way catalytic converter's efficiency.

The electronic throttle assembly is installed between the carburetor and the intake manifold and is controlled by the ECU. It is composed of a controller motor, gear set, throttle valve and position sensors. The ECU drives the controller motor and adjusts the opening and closing angle of the throttle valve based feedback from the position sensors. The electronic throttle assembly controls engine idle speed, maximum governed speed and all intermediate speeds.

FUEL TANK

The fuel tank shown in Figure 9020-10-8 is the reservoir for the LPG system. The fuel tank keeps the fuel in liquid condition. The pressure of the fuel is 1.7 MPa (250 psi) when the tank is full at a temperature of 27°C (81°F). The tank has a pressure relief valve that is set at 3.4 MPa (490 psi). The inlet tube for the pressure relief valve is in the vapor area at the top of the tank. The tank has a fuel gauge that measures the percentage of fuel in the tank. A liquid level valve near the pressure relief valve is used to indicate the maximum liquid level permitted. The tank is filled until liquid fuel flows from the liquid level valve. One end of the outlet tube inside the tank is near the lower surface of the tank. The other end of the tube is fastened to the outlet port. A shutoff valve is connected to the outlet port of the tank. The shutoff valve can prevent fuel from leaving the tank when the outlet line is disconnected. A quick-disconnect fitting is installed for easy tank removal. The tank has a guard for the valves and fittings. The guard has a hole for the alignment dowel on the mount. The tank is fastened to the lift truck by metal straps with latches. A fuel pressure sensor in the line from the tank energizes an indicator light on the instrument panel when the tank is nearly empty and the fuel pressure decreases.



1. AIR BOX
2. MANIFOLD ABSOLUTE PRESSURE (MAP) SENSOR
3. LPG LOCK-OFF VALVE
4. CAMSHAFT POSITION SENSOR
5. ENGINE COOLANT TEMPERATURE (ECT) SENSOR
6. FUEL TEMPERATURE SENSOR
7. ELECTRONIC PRESSURE REGULATOR (EPR)
8. ELECTRONIC THROTTLE BODY
9. CARBURETOR
10. INTAKE AIR TEMPERATURE (IAT) SENSOR

Figure 9020-10-7. LPG Control System Component Location