The Commercial/military Marinediesel Mechanics subcourse, part of the F.A.C.T #B Skill Level 3 subcourse, is designed to teach the knowledge necessary to understand principles of operation, identify types and components, and perform maintenance and troubleshoot internal compression ignited combustion engines. Information is provided on engine inspection, and lubrication and cooling systems. The subcourse is presented in four lessons, each lesson corresponding to a terminal objective as indicated below.

**Lesson 1: FUNDAMENTALS OF COMPRESSION-IGNITION ENGINES**

**TASK:** Describe the fundamentals of compression-ignition engines.

**CONDITIONS:** Given information about the construction and principles of operation of two- and four-stroke-cycle compression-ignition engines and the different types of compression-ignition engines.

**STANDARDS:** Solve 70 percent of the multiple-choice items covering fundamentals of compression-ignition engines.

**Lesson 2: ENGINE INSPECTION**

**TASK:** Describe the inspecting, testing, and troubleshooting procedures for engines.

**CONDITIONS:** Given information about procedures for inspection of the engine and use of test equipment.

**STANDARDS:** Solve 70 percent of the multiple-choice items covering engine inspection and testing.
Lesson 3: ENGINE LUBRICATION SYSTEMS

TASK: Describe the principles of engine lubrication and crankcase ventilation systems.

CONDITIONS: Given information about principles of operation and maintenance of engine lubrication and crankcase ventilation systems.

STANDARDS: Solve 70 percent of the multiple-choice items covering engine lubrication and crankcase ventilation systems.

Lesson 4: ENGINE COOLING SYSTEMS

TASK: Describe the principles of engine liquid-cooling systems.

CONDITIONS: Given information about the fundamentals of liquid-cooling system components and inspecting, testing, and repairing representative engine liquid-cooling systems.

STANDARDS: Solve 70 percent of the multiple-choice items covering engine liquid-cooling systems.
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SUBCOURSE CONTENT

This subcourse contains four lessons, each related to Commercial/Military Marinediesel engines. An introduction presents an overall view of the subject. Each lesson then covers a specific topic pertaining to fundamentals or maintenance of internal combustion engines. Each lesson is followed by a practice exercise. An examination covering all four lessons is provided at the end of the subcourse.

Supplementary Requirements

Materials Needed. You will need a No. 2 pencil and paper to complete this subcourse.

Supervisory Assistance. No supervision is needed for completion of this subcourse.

References. No supplementary references are needed for this subcourse.

GRADING AND CERTIFICATION INSTRUCTIONS

INSTRUCTIONS TO THE STUDENT

This subcourse has an examination that consists of multiple choice test items covering two lessons. You must score a minimum of 70 percent on this test to meet the objectives of the subcourse. Answer all questions on the enclosed ACCP examination response sheet. After completing the examination, place the answer sheet in the self-addressed envelope provided and mail it to the Marinediesel Institute for Professional Development (MIPD) representative for scoring. MIPD will send you a copy of your score.

For on site training a representative of MIPD will be on location to assist.

Eight credit hours will be awarded for successful completion of this subcourse.

Often the maintenance needed on an engine requires a lot of knowledge and very little physical effort. This is the kind of repair work that separates the good mechanics from the bad ones very quickly. Without the proper knowledge, mechanics may work for hours before they correct a simple problem. Sometimes they may never get an engine running correctly. A good mechanic that understands engines can repair one in a few minutes. This subcourse is written with the intention of starting you on the correct road to becoming a good mechanic. In it we describe the different engine parts and how they operate together to make an engine run the way it should.
LESSON 1 FUNDAMENTALS OF COMPRESSION-IGNITION ENGINES

TASK
Describe the fundamentals of compression-ignition engines.

CONDITIONS
Given information about the construction and principles of operation of the two- and four-stroke-cycle compression-ignition engines and the different types of compression-ignition engines.

STANDARDS
Solve 70 percent of the multiple-choice test items covering fundamentals of compression-ignition engines.

REFERENCES
TM 9-8000

Learning Event 1:
DESCRIBE PRINCIPLES OF OPERATION AND CONSTRUCTION OF FOUR-STROKE-CYCLE ENGINES

FOUR-STROKE-CYCLE OPERATION
The four-stroke-cycle diesel engine is constructed about the same as the four-stroke-cycle gasoline spark-ignited engine. The working parts of a diesel engine are made heavier than the gasoline spark-ignited engine. This is because the diesel engine has much higher cylinder pressures. Early diesel engines were made too heavy for use in smaller craft. These heavy diesel engines ran at slow speeds and were used for large ships and power-generating stations.

As time progressed, new metals were developed that were stronger for their weight, and industry soon found it could build a lighter diesel engine. This lighter diesel engine could run at speeds high enough to work well in the automotive and light marine field.
The intake and exhaust systems of the four-stroke-cycle diesel engines are similar to those of gasoline engines. One big difference is that diesel engines do not have carburetors which are found in the intake system of gasoline engines. All present four-stroke-cycle diesel engines have at least one intake and one exhaust valve per cylinder, but some may have two exhaust valves and two intake valves. Most diesel engines have intake and exhaust manifolds with one inlet or outlet port per cylinder. Many compression-ignition engines use a turbo or
supercharger, which is an air blower located in the intake system. It increases the horsepower output of the engine.

Many four-stroke-cycle diesel engines use the turbocharger. The turbocharger is driven by exhaust gases, thereby using some of the energy that is normally wasted. An example would be the VGT series engines.

A turbosupercharger consists of two impellers mounted on the same shaft. The compressor impeller is on one end of the shaft and the turbine impeller on the other. Each impeller works or spins in separate sections of the housing, with seals between to prevent leakage from one housing to the other. The impellers have a series of straight or curved vanes that act much like a fan. The turbine impeller and housing is mounted in the engine exhaust system and is driven by the pressure from the escaping exhaust gases. The compressor impeller is mounted in the air intake system and turns with the turbine, forcing air into the cylinders.

The blower increases normal air pressure and aids in forcing air into the cylinder and the burned gases from the cylinder. It is lubricated by the engine lubrication system.

Most high-speed diesel engines use the full-force oil feed system. An oil pump mounted in the crankcase is driven by gears and shafts. The pump picks up oil from the sump (oil pan) and forces it under pressure through drilled passages to all the working parts of the engine.

Most compression-ignition engines use an oil cooler. The oil cooler is a series of tubes mounted in a raw water passage of the engine cooling system. As the hot lubricating oil passes through these tubes, the heat is transferred into the cooling water.

Compression-ignition engines have fuel injection systems. Although many types of fuel injection systems are used, they must all perform the same functions. These functions are first, to put the fuel under very high pressure (or to pressurize); second, meter or measure an exact amount of fuel for delivery; and third, to inject this fuel into the combustion chamber at the proper time.

Most compression-ignition engines use a governor with the fuel injection pump. The governor controls the maximum (top) engine speed and aids in maintaining a constant operating speed. The operating speeds and power output of the engine are controlled by changing the amount of fuel that is injected into the combustion chamber.
The shapes of the combustion chambers in compression-ignition engines have changed as time has passed. In the open-type chamber, fuel is injected directly into the cylinder itself. This type is used on Marinediesel VGT and TSC models.
The turbulence chamber (Lanova-divided type) is used in smaller, high-speed engines.

This is a type of pre chamber combustion system and is used on all MD 6.5L engines.
The precombustion type of chamber is also used in the smaller, high-speed engines. These chambers are thought to have features that improved the burning of fuel at high engine speeds. Fuel is injected into a smaller ignition chamber to improve burning of fuel. Later, it was learned that as the fuel injectors were improved and engines were built with higher compressions, the open-type combustion chamber worked well at all engine speeds. All Marinediesel 6.5L engines use this type of combustion chamber.

Most of the present high-speed compression-ignition engines use a cold-weather starting aid. This may be a heating element located in the combustion chamber or in the intake manifold. The starting aid located in the intake manifold preheats the air before it enters the engine cylinder (VGT/TSC cold weather option). The combustion chamber heating element directly aids in igniting the fuel-air mixture.

Let's go through the operations of a four-stroke cycle of a diesel compression-ignition engine. By comparing the diesel cycle with the gasoline cycle you will learn just how the four-stroke-cycle (diesel) works.
During the intake stroke (downward movement of the piston), the intake valve is open and air enters the cylinder around the intake valve. With no carburetor and throttle valve, the cylinder fills with air whether the engine is idling or running wide open.
During the compression stroke, the piston moves up with both valves closed. This upward movement squeezes the air into a very small area. This is a much smaller area than is used in the same size gasoline spark-ignited engine. Squeezing the air causes it to get hot, reaching a temperature of 800°F to 1,000°F at about 500 PSI. Just before the piston reaches the end, or top, of the compression stroke, fuel is injected into the hot air in the combustion chamber by the injector nozzle. The fuel is ignited by the hot air and then burns.
As the piston starts down on the power stroke, the burning fuel is now producing extreme heat. The heat expands the gases in the cylinder which pushes down on the piston with great force. Just before the piston reaches the bottom of the power stroke, the exhaust valve opens. The burned gases in the cylinder, still under some pressure, start to rush out by the open exhaust valve.
Thanks to the flywheel, the crankshaft starts the piston moving up on the exhaust stroke. The upward movement of the piston pushes the burned gases out through the open exhaust valve. Just before the piston reaches the top of the stroke, the intake valve opens and clean air rushes in. This forces any burned gases left out through the exhaust valve. This is called scavenging the cylinder. The exhaust valve closes and the piston is then pulled back down by the crankshaft and flywheel, and the intake stroke starts the cycle once again.
PRACTICE EXERCISE

1. What are the two types of combustion systems mainly used in diesel engines?
   a. Two- and four-stroke cycle
   b. Compression-ignition and spark-ignition
   c. Pre chamber and open type combustion chamber

2. Which cylinder arrangement is used in the present Marinediesel diesel engines?
   a. In-line and V-type
   b. In-line only
   c. V-type only

3. Superchargers are used on compression-ignition engines to
   a. Decrease the combustion chamber temperature.
   b. Decrease detonation knock.
   c. Increase the engine horsepower.
LESSON 2 ENGINE INSPECTION TASK

Describe the inspecting, testing, and troubleshooting procedures for engines.

CONDITIONS

Given information about procedures for inspection of the engine and use of test equipment.

STANDARDS

Solve 70 percent of the multiple-choice test items covering engine inspection and testing.

REFERENCES

TM 9-8000

Learning Event 1:
DESCRIBE VISUAL AND OPERATIONAL INSPECTION TECHNIQUES

When you need to repair your automobile, lawnmower, shotgun, or anything else, your first thought is probably the cost. This is good thinking. Why should you spend more money repairing an item than the item is really worth? The same is true with military equipment. How can we be sure of the repair cost of an item? Well, it is very simple. First, you must decide what is wrong and then what parts need repairing or replacing. Time is also something else that must be taken into account; your time is surely worth something. All of these points add up to the cost of repairing an item. Then, you must compare the value of the item to the cost of repair and decide whether to repair the item or buy a new one. Of course, the availability of repair parts and the time involved will also affect your decision. We do this sort of thinking all our lives and being in the military service does not change things very much.

How do we arrive at the right decision when it comes to a vessel engine? By performing an inspection of the engine. By this means, we can locate the trouble and decide what parts are needed and how long it should take to do the job, and only by this means can any of us be good mechanics.

There are ways for us to inspect an engine, or anything else, that will ensure we do a good job. If you are like most people, when you think of an inspection the first thing you imagine is inspecting by the use of your eyes. Really there are other means that ensure a complete job is being done. They are touching, smelling, and hearing. All these methods coupled together will guarantee a complete job of any inspection.

When inspecting an engine or a vessel, the inspector must use a system that permits little or no chance for faults to go undetected. Mechanics do not perform inspections in exactly the same manner. Moreover, each mechanic will vary slightly the system used on different types of vessels to make it suit the arrangement of the engine itself. After you have inspected a few vessels, you will, no doubt, develop some ideas of your own on how to go about an inspection. The inspection of any piece of equipment is the first and most important step in maintenance operations. Therefore, you must develop your own system soon. In the meantime, you can inspect engines using the procedures outlined in this lesson.
RECORD ALL FAULTS

It is important that all the things that need to be repaired, replaced, or adjusted be written down so they are not forgotten. A record of them must be made on Form 2404 (Equipment Inspection and Maintenance Worksheet). Entries on the form can be made by the mechanic while performing the inspection. Form can be requested by MD.

VISUAL INSPECTION

Look the engine over first before you attempt to operate it. Here are some things you should look for.

Oil Leaks

When you look for oil leaks, start on one side or at any given point on the engine. Then work completely around, under, and over the entire engine. Make sure you do not miss a spot where oil may leak.

Oil leaks are most likely to appear where gaskets and oil lines connect to or touch other parts. Some places to pay particular attention to are the valve covers, oil pressure sending units and safety switches, oil filter mountings, all oil lines, and the crankcase oil pan. Keep in mind there is no place on an engine where oil is supposed to leak.

You may ask, "Why should I be so concerned with oil leaks?" Well, the loss of oil cuts down on how far you can travel with a vessel before you have to stop for maintenance or service. Another reason is that dirt will stick to oil and when oil and dirt cover an engine, the engine will overheat. An oil and dirt mixture will burn, so it also gives fire a place to start. Therefore, you must be thorough; make sure all oil leaks are seen and recorded, and then begin inspecting for other faults.

Oil Level

Before inspecting something other than oil, be sure you check the oil level in the crankcase. Usually, the main reason anyone checks the oil level with the dipstick is to find out if there is too little or too much oil in the crankcase. But, when inspecting an engine, there are other reasons too.

Suppose that the oil level is too high and has a milky appearance. The dipstick may also be rusty or show drops of water. All of these things are caused by water getting into and mixing with the oil, making it unfit for use. This means that you will have to find out how the water got into the crankcase, which may be through a leaking head gasket or a cracked engine block or head.

On other occasions, you may find that the oil on the dipstick looks very dark and feels like it has sand in it. This could be caused by the oil not being changed regularly and may indicate more serious trouble, such as excessive wear of engine parts.

Coolant Leaks

Looking for coolant leaks is like checking for oil leaks; make sure all points are covered. In fact, you can combine these two checks and look for both coolant and oil leaks as you move around the engine. Be sure to include the heat exchanger and all connecting hoses when looking for coolant leaks.
Most of the time, coolant leaking onto hot engine parts, such as the cylinder block, can be detected by rusty colored streaks in the area of the leak. The coolant runs onto the parts and, due to the heat, it boils away leaving a rusty stain. Be sure to look for stains like this where the head and the block join. Sometimes this is the only way a head gasket leak is discovered.

Some coolant leaks will only show up when the engine is running or after it has been warmed up. When the engine is running and warm, the coolant is under pressure and may be forced out through small holes where it may not leak otherwise. You must be very careful when inspecting an engine that is running to prevent injuring yourself on the belts, or other moving parts.

**Accessories**

Check the mounting of all accessories for loose, cracked, and missing hardware, such as brackets, nuts, bolts, and washers. Just normal operation, not to mention travelling in rough seas, will cause nuts and bolts to loosen and often fall completely off the engine. Make sure a note is made of all loose and missing bolts and nuts so they are taken care of before they cause more damage.

**Engine Block**

During all phases of engine inspection, look for signs of overheating, such as holes in the engine block, cracks in the block, and leaking water jacket plugs. Check the heat tabs on the back of the cylinder heads that are designed to detect overheating. Any of these items can either cause the engine to be unsuitable for repair or indicate more damage that you cannot see. Bent or damaged parts attached to the engine indicate that a closer inspection of the engine block is required. For instance, mounting pads or bolt holes may be damaged.

**Engine Starting**

Does the engine start within the first few seconds of cranking? The vessel's batteries can only operate the starter system for short time before they run down. Also, cranking the engine for long periods will overheat the starter motor causing damage to it. If the engine is too hard to start, an engine tune-up may be needed. Then again, the cause may be the engine is cranking too slow due to a faulty starter system, undersized battery cables or batteries that are partially discharged. On the other hand, the piston rings may be worn or the valves may be leaking so the compression pressures are too low.

**Oil Pressure**

Once the engine starts, check the reading on the oil pressure gage right away. If the oil pressure gage does not show pressure immediately, stop the engine and determine the cause before going any farther. Operating the engine without oil pressure will ruin it in just a short time.

When the engine is cold and is first started, the oil pressure will be high because the oil is thick and does not flow easily. Then, as the engine and oil warm up, the oil gets thinner and the pressure gets lower. The normal oil pressure for each engine is listed in the technical manuals for the particular engine and for the particular type of oil being used. The oil pressure specifications listed always pertain to readings that are obtained with the engine at operating temperature. Make notes of oil pressure readings that do not agree with the specifications in the proper technical manual.

Do not be too hasty in deciding the cause of faults if the oil pressure reading is not correct. The lubrication system may be all right and the gage could be at fault. Look for simple things first, such as a loose wire,
components not grounded properly, and missing nuts and bolts. Little things are the problem more often than major ones.

**Noises**

Particular attention should be paid to unusual operating noises when the engine is cold and first started, as this is when they are most likely to occur. Most noises, especially engine knocks, are caused by excessive clearance between parts that work together. As the engine warms up, parts expand, reducing operating clearances and noises. Here are some of the noises that you are expected to recognize as being uncommon. Keep in mind that a diesel engine will make more knocking sounds when it is cold.

A piston (wrist) pin knock. Loose piston pins will generally knock louder when the engine is not operating under a load. A piston pin knock is sometimes mistaken for a connecting rod knock although the pin knock is not as loud. If it is possible to adjust the exhaust valve so that it stays open all the time, the pin knock will double up so it makes twice the number of sounds.

The connecting rod knock is caused by excessive clearance between the connecting rod bearing inserts and the bearing surface of the crankshaft throw. It makes a loud, sharp knock while the engine is running at a constant speed without a load. You can detect the faulty connecting rod bearing by disconnecting and connecting the injector lines one at a time. When you disconnect the injector line from the cylinder with the loose rod bearing, the knock will go away or at least change a great deal.

Loose main bearings on the crankshaft cause a heavy, dull, thud type noise which is usually worse with the engine loaded. Loose connecting rod bearings or main bearings will usually cause low oil pressure. This low pressure will be more noticeable at slow engine speeds. This is because the oil pressure leaks off past the loose bearing, and at slow engine speeds, the oil pump turns too slow to pump enough oil to maintain the proper pressure. At higher speeds, enough oil is pumped to overcome the leak and build up the oil pressure. If we have a sharp knock or a dull thud sound and the oil pressure is low, the connecting rods or main bearings are worn.

A piston slap usually sounds off only when the engine is on a pull. Like the connecting rod, disconnecting the injector line to the affected cylinder will generally stop the knock. Pistons have been known to knock quite loud when the engine is cold, then the noise completely disappears after the engine warms up.

Water pumps sometimes make noises that are hard to locate. It may make a grinding noise, may sound like marbles rolling around in a tin can, or may be a high-pitch whistle. One way to find out if a noise is caused by the water pump is to remove the water pump drive belt. But you must keep in mind that the same belt may drive other parts, such as the generator, which could be the noise maker. If this is the case, lay your hand on the components and feel for the vibration that is making the noise. If the parts are hard to reach, use a metal bar or a stick for a sounding bar. To do this, place one end of the sounding bar against the suspected noise maker and touch the opposite end of the bar to your ear.

If the operating clearance between the valve stem and its operating linkage is too great, there will be a tapping noise each time the valve opens. The noise remains the same regardless of the load on the engine. But the tapping will get faster and louder as engine speed increases. This noise can be easily stopped in a few minutes, in most cases, by an adjustment. MD engines use hydraulic lifter and if the lifter gets stuck or clogged up you will get the same or similar noise. Can you imagine how much the unnecessary cost would be if you or someone else were to mistake valve noise as being a loose rod or main bearing? This is why a mechanic with a lot of experience will sometimes get other mechanics to listen to a noise in an engine. Then they talk it over before deciding what the trouble is. Any noise that the engine does not normally make should be investigated. Find out
where the unusual noise is coming from. Then by using your knowledge of the construction and operation of the engine and referring to technical manuals, decide what is causing the noise.

**Engine Temperature**

By the time you have run an engine long enough to check it out for noises and pressure leaks in the coolant and lubrication systems, the engine should be warmed up to its normal operating temperature. Check the temperature gage reading; then look in the maintenance manual to see what the normal operating temperature is for the engine you are working on. Generally, 70-80°C (180°F) will be the normal operating temperature for marine engines.

If the temperature gage pointer is at the very bottom or top of the scale, either the gage or wiring is probably bad. If you suspect that a gage is faulty, check its reading with an antifreeze hydrometer. This instrument is normally used to check the strength of the antifreeze solution in the cooling system. But, it also has a thermometer to indicate the temperature of the coolant. By filling the hydrometer with coolant from the radiator, the coolant temperature will be shown on the thermometer. Compare this reading with the temperature gage reading. Any big difference in reading will indicate that the temperature gage is not reading correctly.

When you remove the heat exchanger cap to use the hydrometer, be very careful. The coolant expands as the engine warms up, so pressure builds up in the cooling system. Removing the heat exchanger cap lets the pressure escape. If the engine happens to be very hot, boiling water and steam can fly out past the cap and scald you seriously.

On the other hand, if the engine is warm and no pressure escapes when the heat exchanger cap is released, there is probably a leak somewhere in the cooling system. If you found no water leaks, the pressure may have leaked above the water level. One place it can do this is through either one of two valves in the heat exchanger cap. Both valves are held closed by a spring. One relieves the system of excess pressure, while the other valves allow outside air to enter the heat exchanger after the engine is stopped and the water cools off.

If the engine actually gets too hot, it could be caused by some internal problem, such as a thermostat or a leaky head gasket, but you should look for more simple faults first. For instance, is there anything that reduces the amount of raw water flow to the heat exchanger? These tubes inside the heat exchanger collect heat from the fresh water passing through the heat exchanger, then raw water or sea water cools the tubes. So, inspect the heat exchanger core for broken tubes or being stopped up with debris or salt buildup from the sea water system. Anything that reduces water flow must be corrected before doing a lot of other repair work in an attempt to correct overheating problems. Pressure testing the heat exchanger is recommended.

**Sea trial**

If the condition of the engine will allow you to operate it, a sea trial should be performed. Some of the questions about engine operation that a sea trial should answer are: does the engine develop full power? Does it accelerate properly? Are there any unusual noises as the engine is operated under different load conditions? Does it run smoothly? Does it smoke excessively?

**Exhaust**

The color of the smoke coming out the exhaust can be a clue to the cause of some engine troubles. Have the driver speed up and slow down the engine while you watch the exhaust. If the engine is running normally and is at operating temperature, the exhaust should be clear or a hazy gray/white. It may be white if the engine is cold.
The color of the smoke may be slightly black as the engine is speeded up, but, when run at a steady speed, the blackness should disappear.

If the blackness does not go away, the fuel is not burning properly. The trouble could be in the air intake system or boost system (supercharger). The vessel should go to your support maintenance if the problem exists after you have checked all of the things you should check, such as the air cleaner, belt system of the supercharger etc.

If the smoke has a blue color, oil is reaching the combustion chamber. This could be caused by bad rings, worn intake valve guides, or oil leaking through the head gasket. In any case, the vehicle should go to your support maintenance for more checks.

If the engine is warmed up and the exhaust smoke is white, water is getting into the combustion chamber. This could be caused by a leading head gasket or a cracked head or engine block. This is also a job for your support maintenance.

The exhaust can also provide a clue if one or more cylinders are not firing. Place your hand about 3 inches from the end of the tail pipe and in line with the exhaust gases as they leave the pipe. The pressure of the gases against your hand should be almost steady, with a slight increase every time a cylinder fires. If a cylinder fails to fire, you can notice it by a drop in the pressure against your hand.

Learning Event 2:
DESCRIBE COMPRESSION-IGNITION ENGINE TESTING PROCEDURES

Thus far, we have been discussing what we should look or listen for when inspecting an engine. Suppose that during the inspection you find one or more things wrong with the engine. Now what do you do?

What you will do depends on a number of things. Some of these are: Just what is your job? Are you just to inspect? Are you also supposed to repair and adjust? What did you find wrong and should there be more checks made to confirm your findings? What tools and equipment do you have? All these things and many others will determine what you will do.

During this part of the lesson, we are going to assume you have the time, tools, and equipment that you need. Also, we are going to try to forget that many of you will be working in harsh conditions. This will have an effect on what you do and how you go about it.

The testing procedures we will be discussing apply only to compression-ignition engines. Most compression-ignition engine problems can only be tested at intermediate support maintenance, so we will not cover them here.

COMPRESSION TESTING

Suppose during the inspection of an MD300SC engine, you find the engine does not develop as much power as it should. The engine may need to be replaced, but it could also be a lot of other things too. More tests should be made to find out for sure. Most often the problem is in the fuel or boost/intake system. Since the tests on these systems are covered in the lessons on fuel and boost system, we will consider tests on the engine alone here. Engine problems that could cause a lack of power are worn rings, leaking valves, and head gasket leaks. Measuring the amount of pressure the cylinders build up on the compression strokes will tell us if these items are bad.
Before making a compression test, run the engine until it is at normal operating temperature. Ensure the batteries are fully charged and the starter system is in good working order. Make the test while cranking the engine. If it does not crank as fast as it should, the compression reading will be low. Next, blow any dirt from around the glow plugs with compressed air and remove the plugs. Now, ensure that the air filter is clean and the belt system is fully operational. This is so the pistons can draw in a full charge of air on each intake stroke.

Obtain a compression gage from the toolroom and make the compression test. To do this, screw in the adapter plug on the compression gage into the glow plug hole of the No 1 cylinder. If possible have someone else crank the engine with the starter. Record the highest reading the gage reaches. Release the pressure trapped in the gage by pressing a relief valve on the gage, so the gage pointer returns to zero. Repeat this test on each cylinder. Each cylinder should reach its highest reading in about the same number of crankshaft turns.

Compare the compression pressure of the cylinders. Normal readings of the MD300SC engine should be 23 bar or higher. There should not be more than 2 bar between the lowest and highest cylinder. If the readings are within the above specifications, the trouble is somewhere else.

Low compression readings of the same amount on two cylinders that are side by side, say No 2 and 4, indicate a leaking head gasket. The head gasket would be allowing the compression pressure to leak from one cylinder to the other. This may be caused by improperly tightened cylinder head bolts. Torque the head bolts according to the manual, being sure to tighten them in the recommended sequence (order). After tightening the bolts, check the compression pressure again. If the pressure is still low on the two cylinders, the head gasket is probably faulty and should be replaced.

If the rings are worn or the valves leak, the compression reading may be low on all or any number of cylinders. To determine which is at fault, put about one squirt of engine oil in the bad cylinder on top of the piston. Retest the compression. If the rings are worn, the oil makes them seal better and a higher compression reading is obtained. If the reading remains about the same, the valves are probably leaking. In the event of leaky valves, their operating clearance should be adjusted and the compression retested. If there is an issue with the rocker arm, pushrod or lifter, this may correct the problem.

**INTAKE MANIFOLD PRESSURE TEST**

Knowing the compression of engine cylinders is very useful in determining engine condition, but this is not the only test you can make for this purpose. You can also measure the amount of suction or pressure that the cylinders have on the intake stroke. This test is only valid for turbo or supercharged engines.

**Pressure Gauge**

The pressure gage that you will be using has a scale and a needle pointer like the compression gage. Each mark on the scale may stand for 1 psi or 0,1 bar depending on the gauge.

**Connecting the Gauge**

The pressure reading is obtained by connecting the pressure gage to the intake manifold on the back of the engine under the brass lid for the intercooler and then operating the engine. Recall that the intake manifold is a common pipe that connects to all of the cylinders. Almost all engines contain some sort of a plug or connection in the intake manifold. Remove the plug or fitting and replace it with a suitable adapter from the pressure gage kit and connect the pressure gage.
Pressure Readings

Start the engine. When it has run long enough to reach operating temperature, look at the pressure reading. Normal pressure readings will vary between different engine models, so be sure to check the proper technical manual for the exact normal readings. Specifications given in the technical manual are for sea-level operations. At higher elevations, the gage readings are lowered for every increase in altitude.

The normal reading for most supercharged Marine Diesel engines is about 2psi with the engine at idle speed. A steady reading in this range indicates that the engine is running as it should at this speed.

As a further check for normal engine operation, open the throttle to reach 3600rpm. If the engine is running as it should, the reading will increase to about 12-14psi (0.9bar) at this rpm.
PRACTICE EXERCISE

1. What is indicated if the engine oil level is too high and the oil has a milky appearance?
   a. Oil of the wrong viscosity
   b. Fuel leaking into the oil
   c. Water leaking into the oil

2. An engine knock that goes away when the proper injection line is disconnected is most likely caused by a loose
   a. rod bearing.
   b. main bearing.
   c. transmission

3. Which parts have too much operating clearance if the engine knocks and the oil pressure is low?
   a. Piston pins
   b. Valve guides
   c. Bearings

4. Loose main bearings in the engine will make the MOST noise when the engine is
   a. hot.
   b. cold.
   c. under load.

5. What should be done first if an engine overheats?
   a. Check the operation of the thermostat
   b. Check the raw water flow through the heat exchanger cores
   c. Flush the heat exchanger
LESSON 3 ENGINE LUBRICATION SYSTEMS TASK

Describe the principles of engine lubrication and crankcase ventilation systems.

CONDITIONS

Given information about principles of operation and maintenance of engine lubrication and crankcase ventilation systems.

STANDARDS

Solve 70 percent of the multiple-choice test items covering engine lubrication and crankcase ventilation systems.

REFERENCES

TM 9-8000

Learning Event 1:
DESCRIBE PRINCIPLES OF OPERATION AND COMPONENTS OF LUBRICATION SYSTEMS

The lubrication and ventilation systems used on modern internal combustion engines are excellent examples of good engineering design. The lubrication system must be designed so it will deliver a large amount of oil to some of the parts while providing mere drops to other parts in the engine. Too much oil in some places can cause as much trouble as too little. If, for example, the lubrication system delivered as much oil to the cylinder walls as it does to the main bearings, the rings could not wipe off the excess oil fast enough. Too much oil in the wrong places will also cause oil seals to fail and valves to stick.

The crankcase ventilation system (also known as the breathing system) plays an important part in the life of an engine. It has the responsibility of removing the vapors that form in the crankcase. If not removed, these vapors form sludge when mixed with the engine oil and destroy the lubricating qualities of the oil.

What are these vapors and where do they come from? Well, part of the vapors are plain water which collects on the walls of the crankcase the same way water forms on the outside of a glass of iced tea. As you know, when the air containing water vapors strikes the cold outside of an iced tea glass, the vapors condense and form drops of water on the glass. The same thing happens in an engine. When the engine is running, the air in the crankcase starts to heat up. When the heated air strikes the cooler sides of the oil pan and crankcase, the moisture in the air condenses and falls as drops of water into the engine oil.
Excess fuel from the combustion chamber can travel by the piston rings and collect in the crankcase oil along with the water. Even with an engine in good condition, some unburned fuel gets by the rings into the crankcase, especially during the time the engine is being cranked or is being operated while it is cold. Much of the fuel that is not burned winds up in the crankcase where it dilutes the oil.

We cannot prevent the water and fuel from getting into the lubricating oil, but we can remove most of both of them through the crankcase ventilation system.

**OPERATION OF LUBRICATION SYSTEMS**

The lubrication system has the job of supplying all of the moving parts in an engine with oil. As you know, the oil helps to reduce friction, clean the moving parts, and cool them by carrying off part of the heat. In the case of the pistons and rings, the oil helps to seal off the combustion chamber and helps to prevent the burning gases from entering the crankcase.

There are four types of lubrication systems used in internal combustion engines. They are the splash, the combination splash and force feed, the force feed, and the full-force feed.

The splash, combination splash, and force-feed systems are no longer used in most marine engines. They are, however, used in such things as lawnmower engines, outboard motors, and motorcycles, so we will discuss them briefly.
FIGURE 51. SPLASH-TYPE LUBRICATION SYSTEM.

Notice on the splash system there is a dipper on the bottom of the connecting rod. This dipper splashes the oil all over the inside of the engine. All of the moving parts are lubricated by the oil splashed on them by the dipper.

A variation of the splash system is used in the two-stroke-cycle engine. Here the lubricating oil is mixed with the gasoline in the fuel tank. During the compression stroke of the piston, the reed valve opens and a fresh charge of oil, fuel, and air enters the crankcase. The fuel, air, and oil moves through the intake port into the cylinder when the piston moves down on its power stroke. The oil in the fuel lubricates the moving parts. This method of lubricating the engine is very common on small two-stroke-cycle engines, especially those used on motorcycles and motorboats. This system is known as the vapor lubrication system.
The amount of oil mixed with the fuel in the two-stroke-cycle engine must be carefully controlled. Too little oil will cause rapid wear of the engine parts. Too much oil will cause carbon to form in the combustion chamber, foul up the spark plugs, and clog the exhaust ports. Spark plug fouling is a very common problem with this type of engine.

An advantage of this type of lubrication system is that the engine can be tilted or operated in any position. If the engine was operated on its side or in an upside down position, it would not last long. This is because the oil in the crankcase would flow away from the dipper and could not be splashed over all of the moving parts.
The combination splash and force-feed systems of engine lubrication were used on some American-made engines until the middle 1950s. An engine using this system still relies on dippers on the connecting rods to lubricate the connecting rod journals, the cylinder walls, and the pistons and rings. Other parts, such as the main bearings, valves, camshaft, and timing gears are lubricated by oil supplied by a pressure pump.

Compare the lubrication system shown with the one above. Notice the parts that have been added to provide oil under pressure to some parts of the engine. Item A is an oil pump. It is usually driven by a gear on the camshaft. The pump picks up the oil through a pickup tube in the engine oil pan B. Item C is the oil passage leading from the oil pump to the main bearings and to other engine parts that are supplied oil under pressure. Notice one oil passage leads to a small jet or nozzle that can spray the
oil directly into the dipper on the connecting rod and into the tray or trough directly below dipper D. With this arrangement, the dipper does not have to reach the oil in the pan. You can imagine what would happen if the oil level in the pan was a bit too low for the dipper to reach. With the oil spray jet, the connecting rod bearings and cylinder walls will be properly lubricated even if the oil level is low in the oil pan.

**FIGURE 53. FORCE-FEED LUBRICATION SYSTEM.**

Shown here is the force-feed lubrication system. Notice there are no dippers on the connecting rods. Instead, the crankshaft has drilled passageways leading from each of the main bearing journals to the connecting rod journals. Oil is delivered to the main bearing by the pump. Part of the oil travels through the drilled passageways to the connecting rod journals. This system is used on all Marinediesel engines.

On some engines, the oil leaking out around the connecting rod bearings is thrown on the cylinder walls by the spinning crankshaft.

On other engines, such as all Marinediesel engines, a small squirt hole is drilled through the rod to spray oil on the piston and cylinder wall.
The full-force-feed system is identical to the force-feed system except that the connecting rod is drilled to supply oil under pressure to the piston pin.

**SUBASSEMBLY OF THE LUBRICATION SYSTEM**

Now let's examine the individual parts found in the lubrication system of an engine.

The reservoir for storing the oil is known as the oil pan. It is sometimes known as the crankcase cover because it does seal the bottom of the engine crankcase.

Most oil pans, especially on Marinediesel engines, have a fairly deep section known as the sump. The sump serves several purposes.

- First, it increases the amount of oil the oil pan can hold.
- Second, it provides a pocket into which dirt, water, and metal particles can settle.
- Third, it reduces the amount of sloshing back and forth that the oil can do.

- Fourth, it houses the pickup screen for the oil pump and ensures the delivery of oil to the pump as long as there is any in the oil pan.

- Finally, the sump makes certain that oil will be available at the pickup screen when the vessel is going through rough seas.

If the oil pan is shallow and has a flat bottom, all of the oil will run to the front or rear of the oil pan when the vessel travels over large waves. With the deep sump, part of the oil will always be present in the sump so the oil pump can pick it up.

Some oil pans also have baffle plates which help to reduce the amount of sloshing the oil can do as the vessel travels through rough seas, all Marinediesel engines are equipped with this. Excessive sloshing is undesirable because it tends to keep the dirt and water mixed with the oil instead of letting them settle to the bottom of the sump.
The oil level gage or dipstick is used to measure the level of the oil in the pan.
FIGURE 56. OIL PICKUP.

The oil pickup or inlet is usually mounted in the engine so that it extends down into the sump portion of the oil pan. It has a screen which is made of wire mesh to strain the oil before it is delivered to the pump.

Some oil pickup screens are designed to float on top of the oil and rise or fall with the oil level in the pan. Since dirt and water tend to settle in the bottom of the sump, the floating screen will pick up the cleanest part of the oil.
From the pickup screen, the oil is usually routed through a pipe or a tube to the inlet side of the oil pump. There are several types of oil pumps in use in modern automotive engines. All of them can be classified as positive displacement pumps, because they are pumping oil anytime the engine is running. Depending on the method used to pump the oil, the pumps are called gear, vane, rotor, or plunger types. The gear and rotor types are the most commonly used in marine engines. In practically all cases, the pumps are driven by a gear on the camshaft. In the case of gasoline engines, this gear is usually the same one that drives the ignition distributor shaft.

**FIGURE 57. GEAR-TYPE PUMP.**

This is a top view of a gear-type pump. The upper gear is the driving gear. The gears revolve in the directions indicated by the arrows. This type is used in all Marinediesel engines.

On the inlet side of the pump, the teeth on the driving and driven gears are moving away from each other. Oil is picked up at the inlet and is carried between the gear teeth and the housing to the outlet side of the oil pump.
At the outlet side of the pump, the gear teeth come back into mesh (engagement). With the teeth of both gears in mesh, there is no longer room for oil between them. The oil is forced out from between the gear teeth into the outlet (discharge) side of the pump.

FIGURE 58. ROTOR-TYPE PUMP.

The rotor-type pump uses an inner rotor with lobes that move in and out of mesh with an outer rotor.

The inner rotor is keyed to, and driven by, a shaft like the gear in the pump in the illustration. As the inner rotor rotates, it carries the outer rotor with it in the same direction.
Notice that the inner rotor is not centered in the outer rotor. The teeth-like lobes of the two rotors are in mesh only at the bottom. As the two rotors turn to the left (counterclockwise), their lobes separate. The space between the rotors fills with oil. As the rotors continue to turn, the lobes start coming back together. As the lobes come together, oil is squeezed out the discharge sides of the pump.

All of the oil pumps discussed are capable of pumping oil under high pressure. In fact, the pressure such pumps can produce is too high for the lubrication systems used in engines. An oil pressure relief valve is used to control the oil pressure at the desired amount (usually 60 PSI or less).

The relief valve, which is also known as a pressure regulator valve, is usually placed in the main oil line (also known as the oil gallery) leading from the pump or built into the discharge side of the pump itself.

The relief valve is usually a spring-loaded ball or plunger type. Oil under pressure is delivered through the main oil line to the parts that are pressure lubricated. The oil exerts pressure on the plunger in the pressure relief valve. When the oil pressure exceeds the plunger spring pressure, the plunger is forced off its seat and oil can flow by the plunger into the oil outlet and from there to the sump. The plunger is held off its seat by the oil pressure in the main oil line until the pressure drops to the point at which the spring can seat the plunger. The spring must have just the right amount of strength. The oil pressure from the pump is controlled by the strength
of the plunger spring. The oil pressure in the system can be increased by increasing the spring tension or it can be reduced by decreasing the spring tension.

FIGURE 60. OIL PUMP WITH RELIEF VALVE.

This is a cutaway view of a gear-type oil pump with the relief valve in the discharge side of the pump. It is common practice by many engine manufacturers to place the relief valve in the pump.
Although the screen in the oil pump pickup in the sump will strain out much of the dirt and carbon, it cannot remove fine particles of dust and other abrasive materials that gather in the oil. An oil filter is used in the lubrication system to remove all the abrasive materials possible. The oil filter is connected in the lubrication system in one of two different ways, full flow or bypass.

FIGURE 61. FULL-FLOW FILTER SYSTEM.

In the full-flow system all the oil from the pump is sent through the filter before being routed through the main oil line to the parts to be lubricated.

Let’s trace the flow of the oil in the system. The oil is drawn from the sump through the pickup screen to the pump. There the oil is pressurized and sent through the discharge side of the pump to the oil cooler and then to the oil filter. Notice the location of the pressure bypass valve in the drawing. Notice, too, that oil getting through the bypass valve is not filtered when entering the engine.
After the oil has been filtered, it is sent through the main oil line to the parts requiring lubrication.

The abrasives removed from the oil by the filter will eventually clog the filter to the extent that no oil can get through if the filter is not serviced. When this happens, a bypass valve, which is usually located by the filter, opens and allows the unfiltered oil to move into the main oil line.

Although most modern marine engines are equipped with the full-flow type of oil filter like all Marinediesel engines, there are many engines that have the bypass type of filter.
Notice that the main oil line divides on the output side of the pump. Part of the oil is directed to the bearings and other moving parts, while part of the oil is directed through another oil line to the filter. Notice that the oil leaving the filter returns directly to the sump in the oil pan.

No bypass valve is needed with this type of filter because oil will still be delivered to the moving parts even if the filter becomes clogged.

At this point, let's study the entire lubrication system on a typical Marinediesel engine.
FIGURE 63. TYPICAL ENGINE LUBRICATION SYSTEM.

The oil passages and the main components for a typical full force-feed system are shown. Notice the location of the oil inlet in the sump of the oil pan. Now trace the flow of oil from the oil pickup to the main oil line. Then trace the small oil lines leading to each camshaft bearing and to each main bearing.
Notice that from two of the camshaft bearings, two oil lines lead to the hollow-valve rocker arm shafts at the top of the engine. These lines are usually very small or have restrictor valves in them to reduce the amount of oil going to the rocker arm shafts to lubricate the valve train.

In most engines the main oil line and oil feeder lines are drilled passages in the engine block and cylinder head. In all cases, the oil passages between the main bearings and connecting rod bearings are drilled holes in the crankshaft

Learning Event 2:
DESCRIBE PURPOSE OF CRANKCASE VENTILATION SYSTEM
OPERATION

The crankcase ventilation system has two important jobs to do. It must get rid of the fuel and water vapors that collect in the crankcase. It must also remove the "blowby" gases that would otherwise build up considerable pressure in the crankcase and cause oil seals and gaskets to leak.

We have already discussed how the fuel and water vapors condense in the crankcase and form sludge when mixed with the oil. Now let's discuss what "blowby" is and what problem it creates.

As you know, the piston rings and the lubricating oil have the job of sealing the high-pressure gases in the combustion chamber that are present during the compression and power strokes of the piston. The rings cannot form a perfect seal because they must have a gap so they can be installed on the piston and to allow for expansion when they become hot. They must also be free to move in the piston ring grooves. Otherwise, they could not expand out against the cylinder walls. The film of oil on the pistons, cylinder walls, and rings can help to seal the gases in the combustion chamber, but the film is not 100 percent effective as a seal. So part of the high-pressure gases in the combustion chamber escape by the rings and oil film into the crankcase. The gases escaping by the rings and into the crankcase are known as blow by gases.

The gases entering the crankcase as a result of blow by can build up enough pressure to cause oil seals and gaskets to leak if they are not allowed to escape. In addition, these gases contain unburned fuel, carbon, and other byproducts of combustion that will mix with and ruin the oil in the crankcase.

Now let's see how one type of crankcase ventilation system works to get rid of the blow by gases and the water and fuel that get into the crankcase.
One of the ventilation systems used on marine engines is shown. Air is drawn into the crankcase through openings in the valve cover. The air circulates around the crankcase and above the oil in the oil pan. The blow by gases and the fuel and water vapors are mixed with the air. This mixture is drawn out of the crankcase through the road draft tube and discharged into the surrounding air.
This system is known as a nonpositive crankcase ventilation system because it will not work unless the vessel is moving forward.

A positive crankcase ventilation system operates anytime the engine is running and does not depend on vessel movement. Notice that the air enters the crankcase through a breather and goes out through a tube leading to the intake manifold. Anytime the engine is running there is a low-pressure area in the intake manifold. The air from the crankcase containing the blowby gases and fuel and water vapors is drawn through the intake manifold to the combustion chamber. There, the combustible gases are burned and discharged through the exhaust system.
FIGURE 65. PCV (or CDR) SYSTEM.

When the intake manifold vacuum is high, too much of the vapors will be drawn into the manifold and will rich the fuel-air mixture coming into the engine if some steps are not taken to prevent it. This would cause a loss of power. To prevent this, a ventilator valve is located in the tube close to the intake manifold.
This valve is normally held open by a spring, but high manifold vacuum will cause the valve to close. When the valve is closed, the amount of air entering the manifold from the crankcase ventilator system is reduced to prevent enriching the fuel-air mixture.
It is very important to remember that neither type of crankcase ventilation system can remove liquids. Fuel and water in the crankcase cannot be removed unless they are changed from a liquid to a gas. For this reason, the engine must get hot enough to change these liquids into a gas. Engines that are operated without proper warm-up, or are used for short runs only, will soon have a crankcase full of sludge. If the thermostat in the cooling system opens too soon or if it is stuck open, the engine will not get hot enough to vaporize the water and gasoline. To keep the lubricating oil clean, the engine must get hot! Keep in mind that even though gasoline turns into vapor at low temperatures, diesel will only in a very limited amount be “cleaned” out through the CDR or PVC system, most of the diesel fuel will be left in the engine oil.

All Marinediesel engines use the positive crankcase ventilation system. The positive crankcase ventilation system is part of the emission control system for engines which reduces the pollution in the air we breathe.
Learning Event 3:
DESCRIBE MAINTENANCE PROCEDURES FOR ENGINE LUBRICATION SYSTEMS

As an engine repairer, the major problem you will probably have with the engine lubrication system is oil leaks. Such leaks are usually visible, so be thorough when looking for oil leaks. When oil leaks are found, look for the causes. An oil leak is almost certain to develop if things, such as the oil pan bolts or valve cover bolts, are loose. Oil levels too high and clogged crankcase ventilation systems are other major causes for oil leaks. Let's go through a step-by-step procedure for checking the lubrication system on an engine. The procedures described here are for the Marinediesel engines, but most of the procedures will apply to any marine or automotive engine.

First, check the level and condition of the oil. If you find the oil level too high, check the level of the coolant in the heat exchanger. Unless someone put too much oil in the crankcase, the most likely cause of a high oil level is water leaking from the cooling system into the oil.

If the coolant level in the heat exchanger is low, allow the vessel to sit (in calm water or on land) without the engine running for awhile, and then remove the oil drain plug slowly. If there is water in the crankcase, it will run out first, because water is heavier than oil and will settle to the bottom of the oil pan sump. Water from the cooling system usually gets into the oil pan by a leaking cylinder head gasket. If the drain plug can not be accessed, pump some oil from the bottom of the sump through the oil dipstick tube.

Of course, if the engine has been running, the oil and water will be mixed. The water may give the oil a milky color or if the oil is cold it will be sludgy. Oil mixed with water also has a different feel when rubbed with the fingers than plain oil.

In checking for oil leaks, look for drops of oil in the bilge under the engine. Then examine all possible places the oil may leak out. In addition to such places as the oil pan, timing gear cover, valve pushrod cover, and valve rocker arm cover gaskets, oil can leak out around the oil filter, vacuum booster pump, oil gage, and any external oil lines. The crankshaft oil seals can also leak. Oil leakage around the front crankshaft oil seal will probably be thrown all over the front of the engine by the crankshaft pulley. The fan belts will probably be oil soaked, too.

Oil leaking around the rear main bearing oil seals usually soaks the coupling and drips out through the drain hole in the bottom of the engine flywheel housing.

If oil has to be added to an engine too often but no leaks are found, the oil is being burned. The most likely causes of oil burning are worn or broken rings, worn or scored pistons or cylinder walls, loose bearings, worn intake valve guides or leaking valve seals (intake valves only), and leaking vacuum booster pump diaphragm. If an engine is burning oil, it usually shows up in the exhaust as smoke. When oil is being burned in the combustion chamber, the exhaust smoke will have a bluish color. Locating the causes of an engine using too much oil is described in the lesson on engine inspection and testing.
All of the Marinediesel engines are equipped with oil filters. All use the full-flow type, while others engines brands may be equipped with the bypass type. The full-flow filter used is the throwaway type.

The oil pressure gages used on the Marinediesel engines are operated electrically. Procedures for testing these gages are described in the lesson on Marinediesel electrical systems.

All Marinediesel engines use the positive crankcase ventilation system. The air that circulates through the crankcase enters the engine through a filter on the breather tube or through the air cleaner. In either case, be sure the filters are clean.

Anytime oil is leaking out of the engine by the front or rear crankshaft oil seals, always suspect the crankcase ventilation system. If the ventilation system is clogged, enough pressure can be built up in the crankcase to blow the crankshaft oil seals.

If a large amount of sludge is found in the breather pipe, vent lines, or in the ventilator valve, check the cooling system—especially the thermostat. Remember the engine must get hot enough to vaporize the water and fuel that gets onto the crankcase. If the engine thermostat opens too soon (at a low engine temperature), sludge is sure to form in the crankcase and breather lines.

Proper care of the lubrication and ventilation systems can lengthen the life of the engine. If care is not given to these systems, you can expect to replace a lot of engines. A practice task list is included with this lesson. Practice as many of the tasks as you can.

**PRACTICE EXERCISE**

1. A passage is drilled in the connecting rod between the rod bearing and piston pin with which type of lubrication system?
   a. Full-force feed  
   b. Force feed  
   c. Splash

2. Under what conditions does the oil bypass valve open?
   a. When the oil filter is clogged  
   b. When the oil pump becomes worn  
   c. When the relief valve closes

3. During which two strokes of the piston is blowby most likely to occur?
   a. Intake and exhaust  
   b. Power and exhaust  
   c. Compression and power
4. If an engine is burning oil, the exhaust smoke will usually have a
   a. black color.
   b. bluish color.
   c. whitish color.

5. Which is the most likely cause of water in the engine oil?
   a. Leaking head gasket
   b. Cracked piston
   c. Worn piston rings

LESSON 5 ENGINE COOLING SYSTEMS TASK

Describe the principles of engine liquid-cooling systems.

CONDITIONS

Given information about the fundamentals of liquid-cooling system components, and inspecting, testing, and repairing representative engine liquid-cooling systems.

STANDARDS

Solve 70 percent of the multiple-choice test items covering engine liquid-cooling systems.

REFERENCES

TM 9-8000

Learning Event 1:
DESCRIBE THE PRINCIPLES OF OPERATION AND COMPONENTS OF LIQUID-COOLING SYSTEMS

All internal combustion engines have some type of cooling system because of the high temperatures created during their operation. The heat is produced both by friction and burning of fuel, with the largest amount being caused by the burning of fuel. There is no sure way of telling just exactly how hot it gets inside the combustion chamber of an engine, but it is thought to be about twice the temperature at which iron melts. Therefore, if an engine is not cooled, the valves will burn and warp, lubricating oil will break down, pistons and bearings will overheat, and pistons will seize in the cylinders.

The engine cooling system is called upon to carry away about one-third of the heat inside the combustion chambers.
Usually, a cooling system works by moving a liquid over the hot cylinder and combustion chamber walls. The liquid absorbs heat and carries it away. This is a liquid-cooling system.

Sometimes a cooling system uses no liquid. Instead, air is moved over the hot walls of the cylinders and combustion chambers to carry away heat. This is an air-cooling system.

**SOME HEAT IS NEEDED**

At the same time, the engine must not be allowed to run too cold either. An engine running too cold does not burn all the fuel taken into the combustion chambers and will cause a lot of sludge to form in the crankcase. This causes poor fuel economy, forms carbon deposits, increases wear, and cuts down on engine power.

**JOBS OF THE COOLING SYSTEM**

The cooling system does three jobs to provide a satisfactory temperature operating range for the engine. First, it removes the unwanted heat. Second, it regulates the engine temperature to keep it just right during all operating conditions. Last, when the engine is first started, it makes the engine warm up to its normal operating temperature as soon as possible.

**METHODS OF COOLING**

**Fuel, Oil, and Exhaust**

Although they are not ordinarily thought of as being a part of the cooling system, the fuel, lubrication, and exhaust systems help a lot toward cooling the engine. The repairer must not overlook these systems as trouble here may appear to be problems in the cooling system.

**Fuel.** When fuel enters the engine, it is cool; therefore, it absorbs or soaks up a lot of the heat.

**Oil.** Lubricating oil helps to keep the engine running cool in two ways. First, it prevents a lot of heat from being produced by friction. Second, it absorbs and carries heat away from parts, such as the pistons and cylinder walls, as it comes in contact with them.

**Exhaust.** The exhaust system aids cooling by carrying hot exhaust gases away from the engine. You have probably already noticed how hot the exhaust is that comes out of the exhaust system on a vehicle. All three of these methods put together do not even come close to cooling the engine as much as needed. The rest of the unwanted heat is carried away by the cooling system.

**LIQUID-COOLING SYSTEM**

At sometime, everyone has cooled something that was too hot by either blowing on it or pouring water over it. Both of these two methods are used in liquid-cooling systems. For a more detailed understanding of how this is done, let's discuss the different parts of the cooling system.

**Coolant Jacket**

You could think of a basic engine as each cylinder and combustion chamber being a separate part, and then all of them enclosed by one container. Thus, if the container is filled with water, the cylinders and combustion chambers would be completely surrounded by a jacket of coolant.
In actual practice, the engine block contains the cylinders which are surrounded by coolant passages. The combustion chambers in the cylinder head also have coolant passages all around them. Coolant transfer ports in the block, head, and head gasket align when the head is bolted to the block so the coolant can flow between the block and head. When coolant is placed in these passages, the cylinders and combustion chambers are then surrounded by a jacket of coolant, generally known as a water jacket.
The pistons, valves, and walls of the combustion chambers and cylinders absorb the heat of the burning fuel. Heat in the combustion chamber and cylinder walls is then passed into the jacket of coolant. The hot pistons are cooled by passing heat into the coolant-filled cylinder walls. Heat from the valves is passed into the valve guides and valve seats and then into the coolant jacket.

If the jacket of coolant remains still, it will absorb just so much heat and then begin to boil away. Therefore, the heated coolant must be moved away and replaced.

**Coolant Pump**

A pump is used to move the coolant in the engine. The pump, generally known as a water pump, is usually located on the front of the engine block. The system is designed so the pump forces coolant into the coolant jacket in through the block and out through the head. The output of the coolant pump and coolant jacket passages must be designed so that all of the heated coolant is moved. If coolant is allowed to stand still in some places, uneven cooling or hot spots will develop.
All Marinediesel engines use a centrifugal (impeller) type pump that consists of a round plate which has blades or vanes on one side of it. The plate, or impeller as it is usually known, is fastened to a turning shaft. As the impeller turns, its blades will throw coolant outward.
The pump is completed by placing the impeller in a closed housing that has a coolant inlet at the center of the impeller and an outlet at its outer edges. On some pumps, the impeller may be placed directly into the coolant jacket of the engine instead of being enclosed in the pump housing. Then the cylinder block will serve as a part of the pump housing.

The impeller shaft turns on bearings in the housing and has a pulley attached to its outer end. A seal assembly prevents coolant from leaking out by the impeller shaft.

The pump is driven by a PK-type belt that generally fits in the pulleys on the crankshaft, generator, and coolant pump.

**Heat Exchanger**

It is not enough just to pump coolant out of an engine and back into it again. When the coolant leaves the engine, it is quite hot. If this hot coolant was pumped right back into the engine, all the coolant would start to boil soon. Therefore, before the coolant can be used again, it must be cooled. This is the job of the heat exchanger.

A heat exchanger has two tanks or containers. The fresh water tank contains an inlet, a filler opening, and an overflow tube. The raw water side has an inlet and an outlet as well as provisions for zink anods. The ends of the system can be removed for inspection and cleaning.
Almost all heat exchangers in use at this time have cores that are made up of a lot of tiny tubes. These tubes are coolant passages between the fresh water and raw water tanks. The tubes are made of copper or copper/nickel material to withstand salt water corrosion.
COOLANT FLOW THROUGH HEAT EXCHANGER.

The heat exchanger is usually mounted on the engine. The outlet on the fresh water tank is connected to the coolant pump inlet and the outlet at the top of the engine. The inlet on the raw water tank is connected to the raw water impeller pump through the oil cooler for the engine. Rubber supports, hoses and hose clamps are used to make these connections to prevent engine vibrations from being transferred to the heat exchanger.

Hot coolant is pumped out the top of the engine into the fresh water side of the heat exchanger. It flows from the inlet tank through the tubes in the core to the outlet tank. As the coolant makes its way down the tubes, it gives off heat to the tubes. The heat is then transferred to the raw water on the other side of the system, cooling it as it passes between through the tubes. By the time the coolant reaches the outlet tank, it is cool enough to reuse in the engine. The coolant pump draws the coolant from the outlet tank and forces it back into the engine.

**Raw water pump**

A raw water pump or impeller pump is used to draw sea water through the heat exchanger core for the cooling action of the heat exchanger. The raw water pump is generally bolted to the engine and is driven by the belt system on the engine. If the belt or the impeller is worn it will reduce the cooling capacity of the system.
FIGURE 71. RAW WATER PUMP

The raw water pump used a serviceable rubber impeller that needs to be changed from time to time, see service schedules. The pump also contains bearings that can cause a noise if they are worn. If the impeller is worn this reduces the amount of raw water flowing through the core and the amount of engine cooling.

**Thermostat**

The coolant jacket, heat exchanger, coolant pump, and raw water pump work together to remove unwanted heat from the engine. But the system, as studied so far, would cool the same amount all the time. The cooling system must be able to vary the amount of cooling it does to reduce the amount of warm-up time and to regulate engine temperature. A thermostat valve is installed in the cooling system to provide this feature.
The thermostat is generally placed under the coolant pump outlet on the engine. Coolant outlets are bowl-shaped on the bottom to house the thermostat and are sometimes known as the thermostat housing.
FIGURE 73. COOLANT FLOW - THERMOSTAT CLOSED.

When the engine is cold, the thermostat shuts off the flow of coolant from the engine to the heat exchanger. This causes the engine to heat up quickly. However, if the coolant is allowed to stand still in the engine at this time,
hot spots may occur and the engine will not warm up evenly. Engines have a bypass passage that allows coolant to be pumped through the engine without going through the radiator to prevent this.
When the proper engine operating temperature is reached, the thermostat valve opens and allows coolant to flow through the heat exchanger. If the weather is cold or if the engine is operating at less than full power, the thermostat does not open up all the way. It will allow just enough coolant to flow through the heat exchanger to keep the engine at the proper temperature. When the engine load changes, the thermostat valve opening changes, providing just the amount of cooling that is needed.
Two kinds of thermostats in common use are the bellows and pellet type (used on all Marinediesel engines). Both types operate on the same principle; the difference is in the unit that opens and closes the valve. The bellows type consists of a flexible metal bellows attached to a valve. The sealed bellows is filled with a liquid such as ether. When the liquid is cold, the bellows is contracted so the valve is closed. When heated, the liquid turns to a vapor and expands the bellows, opening the valve. This thermostat is sensitive to outside pressure, so it does not work very well if the cooling system is pressurized.
The pellet-type thermostat is also commonly known as a cartridge-type thermostat. It has a small cylinder containing a special paste. When the paste is heated, it expands, pushing a piston out of the cylinder to open the valve. The valve allows the coolant to flow through, and the system reaches the desired temperature.
thermostat valve. Tension to hold the valve closed is supplied by a spring. The pellet-type thermostat is not sensitive to pressure, so it works well in a pressurized cooling system.

Thermostats that are used in Marinediesel engines generally start to open at about 60°C of coolant temperature. This may vary a little from one engine manufacturer to another, depending on the engine design. However, the boiling point of the coolant must always be considered when determining just how hot the engine should run. If the coolant is allowed to boil, it will turn to steam and lose its cooling qualities. Therefore, the coolant temperature must always be kept safely below its boiling point (water boils at 100°C or 212°F at sea level).

**Pressure Heat Exchanger Cap**

It has been found that increasing the amount of pressure on water will raise its boiling point. Therefore, most liquid-cooled engines are designed to operate with a pressure in the cooling system to provide a greater difference in the coolant boiling point and operating temperature. Each pound of pressure on the water in the cooling system will raise the coolant's boiling point about 3°. The pressure is regulated by a pressure-type cap on the radiator. On all Marinediesel engines this is set at 14psi or 1 bar.
FIGURE 76. PRESSURE HEAT EXCHANGER CAP.

The pressure heat exchanger cap has two spring-loaded valves that are normally in the closed position. The largest of the two valves is the pressure valve, and the smaller is a vacuum valve. When the cap is installed in the radiator filler neck, it seals at the bottom as well as at the top of the filler neck.

When the engine is cold, there is no pressure in the cooling system. As the water in the cooling system warms up, it expands. Since the cooling system is sealed by the cap, the water expansion causes pressure to build up. When the pressure builds up enough to overcome the spring tension holding the pressure valve closed, it lifts the valve. The excess pressure escapes by the pressure valve and out through the radiator overflow pipe. The amount of pressure the cooling system is able to build up depends on the strength of the pressure valve spring. In Marinediesel engines 14 PSI is developed in the cooling system.

The vacuum valve in the cap operates after the engine has been stopped and begins to cool off. As the water cools, it contracts, forming a vacuum or low pressure in the cooling system. When the vacuum gets great enough, normal air pressure entering the overflow pipe forces the vacuum valve off its seat and flows into the cooling system. If a vacuum valve was not used, the hoses and perhaps the heat exchanger tanks would be drawn together by the vacuum.
**Expansion Plug**

You will not work on many cooling systems before coming in contact with the expansion plugs. These plugs are commonly known by such names as core hole plugs or freeze plugs. Actually, they are metal plugs that are driven into, and seal round core openings in, the outside wall of the engine coolant jacket.

The core openings in the coolant jacket of the cylinder block and head are necessary for the casting process when the block and head are being manufactured. But once they have been built, the openings have no further use, so they are plugged with the expansion plugs.

Expansion plugs may be forced out of the openings if the water freezes in the coolant jacket. However, they cannot be depended upon to keep the engine from cracking in case of a freeze-up.

**Temperature Sending Unit**

A temperature gage sending unit is installed in the cylinder head or some other part at the top of the engine that contains water passages. On all Marinediesel engines an electrical-type unit is used. Electrical units always have a wire attached and are screwed into a hole tapped into a coolant passage. The sending unit has a heat-sensitive element that extends into the coolant. The element senses the temperature and sends corresponding electrical signals to the temperature gage.

**Coolant Solutions**

It is not a good practice to operate a engine with water alone in the cooling system. If just plain water is used, parts in the cooling system will rust and corrode, causing leaks and plugging small passages. Also, in cold weather water will freeze, which may crack the engine block and heat exchanger.
In the summertime when there is no danger of freezing, plain water with a rust inhibitor added is used. The inhibitor will reduce or prevent rusting and corrosion, but it will not remove rust or corrosion that has already formed.

In the wintertime when the temperature falls below 0°C or 32°F, an antifreeze solution must be used in the cooling system to prevent freeze-up. A rust inhibitor is included in the antifreeze mixture, so it is not necessary to add the inhibitor too. Ethylene glycol and an arctic-type solution are two types of antifreeze issued for use by the military.

The ethylene glycol antifreeze must be mixed with water at the time of installation to lower the freezing point of water. The best protection from freezing can be obtained from a mixture of 40 percent water and 60 percent ethylene glycol antifreeze. This lowers the freezing point to -65°F. Although it may sound odd to you, adding either more or less ethylene glycol to this mixture will raise the freezing point. Ethylene glycol antifreeze solutions are used where the temperature is not expected to go lower than -55°F.

In arctic climates where temperatures often go lower than -55°F, the arctic-type antifreeze is used. It provides freeze-up protection to -90°F. Arctic-type antifreeze is premixed at the factory and is used full strength. It should never have water or any other type of antifreeze added to it.

Other types of antifreeze containing alcohol or glycerin are made, but they should never be used in a Marinediesel engines unless it is an emergency. If they are used, they must be drained at the first opportunity and replaced by an ethylene glycol or arctic-type antifreeze. Alcohol and glycerin antifreeze will boil and evaporate at a low temperature very close to that of the engine's normal operating range. To use them, you must mix them with water at the time of installation.

It needs to be taken into the consideration that the raw water side of a marine engine does not have freezing protection and will freeze when exposed to temperatures below 0°C or 32°F. The raw water needs to be drained, flushed with glycol mix or have an engine heater installed.

Learning Event 2:
DESCRIBE MAINTENANCE AND TROUBLESHOOTING PROCEDURES OF LIQUID-COOLING SYSTEMS

The inspection procedures for the cooling system are about the same for all engines. But repair procedures vary a great deal. You should always refer to the technical manual for the engine you are working on for specific procedures and specifications. When you are working on the cooling system of an engine, you will probably inspect the complete system before making any repairs. But in this lesson, let's discuss the inspection, repair, and replacement of parts, one part at a time, to prevent confusion and repetition.

Heat exchanger

Examine the heat exchanger for proper coolant level, leaks, blocked water passages, secure mounting, and plugged overflow. White, rusty, or colored stained spots indicate a leak. If plain water is used as the coolant, these spots may not be damp as water evaporates quickly when it is hot. If an ethylene glycol antifreeze is used, small leaks are more likely to be damp as this type of antifreeze does not evaporate. The heat exchanger should be replaced if any leaks are found.
When coolant is lost from the cooling system, refill it to check for leaks. But if the engine is overheated, do not just pour in cold water right away. Allow the engine to cool, or refill the heat exchanger slowly while the engine is running. If cold water is poured into the heat exchanger when the engine is overheated, there is danger of cracking the cylinder block or head.

Remove any leaves or other foreign matter in the heat exchanger core and flush the system if needed. Foreign matter that is stuck in the heat exchanger will not only reduce flow but indicate a bad raw water filter and other parts of the raw water system may be blocked. If foreign matter is found the entire raw water system needs to be investigated. However, you should first check the complete cooling system for leaks.

Check the heat exchanger mounting for loose or missing bolts or clamps. Also check the heat exchanger for being loose where the tanks are soldered together. Tighten or replace any loose or missing bolts/clamps. If the heat exchanger soldered joints are loose, the heat exchanger should be replaced or it may be repaired at a higher maintenance level.

If the heat exchanger overflow tube is plugged, too much pressure may build up in the cooling system and cause damage to the radiator or hoses. Check the tube for being plugged by blowing through it with the heat exchanger cap removed. If the tube is stopped up, clear it out by running a flexible wire or an old speedometer cable through it.

**Heat Exchanger Cap***

The heat exchanger pressure cap should seal and regulate the pressure in the cooling system. If the cap fails to seal, pressure will not build up in the system. Without the proper pressure, coolant will be lost through excessive evaporation and boiling. If the cap seals but maintains a pressure that is too high, the heat exchanger and hoses may be damaged.

Always use extreme care when removing the heat exchanger cap from a warm or running engine. In overheated systems the sudden release of pressure when the cap is loosened will cause steam and hot water to boil out. This can burn you very badly. To remove the heat exchanger cap when the engine is hot, place a cloth over the cap for protection. Then turn the cap counterclockwise until a click or notch is felt (about one-quarter turn) to release the trapped pressure. When all the pressure has escaped, press down on the cap and turn it counterclockwise until it can be removed.

The best way to find out if the heat exchanger cap is operating properly is to test it with a pressure tester. The pressure tester consists of a hand pump, pressure gage, and adapters. To use the tester, select an adapter that fits the radiator cap to be tested. Install the adapter and cap on the tester and operate the hand pump. Watch the pressure gage and stop pumping when a higher pressure reading cannot be obtained on the gage.

Watch the gage for a while to see if the pressure bleeds off. If the pressure does bleed off, the radiator cap is leaking and should be replaced. The highest reading obtained on the pressure tester gage is the amount of pressure that the cap will maintain in the cooling system. If this reading does not agree with the radiator cap specifications, replace the cap. The proper amount of pressure varies among the engine models, so you must always check the engine technical manual for specifications.

If you do not have a pressure tester, make a visual inspection of the radiator cap. Check the rubber sealing surfaces of the pressure and vacuum valves of the cap. Check the valves for freedom of operation. If the cap is damaged or worn in any way that will prevent it from sealing or operating, replace it.
To further ensure that the radiator cap will seal, clean the radiator filler neck and examine it for damage. Install the cap by placing it on the radiator filler neck and turning it clockwise as far as it will go. If the cap fits properly, two distinct clicks or notches can be felt as it is being turned.

**Hoses**

Coolant hoses should be examined for leaks, condition, and proper installation. If the hose connections are leaking, tighten the hose clamps and recheck for leaks. Hoses that are collapsed, cracked, or have a soft spot should be replaced. Ensure that the hoses are positioned so they do not rub against other parts. All clamps and hoses should be installed over the connections far enough to provide secure fastening. The normal pressure in the cooling system can blow off improperly installed hoses.

**Drive Belts**

Drive belts must be checked often to ensure that they are in good condition and properly adjusted. Belts that are badly frayed, worn, or cracked should be replaced before they break in operation. When more than one belt is used, they must be replaced in matched sets.

If a belt is too tight, it will put undue strain on the water pump and generator bearings. If the belt is too loose, it will prevent the water pump and generator from operating properly. This can cause an overheated engine or undercharged batteries.

**Fresh Water Coolant Pump**

A coolant pump may be defective due to faulty bearings, leaks, or failure to pump. The coolant pump is checked with the engine stopped and then again when it is running.

With the engine stopped, check the pump bearings for looseness by attempting to move one of the coolant pump pulley back and forth lengthwise with the pump shaft.

Unless the coolant pump leaks bad enough to drip, the leak can be hard to locate. The coolant usually leaks past the pump shaft seal and then escapes through a drain hole in the pump housing. The drain hole is located on the bottom of the housing, and on most engines it is covered by the belt pulley. However, it can usually be viewed by using a small mirror or flashlight. Any dampness or water stains left by evaporation around the drain hole indicate a coolant leak.

On some engines you can look in the radiator filler neck to see if the pump is operating. Run the engine until the thermostat opens; then look through the filler neck into the heat exchanger. If you see the coolant circulating, the pump is operating. If the heat exchanger inlet or baffles in the tank prevent you from being able to see the circulation of coolant, squeeze the upper radiator hose almost together. Accelerate the engine. If the pump is operating, you can feel the coolant force its way through the hose.

The coolant pump should be replaced if it has loose bearings, is leaking, is noisy, or does not operate.

**Thermostat**

If the thermostat fails to close, the engine will warm up slowly. If it fails to open, the engine will overheat. When thermostat trouble is suspected, the thermostat should be removed and tested. The thermostat is located at the coolant outlet of the engine.
If the thermostat appears to be in good condition, test it in the following manner. Force the thermostat valve open and place a 0.003-inch thickness gage between the valve and frame. Release the valve. If the valve does not close on the gage tight enough so the thermostat can be suspended by the gage, discard the thermostat.

If the thermostat valve holds onto the gage, place it in water that has been heated to 150°F. If the gage is released, discard the thermostat. If the gage is not released, continue to heat the water. A good thermostat will release the gage when the water temperature is between 150° and 154°F. If the thermostat holds onto the gage above 160°F, discard it.

Cylinder Block and Head

Coolant may be lost through external (outside) or internal (inside) leaks in the engine. External leaks occur at the core hole expansion holes, at gaskets where joints are sealed, and through cracked parts. If coolant leaks internally, it will be into the crankcase or a combustion chamber. Internal leaks usually occur at the head gasket or through a cracked cylinder head or block.

Inspect the engine for external leaks by examining the expansion plugs, the outside surfaces, and the point where the cylinder block and head join. When needed, use a mirror and flashlight to aid in the inspection. Some engines contain expansion plugs that you cannot see because they are in the rear of the cylinder block and are covered by the flywheel housing. If one of these plugs is leaking, the coolant will run out of the drain hole in the flywheel housing cover.

Coolant leaks in the cylinder block and head will be affected by the amount of pressure in the coolant jacket. Pressure is created by the coolant pump as well as by expansion of the coolant when the radiator cap is in place. Also, expansion and contraction of the cylinder block and head, resulting from temperature changes, will affect leaks. For these reasons, check the engine for leaks when it is stopped and cold and then again when it is running and warm.

All leaks must be corrected even though they may appear as no more than a stain spot where leakage has evaporated. A leaking drain cock or pipe plug that cannot be tightened should be replaced. Leaking expansion plugs must be replaced. If tightening gasketed joints will not correct leaks, replace the gaskets.

Since you cannot see internal coolant leaks in an engine, you must detect these leaks by looking for their results instead of the actual leak. Coolant leaking into the crankcase can often be detected by checking the level and condition of the engine oil. Any large leaks will raise the oil level a noticeable amount. Also, if the engine has been operated recently, any coolant in the crankcase will be mixed with the engine oil. Coolant mixed with oil will cause the oil to have a milky color.

On the other hand, if the engine has not been operated for some time, the coolant and oil in the crankcase will separate. The coolant, being heavier than oil, will settle to the bottom of the oil pan. Therefore, to check for coolant in the crankcase when the engine is cold, slowly remove the oil drain plug and watch for any coolant. The results of coolant leaks into a combustion chamber will depend on the size of the leak. A liquid, such as engine coolant, cannot be compressed at ordinary pressure. Therefore, if the leak is large, enough coolant will leak into the combustion chamber to lock the engine as the piston comes up on the compression stroke. When an engine is locked up by any kind of liquid in the combustion chamber, it is referred to as a "hydrostatic lock."

If an engine will not crank and a hydrostatic lock is suspected, remove the glow plugs and then attempt to crank the engine manually at first then with the starter motor. Any liquid that is trapped in a combustion chamber will
be forced out of the glow plug hole, relieving the hydrostatic lock. The cause of the engine lockup should be corrected before the engine is operated.

Small coolant leaks in the combustion chamber may be indicated by white smoke (steam) from the exhaust, loss of coolant, engine overheating, and engine misfiring. To check for a small leak, either remove the thermostat or operate the engine until the thermostat has opened. Remove the belts so the coolant pump will not operate, and then fill the radiator all the way to the top.

Operate the engine and look for bubbles in the coolant at the radiator filler neck. If there are any bubbles, there is a leak between a coolant passage and a combustion chamber. The bubbles are caused by pressure leaking from the combustion chamber into the coolant during the compression and power strokes. Do not operate the engine any longer than necessary to make this test as it will overheat very quickly with the belts removed.

If the engine has an internal coolant leak, the problem is most likely a faulty head gasket or a cracked cylinder block or head. The cylinder head will have to be removed to determine if these faults exist.

To test the sending unit, first run the engine until it has had time to warm up. If no reading is indicated on the gage, remove the wire from the sending unit and momentarily ground the wire to the engine block. If the gage now indicates, the temperature sending unit is faulty and must be replaced. If the gage still does not indicate, the gage or wiring is probably defective.

If the gage or circuit is defective but still indicates, it will most likely read full scale. When the gage reads full scale, disconnect the wire from the sending unit. If the gage pointer moves all the way to the cold position, the sending unit is defective. If the pointer remains at full scale, the gage or wiring is defective.

**PREVENTIVE CLEANING**

Sometimes it is recommended that the cooling system be flushed out twice a year--once in the fall when antifreeze is added and again in the spring when antifreeze is drained. Other times flushing may only be done when the coolant is contaminated. At any rate, regular flushing by organizational repairers will reduce clogging and overheating so that corrective cleaning by higher maintenance will not be needed very often. However, anytime the cooling system is clogged enough so that it causes the engine to overheat, turn the vehicle in to higher maintenance for repairs.

**Cleaning Compound**

To do a good job, you should use a cleaning compound before flushing the cooling system. The cleaner is a very strong acid that will loosen rust, scale, and sludge. The acid will damage cooling system parts if it is allowed to stay in the system, so its use must always be followed by a neutralizer to stop the action of the cleaner. The cleaner and the neutralizer normally come packed in separate compartments of the same container. Always read and use the instructions printed on the cleaner container and in the -20 technical manual for the engine you are working on.

**Normal Flushing**

With the drain cocks closed and the engine temperature below 200°F, fill the cooling system with clean, fresh water. Install the heat exchanger cap and run the engine for about five minutes after it has reached normal operating temperature. Stop the engine and drain the cooling system. If the water is discolored to any extent, repeat this flushing process until it drains clear.
Pressure Flushing

Always flush the cooling system by the pressure flushing method if a flushing gun is on hand. The pressure method is more effective than normal flushing for removing loosened rust and scale. Pressure flushing is done through the system in a direction opposite to the normal coolant flow. This allows the flushing pressure to get behind the deposits, forcing them out.
Coolant Service

The cooling system should never be allowed to stay for an extended time without the protection of a rust inhibitor. This is particularly true just after cleaning as considerable corrosion may take place in a few hours. Use an antifreeze hydrometer to check the amount of protection given by the antifreeze.

After cleaning and flushing a cooling system and the temperature is expected to stay above 32°F, add the amount of inhibitor that is recommended on the inhibitor container or in the technical manual. Start the engine and operate it until operating temperature is reached. This is to open the thermostat valve so the inhibitor will circulate through the entire system. If antifreeze is to be added to the system, do not add the inhibitor.

When the temperature is expected to go below 32°F or if the vehicle is to be maintained combat ready, antifreeze is used. If temperatures are expected to go lower than -55°F, completely drain the cooling system and refill it with arctic-type antifreeze.

If the freezing temperatures are expected to remain above -55°F, fill the cooling system with a mixture of water and ethylene glycol antifreeze. Prepare the mixture according to the protection tables given on the antifreeze containers. Always tie a tag on the radiator, telling how long it is protected.

TROUBLESHOOTING

When you are asked to locate trouble in a cooling system, it will probably be because one or more of the following complaints: the engine overheats, coolant is being lost, or the engine fails to reach operating temperature. Because of the differences in the design of different engines, the causes for these complaints may vary. For this reason, you should always refer to the troubleshooting section of the technical manual for the engine you are working on.

Engine Overheats

Let's assume that you are trying to locate the cause for an engine overheating. As you check the engine out, do not be too hasty in deciding that the cooling system is at fault. There are many things other than the cooling system that may cause the engine to overheat.

Outside the cooling system, incorrect ignition timing is a common cause of engine overheating. Therefore, this possibility should be checked out and the timing corrected if needed.

Another cause for overheating, other than the cooling system, is a clogged muffler or exhaust outlet pipes. Recall that the exhaust carries heat away from the engine. If the muffler or pipes are restricted so they fail to carry exhaust and heat away from the engine as they should, replace the clogged parts.
Still another cause for overheating, outside the cooling system, is excessive friction in the power train. This could be anything, such as binding gearboxes, marine growth on the hull or defective propellers, which will put an excessive load on the engine. In this case, the binding must be located and corrected.

If the overheating is actually caused by the cooling system, one common cause is low coolant level. When the coolant is low, refill the radiator and inspect the system thoroughly for leaks. All leaks must be corrected. Another common trouble that causes overheating is loose or worn fan belts. Always adjust or replace loose or worn belts.

A thermostat that fails to open will cause the engine to overheat very quickly. If the thermostat is suspected of being faulty, remove and test it.

Anything that blocks or reduces water flow through the heat exchanger core will cause overheating. Therefore, you should always check for and remove any obstructions that may restrict the flow of cooling water.

If the coolant pump does not pump, the coolant will not flow through the system well enough to keep the engine cool. The coolant pump will fail to operate if the impeller comes loose from the pump shaft or the shaft breaks. This may happen if the engine is started and the coolant is frozen. In any event, if the pump does not operate it must be replaced.

**Loss of Coolant**

If the complaint is that the cooling system is losing coolant, the trouble is most likely caused by a leak. The most likely spots where leaks occur are at the hoses, drain cock, cylinder head gasket, radiator cap, coolant pump, radiator, and cracks in the cylinder head or block. When a leak cannot be stopped by tightening, the leaky part must be replaced.

**Engine Fails to Reach Operating Temperature**

The temperature gage may not reach the normal operating range in a reasonable time when the engine is started. This could be caused by a faulty thermostat or gage circuit. The thermostat may be faulty or be of the wrong heat range. You would have to remove, inspect, and test the thermostat to check this. If the temperature gage does not indicate any temperature, but the engine gets warm, the trouble will be a defensive gage, wiring, or gage sending unit.

In this lesson, the major topics for discussion have been why an engine cooling system is needed; why the engine needs some heat; the three jobs of the cooling system; how fuel, oil, and exhaust aid the cooling system; how the liquid-cooling system parts are constructed and operate; how to inspect and repair cooling system parts; how to do preventive cleaning of the cooling system; and how to troubleshoot the cooling system. If there is any part of the lesson that you do not understand, go back and review that part of the lesson. Then turn to the practice tasks at the end of this lesson and do all of the suggested tasks that you can.

Lesson 5
PRACTICE EXERCISE

1. The heat exchanger consists of
   a. tubes and fins.
   b. tanks and tubes.
   c. an impeller and a housing.

2. What are the two spring-loaded valves in a radiator cap called?
   a. Pressure and steam
   b. Hot flow and cold flow
   c. Pressure and vacuum

3. Small coolant leaks are likely to be moist if the cooling system contains
   a. arctic antifreeze.
   b. ethylene glycol.
   c. plain water.

4. What is indicated if the oil on the dipstick is a milky color?
   a. Improper grade of oil
   b. Oil level too low
   c. Coolant in the oil

5. If an engine does not reach its normal operating temperature, the cause is most likely to be a
   defective
   a. coolant pump.
   b. thermostat.
   c. head gasket.