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Exam Preview:

1. According to the reference material, a four-stroke engine is typical of the General Motors series, which uses a blower to send fresh air into the cylinder and to clear out the exhaust gases.
   a. True
   b. False
2. Horsepower is a unit for measuring work per unit of time. One horsepower is equivalent to ______ foot-pounds of work per minute. Horsepower is determined by either measuring mechanically or computing mathematically.
   a. 28,000
   b. 31,000
   c. 33,000
   d. 35,000
3. According to the reference material, the three basic factors that affect an internal combustion engine's power are as follows: COMPRESSION, IGNITION, and CARBURETION.
   a. True
   b. False
4. According to the reference material, __________ is the actual amount of power that an engine can deliver at a certain speed with a wide-open throttle.
   a. Drawbar horsepower
   b. Brake horsepower
   c. Friction horsepower
   d. Belt horsepower

5. Theoretically, the power stroke of a piston continues for 180° of crankshaft rotation on a four-stroke-cycle engine.
    a. True
    b. False
6. The effect of ALTITUDE on engine power must also be considered. As a rule, 2 1/2 percent of the output of an engine is lost for every ____-foot increase in elevation above sea level.
    a. 250
    b. 500
    c. 1,500
    d. 1,000
7. According to the reference material, if the vacuum gauge reading drops to about __ inches and remains there, it would indicate compression leaks between the cylinder walls and the piston rings or power loss caused by incorrect ignition timing,
    a. 10
    b. 15
    c. 20
    d. 25
8. According to the reference material, the compression pressures in the different cylinders of an engine may vary as much as 50 pounds.
    a. True
    b. False
9. According to the Engine Noises section of the reference material, which of the following noise are characterized by a heavy, dull, metallic knock that is noticeable when the engine is under load or accelerating?
    a. Piston-pin knock
    b. Piston slap
    c. Crankshaft knock
    d. Rod knock
10. Crank the engine with the starting motor until it makes at least four complete revolutions. Normal compression readings for gasoline engine cylinders are usually ___ psi or slightly higher.
    a. 50
    b. 70
    c. 80
    d. 100

ENGINE TROUBLESHOOTING AND OVERHAUL

The engine of any piece of equipment is taken for granted as long as it runs smoothly and efficiently. But all engines lose power sooner or later from normal wear. When this happens, the mechanic must be able to determine the cause and know what is needed to correct the trouble.

Generally speaking, it is not the supervisor's job to perform engine repairs, but it is the supervisor's job to see that these repairs are performed correctly and to assist and instruct those doing the work.

Since the SEABEEs use many models of internal combustion engines, it is impossible to specify the detailed overhaul procedures for all the engines. However, here are several basic principles that apply to all engine overhauls.

1. Consult the detailed repair procedures given in the manufacturers' instruction and maintenance manuals. Study the appropriate manuals and pamphlets before attempting any repair work. Pay particular attention to tolerances, limits, and adjustments.
2. Observe the highest degree of cleanliness in handling engine parts during overhaul.
3. Before starting repair work, be sure all required tools and replacements for known defective parts are available.
4. Keep detailed records of repairs, such as the measurements of parts, hours of use, and new parts installed. An analysis of these records will indicate the hours of operation that may be expected from the various engine parts and help in determining when a part should be renewed to avoid a failure.

Since maintenance cards, manufacturers' technical manuals, and various instructions contain repair procedures in detail, this chapter will be limited to general information on some of the troubles encountered during overhaul, their causes, and methods of repair.

HORSEPOWER AND HORSEPOWER RATINGS

Horsepower is a unit for measuring work per unit of time. One horsepower is equivalent to 33,000 foot-pounds of work per minute. Horsepower is determined by either measuring mechanically or computing mathematically.

Maintenance manuals should be consulted for engine performance data and specifications. These manuals will also have additional horsepower designations and the many different horsepower ratings used by manufacturers in describing the equipment. The method used in measuring power and the purpose for which it is intended account for the variety of horsepower and horsepower ratings.

INDICATED HORSEPOWER

INDICATED HORSEPOWER is the theoretical power that an engine would deliver if all frictional losses were eliminated. It is used mainly by experimental engineers in designing new and more efficient engines. Indicated horsepower may be computed from the following formula:

$$\text{Indicated HP} = \frac{PLANK}{33,000}$$

Where

- P = Mean effective pressure in pounds per square inch (This is the average pressure on the piston during the power stroke minus the average pressure during the other three strokes.)
- L = Length of stroke in feet
- A = Area of piston head in square inches
- N = Working strokes per minute
- K = Number of cylinders in the engine
- 33,000 = The equivalent of one horsepower in foot-pounds per minute

Of all the factors given in this formula, only cylinder pressure (P) and engine rpm (N) can be changed during the normal operation of the engine. The remaining factors are constant.

BRAKE HORSEPOWER

BRAKE HORSEPOWER is the actual amount of power that an engine can deliver at a certain speed with a wide-open throttle. The term *brake horsepower* is derived from the braking device (usually a dynamometer) that is applied to measure the horsepower an engine develops. The dynamometer consists of a resistance-creating device, such as an electric armature revolving in a magnetized field. A paddle wheel revolving in a fluid may also be used to absorb the energy.

An ENGINE DYNAMOMETER maybe used to test an engine that has been removed from the vehicle it drives. If the engine does not develop the manufacturer's recommended horsepower and torque at specific rpms, the engine must be tuned up or repaired.

The CHASSIS DYNAMOMETER can give a quick report on engine conditions by measuring output at various speeds and loads. It is useful in shop testing and adjusting automatic transmissions.

On the chassis dynamometer (fig. 3-1), the driving wheels of the vehicle are placed on rollers. The engine drives the wheels, and the wheels drive the rollers. By loading the rollers varying amounts and by running the engine at different rpms, nearly all normal driving conditions can be simulated. The tests and checks can be made without the interference of body noises, as happens when the vehicle is driven on the road.

FRICTION HORSEPOWER

FRICTION HORSEPOWER is the difference between indicated horsepower and brake horsepower. Actually, it is the power required to overcome friction within the engine, such as friction between engine parts, resistance in driving accessories, and, among other things, loss due to pumping action of the pistons. The latter maybe compared to the effort required to raise the handle of a hand-operated tire pump. It may be difficult to define friction horsepower properly, but with proper maintenance, it can be reduced to improve the mechanical efficiency of the engine.

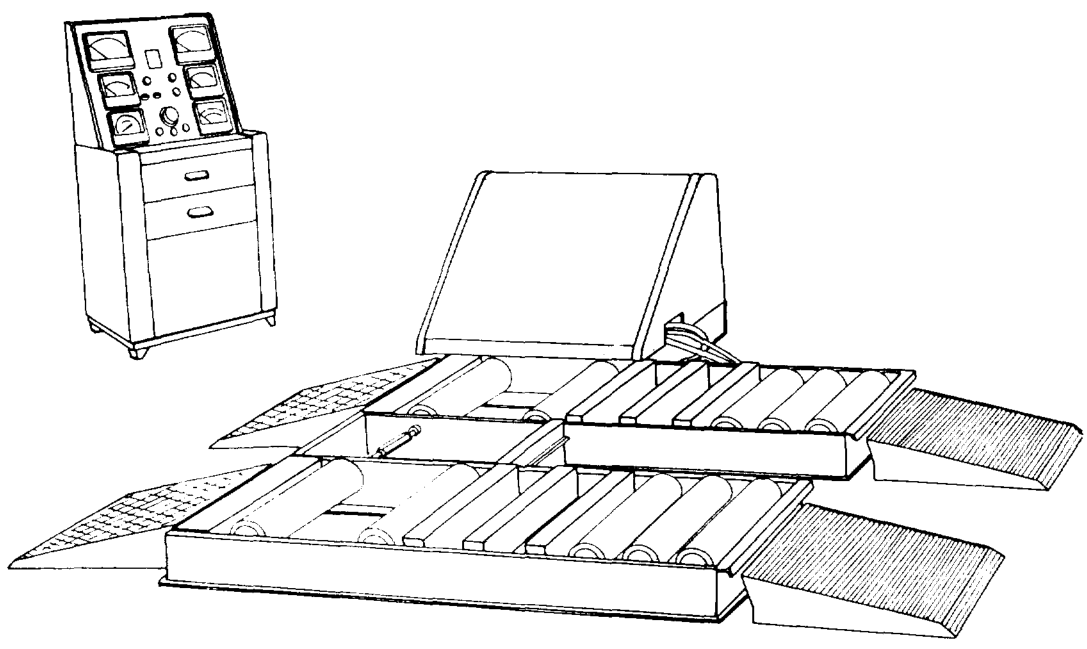

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Figure 3-1.—Chassis dynamometer.

DRAWBAR AND BELT HORSEPOWER

There are two kinds of horsepower commonly used by manufacturers in rating the power of construction vehicles: drawbar and belt horsepower.

DRAWBAR HORSEPOWER is the power that can be exerted in pulling a load. Specifications of the Caterpillar D-8 H series with a D-342 engine, for example, rate the drawbar horsepower at 180.

BELT HORSEPOWER is equivalent to the rated engine power except in cases where the belt pulley is driven through a gear train. In that case, there is a slight loss of power caused by gear friction. Also, while there may be some belt-pulley slippage, it is disregarded in arriving at the belt horsepower rating.

The national Automotive Chamber of Commerce has developed a simplified method of determining taxable horsepower based on the bore of the engine and the number of cylinders. This specification is listed in most manufacturers' manuals, but it does not truly represent the actual horsepower of modern high-speed, high-compression engines. It is used for licensing purposes only in some states.

GRAPHS AND DIAGRAMS

Graphs and diagrams are abbreviated methods of recording operational and maintenance data.

Manufacturers' operational and maintenance manuals often contain graphs and diagrams. The technical bulletins, prepared chiefly for tune-up mechanics, may use a particular graph or diagram to eliminate pages of written description that otherwise would be necessary.

PERFORMANCE CURVES

Figures 3-2 and 3-3 are examples of graphs that describe engine performance in terms of brake horsepower and fuel consumption. Dynamometer tests provide the data used in plotting the performance curves for each engine.

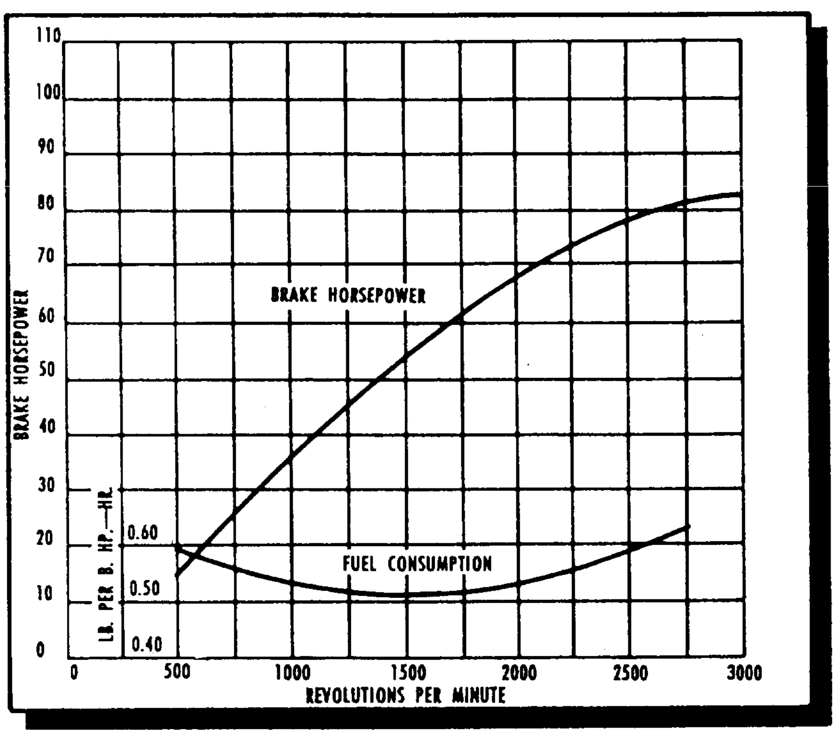


Figure 3-2.—Performance curves of a typical six-cylinder gasoline engine.

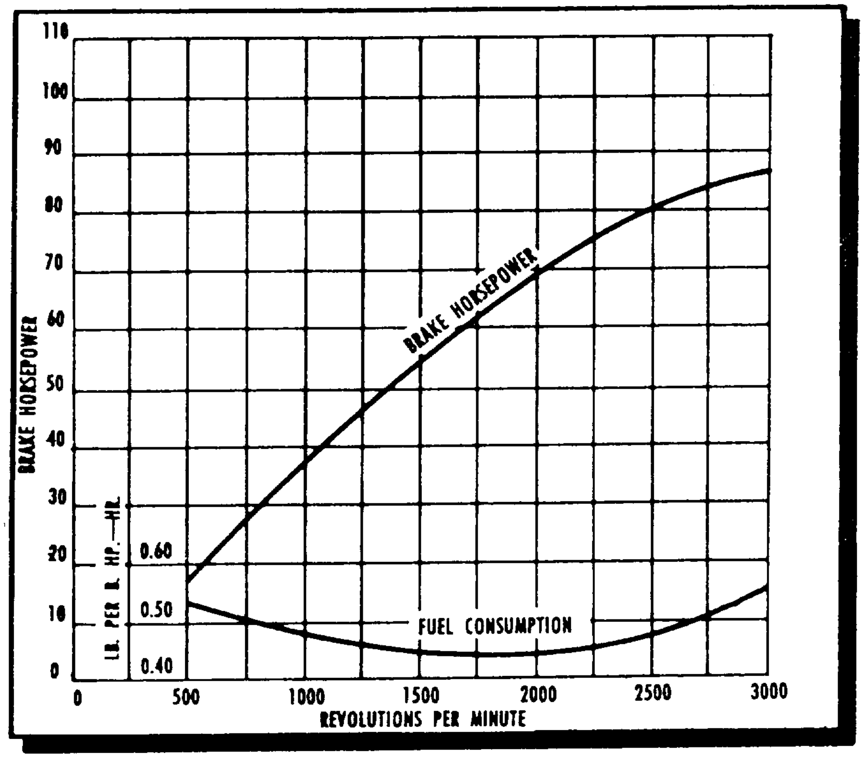


Figure 3-3.—Performance curves of a typical six-cylinder diesel engine.

Figure 3-4 is another example of a graph. It shows that the amount of torque an engine produces varies with its speed. The relationship between torque and horsepower is shown in figure 3-5.

Horsepower is related to both torque and speed. When both are increasing, as they do between 1,200 and 1,600 rpm, then horsepower goes up sharply. As torque reaches maximum and begins to taper off, horsepower continues to rise to maximum. The horsepower starts to decline beyond rated speed where torque falls off sharply.

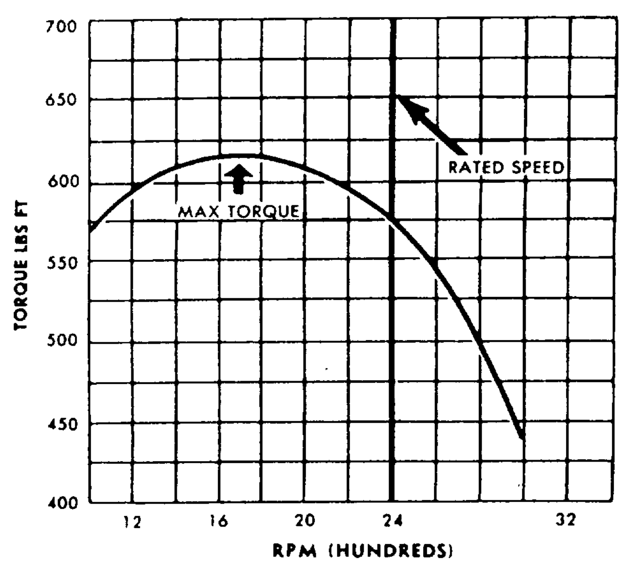


Figure 3-4.—Graph showing relationship between torque and speed.

TIMING DIAGRAMS

Engine timing is largely a matter of opening and closing valves or ports and of adjusting ignition or fuel injection so that these events occur at the proper time in the cycle of engine operation. Timing diagrams picture these events in relation to each other and in relation to top dead center (TDC) and bottom dead center (BDC). They are useful to the CM for quick and easy reference. However, before timing diagrams can be useful, the mechanic must recall a few facts about engine cycles.

The four-stroke-cycle engine makes two complete crankshaft revolutions in one cycle

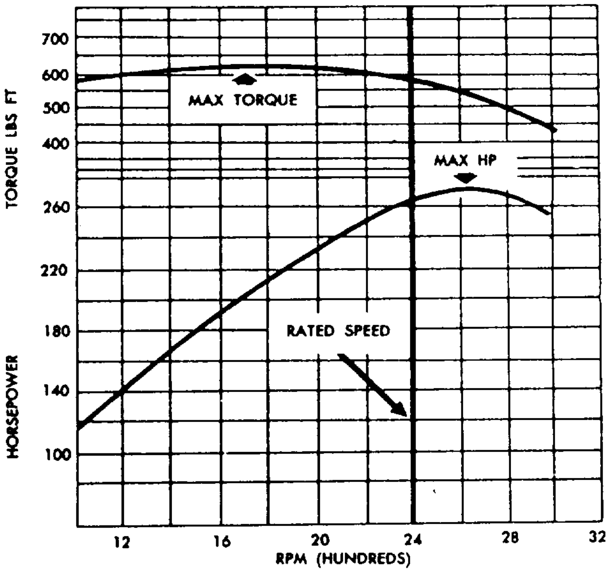


Figure 3-5.—Relationship between torque and horsepower.

(intake, compression, power, and exhaust). The two-stroke-cycle engine completes a cycle with just one crankshaft revolution. With diesel engine cycles (two- and four-stroke), the event of fuel injection will be shown on the timing diagram instead of spark ignition, which is common to gasoline engine operating cycles.

Four-Stroke-Cycle Engine Timing

Figure 3-6 shows a typical timing diagram for a four-stroke-cycle diesel engine. The actual length of the strokes shown and the beginning of fuel injection will vary a few degrees in either direction, depending on the specific manufacturer's recommendations. Follow the events in this cycle by tracing the circular pattern around two complete revolutions in a clockwise direction.

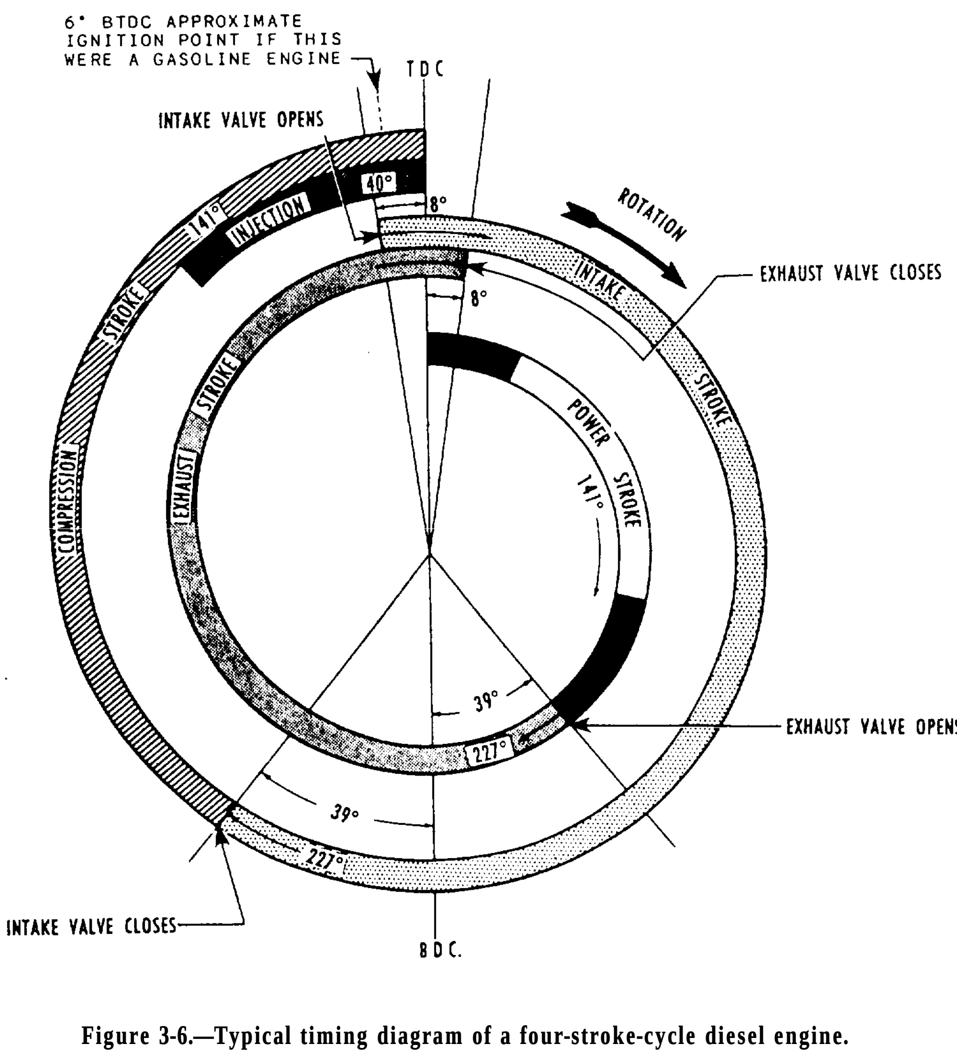


Figure 3-6.—Typical timing diagram of a four-stroke-cycle diesel engine.

Start TDC with the beginning of the POWER STROKE. Compression is at its peak when fuel injection has been completed and combustion is taking place. Power is delivered to the crankshaft as the piston is driven downward by the expanding gases in the cylinder. Power delivery ends when the exhaust valve opens.

After the exhaust valve opens, the piston continues downward to BDC and then upward in the EXHAUST STROKE. The exhaust gases are pushed out of the cylinder as the piston rises to TDC, and the exhaust valve closes a few degrees after TDC to ensure proper scavenging. The crankshaft has made a complete revolution during the power and exhaust strokes.

The intake valve opens a few degrees before TDC near the end of the upward exhaust stroke to aid in scavenging the cylinder. As the crankshaft continues to rotate past TDC, the INTAKE STROKE begins. The intake stroke continues for the whole downward stroke and part of the next upward stroke to take advantage of the inertia of the incoming charge of fresh air.

The rest of the upward stroke is the COMPRESSION STROKE, which begins at the instant of intake valve closing and ends at TDC FUEL INJECTION may begin as much as 40° before TDC and continue to TDC, thus completing the power cycle and the second complete revolution of the engine.

By showing an approximate ignition point in place of fuel injection, figure 3-6 could easily represent a timing diagram for a typical gasoline engine.

For additional information on diesel fuel injection system tests that can be made both in the shop and in the field, refer to the manufacturer's service manual.

Two-Stroke-Cycle Engine Timing

Figure 3-7 shows a timing diagram of a two-stroke-cycle diesel engine. This engine is typical of the General Motors series, which uses a blower to send fresh air into the cylinder and to clear out the exhaust gases. The movement of the piston itself does practically none of the work of intake and exhaust, as it does in a four-stroke-cycle engine. This fact is important to the mechanic in detecting two-stroke-cycle diesel engine power losses.

Beginning at TDC (fig. 3-7), the fuel has been injected, and combustion is taking place. The piston is driven down, and the power is delivered to the crankshaft until the piston is just a little more than halfway down. The exhaust valves (two in each cylinder) open 92 1/2° after TDC. The exhaust gases blow out through the manifold, and the cylinder pressure drops off rapidly.

At 132° after TDC (48° before BDC), the intake ports are uncovered by the downward movement of the piston. Scavenging air under blower pressure swirls upward through the cylinder and clears the cylinder of exhaust gases. This flow of cool air also helps to cool the cylinder and the exhaust valves. Scavenging continues until the piston reaches 44 1/2° after BDC. At this point, the exhaust valves are closed. The blower continues to send fresh air into the cylinder for just a short time (only 3 1/2° of rotation), but it is sufficient to give a slight supercharging effect.

The intake ports are closed at 48° after BDC, and compression takes place during the remainder of the upward stroke of the piston. Injection begins at about 22 1/2° before TDC and ends about 5° before TDC, depending on the engine speed and load.

The whole cycle is completed in one revolution of the crankshaft, and the piston is ready to deliver the next power stroke.

Multiple-Cylinder Engines

Theoretically, the power stroke of a piston continues for 180° of crankshaft rotation on a four-stroke-cycle engine. Best results can be obtained, however, if the exhaust valves are opened when the power stroke has completed about four-fifths of its travel. Therefore, the period that power is delivered during 720° of crankshaft rotation, or one four-stroke cycle, will be 145° multiplied by the number of cylinders in the engine. This may vary slightly according to the manufacturers' specifications. If an engine has two cylinders, power will be transmitted for 290° of the 720° necessary to complete the four events of the cycle. The momentum of the flywheel rotates the crankshaft for the remaining 430° of travel.

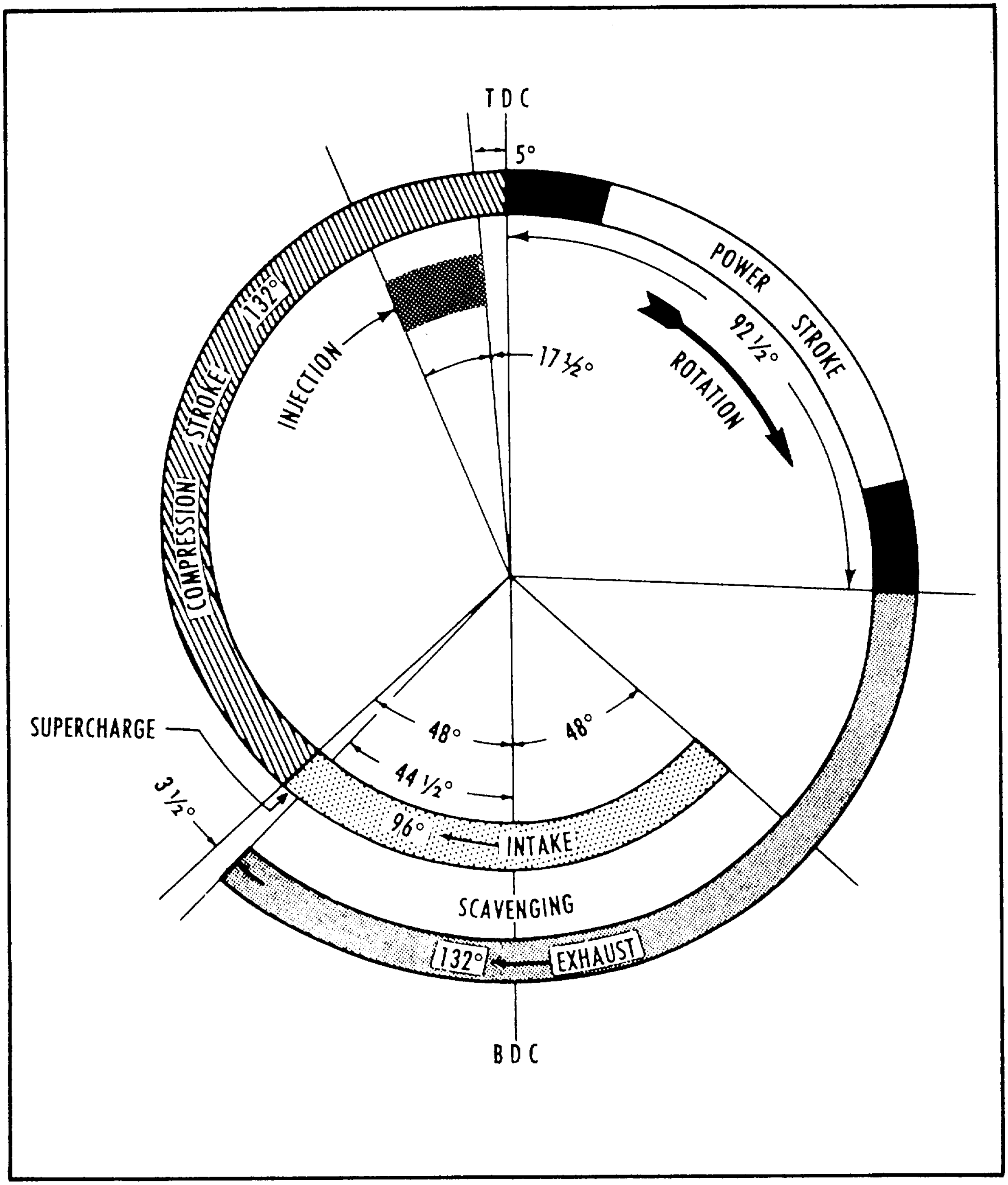


Figure 3-7.—Timing diagram of a two-stroke-cycle diesel engine.

As cylinders are added to an engine, each one must complete the four steps of the cycle during two revolutions of the crankshaft. The number of power impulses for each revolution also increases, producing smoother operation. If there are more than four cylinders, the power strokes overlap, as shown in figure 3-8. The length of overlap increases with the number of cylinders. The diagram for the six-cylinder engine shows a new power stroke starting each 120° of crankshaft rotation and lasting 145°. This provides an overlap of 25°. In the eight-cylinder engine, a power stroke starts every 90° and continues for 145°, resulting in a 55° overlap of power. Because the cylinders fire at regular intervals, the power overlap will be the same regardless of firing order and will apply to either in-line or V-type engines.

POWER LOSSES AND FAILURE

Power failures can result from minor troubles, such as loose or bare wires and disconnected or damaged fuel lines. When reported by the

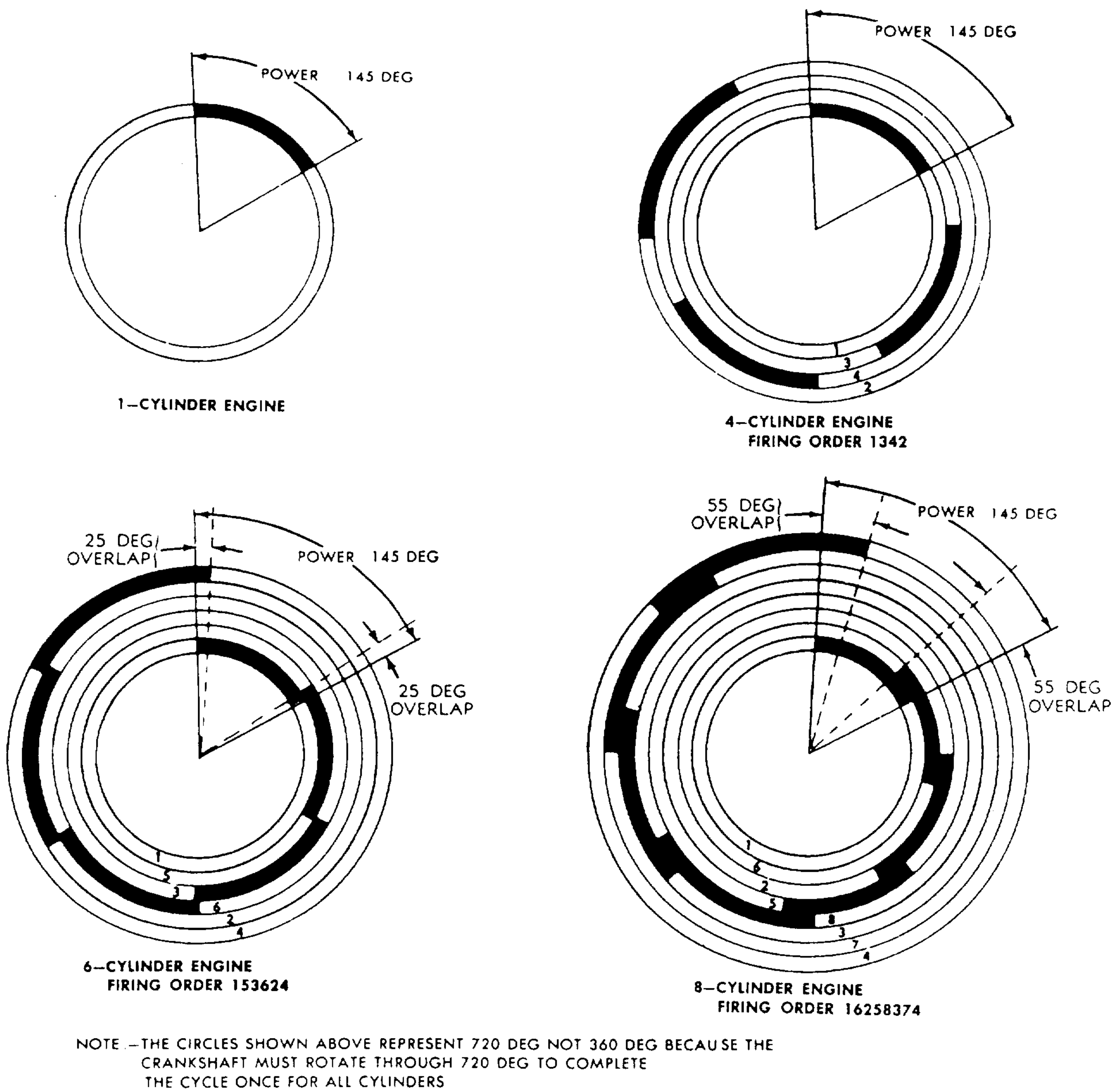


Figure 3-8.-Power strokes in one-, four-, six-, and eight-cylinder engines.

Equipment Operator, these troubles are easy to detect without too much checking and testing. The supervisor must, however, make the mechanics aware that there probably was, in addition, an actual or contributing cause to the power failure. The supervisor must train the mechanics to look for this cause while making repairs. Unless eliminated, this may be the cause of major trouble later on.

Too often, troubles concerned with power loss occur within the engine and are not easily found. It is these hard-to-find troubles, with little or no visual indication, that keep the CMs busy. An operator may notice a decided power loss in the equipment and, because there is excessive smoke coming from the exhaust, report the trouble as improper carburetion, or, in the case of a diesel engine, as injector trouble.

An inexperienced mechanic may notice an increased engine temperature in addition to the exhaust smoke and diagnose the loss of power as improper valve action or as trouble in the cooling system. The diagnoses are comparatively simple through visual indications. But, as a CM1, you know that there are many causes of power loss that have little or no visual indications. Examples are incorrect ignition timing, faulty coil or condenser, defective mechanical or vacuum spark advance, worn distributor cam, or slipping clutch. Any of them can cause a power loss.

After a deficiency has been located in an engine, it is usually easy to make the necessary corrections to eliminate the conditions causing the deficiency. Careful analysis and straight thinking, however, are often needed to find the cause of engine deficiencies. If a supervisor has a thorough knowledge of the basic engineering and operating principles of an engine, his or her job of training the mechanics will be easier and more interesting. In diagnosing engine deficiencies, the supervisor must never jump to conclusions and make a decision on the nature of repairs to be made before being sure that what will be done will eliminate the trouble. The mechanics must be able to interpret the engine instrument indications as well as use the proper testing devices. Furthermore, they must be able to road test the equipment to determine whether repairs have been made satisfactorily and whether a part or several parts should be adjusted or replaced. Besides, the mechanic must know when and how to make emergency adjustments for every unit on the engine.

It may seem that some of the qualifications required of a good mechanic point to the know-how of an automotive engineer. However, no one person can know all about engines and also be an expert in repairing all kinds of powered equipment used by the SEABEEs. For instance, if the checks or instrument tests indicate some internal trouble in a magneto, carburetor, or fuel injection unit, the repairs should be made by mechanics who have experience or have been specially trained to use the equipment to do the particular job at hand. It is the supervisor who will be expected to have the answers to all the questions asked by less experienced mechanics.

The three basic factors that affect an internal combustion engine's power are as follows: COMPRESSION, IGNITION, and CARBURETION. In the diesel engine, fuel is injected into each cylinder, and ignition depends on the heat of compression; in the gasoline engine, ignition and carburetion are independent. In both engines, of course, proper action and timing of all three factors are necessary for the engine to produce its rated power.

It is obvious then that an engine runs and develops rated power only if all of its parts function or operate as they should. If any of these parts wear or break, requiring replacement or adjustment, the performance charts and engine specifications are "tools" that will help the mechanic to bring those parts back to their original relationship to each other.

There are more factors NOT directly associated with engine working parts that must be considered in correcting engine power losses.

OPERATING CONDITIONS can affect engine power. For example, the usable horsepower of an engine is reduced by the number of accessories it must operate. If the engine is required to provide power for lifting operations at the same time it is delivering power to wheels or tracks, the engine may be overloaded and may not be able to develop its rated rpm; consequently, the rated horsepower would NOT be reached.

The effect of ALTITUDE on engine power must also be considered. As a rule, 2 1/2 percent of the output of an engine is lost for every 1,000-foot increase in elevation above sea level. Overheated air entering the cylinders has the same effect on engine power as an increase in altitude. In computing horsepower output, engineers will deduct as much as 1 percent for each 10°F rise in the intake air temperature above a "normal" temperature of 70°F.

ENGINE TROUBLESHOOTING

"Diagnosing" may be defined as a systematic means of identifying a problem by using all available information and facts. Usually, the Equipment Operator will be able to tell the symptoms, such as the engine lacks power, uses excessive oil, has low oil pressure, or makes certain noises.

Some internal engine problems may be found by listening for unusual noises and knocks or by examining the exhaust gases for indications of incomplete combustion. Then too, placing an artificial load on an engine can emphasize certain noises; for example, applying the brakes and partially engaging the clutch with the vehicle transmission in high gear. In this manner, the engine operating under a load can be heard without the interference of body noises.

There are also other tricks of the trade that a mechanic may use, such as feeling the oil or shorting out the spark plugs to get an idea of the source of trouble.

EXCESSIVE OIL CONSUMPTION

Excessive oil consumption would probably first be noted by the Equipment Operator who has to add oil to maintain the proper oil level. There are two main causes of excessive oil consumption: external leakage and burning in the combustion chamber.

External oil leaks can often be detected by inspecting the seals around the oil pan, valve covers, timing gear housing, and at the oil line and oil filter connections.

The burning of oil in the combustion chamber usually produces a bluish tinge in the exhaust gas. Oil may enter the combustion chamber in two ways: (a) through clearances caused by wear between the intake valve guides and stems and (b) around the piston rings.

Excessive oil consumption caused by worn valve guides or stems may be indicated by too much carbon on the undersides of the intake valve. In this case, it is usually necessary to install valve seals, new valve guides, or new valves. If excessive oil consumption is caused by worn rings or worn cylinder walls, the supervisor may have the mechanics do a complete engine overhaul.

LOW OIL PRESSURE

Low oil pressure often indicates worn engine bearings. Worn bearings can pass so much oil that the oil pump cannot maintain oil pressure. Other causes of low oil pressure include a weak relief-valve spring, a worn oil pump, a broken or cracked oil line, or a clogged oil line. Oil dilution, foaming, sludge, insufficient oil, incorrect oil, or oil made too thin by the engine overheating will also cause low oil pressure.

ENGINE NOISES

A variety of engine noises may occur, Although some noises have little significance, others can indicate serious engine trouble that will require prompt attention to prevent major damage to the engine.

A listening rod can be of help in locating the source of a noise. The rod acts somewhat like the stethoscope a doctor uses to listen to a patient's heartbeat or breathing. When one end is placed at the ear and the other end at some particular part of the engine, noises from that part of the engine will be carried along the rod to your ear. By determining the approximate source of the noise, you can, for example, locate a broken or noisy ring in a particular cylinder or a main bearing knock.

Valve and Tappet Noise

Valve and tappet noise is a regular clicking sound that increases in intensity as the engine speed increases. The cause is usually excessive valve clearance. A feeler gauge inserted between the valve stem and lifter or rocker arm will reduce the clearance, and the noise should decrease. If the noise does not decrease when the feeler gauge is inserted, it is probably caused by weak lifter springs, worn lifter faces, lifters loose in the block, a rough adjustment-screw face, a rough cam lobe, or possibly the noise is not from the valves at all.

A noisy hydraulic valve lifter maybe sticking because of dirt in the ball or disk valve. When this happens, you must disassemble the lifter and clean all the parts in a clean solvent. Then reassemble the lifter and fill it with clean, light engine oil.

Connecting Rod Noise

Connecting rod noise usually tends to give off a light knocking or pounding sound. The sound is more noticeable when the engine is "floating" (not accelerating or decelerating) or as the throttle is eased off with the vehicle running at medium speed. To locate a noise in the connecting rod, short out the spark plugs one at a time. The noise will be greatly reduced when the piston in the cylinder that is responsible is not delivering power.

Piston-Pin Knock

Piston-pin knock is identified more as a metallic double-knock rather than a regular clicking sound like that heard in valve and tappet noise. In addition, it is most noticeable during idle with the spark advanced. A check can be made by idling the engine with the spark advanced and then shorting out the spark plugs. Piston-pin noise coming from a cylinder will be reduced somewhat when the spark plug for that cylinder is shorted out. Causes of this noise are a worn or loose piston-pin, a worn bushing, and a lack of oil.

Piston-Ring Noise

Piston-ring noise is also similar to valve and tappet noise since it is identified by a clicking, snapping, or rattling sound. This noise is most noticeable on acceleration. Low-ring tension, broken or worn rings, or worn cylinder walls will produce this sound. To avoid confusing this sound with other engine noise, make the following test: remove the spark plugs and add an ounce or two of heavy engine oil to each cylinder. Crank the engine for several revolutions to work the oil down past the rings. Replace the spark plugs and start the engine, If the noise has decreased, it is probable that the rings are at fault.

Piston Slap

Piston slap may be detected by a hollow, bell-like knock and is due to the rocking back and forth of the piston in the cylinder. If the slap occurs only when the engine is cold, it is probably not serious. However, if it occurs under all operating conditions, a further examination is called for. The slap can be caused by worn cylinder walls, worn pistons, collapsed piston skirts, or misaligned connecting rods.

Crankshaft Knock

Crankshaft knock is a heavy, dull, metallic knock that is noticeable when the engine is under load or accelerating. When the noise is regular, it can be contributed to worn main bearings. When irregular and sharp, the noise is probably due to worn thrust bearings.

ENGINE TESTING

In most shops, the Navy provides accurate and dependable testing equipment. But having the testing equipment in the shop is NOT enough. The supervisor and the crew must know how to use this equipment since proper use provides the quickest and surest means of finding out what is wrong and where the fault lies.

Four of the most widely used testing instruments are the cylinder compression tester, vacuum gauge, cylinder leakage tester, and tachometer.

Compression Test

As you have learned, engine power results from igniting a combustible mixture that has been compressed in the combustion chamber of an engine cylinder. The tighter a given volume of fuel mixture is squeezed in the cylinder before it is ignited, the greater the power developed. Unless approximately the same power is developed in each cylinder, the engine will run unevenly. The cylinder compression tester (fig. 3-9) is used to measure cylinder pressure in psi, as the piston moves to TDC on the compression stroke.

By measuring compression pressures of all cylinders with a compression gauge, then comparing them with each other and with the manufacturer's specifications for a new engine, you get an accurate indication of engine condition.

The compression pressures in the different cylinders of an engine may vary as much as 20 pounds. The variation is caused largely by the lack of uniformity in the volume of the combustion chamber. It is nearly impossible to make all the combustion chambers in a cylinder head exactly the same size. For example, in a given engine with

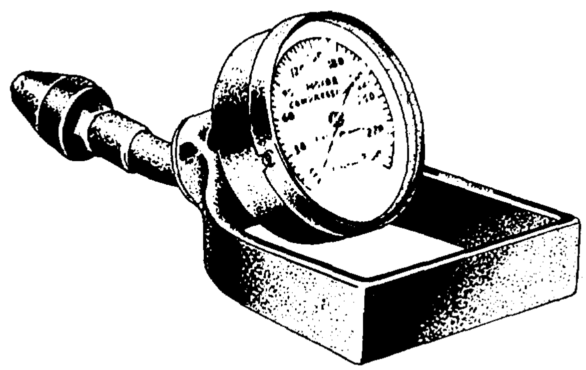


Figure 3-9.—Cylinder compression tester.

a 7 to 1 compression ratio with all combustion chambers the same volume, the compression pressure would be about 120 pounds in all cylinders. However, if one combustion chamber is 1/3 cubic inch too small, the pressure will be about 126 pounds, and if it is 1/3 cubic inch too large, the compression pressure would be about 114 pounds. This is a variation of 12 pounds. Also note that a carbon deposit will raise the compression pressure at any given ratio by reducing the combustion chamber volume—the greater the deposit, the higher the pressure.

To make a compression test, first, warm up the engine. Warming up will allow all the engine parts to expand to normal operating condition and will ensure a film of oil on the cylinder walls. Remember that the oil film on the walls of the cylinder helps the expanded piston rings to seal the compression within the cylinder. After the engine is warmed to operating temperature, shut it down and remove all the spark plugs. Removing all the plugs will make the engine easier to crank while you obtain compression readings at each cylinder. The throttle and choke should be in a wide-open position when compression readings are taken. Some compression gauges can be screwed into the spark plug hole. Most compression gauges, however, have a tapered rubber end plug and must be held securely in the spark plug opening until the highest reading of the gauge is reached.

Crank the engine with the starting motor until it makes at least four complete revolutions. Normal compression readings for gasoline engine cylinders are usually 100 psi or slightly higher. Compression testing is faster and safer when there are two mechanics assigned to the job. Remember that the compression test must be completed before the engine cools off.

Unless the compression readings are interpreted correctly, it is useless to make the tests. Any low readings indicate a leakage past the valves, piston rings, or cylinder head gaskets. Before taking any corrective action, make another check to try to pinpoint the trouble. Pour approximately a tablespoon of heavy oil into the cylinder through the spark plug hole, and then retest the compression pressure. If the pressure increases to a more normal reading, it means the loss of compression is due to leakage past the piston rings. If adding oil does not help compression pressure, the chances are that the leakage is past the valves. Low compression between two adjacent cylinders indicates a leaking or a blown head gasket. If the compression pressure of a cylinder is low for the first few piston strokes and then increases to near normal, a sticking valve is indicated. Near normal compression readings on all cylinders indicate that the engine cylinders and valves are in fair condition. Indications of valve troubles by compression tests may be confirmed by taking vacuum gauge readings.

Vacuum Gauge Test

When an engine has an abnormal compression reading, it is likely that the cylinder head will have to be removed to repair the trouble. Nevertheless, the mechanics should test the vacuum of the engine with a gauge. The vacuum gauge provides a means of testing intake manifold vacuum, cranking vacuum, fuel pump vacuum, and booster pump vacuum. The vacuum gauge does NOT replace other test equipment, but rather supplements it and diagnoses engine trouble more conclusively.

Vacuum gauge readings are taken with the engine running and must be accurate to be of any value. Therefore, the connection between the gauge and intake manifold must be leakproof. Also, before the connection is made, see that the openings to the gauge and intake manifold are free from dirt or other restrictions.

When a test is made at an elevation of 1,000 feet or less, an engine in good condition, idling at a speed of about 550 rpm, should give a steady reading of from 17 to 22 inches on the vacuum gauge. The average reading will drop approximately 1 inch of vacuum per 1,000 feet at altitudes of 1,000 feet and higher above sea level.

When the throttle is opened and closed suddenly, the vacuum reading should first drop to about 2 inches with the throttle open, and then come back to a high of about 24 inches before settling back to a steady reading as the engine idles, as shown in figure 3-10. This is normal for an engine in good operating condition.

If the gauge reading drops to about 15 inches and remains there, it would indicate compression leaks between the cylinder walls and the piston rings or power loss caused by incorrect ignition timing, A vacuum gauge pointer indicating a steady 10, for example, usually means that the valve timing of the engine is incorrect. Below-normal readings that change slowly between two limits, such as 14 and 16 inches, could point to a number of troubles. Among them are improper carburetor idling adjustment, maladjusted or

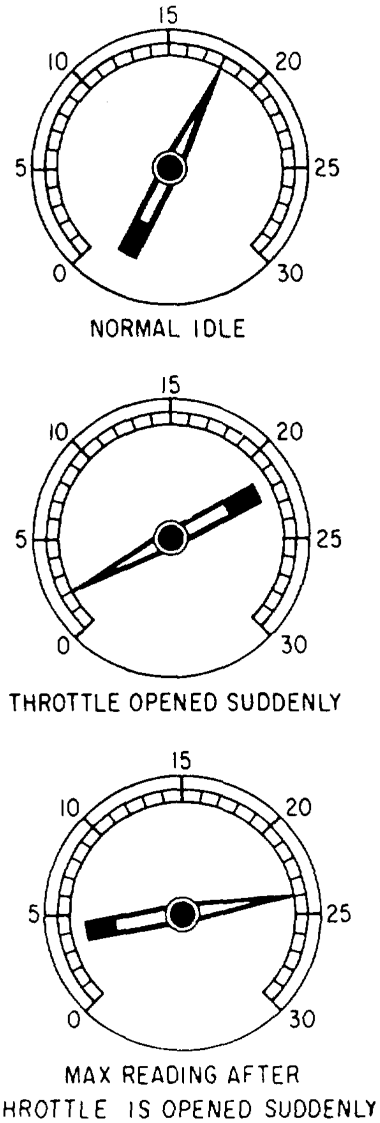


Figure 3-10.—Approximate vacuum gauge readings on a normal operating engine.

burned breaker points, and spark plugs with the electrodes set too closely.

A sticking valve could cause the gauge pointer to bounce from a normal steady reading to a lower reading and then back to normal. A broken or weak valve spring would cause the pointer to swing widely as the engine is accelerated. A loose intake manifold or a leaking gasket between the carburetor and manifold would show a steady low reading on the vacuum gauge.

Vacuum gauge tests only help to locate the trouble. They are not always conclusive, but as you gain experience in interpreting the readings, you can usually diagnose engine behavior.

Cylinder Leakage Test

Another aid in locating compression leaks is the cylinder leakage test. The principle involved is that of simulating the compression that develops in the cylinder during operation. Compressed air is introduced into the cylinder through the spark plug or injector hole, and by listening and observing at certain key points, you can make some basic deductions.

There are commercial cylinder leakage testers available, but actually the test may be conducted with materials readily available in most repair shops. In addition to the supply of compressed air, a device for attaching the source of air to the cylinder is required. For a gasoline engine, this device can be made by using an old spark plug of the correct size for the engine to be tested. By removing the insulator and welding a pneumatic valve stem to the threaded section of the spark plug, you will have a device for introducing the compressed air into the cylinder.

The next step is to place the piston at TDC or “rock” position between the compression and power strokes. Then you can introduce, the compressed air into the cylinder. Note that the engine will tend to spin. Now, by listening at the carburetor, the exhaust pipe, and the oil filler pipe (crankcase), and by observing the coolant in the radiator, when applicable, you can pinpoint the area of air loss. A loud hissing of air at the carburetor would indicate a leaking intake valve or valves. Excessive hissing of air at the oil filler tube (crankcase) would indicate an excessive air leak past the piston rings. Bubbles observed in the coolant at the radiator would indicate a leaking head gasket.

As in vacuum testing, indications are not conclusive. For instance, the leaking head gasket may prove to be a cracked head, or the bad rings may be a scored cylinder wall. The important thing is that the source of trouble has been pinpointed to a specific area, and a fairly broad, accurate estimate of the repairs or adjustments required can be made without dismantling the engine.

In making a cylinder leakage test, remove all the spark plugs so that each piston can be positioned without the resistance of compression of the remaining cylinders. The commercial testers, such as the one shown in figure 3-11, have a gauge indicating a percentage of air loss. The gauge is connected to a spring-loaded diaphragm. The source of air is connected to the instrument and counterbalances the action of the spring against the diaphragm. By adjusting the spring tension, you can calibrate the gauge properly against a variety of air pressure sources within a given tolerance.

Tachometer

The tachometer is a speed-indicating instrument that measures the rpms of a rotating shaft. It maybe either manually or electrically operated.

A manual tachometer (fig. 3-12) is held by its tip against the end of an exposed rotating shaft. Make sure the end of the shaft is clean and there is no slippage between the tip of the tachometer and the shaft. Read the speed directly on the tachometer dial, which is calibrated in revolutions per minute. No timing is necessary, as variations in speed will be reflected by movement of the pointer on the dial during the test.

When using the manual tachometer on a shaft, make sure that that shaft turns at the same speed as the crankshaft or you will not get an accurate reading of engine rpms. In many instances, it is easy to take manual tachometer readings from a camshaft or fuel pump shaft. On four-cycle engines, this shaft runs at one-half engine speed. Consequently, any manual tachometer reading taken from this shaft must be doubled to get the true engine speed.

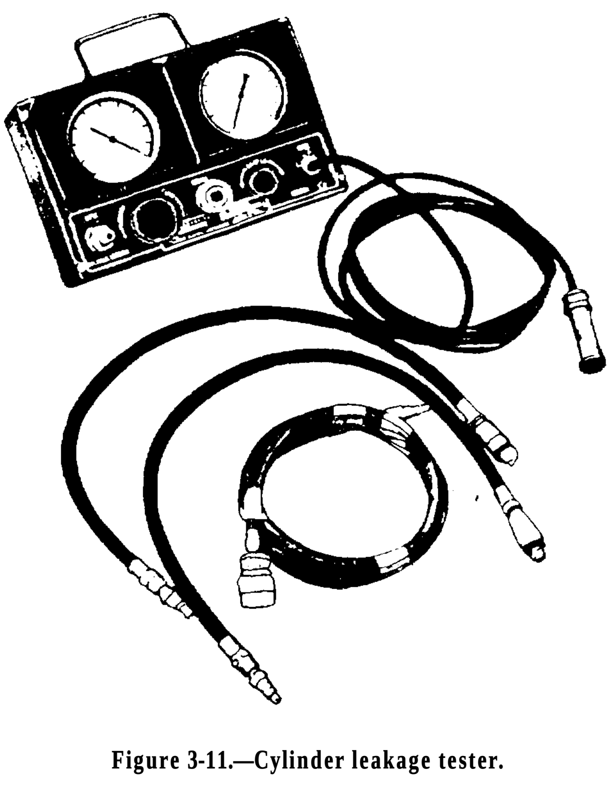


Figure 3-11.—Cylinder leakage tester.

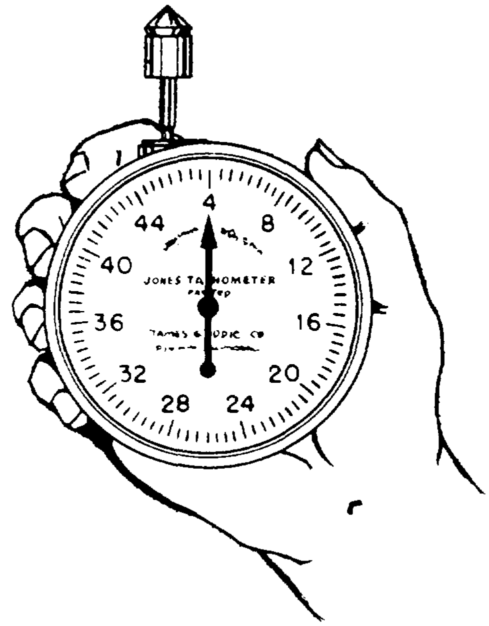


Figure 3-12.—Manually operated tachometer.

The electric tachometer is connected to the ignition primary circuit to measure the number of times per minute the primary circuit is interrupted. It then translates this information into engine speed.

The electric tachometer may have a selector switch on it that can be turned to correspond with the number of lobes on the distributor cam. The number of lobes will be the same as the number of cylinders in the engine. For the proper method of hooking up and using the electric tachometer, check the manufacturer's instructions for the tachometer you are using.

GAUGE CARE AND MAINTENANCE

As a CM1, you will probably be responsible for the care and maintenance of the engine testing equipment, such as cylinder compression tester, vacuum gauge, cylinder leakage tester, and tachometer. You, as the supervisor, must impress upon the mechanics that these gauges and testers are fragile instruments that can be damaged through improper use or rough handling. They should be kept in a safe place in the toolroom and should be returned there immediately after being used. Keeping the gauges and testers clean is about all the maintenance that is required. If they are dropped, broken, or jarred out of calibration, it is generally necessary to return them to the manufacturer for repairs or to replace them.

VALVES, VALVE MECHANISMS, AND CYLINDER HEADS SERVICING

When an engine has been properly maintained and serviced, the first major repair job it will need will normally involve the valves. A general procedure for servicing valves is described in the NAVEDTRA training manual for second class Construction Mechanics. Here, you will get more details on the servicing and troubleshooting of valves, valve mechanisms, and cylinder heads.

VALVE TROUBLES

Some of the common valve troubles that you may encounter in working with engines, and possible causes of these troubles, are indicated below.

- carbon deposits, worn valve guides, a warped valve stem, insufficient oil, cold engine operation, or overheating.
- valve, insufficient valve tappet clearance, a distorted seat, overheated engine, lean fuel-air mixture, preignition, detonation, or valve seat leakge.
- overheating, detonation, excessive tappet clearance, seat eccentric to stem, cocked spring or retainer, or scratches on the stem caused by improper cleaning.
- tappet clearance, dirt on the face, or distortion.
- in the fuel, a rich fuel mixture, poor combustion, worn valve guides, dirty oil, or the use of a wrong oil.

VALVE ADJUSTMENTS

Proper and uniform, valve adjustments are required for a smooth running engine. Unless the clearance between valve stems and rocker arms or valve lifters is adjusted according to the manufacturer's specifications, the valves will not open or close at the proper time, and engine performance will be affected. Too great a clearance will cause the valves to open late. Excessive clearance may also prevent a valve from opening far enough and long enough to admit a full charge of air or fuel mixture (with either a diesel or gasoline engine), or it will prevent the escape of some exhaust gases from the cylinder. A reduced charge in the cylinder obviously results in engine power loss. Exhaust gases that remain in the cylinder take up space, and when combined with the incoming charge, reduce the effectiveness of the mixture. Valves adjusted with too little clearance will overheat and warp. Warped valves cannot seat properly and will permit the escaping combustion flame to burn both the valve and valve seat.

When reassembling an engine after reconditioning the valves, make sure the adjusting screws are backed off before rotating the engine. A valve that is too tight could strike the piston and damage either the piston or the valve, or both. Adjust the valves according to the manufacturer's specifications, following he recommended procedure.

On any engine where valve adjustments have been made, be sure that the adjustment locks are tight and that the valve mechanism covers and gaskets are in place and securely fastened to prevent oil leaks.

Overhead Valves

Most overhead valves are adjusted "hot"; that is, valve clearance recommendations are given for an engine at operating temperatures. Before valve adjustments can be properly effected, the engine must be run and brought up to normal operating temperature.

To adjust a valve, remove the valve cover and measure the clearance between the valve stem and the rocker arm. Loosen the locknut and turn the adjusting screw in the rocker arm, in the manner shown in figure 3-13. On engines with stud-mounted rocker arms, make the adjustment by turning the stud nut.

Valves in Block

This type of valve arrangement is not commonly seen in the field; however, we will describe the adjustment procedure in case you should happen to run across this type.

Valves within the block are generally adjusted "cold"; that is, recommended valve clearance are given for a cold engine. These valves have mechanisms quite similar to those of overhead valves. They are adjusted by removing the side plates, usually found beneath the intake manifold on the side of the engine block (fig. 3-14). Since you must stop this engine to adjust the valves, the piston in the cylinder to be adjusted must be on TDC of the compression stroke. You can determine this by watching the valves of the piston that is paired with the one that is being set. As the cylinder that is being positioned is coming up on the compression stroke, the paired cylinder will be coming up on the exhaust stroke. Therefore, an exhaust valve will be open. Just as the exhaust valve closes and the intake valve begins to open, the cylinder that is to be set will be on TDC of the compression stroke, and you can set the two valves. Once the No. 1 cylinder is positioned, follow through according to the firing order of the engine, as this makes the job easier and faster. You may also use this procedure when adjusting valves on overhead valve engines.

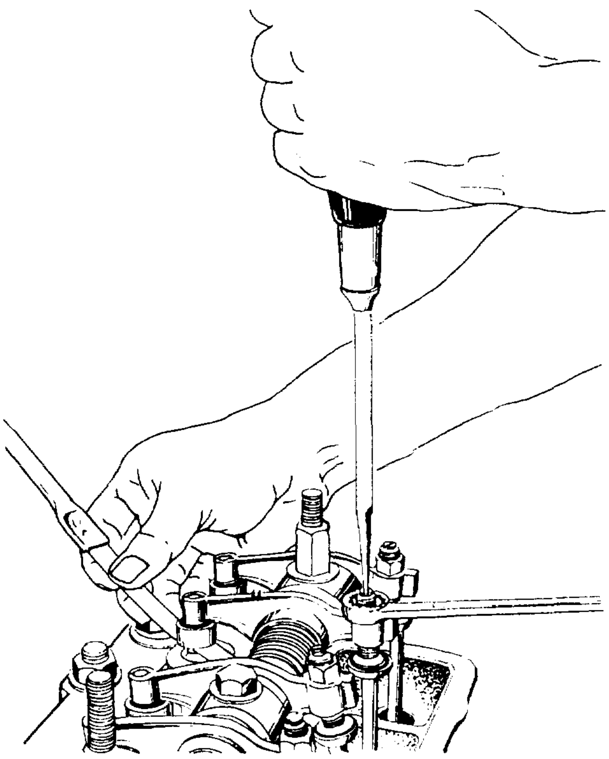


Figure 3-13.—Adjusting overhead valves.

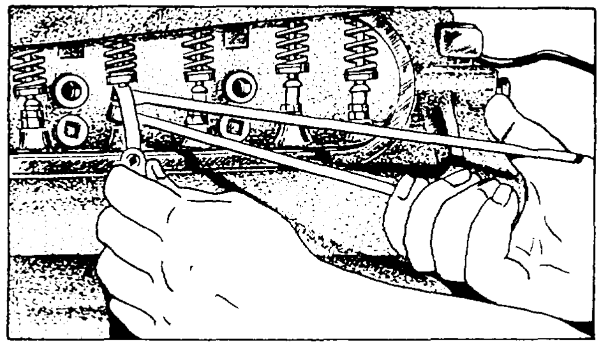


Figure 3-14.—Adjusting valve in block.

Hydraulically Operated Valves

On engines equipped with hydraulic valve lifters (fig. 3-1 5), it is not generally necessary to

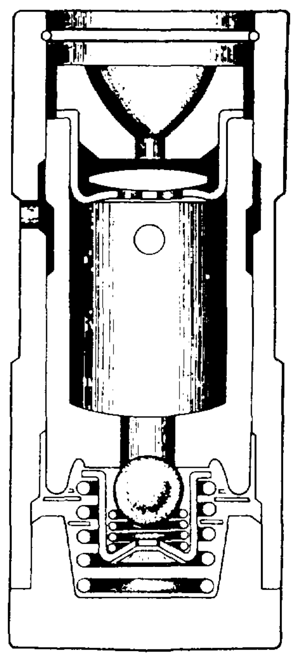


Figure 3-15.—Hydraulic valve lifter.

adjust the valves periodically. The engine lubrication system supplies a flow of oil to the lifters at all times. These hydraulic lifters operate at zero clearance and compensate for changes in engine temperature, adapt automatically for minor wear at various points, and thus provide ideal valve timing.

The first indication of a faulty hydraulic valve lifter is a "clicking" noise. In one method for locating a noisy valve lifter, you use a piece of garden hose. Place one end of the hose near the end of each intake and exhaust valve and the other end of the hose to your ear. In this way you can localize the sound, making it easy to determine which lifter is at fault. Another method is to place a finger on the face of the valve spring retainer. If the lifter is not functioning properly, a distinct shock will be felt when the valve returns to its seat.

Usually, where noise exists in one or more of the valve lifters, you should remove all lifter units, clean them in a solvent, reassemble them, and reinstall them in the engine. If dirt, carbon, or the like, is found in one unit, it more than likely is present in all of them; and it will be only a matter of time before the rest of the lifter units will give trouble.

VALVE REMOVAL

For such services as valve or valve seat grinding, valve seat insert replacement, and valve guide cleaning or replacement, you need to remove the cylinder head and valves from the engine. Avoid interchanging valves; each valve must be replaced in the valve port from which it was removed. A valve rack in which the valves may be placed in their proper order—along with their valve springs, retainers, and locks—is normally provided. Different tools and procedures for removal are used for different engines. Check the manufacturer's maintenance manual for your particular engine.

VALVE GRINDING

The first step in servicing valves after they have been removed from the engine is to rid them of carbon. The best method for doing this is cleaning them with a wire buffing wheel or brush.

WARNING

When using the wire buffing wheel, always wear goggles to protect your eyes from wire or carbon that may fly off the buffing wheel.

After the cleaning process, inspect each valve to determine whether it can be serviced and reused or must be replaced. The valve should be checked with a run-out gauge for eccentricity and inspected for worn valve stem and badly cracked, burned, or pitted valve face. Minor pits, burns, or irregularities in the valve face may be removed by grinding.

To grind valves, clamp the valve stem in the chuck of the valve-refacing machine so that the face of the valve will contact the grinding wheel. (See fig. 3-16.) Set the chuck at the proper angle to give the correct angle to the setting face. This angle must just match the valve seat angle. It is becoming common, however, in some engines to reface the valves at a slightly flatter angle than the seat, usually 1/4° to 1°, to provide what is known as an "interference angle." This angle provides greater pressure at the upper edge of the valve seat, which aids in cutting through any deposits that form and provides for better sealing. Some engines use the interference angle on the exhaust valve only, and others use it on both the intake and exhaust valves. Check the manufacturer's manual for the recommended angle for both valve and valve seat.

CAUTION

Because of the different angles between the valve and the valve seat, do NOT use grinding compound to finish the surface.

At the start of the grinding operation, make the first cut a light one. If metal is removed from only one-third or one-half of the valve face, check to make sure you have cleaned the valve stem and grinder chuck thoroughly and centered the valve

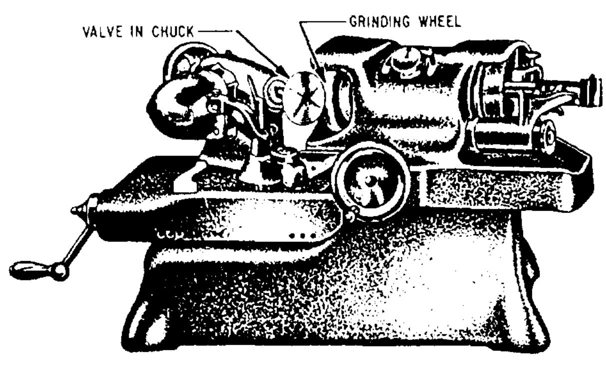


Figure 3-16.—Valve-refacing machine.

in the chuck. If the valve is centered properly, then the valve stem is bent and the valve must be replaced. Remove only the amount of metal necessary to true up t he face and remove the pits. Make sure there is a proper margin of thickness, as shown in figure 3-17. If this margin cannot be retained after refacing, the valve must be discarded.

There are many different makes and models of valve-refacing machines. Make sure that you read and understand the instructions that apply to the machine you are using.

VALVE GUIDE SERVICING

When servicing valve guides, remember that the guides must be clean and in good condition for normal valve seating. If, after cleaning a valve guide, you find it worn, remove it and install a new one. To remove old or worn valve guides and install new ones, you need special guide removing and replacing tools.

One procedure for checking valve guide wear is as follows. Remove the cylinder head from the vehicle to a clean safe working area. Remove the valve springs and clean the valves and valve guides. Insert the valve into the guide, allowing the valve to remain off of its seat. Attach a dial indicator to the cylinder head with the gauge button just touching the edge of the valve head. Watch the dial indicator gauge face, and move the valve head sideways to determine the amount of valve guide wear.

Another checking procedure involves the use of a small hole gauge to measure the inside diameter of the guide and a micrometer to measure the valve stem; the difference in the readings will be the clearance. When the maximum clearance is exceeded, the valve guide needs further servicing before you can proceed. If the valve guide is of the integral type, you must ream it to a larger size and install a valve with an oversized stem. But if the guide is replaceable, you should remove it and install another one.

To remove valve guides, you will need a special puller. On many L-head engines, you can drive the guides down into the valve spring compartment and then remove them. You can use an arbor press to remove guides from the overhead type of engines.

To replace the guides, use a valve guide driver or a valve guide replacer except on overhead valve engines, where an arbor press is necessary. In any case, the guides must be installed to the proper depth in either the block or head, as specified by the manufacturer.

After the valve guides are serviced and the valve seats ground, check the concentricity of the two with a dial indicator. (See fig. 3-18.) Any irregularity in the seat will register on the dial.

VALVE SEAT GRINDING

Two general types of valve seat grinders are in use. One is a concentric grinder; the other, an eccentric grinder. Only the concentric grinder is discussed here because of its greater availability.

In the concentric valve seat grinder (fig. 3-19), a grinding stone of the proper shape and angle

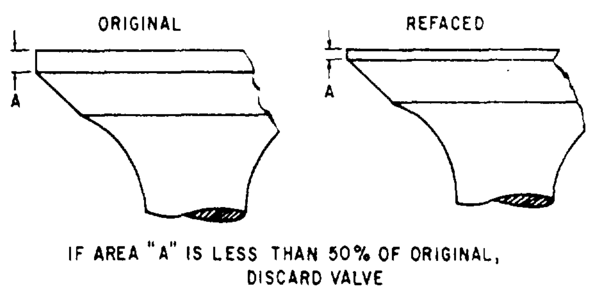


Figure 3-17.—Proper valve margin of thickness after refacing.

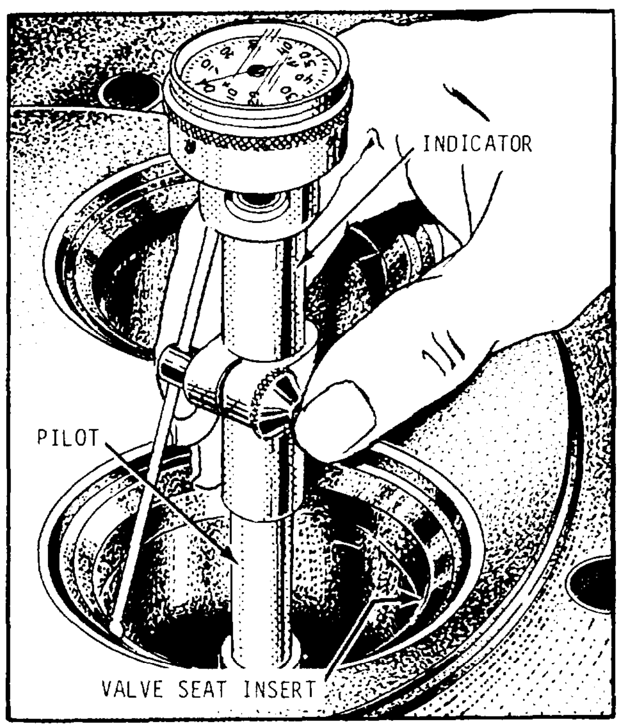


Figure 3-18.—Determining concentricity of the valve seat with a dial indicator.

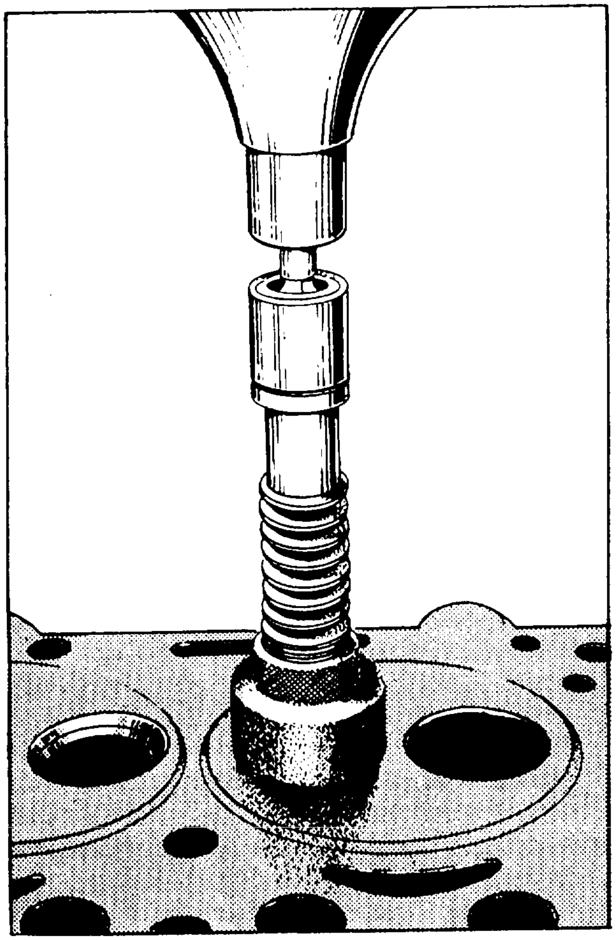


Figure 3-19.—Grinding valve seats using a concentric type of grinder.

Figure 3-20.—Self-centering pilot.

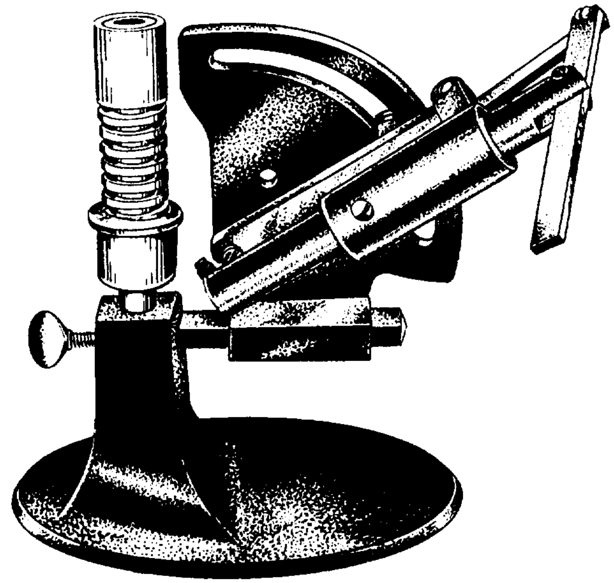


Figure 3-21.—Stone dresser.

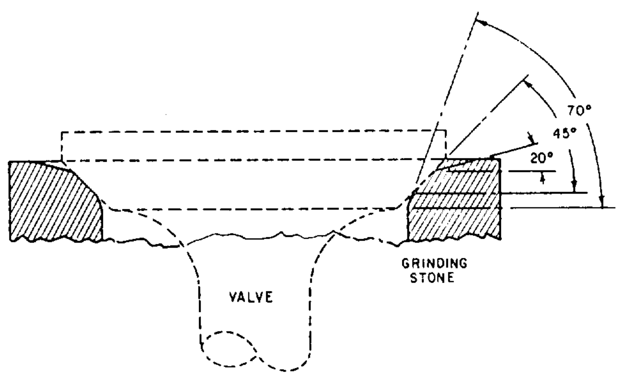


Figure 3-22.—Valve contact correction.

is rotated in the valve seat, The stone is kept concentric with the valve guide by means of a self-centering pilot (fig. 3-20), which is installed in the guide. Check the self-centering pilot for trueness before using, A damaged pilot will cause the seat position to move in relation to the valve guide. The valve guide must be kept clean and in good condition. Most of the concentric grinders of the Navy automatically lift the stone off the valve seat about once every revolution to allow the stone to clean itself of dust and grit by centrifugal action.

The abrasive stone must be dressed frequently with a diamond-tipped dressing tool, such as that shown in figure 3-21. Dressing the stone will ensure a uniform, even grinding of the valve seat.

After the seat is ground, it will be too wide. To narrow it, use upper and lower grinding stones to grind away the upper and lower edges of the seat. Figure 3-22 shows a typical valve seat that was ground at 45°, then narrowed at the top with a 20° grinding stone, and then ground at the bottom with a 70° grinding stone to narrow and center the valve seat.

To test the contact between the valve seat and the valve, mark lines with a soft pencil about one-fourth inch apart around the entire face of the valve. Next, put the valve in place and rotate, using a slight pressure, one-half turn to the right and then one-half turn to the left. If rotating removes the pencil marks, the seating is good.

Another method for checking the valve seating is to coat the valve face lightly with Prussian blue and turn it about one-fourth turn in the seat. If the Prussian blue transfers evenly to the valve seat, it is concentric with the valve guide. Be sure to wash all the Prussian blue from the seat and valve. Then lightly coat the valve seat with Prussian blue. If the blue again transfers evenly, this time to the valve when it is turned in the seat, you can consider the seating to be normal.

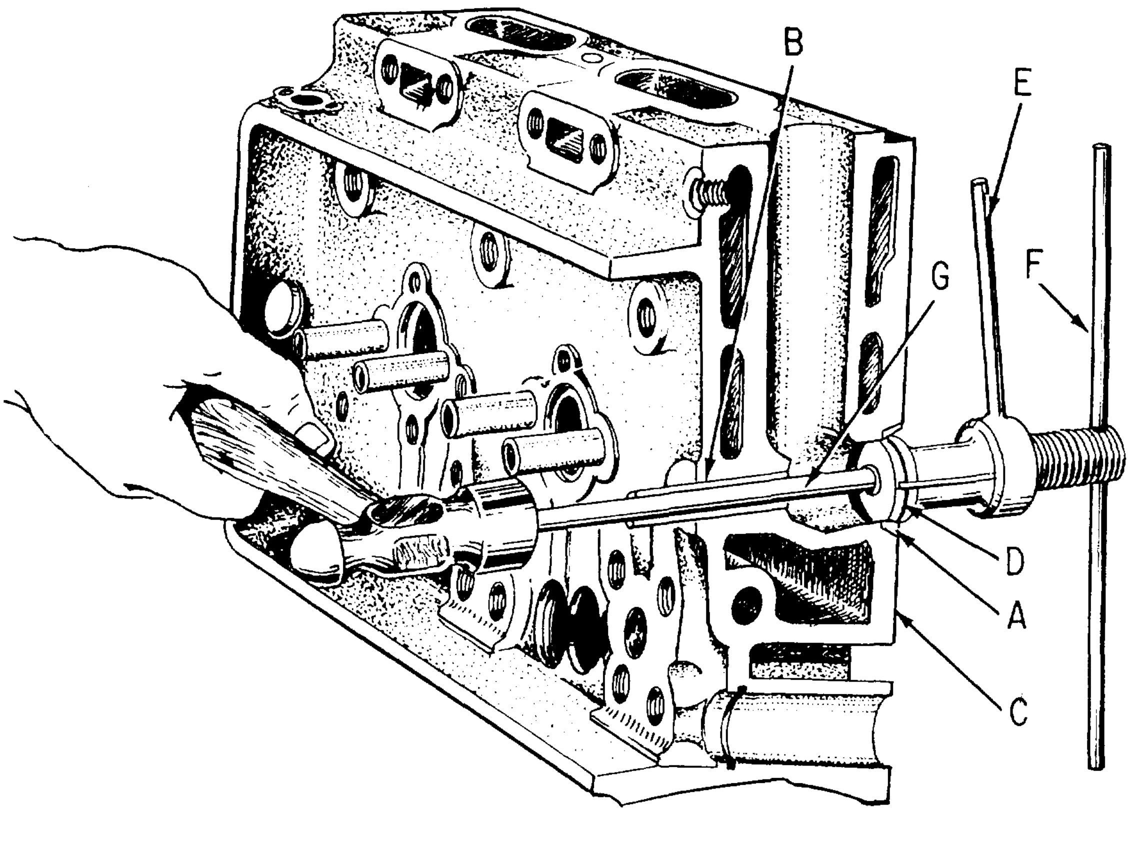
VALVE SEAT INSERT REPLACEMENT

Some engines are equipped with valve seat inserts that may be replaced when they are badly worn or burned or have been ground down to the point where there is not enough metal to permit another grind. You can remove the old valve seat by using a special puller, such as the one shown in figure 3-23. However, if a puller is not available, you can punch mark each side of the insert and then drill almost through. After drilling, take a hammer and chisel and break the insert into halves for easy removal.

Before installing a new insert, chill it for 15 minutes in dry ice or by any other chilling method. Chilling shrinks the insert so that it will fit in place. You may then drive it in place and grind the seat.

VALVE SPRING TESTING

Valve springs should be tested for uniform height and proper tension. To test for uniformity



A. Insert, Valve Seat
B. Guide, Exhaust Valve
C. Cylinder Head
D. Collet
E. Handle, Collet
F. T Handle
G. Bar, Drive

Figure 3-23.—Puller used in removing valve seat inserts.

of height, place the used springs on a level surface beside a new pair of springs. Use a straightedge to determine any differences in height. Unequal or cocked valve springs may cause faulty valve and engine performance.

The preferred method of testing valve springs for proper tension is by using a valve spring tester. The pressure required to compress the spring to the proper length is measured according to the manufacturer's specifications. Never use shims to compensate for a weak valve spring. Shims should be used to adjust the valve spring to the installed height only.

VALVE LIFTER SERVICING

There are two types of valve lifters: the solid type and the hydraulic type. Procedures for removing and servicing the two types are quite different.

Solid lifters are removed from the camshaft side on some engines. This requires removal of the camshaft. The lifters must be held up by clips or wires so that the camshaft can be extracted. Then the clips or wires are removed so that the lifters may be extracted. Most valve lifters may be extracted from the pushrod or valve side of the engine block, in which case extraction of the camshaft is not necessary. Be sure to keep the lifters in the proper order so that they may be replaced in the same bores from which they were removed.

If the lifter screw face is worn or pitted, it may be refaced on a valve-refacing machine. If the lifter bore in the block becomes worn, it maybe rebored by reaming; then oversized lifters must be installed.

Hydraulic lifters on some engines are tested by the leak-down-rate test. In testing, insert a feeler gauge between the rocker arm and the valve stem, and note the time it takes the valve lifter to leak enough oil to permit the valve to seat. As the valve seats, the feeler gauge becomes loose and signals the end of the test. If the leak-down-rate time is too short, the lifter is defective and must be replaced. In any case, be sure to follow the manufacturer's recommended procedures for performing this test.

To remove the hydraulic lifters, remove the pushrod. On engines with shaft-mounted rocker arms, the rocker arm may be moved by compressing the spring so that the pushrod can be removed. Thus, the rocker arm assembly does NOT have to be removed.

After the lifter has been removed, check the bottom or cam side to ensure that it is flat. To do this, place a straightedge across the lifter bottom. If light can be seen between the straightedge and the lifter, the lifter should be discarded.

When disassembling the lifter, be sure to clean all the parts in a cleaning solvent. Reassemble and fill the lifter with clean, light engine oil. Also, make sure that all lifters are replaced in the same bore from which they were removed. Work on one lifter at a time so that parts are not mixed between lifters.

ROCKER ARM SERVICING

After removing rocker arms, inspect them for wear or damage. Rocker arms that are equipped with bushings may be rebushed if the old bushing is only worn. As you know, the worn valve on slightly worn rocker arm ends can be ground down on a valve-refacing machine, whereas excessively worn rocker arms should be discarded.

When installing rocker arms and shafts in the cylinder head, make sure that the oil holes (in shafts so equipped) are on the underside so that they will feed oil to the rocker arms. If the springs and rocker arms are suitable for continued use, they should be reinstalled in their original positions in the head.

CAMSHAFT CHECKING

The camshaft must be checked for bearing-journal or cam wear and alignment. In checking alignment, place the camshaft in a set of V-blocks, and use a dial indicator to check the runout of the journals when the shaft is turned. Journals should be checked with a micrometer and the reading compared to the manufacturer's specifications. The cam wear should be measured with a micrometer; however, if wear shows across the full face of the cam, you can be almost certain that excessive wear has taken place.

CAMSHAFT BEARING REPLACEMENT

When camshaft bearings are worn or show excessive clearance, they should be replaced. Special tools are required to remove and replace cam bearings. When installing new bearings, be sure that the oil holes are aligned with those in the block. Also, make sure that new bearings are staked in the block if the old bearings were staked. On some engines that do not use precision-insert bearings, line reaming of the bearings is required after they have been installed.

VALVE TIMING

The relationship between the camshaft and the crankshaft determines the valve timing. Gears, drive chains, and reinforced neoprene belts are used to drive the camshafts that open and allow the valves to close in relation to the position of the pistons in the cylinders. The gears, drive sprockets, or cogs, as the case may be, of the camshaft and crankshaft are keyed in position so they cannot slip.

With directly driven timing gears (fig. 3-24), one gear usually has a mark on two adjacent teeth and the other, a mark on only one tooth. To time the valves properly, you need to mesh the gears so that the two marked teeth of the one gear straddle the single marked tooth of the other gear.

In chain-driven sprockets, you can obtain correct timing by having a certain number of chain teeth between the marks or by lining up the marks with a straightedge, as shown in figure 3-24.

Engines using a continuous neoprene belt have sprockets, or cogs, attached to the camshaft and crankshaft. The belt has square-shaped internal teeth that mesh with the teeth on the sprockets. All engines with this system use a timing belt tensioner. Timing marks on this system vary with each manufacturer.

Before setting the valve timing on any engine that you are overhauling, always check the manufacturer's specifications and instructions.

CRANKSHAFT SERVICING

Most modern engines have main and connecting rod bearings of the precision-insert type, which can be replaced without removing the crankshaft. However, if oil passages are blocked, journals are tapered out of round, or the crankshaft is bent, simply replacing the bearings will not correct the trouble.

If the bearings appear to have worn uniformly, probable the only requirements are crankshaft journal checks and bearing replacement. If bearing wear appears uneven, then the safest procedure is to remove the crankshaft from the engine and check it.

BEARING CAPS REMOVAL

When removing bearing caps, if they are not already marked, be sure to mark them so they will be replaced on the same journal from which they were removed. If bearing caps stick, carefully work them loose by using a soft-faced hammer,

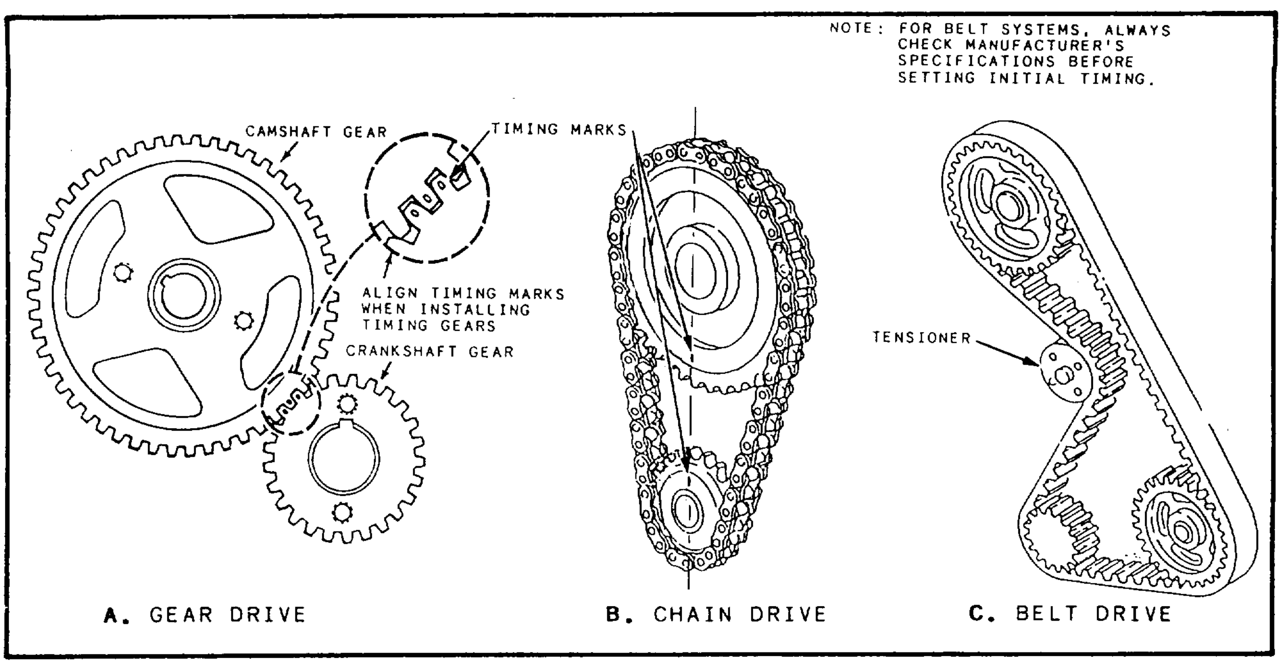


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Figure 3-24.—Driving the camshaft.

to avoid distorting them, and tapping the cap lightly on one side and then the other.

CRANKSHAFT REMOVAL

Once the bearing caps have been removed, lift the crankshaft out of the engine block. Usually one or two people do this seemingly simple operation by hand. With larger crankshafts, use a hoist (fig. 3-25), lifting above the center with a rope sling around two of the throws.

CAUTION

Do not bang the crankshaft around causing damage that will have to be repaired before the crankshaft may be put back in service.

CRANKSHAFT JOURNAL CHECK

The preferred method of measuring crankshaft journals is as follows. Remove the crankshaft from the engine block and clean the surfaces to be measured. Using the appropriate outside micrometer, measure the journals at several points around and across the bearing surface (fig. 3-26). Measurements around the journal will show if the journal is out of round. Those measurements across the surface show if the journal is tapered. Journals that are tapered or out of round more than .003 must be reground. BE SURE THAT YOU ALWAYS REFER TO MANUFACTURER'S SPECIFICATIONS WHEN PERFORMING ANY CRANKSHAFT WORK.

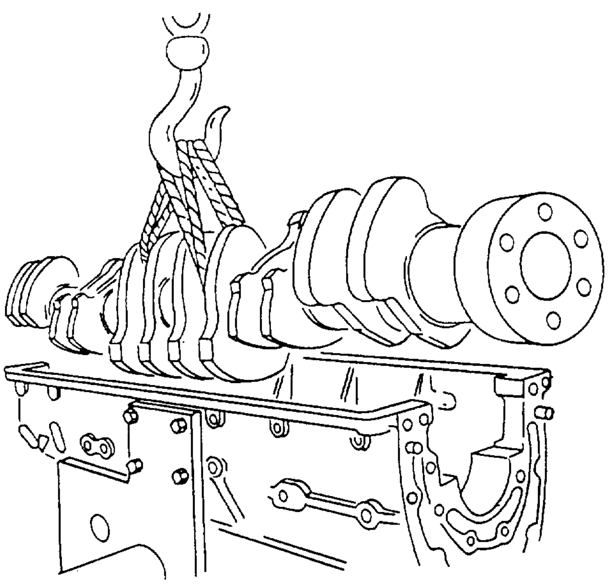


Figure 3-25.—Crankshaft removal using hoist.

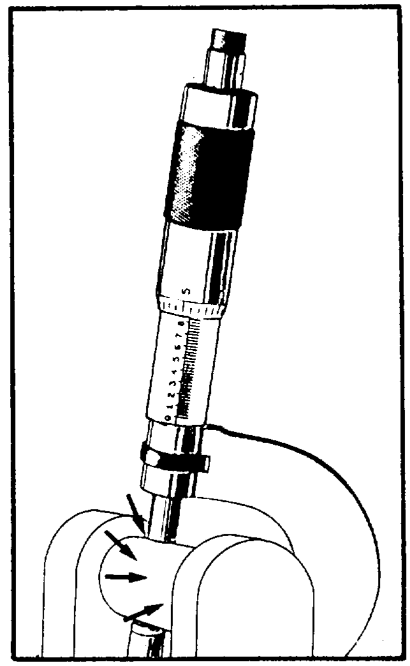


Figure 3-26.—Measuring the journals at different points around the diameter and along the length of the bearing surface.

CHECKING OF BEARING FIT

You should always check bearing fit or oil clearance when installing new bearings. When the bearing caps are off, you should measure the journals so that you can detect wear, out of roundness, or taper.

You can check bearing clearance with either feeler stock or Plastigage. Plastigage is a plastic material that is flattened by pressure. The amount it flattens indicates the amount of clearance.

Before checking bearing clearance with Plastigage, wipe the journal and the bearing clean of oil. Then place a strip of the Plastigage lengthwise in the center of the bearing cap (fig. 3-26). Install the cap next and tighten it into place. When the cap is removed, you can measure the amount of flattening of the strip with a special scale (fig. 3-26). Do NOT remove the flattened strip from the cap or the journal to measure the width, but measure it in place, as shown in figure 3-27. Not only does the amount of flattening measure bearing clearance, but uneven flattening also indicates a tapered or worn crankshaft journal or bearing.

CAUTION

Do not turn the crankshaft with the Plastigage in place.

When using feeler stock to check main bearing clearances, you should place a piece of stock of the correct size and thickness in the bearing cap after it is removed. The feeler stock should be coated lightly with oil. Then you should replace and tighten the bearing cap. Note the ease with which the crankshaft can be turned. As a word of caution, do not completely rotate the engine, which could damage the bearing. Turn it only about an inch in one direction or the other.

If the crankshaft is locked or drags noticeably after the bearing cap has been replaced and tightened, then the bearing clearance is less than the thickness of the feeler stock. If it does not tighten or drag, place an additional thickness of feeler stock on top of the first and again check the ease of crankshaft movement. Clearance normally should be about .002 inch. Be sure to check the engine manufacturer's shop manual for exact specifications.

CRANKSHAFT INSTALLATION

After preparing the engine block and crankshaft for reassembly, install the upper halves of the insert bearings into the engine block. Make sure all oil passages are aligned and open (fig. 3-28). Coat the bearings with lubricating oil and lower the crankshaft into place by hand or by the use of a hoist (fig, 3-25). Install the lower bearing inserts into the main bearing caps and fit them into place on the cylinder block. Tighten the main bearing caps, using proper sequence (fig. 3-29) and torque specifications. After the main bearings have been secured, the crankshaft should rotate without drag or binding.

CRANKSHAFT END PLAY CHECK

Crankshaft end play will become excessive if the thrust bearings are worn, producing a sharp, irregular knock. If the wear is considerable, the knock will occur each time the clutch is engaged or released; this action causes sudden endwise movement of the crankshaft. Crankshaft end play should only be a few thousandths of an inch. To measure this end play, force the crankshaft endwise as far as possible by using a pry bar, and then measure the clearance between the thrust bearing and the block with a feeler gauge.

CRANKSHAFT STORAGE

After the crankshaft has been removed from the engine, protect the crankshaft and prevent it

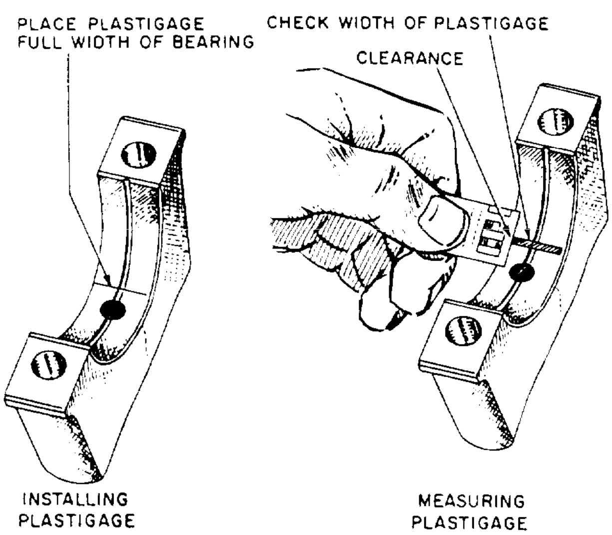


Figure 3-27.—Checking bearing clearance with Plastigage.

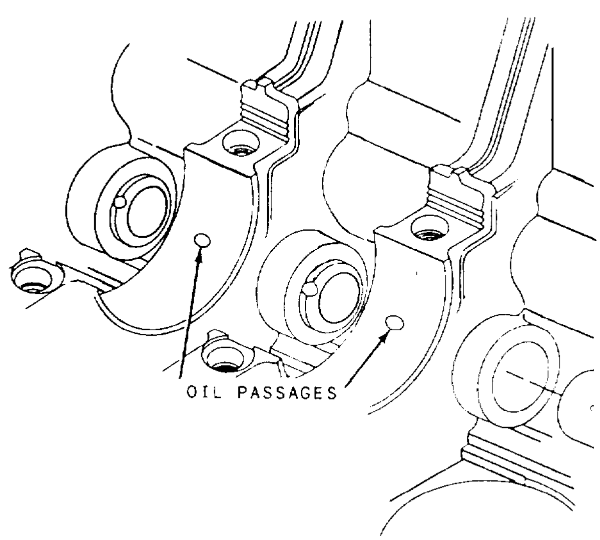


Figure 3-28.—Align these passages with passages in the cylinder block.

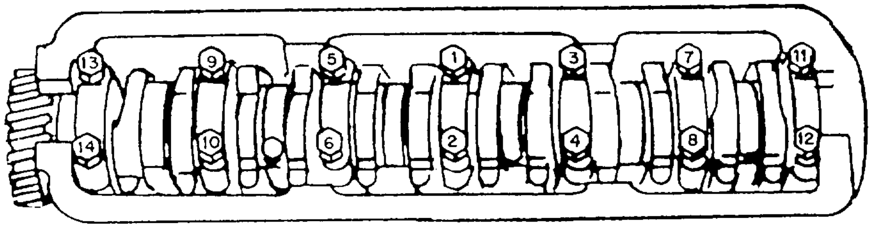


Figure 3-29.—Tighten bolts in proper sequence.

from becoming warped by storing it on end in a safe area.

CYLINDER SERVICING

There are certain limits to which cylinders may become tapered or out of round before they require refinishing. If they have only a slight taper or are only slightly out of round (consult the manufacturer's manual for the maximum allowable taper or out of round), new standard rings can be installed.

When cylinder wear goes beyond the point recommended in the engine manufacturer's specifications, loss of compression, high oil consumption, poor performance, and heavy carbon accumulations in the cylinder will result. In such cases, the only way to put the engine back into good operating condition is to refinish the cylinders and fit new pistons (or oversized pistons) and rings.

CYLINDER WALLS CHECK

As a first step in checking cylinder walls, wipe them clean and examine them carefully for scored places and spotty wear (which shows up as dark, unpolished spots on the walls). Holding a light at the opposite end of the cylinder from the eye will help in the examination. If scores or spots are found, you should refinish the cylinder walls.

Next, measure the cylinders for taper and oval wear. This can be done with an inside micrometer or by a special dial indicator, as shown in figure 3-30. As the dial indicator is moved up and down in the cylinder and turned from one position to another, any irregularities will cause the needle to move. This will indicate how many thousandths of an inch the cylinder is out of round or tapered.

The permissible amount of taper or out of roundness in a cylinder varies somewhat with different engines. Engine manufacturers issue recommendations based on experience with their own engine. When the recommendations are exceeded, the cylinders have to be refinished.

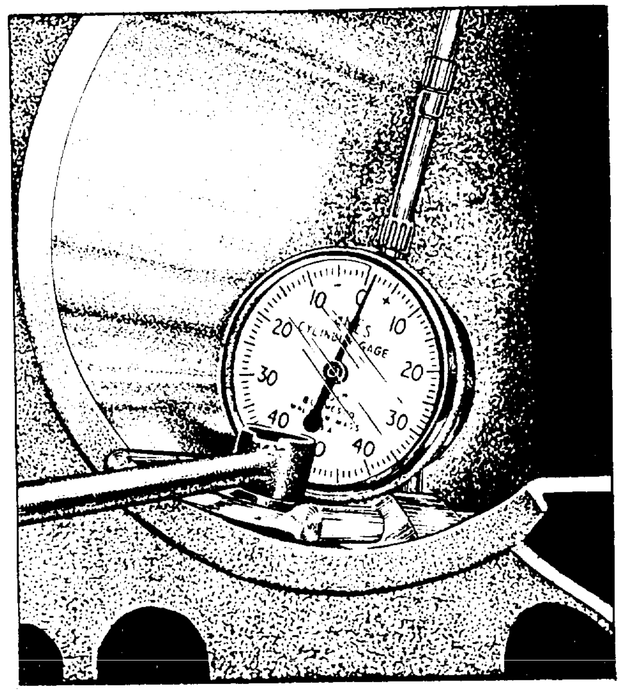


Figure 3-30.—Dial indicator for measuring cylinders.

CYLINDER REFINISHING

There are two methods of refinishing cylinders: honing and boring. Cylinders are refinished by honing when wear is not too great; otherwise, they are bored with a machine, and oversized pistons and rings are installed. This machine consists of a boring bar and cutting tool, and operating the boring machine will vary among different makes of equipment. Consult the manufacturer's operating manual for the procedures recommended.

In honing, two sets of stones—coarse and fine-are generally used along with honing oil or cutting fluid. If a lot of material must be removed, start with the coarse stones. You must leave sufficient material, however, so that the rough-honing marks can be removed with the fine stones. The final honed size must equal the size of the piston and rings to be installed.

During the final honing stage, occasionally clean the cylinder walls and check the piston size to guard against removing too much material or honing the cylinder oversize.

Honing is sometimes used to "break" or "crack" the glaze on cylinder walls when new rings are installed. The idea behind this is to remove the smooth glaze that has formed on the cylinder walls, thus giving the new rings a change to set quickly.

CYLINDER LINERS REPLACEMENT

Using replaceable cylinder liners can save time and costly machine work. First, determine the type of liners—wet or dry—that are used in the unit being rebuilt. Dry liners do not require a water seal and can simply be pulled out (fig. 3-31) and the new liner pressed into place. Wet liners have grooves cut into them (fig. 3-32) for fitting O-ring seals to prevent water leakage into the crankcase.

CAUTION

When installing the wet type of liners (fig. 3-33), use care to prevent damage to the O-ring seals.

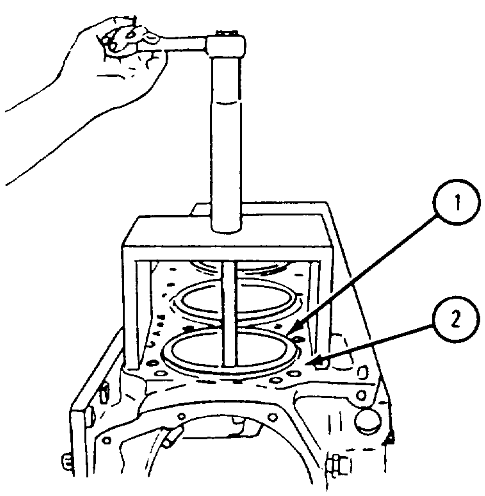


Figure 3-31.—Cylinder liner removal.

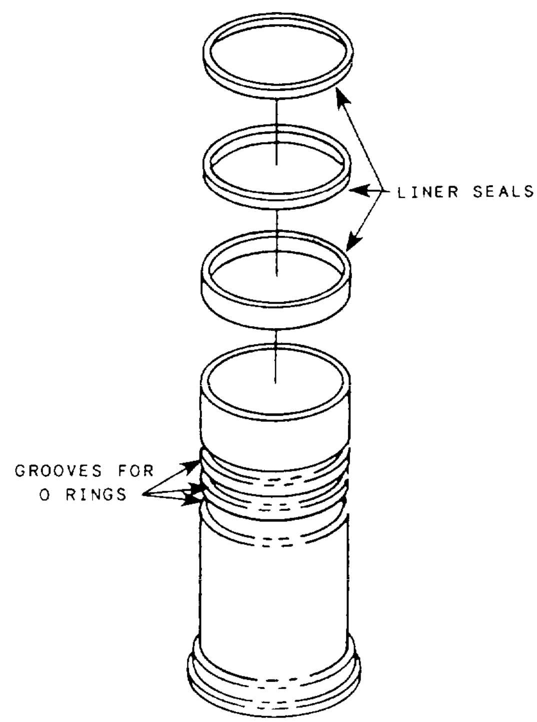


Figure 3-32.—Wet type of cylinder liner.

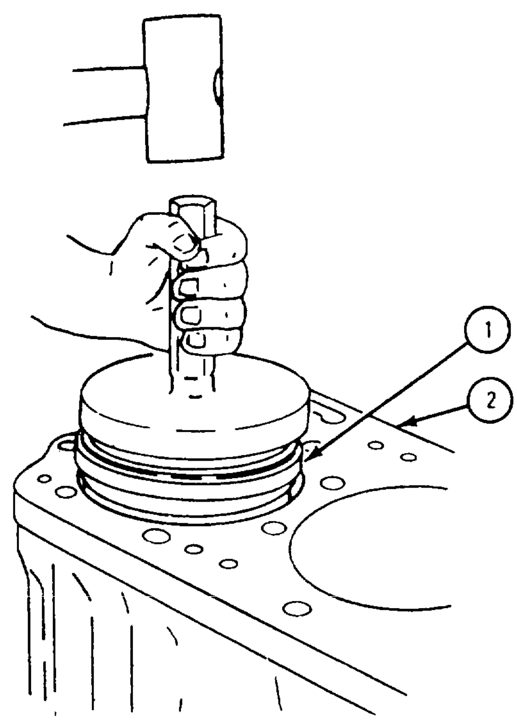


Figure 3-33.—Cylinder liner installation.

PISTONS AND RINGS SERVICING

When service is required on pistons and rings, they must first be removed from the engine. Where removal is to be from the top of the cylinder block, take the cylinder head off and examine the cylinder for wear. If the cylinder is worn, there will be a ridge at the upper limit of the top ring travel. Remove this ridge. If not removed, it will damage the piston and rings as they are forced out of the top of the cylinder.

To remove this ridge, use a reamer of the type shown in figure 3-34. Before placing the ridge reamer in the cylinder, be sure the piston has been placed at BDC. Stuff rags into the cylinder to protect the piston and piston rings from metal shavings during the reaming operation. Be sure to adjust the cutters to the correct depth of cut. After the reaming operation is complete, remove the rags and wipe the cylinder wall clean. Repeat the operation for each cylinder.

Before the connecting rods can be detached from the crankshaft, the oil pan must be removed. With the cylinder head and oil pan off, crank the engine so that the piston of the No. 1 cylinder is near BDC. Examine the piston rod and rod cap for identifying marks, and, if none can be seen, mark them with numbering dies to ensure replacing them in the same cylinders from which they were removed. Remove the rod nuts and cap them with a wrench, and slide the rod and piston assembly up into the cylinder away from the crankshaft and out of the cylinder. Place the assembly on a workbench and repeat this operation until all piston and rod assemblies have been removed.

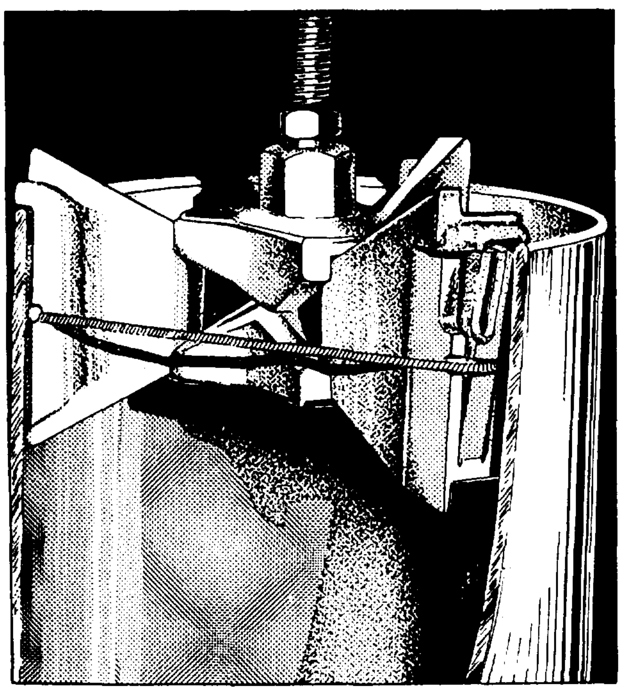


Figure 3-34.—Ridge reamer.

PISTON CLEANING

Before determining whether the pistons may be reused, you should clean them of all accumulations of varnish or carbon inside and out. Examine the old pistons carefully. Cracked skirts, scuffed sides, and broken ring lands are all reasons for piston replacement. It should be obvious that cylinders that are rebored require oversized pistons and rings. In this case, do not waste valuable time cleaning parts that are being discarded. Do not scrape the sides or skirts of the piston, since this may scratch the finish and cause excessive cylinder wall wear. Use a ring groove cleaner to remove built-up carbon from the ring grooves. When pulling this cleaner through the groove, remove only the carbon; do not remove any of the metal.

PISTON FITTING

After a piston has been cleaned, it should be measured with an outside micrometer. The measurements must be taken in various places to determine whether the piston is excessively worn or collapsed. Compare the measurements with those of the cylinder to determine if correct clearance exists. Consult the engine manufacturer's maintenance manual for details of measurements and allowable clearance as well as for maximum allowable piston and cylinder wall taper. Most of the pistons you will encounter will be of the cam-ground type. This type is not round when cold but slightly elliptical in shape. On this type of piston, taper is measured over the largest dimension, which is perpendicular to the piston-pin holes.

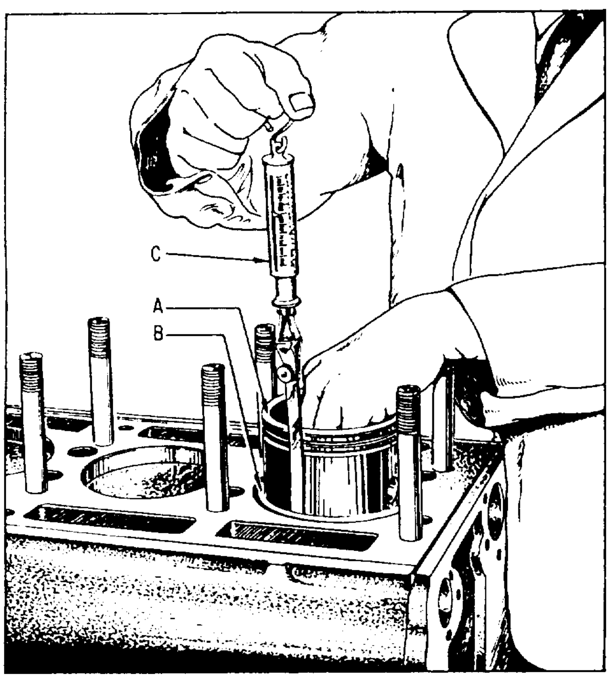
The fit of the piston in the cylinder must be accurately determined. You can measure this fit with a piece of feeler stock of the proper thickness and a spring gauge. Insert the piston into the cylinder upside down with the feeler stock (lightly oiled) placed at right angles to, and 90° from, the piston-pin holes.

(See fig. 3-35.) Measure the fit at the point of greatest piston size. Check the amount of force required to pull out the feeler stock on the spring gauge. If the feeler stock pulls out too easily, the fit is too loose. If it pulls out too hard, the fit is too tight. Check the manufacturer's maintenance manual for the correct amount of clearance.

PISTON PINS FITTING

If the piston-pin bushings are worn, they should be reamed or honed oversize and oversize pins installed. The pins should also be replaced if they are worn, pitted, or otherwise defective.

Where the pin is of the type that floats or turns in the piston-pin bushing, the fit is correct if the pin will pass through with a light thumb pressure when the piston and the pin are at room temperature. Where the pin is of the type that does NOT turn in the piston-pin bushing, the pin is forced in place under pressure. Check the manufacturer's maintenance manual for the correct pressure. If the pressure is too low, the fit is too loose and will result in noise. Excessive pressure indicates that the fit is too tight and may fracture the piston-pin bosses.



A. Piston
B. Cylinder Sleeve
C. Thickness Ribbon and Spring Scale

Figure 3-35.—Checking piston fit in sleeve.

PISTON RINGS FITTING

Piston rings must be fitted to their cylinder and to their grooves on the piston. First, check the gap or space between the ends of each ring. To do so, push a ring down into the cylinder with a piston, and measure the ring gap with a feeler gauge (fig. 3-36). If the ring gap is too small, try a slightly smaller ring, which will have a larger gap. If the cylinder is worn tapered, the diameter at the lower limit of ring travel (in the assembled engine) will be smaller than the diameter at the top. In this type of cylinder, the ring must be fitted to the diameter at the lower limit of ring travel. If the piston ring is fitted to the upper part of the cylinder, the ring gap will NOT be great enough as the ring is moved down to its lower limit of travel. This means that ring ends will come together and the ring will be broken or the cylinder walls scuffed. In tapered cylinders, make sure that the ring fits the cylinder at the point of minimum diameter or at the lower limit of ring travel.

After the ring gap has been corrected, install the ring in the proper ring groove on the piston and roll it around in the ring groove to be sure that the ring has a free fit around the entire circumference of the piston. An excessively tight fit means the ring groove is dirty and should be cleaned. After the rings are installed in the ring groove, test each ring for clearance by inserting

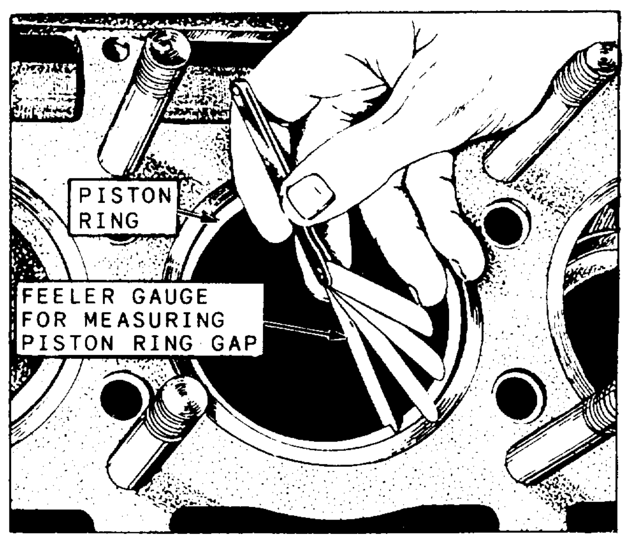


Figure 3-36.—Measuring ring gap clearance in cylinder bore.

a feeler gauge between the ring and the side of the ring groove, as shown in figure 3-37. Check the manufacturer's repair manual for proper clearance. If it is excessive, the piston should be replaced.

OPERATIONAL TESTING

Large engines are expensive items. Repairs, as evidenced by the preceding overhaul procedures, are costly and time consuming. Because of this, to get the most out of the newly overhauled engine, use proper initial start-up and run-in procedures.

PRESTART-UP

Normally, the engine will be set in its own mountings in a piece of CESE. For this reason, more than just engine connections are involved, First, check the level of all of the fluids: coolant, oil, hydraulic, and fuel. Then check things like electrical hookups, mechanical linkage, and cable connections. Recheck all mounting bolts, and be sure that all drive belts are in place and tight. Be sure that there are no loose items lying around that can get caught in the running gear.

WARNING

ENSURE THAT ANY EMERGENCY SHUT-DOWN SYSTEMS ARE OPERATIONAL.

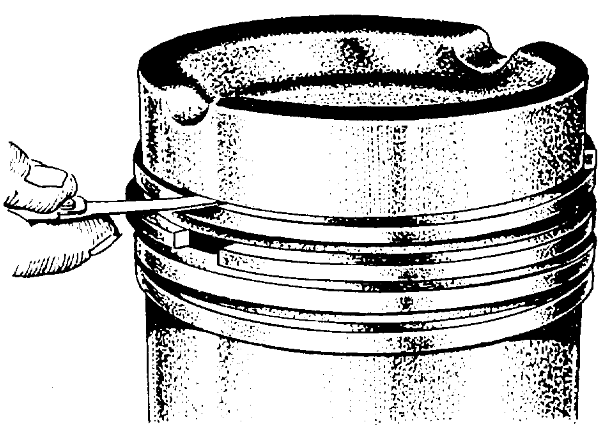


Figure 3-37.—Checking ring groove side clearance.

INITIAL START-UP AND RUN-IN

Upon starting the newly overhauled engine, if no oil pressure is observed in the first 10 to 15 seconds, shut the engine down and find the cause. If oil pressure is observed, allow the engine to warm up at an idle. Do NOT load the engine before it is fully warmed up. During this warm-up period, check for any leaks and listen for any abnormal noises that could indicate trouble. After the warm-up period, shut the engine down and check all fluid levels, repair any leaks, and retorque any bolts, as required.

500-MILE/50-HOUR CHECK

The most probable time for a newly overhauled engine to malfunction is during its initial run-in and break-in period. Therefore, it is absolutely necessary that when these units are returned to service, they are done so with special instructions to the dispatcher and yard boss; for instance, only light loads for the first 500 miles/50 hours, and watch all fluid levels, temperatures, and pressures carefully. Last, ensure that the unit is brought into the shop after the break-in period for an oil and filter change. The unit is now ready for full service.

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