REPORT RESUMES

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AUTOMOTIVE DIESEL MAINTENANCE 1. UNIT XXIX, REVIEWING THE CONSTRUCTION OF ENGINE COMPONENTS.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

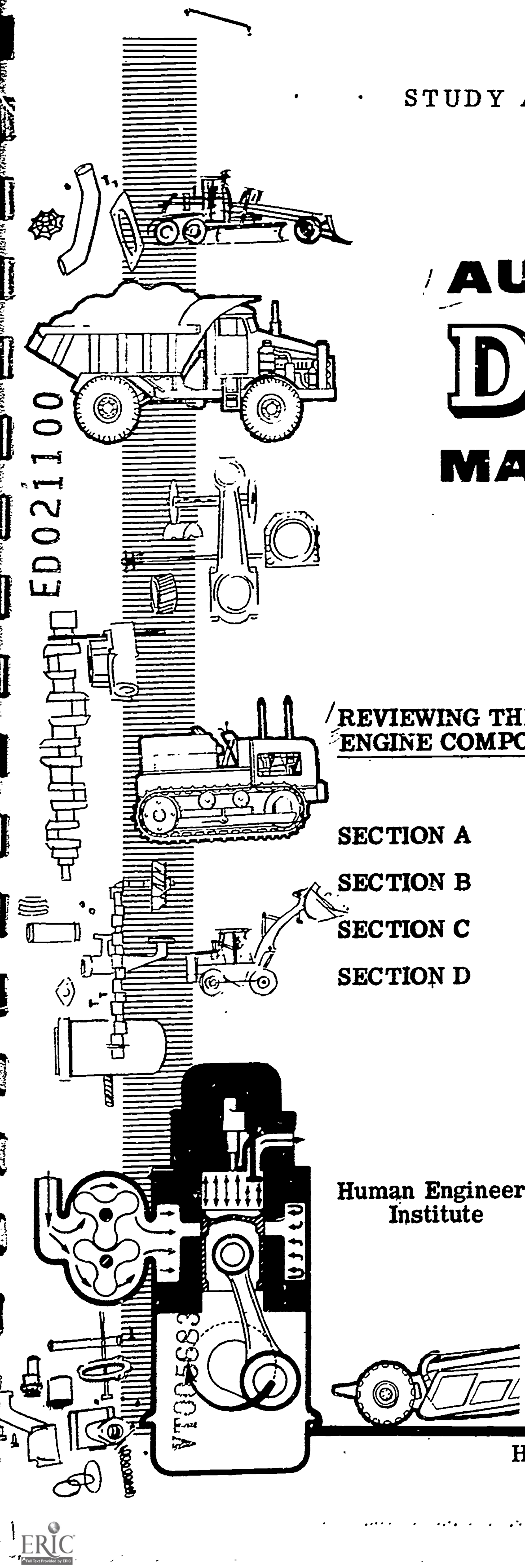
REPORT NUMBER AM-1-29 PUB DATE 13 OCT 66

EDRS PRICE MF-$0.25 HC-$1.24 29P.

DESCRIPTORS- *STUDY GUIDES, *TEACHING GUIDES, *TRADE AND INDUSTRIAL EDUCATION, *AUTO MECHANICS (OCCUPATION), *DIESEL ENGINES, ADULT VOCATIONAL EDUCATION, TRANSPARENCIES, PROGRAMED MATERIALS, INDIVIDUAL INSTRUCTION, INSTRUCTIONAL FILMS, PROGRAMED INSTRUCTION, MOTOR VEHICLES, EQUIPMENT MAINTENANCE,

THIS MODULE OF A 30-MODULE COURSE IS DESIGNED TO PROVIDE A REVIEW OF THE CONSTRUCTION AND OPERATION OF DIESEL ENGINE COMPONENTS. TOPICS ARE STATIONARY PARTS, ENGINE MOVING PARTS, PISTON RINGS, AND CONNECTING RODS AND PISTON PINS. THE MODULE CONSISTS OF AN INSTRUCTOR'S GUIDE, TRANSPARENCIES, A LIST OF SUGGESTED SUPPLEMENTARY MATERIALS, AND TRAINEE TEXT MATERIAL. SEE VT 005 665 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 655 - VT 005 684. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 2" ARE AVAILABLE AS VT 005 685 - VT 005 709. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL AND TRANSPARENCIES MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

STUDY AND READING MATERIALS



AUTOMOTIVE DIESEL MAINTENANCE 1

REVIEWING THE CONSTRUCTION OF ENGINE COMPONENTS

UNIT XXIX

SECTION A	STATIONARY PARTS
SECTION B	ENGINE MOVING PARTS
SECTION C	PISTON RINGS
SECTION D	CONNECTING RODS AND PISTON PINS

AM 1-29
10/13/66

Human Engineering Institute - Minn. State Dept. of Ed. Vocational Education

HUMAN ENGINEERING INSTITUTE

This Unit covers a review of major engine components, with emphasis placed on Caterpillar diesel engines.

SECTION A -- STATIONARY PARTS

ENGINE BLOCK OR FRAME -- The original design of the diesel engine used the so-called "A-frame". Many engines built during the next 25 years followed this general construction. In "A-frame" design, the cylinder jacket casting was extended down to the bed plate in the form of two legs, the casting having a cross section similar to the letter"A". Removable cylinder liners were inserted in each of the separate cylinder castings. The complete engine, then, was made up of a series of these vertical frames bolted to the bed plate. A variation of the original "A-frame" construction is used on some large 2-cycle engines.

Most diesel and gas engines employ the unit type construction. However, radical variations are found among present day engines. Many engineers have contributed to the design found in use today, and since their ideas differed widely, it is not surprising that many variations are found in designs used successfully in our modern diesel and gas engines.

ENGINE BASES -- In medium and low speed engines, the base is generally a heavy cast or welded structure which supports the engine and serves as collecting basis, and in some cases, storage space for lubricating oil. Ruggedness of such a structure is necessary to support the crankshaft. In most high speed engines, the crankshaft is carried underslung from the frame or block.

Most bases are made of a good grade cast iron, but may also be a welded structure of steel plates and castings. Welding provides a means of obtaining the same strength and rigidity with a definite saving in weight. In higher speed engines of automotive or industrial types, the engine may be supported by the frame or block which also carries the crankshaft. In such engines the base is in reality only an oil pan of thin cast material (aluminum) or sheet steel.

Some engine blocks are cast Meehanite (a special grade of alloy iron). Additional rigidity in the frame may be obtained by use of horizontal through-bolts, below the crankshaft, which pass through the main bearing caps. The crankshaft is carried underslung from the frame. Another variation of rigidity is provided by horizontal cap screws into the main-bearing caps.

CYLINDER LINERS -- Except in a few small high-speed diesels, the cylinder wall is a replaceable sleeve, or liner. A few large engines are built with individual cylinders, no liners, and cast-on jackets.

Cylinder liners may be classified as (1) DRY, (2) WET, or (3) having an INTEGRAL WATER JACKET. The term DRY is applied to any liner which never contacts the coolant but fits as a sleeve inside an already complete cylinder. WET liners are those which form not only the cylinder wall, but also the inside of the water jacket.

LINER MATERIAL AND HARDNESS -- When no liner is used in small diesels, the cylinder block is made of alloy cast iron. If the cylinder walls are fairly hard, the wear is reported to be less than 0.001 inch per 1,000 hours of operation.

Most liners are made of alloy cast iron, advantage being taken of various alloying elements such as nickel, chromium, molybdenum and titanium. Many of the small sizes are cast centrifugally (spun cast).

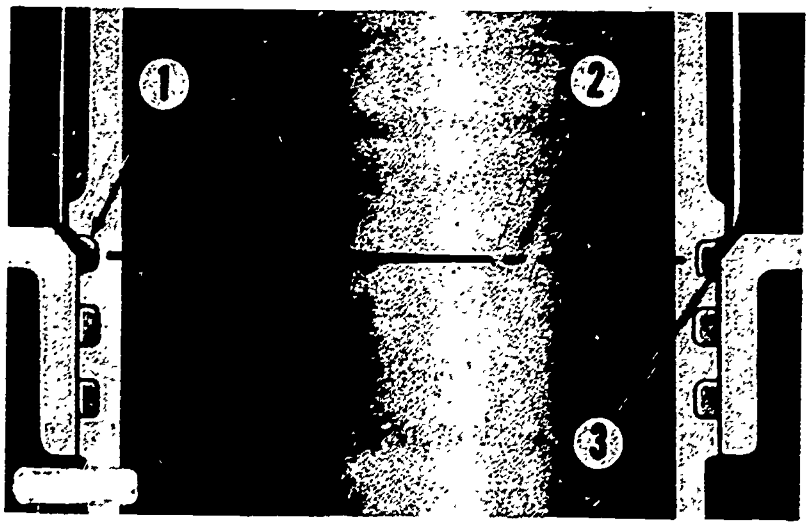
For small high speed engines, many of the liners are induction hardened. Several manufacturers employ an additional surface treatment on hardened liners for quick break-in, such as Parker lubrite coating, or a chemical etching process.

CATERPILLAR CYLINDER LINERS -- Cylinder liner surfaces are machined, hardened, ground, honed, and chemically treated to assure proper break-in. The resultant surface is so hard that ordinary boring tools will not machine it. Liners, pistons and rings are available from the factory in standard sizes only, and require no fitting when they are installed.

Three O-ring seals fit into grooves on the lower end of the liner; see Figure 1. The top seal (1) protects the cylinder bore chamfer (3) from rust and scale. The cylinder bore chamfer is machined to permit the lower edge of the chamfer to align with the center line (2) of the top seal ring groove as illustrated in Figure 1. NOTE: Properly installed liners should extend slightly above the face of the cylinder block. This insures proper holding and sealing of the cylinder liner against the cylinder head gasket when the cylinder head is drawn down. Some liners may feel slightly loose in the cylinder block, yet serve satisfactorily without water or antifreeze leaking past the rubber seals.

CYLINDER HEADS -- Cylinder heads for most high speed diesel engines are one-piece castings, with some exceptions. Some heads are made of two or three castings, with each casting forming the head for two or three cylinders. As the engine size is increased, it is found that most medium and low speed engines use individual cylinder heads. This is to reduce the size for ease of handling and also to avoid heat problems which develop in a long shallow casting.

In some two cycle engines, the heads are comparatively simple, since no intake valves are required. Some two cycle engines have two or four exhaust valves and the required porting for these valves. Four cycle engines generally have one intake and one exhaust valve, or two intake and two exhaust valves.



1–Liner top seal. 2–Center line of the top seal ring groove. 3–Cylinder bore chamfer.

Fig. 1 Liner seals

COOLING CYLINDER HEAD AND ASSOCIATED PARTS -- Cooling water enters the head from the cylinder's water jacket and may pass through mating holes in the block or liner, the head gasket, and cylinder head. To provide more positive water seal, independent of the pressure-seal gasket, most diesel engines use water connections consisting of ferrules and gaskets, or O-rings and water (coolant) directors.

To provide necessary cooling, exhaust valve guides are more completely jacketed than intake valves. The exhaust valve seat and port may receive more positive cooling than the intake if the water entering the head is directed at the exhaust-valve seat by a jet from the water ferrule. The combustion chamber surface requires ample cooling. This is provided in some engines by a baffle plate, which directs the water over this surface before it passes to the upper portion of the head.

MATERIALS -- A few small air cooled diesel engines use cast aluminum alloy heads. With this exception, cylinder heads are made of some type of alloy cast iron. The alloys vary quite widely and may include nickel, molybdenum, chrome-nickel, and chrome-nickel-molybdenum. Two special alloy irons are also used, nodular iron and Meehanite.

HEAD GASKETS -- Small high speed engines, with one piece head on each bank of cylinders, use either the conventional copper-asbestos or a soft sheet copper gasket. On large engines with individual cylinder heads, a copper ring gasket is commonly used in a step joint that is provided between the head and the cylinder sleeve. A few engines have a very narrow contact area in this step joint, which provides very high unit contact pressure and a seal is formed without use of a gasket.

TIGHTENING HEAD BOLTS -- Since the joint between the head and cylinder liner must withstand gas pressures of around 1000 psi, extreme care must be taken to insure a uniformly tight joint. This can be obtained by the following procedure. Assume an individual head with 12 studs, and that they are numbered as the hours on a clock face:

1. Run all the nuts down finger tight.
2. Tighten all nuts with a light pull in the following order, 12, 6, 3, 9, 1, 7, 4, 10, 2, 8, 11, 5, or some similar criss-cross pattern.
3. Repeat the pattern with a torque wrench to about one-half of the specified torque.
4. Repeat, using the specified torque.

On small engines, start at the center of the head and work toward the ends of the head, using successively greater torques as suggested above, in steps 1 to 4.

VALVE SEAT INSERTS -- Many engines use valve seat inserts. They provide two advantages: (a) a better long-lived seat material, and (b) possibility of insertion of new seats. There is one decided disadvantage, in the poor transfer of heat from the valve to the cooling water. Installation of inserts will cause valve operating temperatures to rise at least 100 to 200 degrees F.

Materials used in valve inserts vary from heat-resistant Meehanite and other alloy cast irons for the intake valves, to Stellite, hardened chrome-vanadium steel, and stellite-faced, cooper-plated nickel cast iron for the exhaust valves.

The inserts usually are installed in the head with an interference fit. The head may be heated and the insert chilled to facilitate installation.

VALVE GUIDES -- It is universal practice in heavy duty engines to use valve guide inserts. This construction provides for easy replacement, and also permits use of a more suitable material for this service than the material used in the head casting.

VALVE SEAT ANGLE -- The seat angle is the angle between the seat surface and the cylinder head surface. This angle is either 30 to 45 degrees. The more desirable angle is dictated by the individual engine but each angle has certain advantages. The seating force is about 20% greater with the 45 degree seat. This assists in preventing the accumulation of valve seat deposits but increases seat deformation from pounding. The valve opening for gas flow is approximately 20 percent greater with the 30 degree seat for the same valve lift. In the case of head or valve distortion, the leakage area is 40 percent greater with 45 degree seats.

SEATS WIDTH -- Even though a narrow seat has less chance of being held open by foreign material, it will not cool the valve as well as a wide seat. In small, high speed engines, seat width is generally at least 1/8 in. Seat widths increase somewhat in proportion to engine size.

INTERFERENCE ANGLE -- In some engines, the angle of the valve face is made one-half to one degree less than the angle of the seat. This provides for a line contact at the largest diameter of the seat, next to the combustion chamber. Use of this small interference angle gives a high unit surface pressure and quick seating, and also tends to break up any seat deposits. However, the initial seat is very narrow and the cooling is very poor. The interference angle should never be used with valve rotators.

SECTION B -- ENGINE MOVING PARTS

CAMSHAFT DRIVE -- The type of drive used for the camshaft depends somewhat upon the relative location of the camshaft and crankshaft. It may be a gear drive, a chain drive, or a combination of the two. In high speed engines, where the camshaft is located in the crankshaft near the crankshaft, the camshaft is driven by a pair of gears, or by a short roller on silent chain. In large engines the camshaft may be located high on the side of the frame, or even on the cylinder heads, to reduce the required length of the push rods. Drive for such camshafts requires either a train of several gears or a fairly long chain. Many high speed industrial and automotive diesels use helical gear drives for camshaft and auxiliaries. The camshaft drive may be located at the flywheel end to avoid the effect of torsional vibration of the crankshaft.

CAMSHAFTS -- Camshafts for small and medium size engines are generally made as an integral forging. One intake and one exhaust cam are provided for each cylinder, along with the camshaft bearing journals. The journals are large enough to permit endwise removal of the shaft from the bearing sleeves.

The dual overhead camshafts used on CATERPILLAR D 343 engines are an innovation in diesel engine design. One camshaft operates the two intake valves per cylinder while the other operates the two exhaust valves. The cams contact adjustable follower-tappets which are in line with each valve stem. The camshaft and their bearings are easily removed from the cylinder head as a unit.

Shape and contour of the cam surface depends upon the desired valve timing, valve lift, type of cam follower, and engine speed. To control stress in the valve mechanism, valves are opened and closed rather gradually by a ramp on the cam. In slow speed engines this is not a serious problem, but since forces involved increase with the square of the speed, high speed cams require careful design. Many cams are made to impart approximately constant acceleration and deceleration to the valves, but high speed engines demand a slower start of lift and a more gradual seating. As a result, high speed cam design has developed into a very specialized subject.

CAM FOLLOWERS -- Followers which contact each cam lobe may be (a) flat, (b) roller, or (c) a rocker mounted roller. The follower is commonly made of low carbon steel, and ground to provide a long wearing surface against the cam. In a few engines, the flat cam followers are faced with tungsten carbide.

VALVE SPRINGS -- The required spring force depends upon weight of reciprocating parts of the valve mechanism, cam contour, and maximum engine speed. This force is greatest when the valve is near its wide-open position. The spring is commonly made to deliver a force up to 30 percent over the calculated value. Valve spring material often is peened by shot blasting to improve the fatigue strength.

HYDRAULIC LIFTERS -- To insure proper seating of the valves with the conventional valve mechanism, sufficient lash, or play, must be provided between the rocker and the valve stem to allow for expansion and still permit the valve to seat. This lash causes pounding on the end of the valve stem and the valve seat. Hydraulic valve lifters eliminate this difficulty and have been found to reduce valve failures from leakage, etc.

VALVE ROTATORS -- It has been found that valve life can be improved if the valve is free so that it may rotate of its own accord or is rotated positively by a rotator. There are several types in use. A Rotocap rotator is used on some CATERPILLAR engines and has been mentioned in previous Units. Positive rotation of the valve is provided by the movement of the balls in their inclined recess.

As much as two to five times better valve life is obtained by the use of valve rotators.

MAIN BEARINGS -- The main bearings and caps support the crankshaft in place in the cylinder block.

The main bearings are of the steel backed, aluminum lined precision type with a lead-tin overlay. Tabs are punched outward on the bearing half at the parting line, and fit into recesses in the cylinder block and bearing cap, securing the bearing and preventing it from rotating. This provides an uninterrupted bearing surface in the most highly loaded area, improving the loading conditions and giving minimum resistance to fatigue failures.

The crankshaft thrust is taken on the flange on the lower half of the rear main bearing. The upper half of the rear main bearing does not include a flange.

NOTE: On four cylinder engines, it will be necessary to remove the balancer shafts to gain access to the main bearing caps. More will be said on the balancer shafts later in the Unit.

MAIN BEARING INSPECTION -- Abrasive materials may roll around between the bearing and the crankshaft journal causing scratches in the aluminum bearing without actually becoming embedded in the aluminum. Such scratches are not necessarily harmful and do not indicate that the bearings should be replaced.

NOTE: The main bearings have a lead-tin overlay which will turn blackish with normal use. This discoloration is not an indication of bearing failure.

REPLACEMENT MAIN BEARINGS -- Precision main bearing halves, machined to provide proper clearance, are obtainable in complete sets and are to be installed without further machining or hand fitting. Single replacement bearings (both upper and lower half) can also be obtained and installed without special fitting. As a rule, however, it is good practice to replace the complete set if any one of the bearings needs to be replaced. If only one new bearing is installed and the other bearings are worn to any extent, the new bearing will carry more than its normal share of the load and might be damaged as a result.

Precision main bearings are also available for use with crankshaft reground to .025" and .050" undersize.

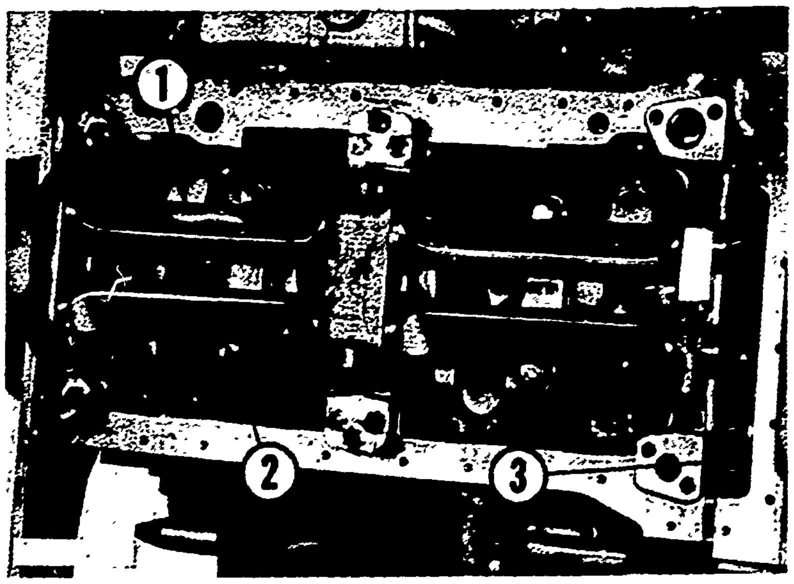
CRANKSHAFT -- The crankshaft is supported by five main bearings, (steel backed, aluminum lined). The end thrust is taken by a flange on the lower half of the rear main bearing.

The crankshaft timing gear is cut integrally on the rear of the crankshaft. During manufacture, holes are drilled in the center of each crankpin, to lighten the shaft. The holes are then plugged to provide a reservoir for oil from the main bearings to the connecting rod bearings. Counterweights are forged integrally with the shaft and drilled for balance.

The crankshaft should be replaced or reground if the wear or out-of-roundness exceeds the maximum value given in the specifications. If the crankshaft is to be reground, check the maintenance manual or follow dimension standards as established because different engines vary in maximum and minimum tolerances.

BALANCER SHAFTS -- Vertical unbalanced forces are counteracted by the balancer shafts, see Figure 2 (1) and (2), which run the length of the cylinder block. The shafts are gear driven at twice engine speed and rotate in opposite directions. Power is transmitted from the crankshaft gear, to the idler gear, see Figure 2 (3), to drive the right balancer shaft (2), which in turn drives the left balancer shaft (1). The shafts are supported at each end and in the center by pressure lubricated bearings in removable supports.

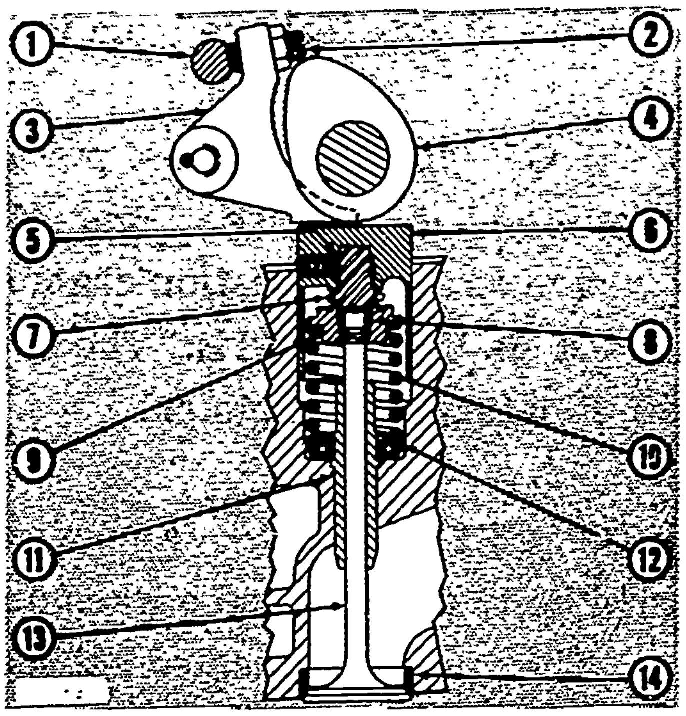
ROCKER ARMS -- Most engines use a push rod to transmit cam motion to a rocker arm on the cylinder head. This rocker arm then opens the valve. When a cylinder has two exhaust or two intake valves, both valves may be operated by a bridge between the rocker arm and the valve stems. When some of the valves are on the opposite side of the cylinder from the camshaft, a second push rod and rocker arm set is used.



1-Left balancer shaft. 2-Right balancer shaft. 3-Idler gear.

Fig. 2 Engine balancer

CATERPILLAR engines with the double overhead cam eliminate the need for rocker arms, since the cam lobe comes in direct contact with the cam follower, as shown in Figure 3.



1-Compression release shaft. 2-Adjusting screw. 3-Compression release rocker arm. 4-Camshaft. 5-Valve adjusting mechanism lock. 6-Cam follower. 7-Gear on adjusting mechanism. 8-Keeper. 9-Spring retainer. 10-Valve spring. 11-Valve guide. 12-Valve rotator. 13-Valve. 14-Valve seat insert.

Fig. 3 Valve mechanism

PISTONS AND RINGS -- The PISTON is one of the most important parts of a diesel engine. It, therefore, deserves serious attention from the designer and from the operator who should understand the conditions that the piston encounters. The piston performs a dual function. First, it must transmit the thrust resulting from combustion to the connecting rod. Second, with the aid of the piston rings, it must seal the cylinder against leakage of combustion gases.

Combustion of the fuel charge inside the diesel cylinder causes the products of combustion to reach a temperature of from 2500 F to over 3500 F. Intensity of a temperature as high as 3500 F may be realized by comparing it to 1000 F, the temperature of iron heated to a dark red, or to 1800 F, the temperature at which steel is soft enough for forging.

The piston may absorb 18 percent or even more, of the heat in the burning gases and, if not cooled in some manner, would soon begin to melt. Any piston, then, must have some means of passing this heat to some cooling agent. As will be discussed in small pistons, this heat is passed from the piston to the cylinder through direct contact and through the rings. On large engines much of this heat is carried away by oil which is introduced into the cavity under the top of the piston. With any method of heat removal, piston-crown temperature is quite high.

Rings must assist the piston in passing heat to the cylinder walls and also in preventing gas leakage from the cylinder to the crankcase.

TYPES OF PISTONS -- Most pistons used in internal combustion engines are of the trunk type; see Figure 4. Form of the piston crown is dictated by choice of the combustion chamber. Types of chambers were discussed in previous Units. **NOTE:** The new GM diesel (149 series) uses the Full-Floating type of piston.

PISTON CLEARANCE -- A conventional trunk piston consists of a crown, a ring belt, a skirt, and bosses or other means of mounting the piston pin. The ring belt, located between the crown and skirt, is that portion which carries all the compression rings and oil rings which are located above the piston pin. The skirt of the piston furnishes support for the piston in the cylinder and provides bearing surface to carry the side forces created during operation. The ring belt is made smaller in diameter than the skirt to allow for its greater expansion due to higher operating temperature, and to prevent the ring belt surface from contacting the cylinder wall.

The most desirable clearance between piston skirt and cylinder wall depends upon size of the engine, design of the piston and liner, method of piston cooling, piston material, and type and furnish of the mating surfaces.

RELIEVED PISTONS, CAM GRINDING -- One-piece pistons are commonly made with the piston-pin bosses supported by columns or ribs leading from

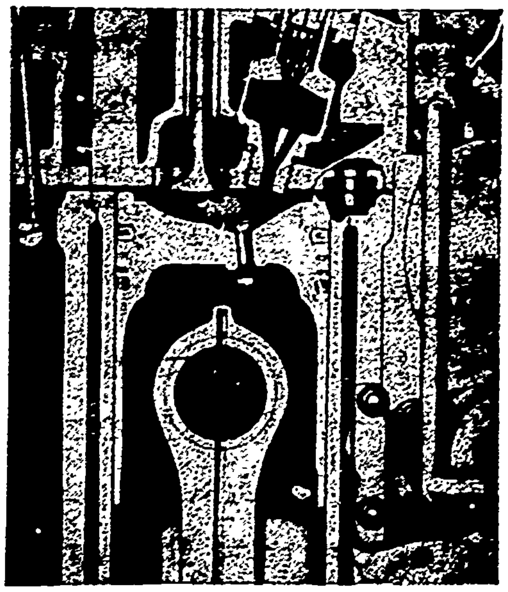


Fig. 4 Trunk type piston

the boss to the piston head. The section of material at the boss is therefore, much thicker than the remainder of the piston wall. These sections tend to deflect outward when at operating temperature, particularly in aluminum pistons.

Relief may be cast or machined in the piston skirt at the bosses. This prevents possibility of this surface binding against the cylinder wall. Small pistons may provide for this unequal expansion by grinding the skirt to an elliptical shape, or "cam ground". This reduces the diameter of the piston parallel to the pin a few thousandths of an inch below the nominal diameter which is measured 90 degrees to the pin.

PISTON PIN LOCATION -- The piston skirt supports the piston in the cylinder and carries the side thrust from the piston pin to the cylinder wall. On this basis, the pin should be located at the middle of the piston skirt. It will be noticed in the examples shown in this and other units that the pin is at the center of the skirt or most generally, somewhat above the center.

PISTON MATERIALS -- Materials used in pistons are, for the most part, either aluminum alloy or some form of cast iron. A few engines use malleable cast iron. Pin carrier inserts are generally cast iron but sometimes are made of heat-treated steel forging.

The coefficient of expansion, the increase in size per degree of temperature increase, of aluminum is approximately twice that of cast iron. This fact must be taken into account when determining minimum piston clearance.

The heat conductivity, the rate of heat flow, of aluminum is approximately three times that of cast iron. The result is that an aluminum piston has less variation in temperature from top to bottom.

WEIGHT -- Cast iron weighs approximately three times as much as aluminum. This does not mean that an aluminum piston weighs only one third as much as a cast iron piston, because strength and heat transfer problems dictate that the metal sections of an aluminum piston be made proportionately thicker.

Strength of aluminum decreases faster than cast iron when the temperature is increased. In pistons, this is compensated for by the use of thick sections.

WEAR of aluminum pistons in many instances may be greater than for corresponding cast iron pistons. However, this is compensated by the protection against serious scoring furnished by aluminum. In cases where an engine is subjected to heavy loads before complete break-in, localized points may develop metal-to-metal contact between piston and liner. With cast iron pistons this will probably result in serious scoring of the piston, the liner, or both. With an aluminum piston, localized heat may be conducted away fast enough to prevent trouble. At the worst, some aluminum may tear off the piston and be deposited on the liner. In many instances, the aluminum can be scraped off the liner, the piston smoothed up, and the engine put back in service.

RING GROOVE INSERTS -- Aluminum melts at a temperature of 1220 F in comparison to 2800 F for cast iron. At temperatures encountered at the top of the piston, aluminum is much softer than at low temperatures. The top compression ring is in the hottest section of the ring belt and, at the same time, is subjected to full force of the cylinder pressure. This force causes a hammering action of the ring against the ring land, or supporting flange. As a result, the combination of this hammering, the sliding action of the ring on the land, and reduced heat strength of the material causes a fairly rapid rate of ring groove wear.

Many aluminum pistons overcome this problem by use of a ring of hard cast iron, cast into the piston to form the ring groove for one or more of the top compression rings; see Figure 5.

These rings are molecularly bonded to the aluminum by the Al-Fin or some similar process. Ni-Resist, a nickel-bearing iron, is commonly used for these rings. It is resistant to high temperatures, has excellent wear characteristics, and also expands at about the same rate as the aluminum alloy. This last feature is important to avoid breaking of the bond and loosening of the ring in service. In addition to the molecular bond, several methods have been devised to form a mechanical lock between the two metals.

Fig. 5 Aluminum piston

PISTON TEMPERATURE -- Tests have shown that full-power operation produces temperatures in the center of the piston head of over 1000 F in cast iron pistons and around 500 to 600 F in aluminum pistons. An increase in the thickness of the head and ring belt reduces the maximum temperature with either material.

Across the head (in the tests mentioned above) the cast iron pistons had much higher temperatures near the center than at the edge, while there was only a small difference in the aluminum piston. Highest temperature was 990 F for the cast iron piston and only 490 F for the aluminum piston. At the top compression ring, the cast iron piston had a temperature of 560 F while the aluminum piston was 420 F. This is a critical point in ring operation. It should be noted that the heat travels so fast through the aluminum piston that the lower ring lands and the skirt were hotter than the cast iron pistons.

PISTON COOLING -- Need for piston cooling is determined by the size of the piston and the bmep (brake mean effective pressure) of the engine. With few exceptions, uncooled pistons are made of aluminum alloy. Practically all two cycle, and all medium and large four cycle pistons need some type of cooling. In cooling pistons, another chore is added to the duties of the engine lubricating oil. The most widely used piston cooling is the spray method. An example is shown in Figure 5, where a jet of oil is directed against the under-side of the piston crown.

SURFACE TREATMENT -- To assist in the initial break-in, many piston skirts are given a special surface treatment. A thin coat of tin plating is often used on both aluminum and cast iron pistons. Some cast iron pistons are treated with a Parker Lubrite coating, or an acid etching, which leaves a phosphate coating on the surface. This coating absorbs oil and helps distribute it evenly over all surfaces. Promising experimental results are being obtained from ceramic and plastic coatings.

A serrated or knurled piston skirt surface is used on some small aluminum pistons as a means of improving skirt lubrication. The grooves serve as oil reservoirs, and distribute the oil over the cylinder wall surface. Serrations may be formed with a knurling tool on the skirt of a worn piston to restore it to orginal size.

SECTION C -- PISTON RINGS

Piston rings, along with cylinder liners, present the major wear and maintenance problems existing in diesel and gas engines. There are actually hundreds of types of piston rings available. A few of the more common types and their uses will be discussed.

Major duties of piston rings are two fold: (a) sealing the high pressure gases in the combustion chamber, and (b) preventing excessive lubricating oil from reaching the combustion space. Two types, compression rings and oil rings, are used on the piston to perform these functions.

Compression rings, generally two or more, are located near the top of the piston to block downward flow of gases from the combustion space. Oil rings, one or more, are placed below the compression rings to limit the upward flow of lubricating oil to the amount required for lubrication of the cylinder wall and the compression rings.

For reference while discussing piston rings and their operation, nomenclature applied to various portions of a ring is shown in Figure 6.

Piston rings are made with a free diameter larger than the cylinder bore so that when a ring is placed in the cylinder it will exert a radial pressure against the wall to assist in the sealing operation. Compression rings, particularly in the first two grooves, receive a major part of their sealing force from the high pressure gases in the cylinder shown in Figure 7. The rings have a small side clearance which allows the gases to press the ring down on the land and also get behind the ring and force it against the cylinder wall. The top ring gets the greatest assist from cylinder pressure in being forced against the cylinder walls. Gas pressure behind and on top of the second ring is only what leaks through the top ring gap. Pressure on the third ring is even less.

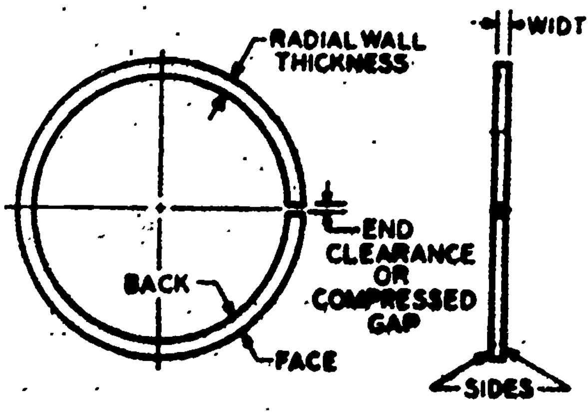


Fig. 6 Ring (confined state)

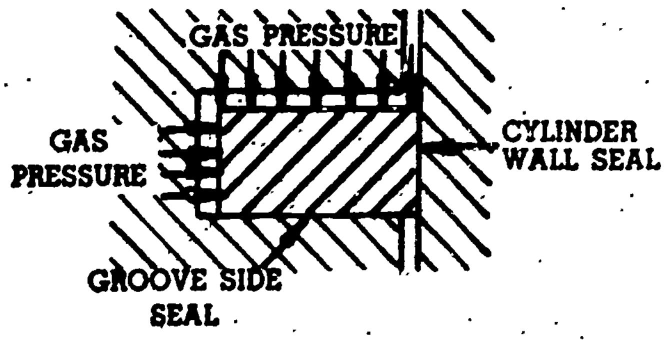


Fig. 7 Ring sealing force

Time is one factor in sealing against leakage. At lower engine speeds, more time is available for gases to leak through ring gaps. A greater number of rings or use of joint-seal types may be required in such engines. The preferred piston ring material is cast iron. In addition to the open oil retaining structure of cast iron, the graphite further provides for self lubrication.

The cast iron used in piston rings has been improved in strength with no sacrifice in its self-lubricating qualities. This has been accomplished by the use of alloys, centrifugal casting of individual rings and by heat treatment to produce high strength and increased elasticity. Stainless steel and chrome plated steel are used for compression rings in a few engines.

COATED RINGS -- Two types of coatings are used on piston rings and their functions are quite different. They are (a) the scuff-resistant and quick seating coating, and (b) the wear and corrosion-resistant coating or plating. All new rings pass through a critical stage during the time that they must form a seal with the cylinder wall. If this seal is not provided very quickly, blow-by will erode the ring and cylinder wall, and subsequent performance will be exceptionally poor.

There are several methods employed to produce the scuff-resistant, quick-seating coating. One method consists of a phosphate coating which has some oil-retaining ability. It resists scuffing mainly by the presence of the foreign material, which prevents the welding of a non-lubricated small section of the piston with a section of the cylinder wall when it is brought to welding temperature. Practically all scuffing and scoring is the result of localized welding and tearing away of the material. The phosphate coat forms a barrier to this welding action. Similar results come from coating of titanium compounds.

A second method of preventing localized welding is providing the ring with

A soft metal plate. The low melting temperature of the soft metal will induce this material to melt and to serve as a temporary lubricant when the two mating surfaces are locally overheated.

A third method consists of etching the ring to provide a large number of interruptions, or very small pits, which are then filled with a graphite and oil. This type of surface actually contains a reservoir which supplies lubricant to a temporarily dry spot and prevents the localized welding.

A widely used wear and corrosion-resistant coating is the hard chrome plate. At first, chrome plating was applied only to the top compression ring. The present trend in some engines is to plate two or more of the compression rings. Chrome-plated steel oil rings are becoming popular in the high speed engines. Chrome plating reduces ring wear by several means:

1. Its extreme hardness resists abrasive wear, which is understandable.
2. Its resistance to the effects of high temperatures makes it less susceptible to scuffing, since its welding temperature is much higher than that of cast iron. Thus it is an ideal fire ring.
3. It is much more resistant to the corrosion effects of the combustion products, which are especially destructive when high sulfur fuels are used.

Ring plating may be the "hard" chrome or the porous-chrome type. It would normally be expected that cylinder wear would increase because the very hard chrome is operating against a relatively soft cast iron cylinder surface. The only satisfactory explanation for this reduced wear is the lack of embedability of the face of the chrome-plated ring. Abrasive particles cannot embed themselves into this hard surface and then act as cutting edges on the cylinder wall. It should be pointed out that rings with scuff-resistant or quick seating coatings may be used with any type of cylinder liner. The liners may be heat-treated or chrome plated. However, chrome plated rings should never be used with chrome plated cylinder liners.

Currently, a new line of heavy-duty rings with a molybdeum face are being introduced. Results are reported to be excellent.

NOTE: Before installing pistons in the engine a careful inspection should always be made to see that the ring gaps are staggered 180 degrees to prevent blow-by.

SECTION D -- CONNECTING RODS AND PISTON PINS

The connecting rod and the piston pin are the connecting link between the piston and crankshaft. They transmit and transform the power delivered to the reciprocating piston into a rotating torgue in the crankshaft.

Most engines have the conventional two piece connecting rods as shown in Figure 8. The whole rod may be forged in one piece, the bearing cap being cut off, faced and bolted in place for the final machining of the big end. In large sizes, the cap is forged separately, the joint machined, and then bolted to the rod for the final machining.

The small end of the rod is generally made as a solid eye, as shown in Figure 8. However, it may be formed as a slipper for bolting to the piston pin.

LOADS ON CONNECTING ROD -- During the compression and power strokes, the connecting rod functions as a column, and is subject to compressive loads due to downward forces on the piston. The resultant piston force is the gas pressure in psi times the piston area in square inches, minus the inertia force of the piston and rod.

In two cycle engines, the load is partially released during the operational cycle, but never completely. There is always a compressive load on the rod due to (a) compression of the air, (b) the power impulse or, near bottom dead center, (c) the inertia force of the piston and rod.

In four cycle engines, there is a reversal of loading on the connecting rod from compression to tension each cycle. Compression loads are present during compression and power strokes. But during the last part of the exhaust stroke and first part of the intake stroke the rod is in tension to absorb the inertia forces, since there is no gas pressure in the cylinder. In high speed engines this tensile load may be even greater than the compressive load on the power stroke.

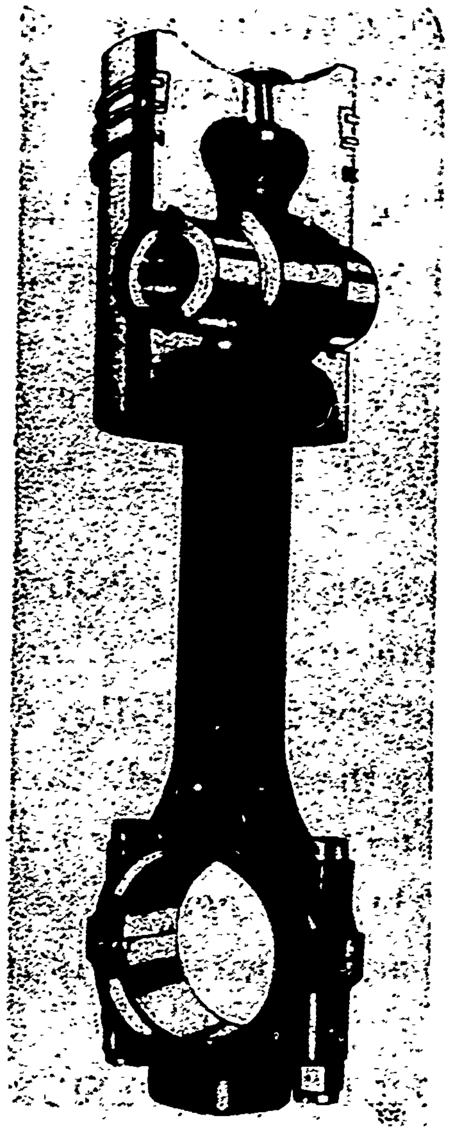


Fig. 8 Connecting rod and piston assembly

Maximum allowable stress in a four cycle rod is less than in a two cycle rod. The four cycle stress reversal condition is more severe than a two cycle partially relieved compressive load.

A connecting rod is subjected to an additional stress due to bending as the rod is whipped back and forth by the crankpin. The condition is the same as if the rod was swung back and forth rapidly by a force at the big end while supported on a stationary piston pin. Weight of the rod creates a bending stress which is a maximum at the outer limits of swing and is dependent on rod weight, length, shape of cross section, radius of the crank arm and engine speed.

Most connecting rods are made with I-beam sections. Most rods have a rifle drilled hole from end-to-end to carry oil for pin lubrication and piston cooling.

The I-beam is positioned to give the greatest support against flexure around the bearings, as shown in Figure 8.

The duty of the connecting rod is to transmit the load received from the piston pin to the crankpin.

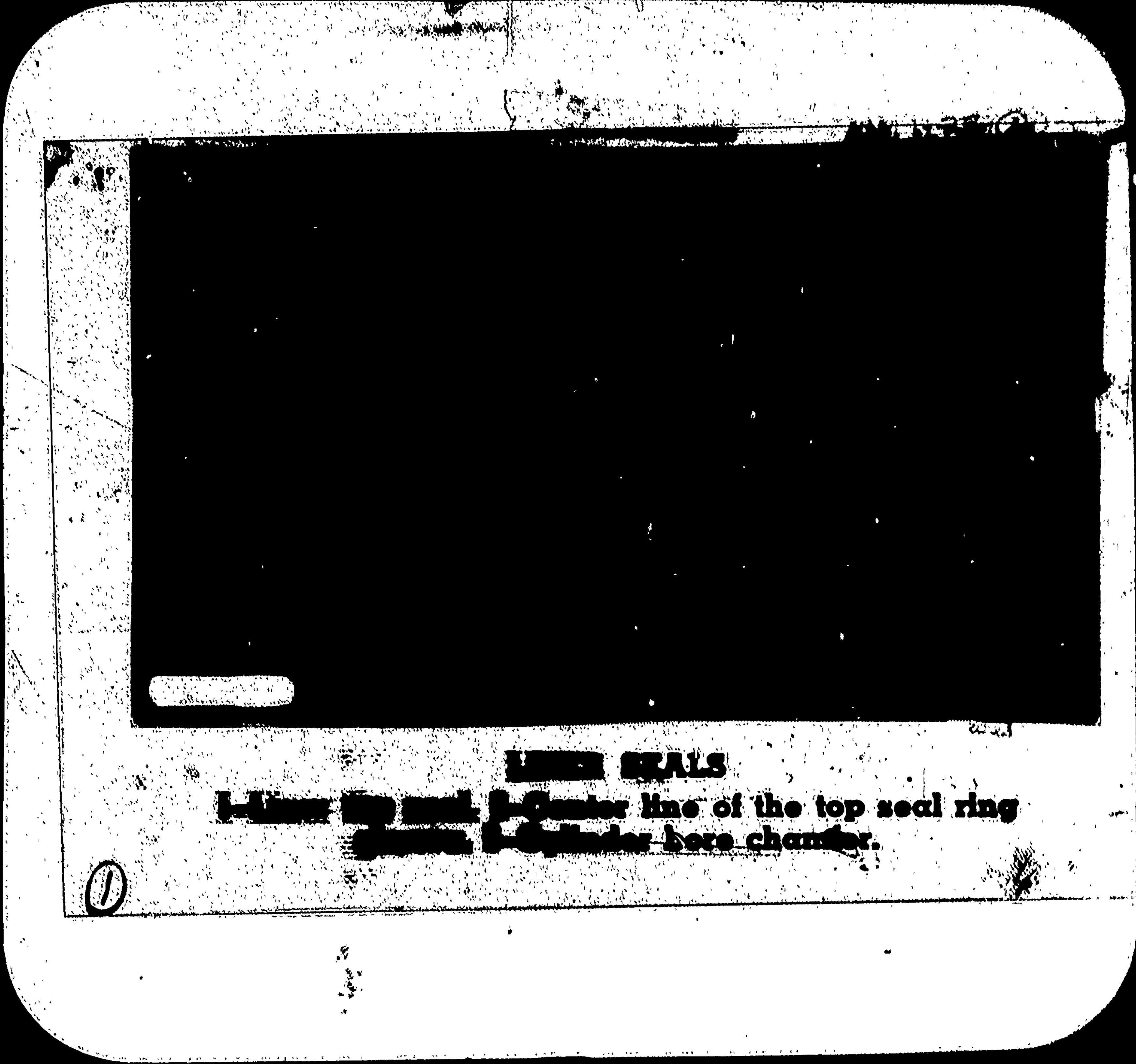
CONNECTING ROD MATERIALS -- Most connecting rods are made of medium-carbon steel or alloy steel forgings. Piston pins generally are made of low carbon alloy steel and carburized. Size of the pin is dictated more by the required bearing area than by bending loads and, as a result, many are made tubular rather than solid, particularly in high speed engines. This reduces the reciprocating weight of the piston assembly in small engines where it is important.

PISTON PIN DESIGN -- Most piston pins are made and installed so that they are free and have bearing surface in both the piston and the connecting rod eye. They are referred to as "floating" pins. Several methods are used to retain the pin and preventing it from contacting the cylinder walls. One of the most commonly used methods is the use of snap rings in the ends of the piston boss; see Figure 8. Another method uses aluminum plugs in the piston at each end of the pin. These plugs are rounded to fit the cylinder wall and doweled in the piston to prevent rotation.

VEE-TYPE CONNECTING RODS -- In vee-type engines, the connecting rods from two cylinders, one in each bank, work on a common crankpin. Three methods of mounting are used: (a) side-by-side, (b) fork-and-blade and (c) articulated or hinged. The side-by-side method provides the most simple construction in that conventional connecting rods are employed. However, the crankpin length must be doubled, with bending stress increasing as a result. It is also necessary for the cylinders in one bank to be staggered, moved forward or backward, a distance equal to the length of a connecting rod bearing. Depending upon other design features, the spacing between successive cylinders may need to be increased, as there may be a corresponding increase in engine length.

CONNECTING ROD ALIGNMENT -- If the connecting rod, piston pin, and crank pin are not in correct alignment, abnormal wear may develop in the ends of the crankpin bearing, and the piston skirt may bind in the cylinder causing wear at the bottom of the skirt on one side and at the top on the opposite side. If any evidence of such a condition is found or suspected, the connecting rod should be checked carefully to see that the rod is not twisted or bent, and that the piston pin and crankpin bearings are parallel.

Today's engines are lighter and with their higher outputs, parts are more highly stressed. Uneven tightening of fastenings can introduce harmful distortion even in seemingly heavy parts and also contributes to fatigue failures. For this reason the importance of proper tightening cannot be over-emphasized.



[illegible] SEALS

[illegible] line of the top seal ring

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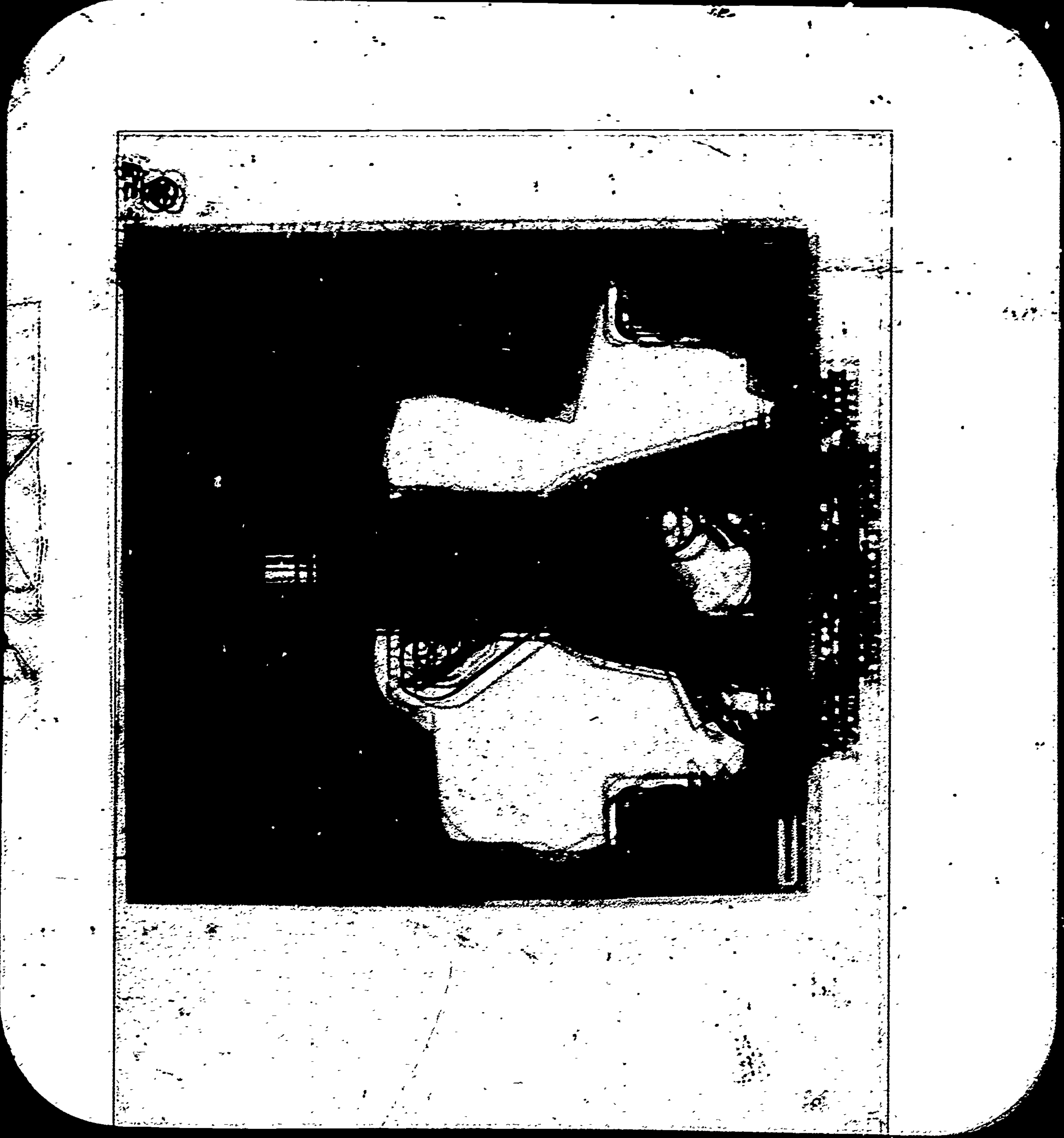
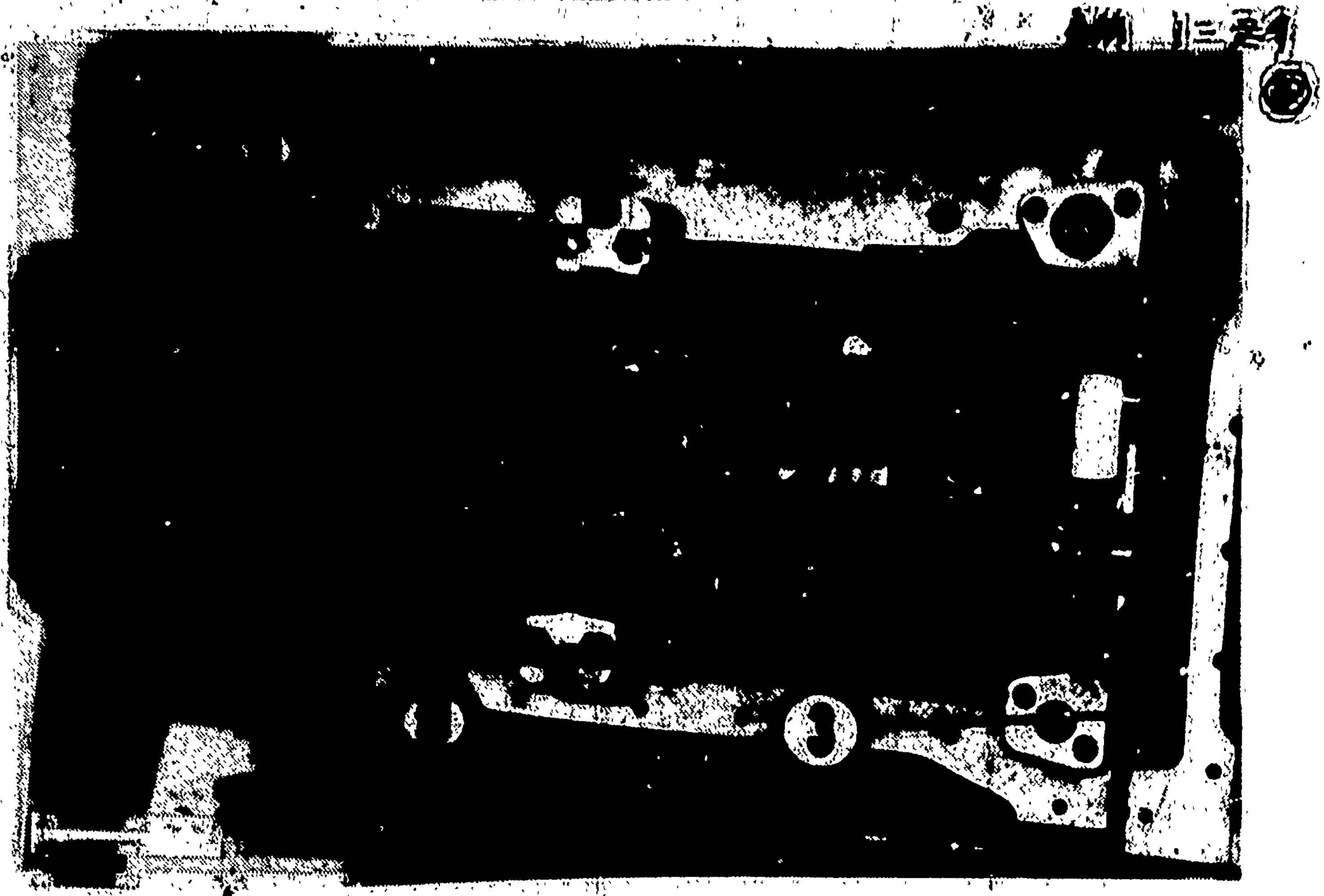
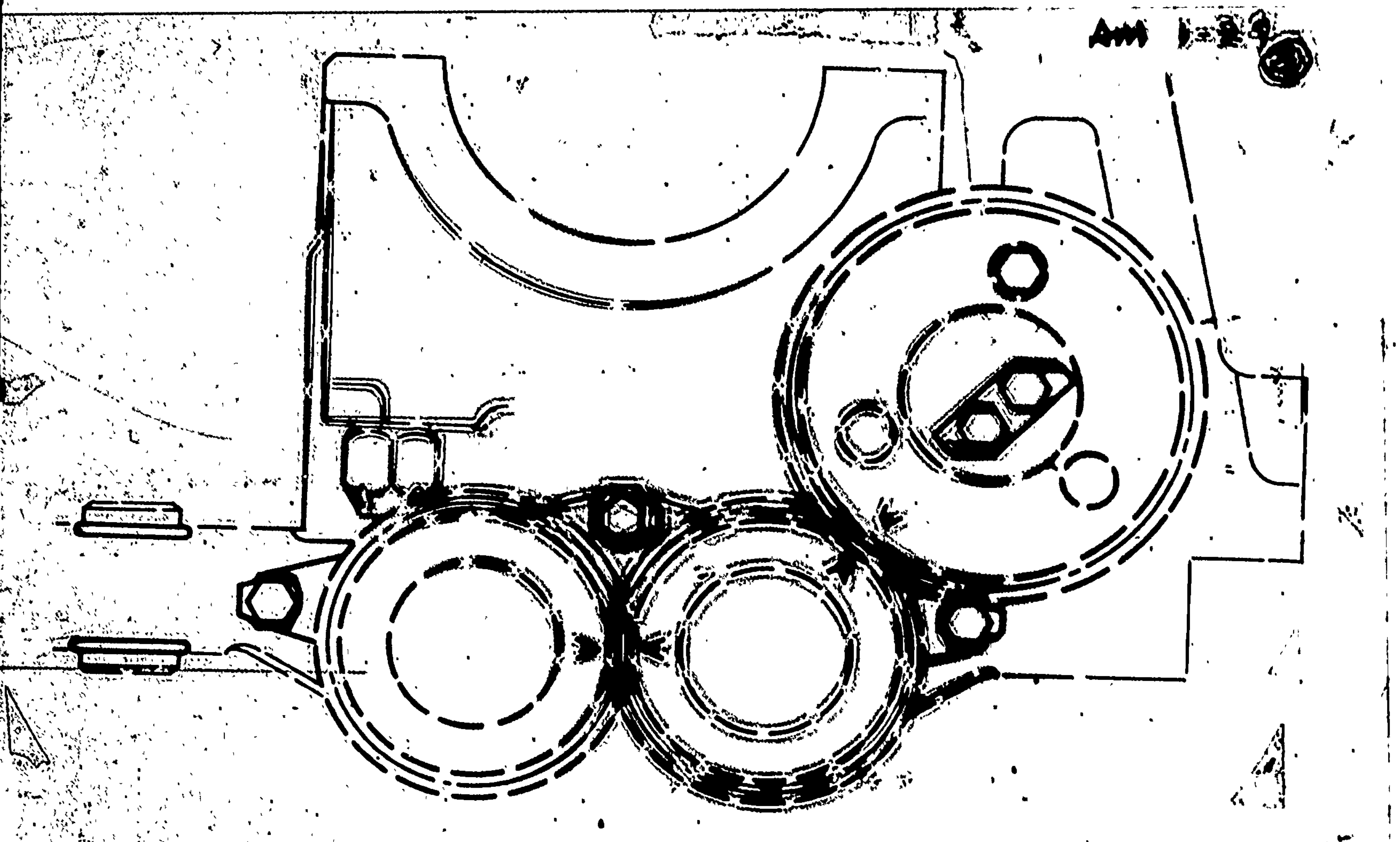




ENGINE BALANCER
1—Left balancer shaft. 2—Right balancer shaft.
3—Idler gear.



TIMING MARKS ON BALANCER SHAFTS
AND IDLER GEAR

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INSTRUCTOR'S GUIDE

Title of Unit: REVIEWING THE CONSTRUCTION OF ENGINE COMPONENTS

AM 1-29
10/13/66

OBJECTIVES:

1. To review parts of an engine, how they are constructed, the various designs, and how critical parts are strengthened. Both stationary and movable parts and assemblies are discussed.
2. As basic engine parts are covered in earlier Units, emphasis is placed on Caterpillar engines here.

LEARNING AIDS suggested:

Visual Aids:

AM 1-29 (1)	Liner Seals
AM 1-29 (2)	Pulling Cylinder Liner with Hydraulic Cylinder
AM 1-29 (3)	Engine Balancer
AM 1-29 (4)	Timing marks on balancer shafts and idler gear

Models: Any engine components that can be brought to class easily would be helpful for this lesson.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. What is meant by a wet cylinder liner?
2. What is the purpose of the O-rings on the Caterpillar liners?
3. What is the purpose of individual cylinder heads on certain engines?
4. Why is it advisable to tighten head bolts using a pattern rather than starting at one end and going to the other?
5. What are the advantages of valve seat inserts? The disadvantages?
6. What is meant by the valve seat angle? Does one angle have any advantage over the other?
7. Do valve seat widths increase with engine size?
8. Why are valve rotators used on engines?
9. Is there a definite advantage for having overhead cams in an engine?
10. What do hydraulic lifters do for an engine?

11. When replacing main bearings, why is it a good idea to replace all of them?

12. Why is it necessary to regrind a crankshaft in certain increments of an inch?

13. What are some of the advantages/disadvantages of using aluminum pistons vs. cast iron pistons?