WAR DEPARTMENT TECHNICAL MANUAL

TM 1-405

AIRCRAFT ENGINES

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SECTION I

INTERNAL-COMBUSTION ENGINE PRINCIPLES

1. GENERAL. a. In order to grasp the fundamentals governing the operation of an aircraft powerplant, it is necessary to understand the operating principle of the internal-combustion engine. The study of the powerplant begins with the definition of the term "internal-combustion engine." Internal

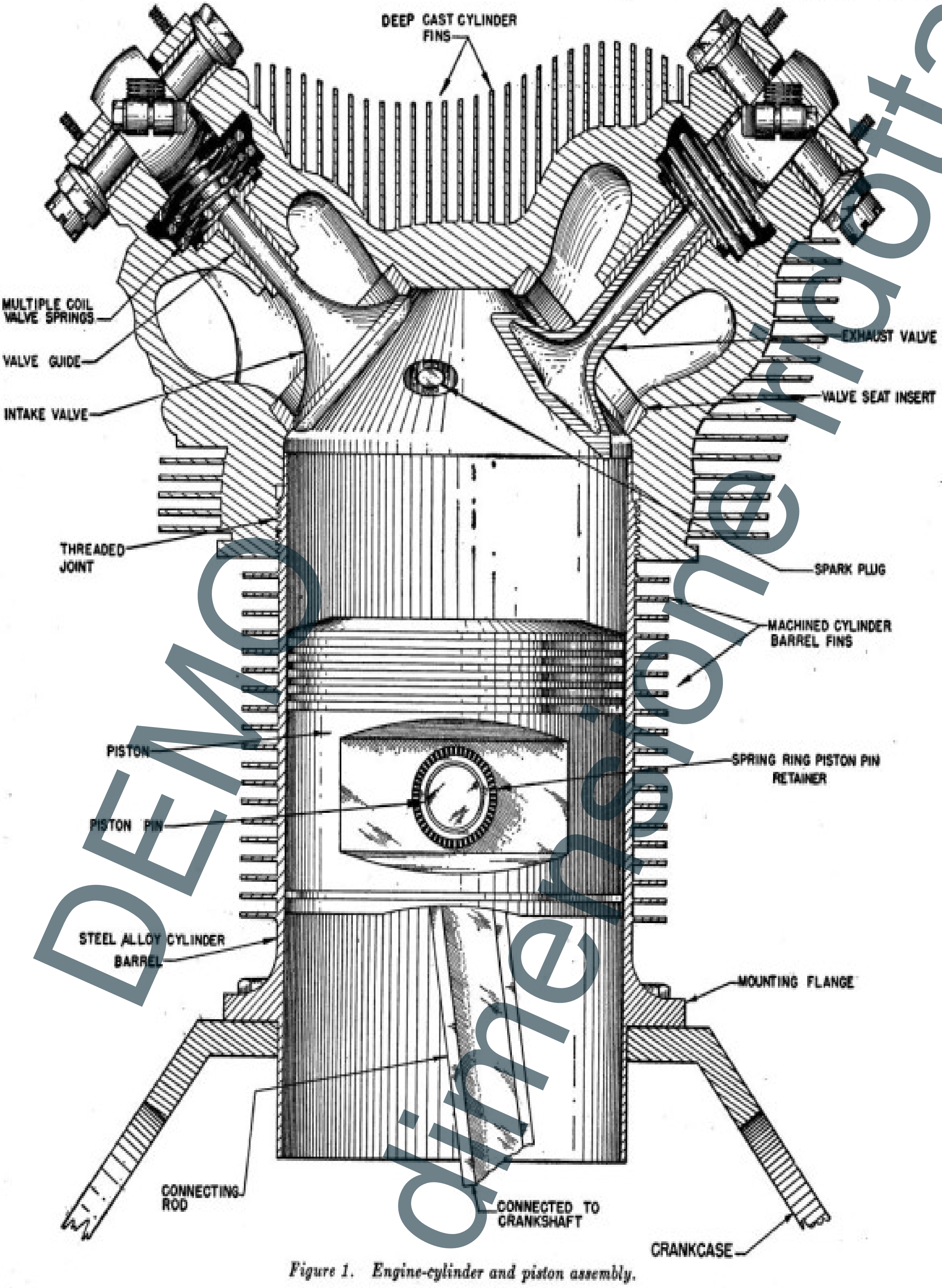


Figure 1. Engine-cylinder and piston assembly.

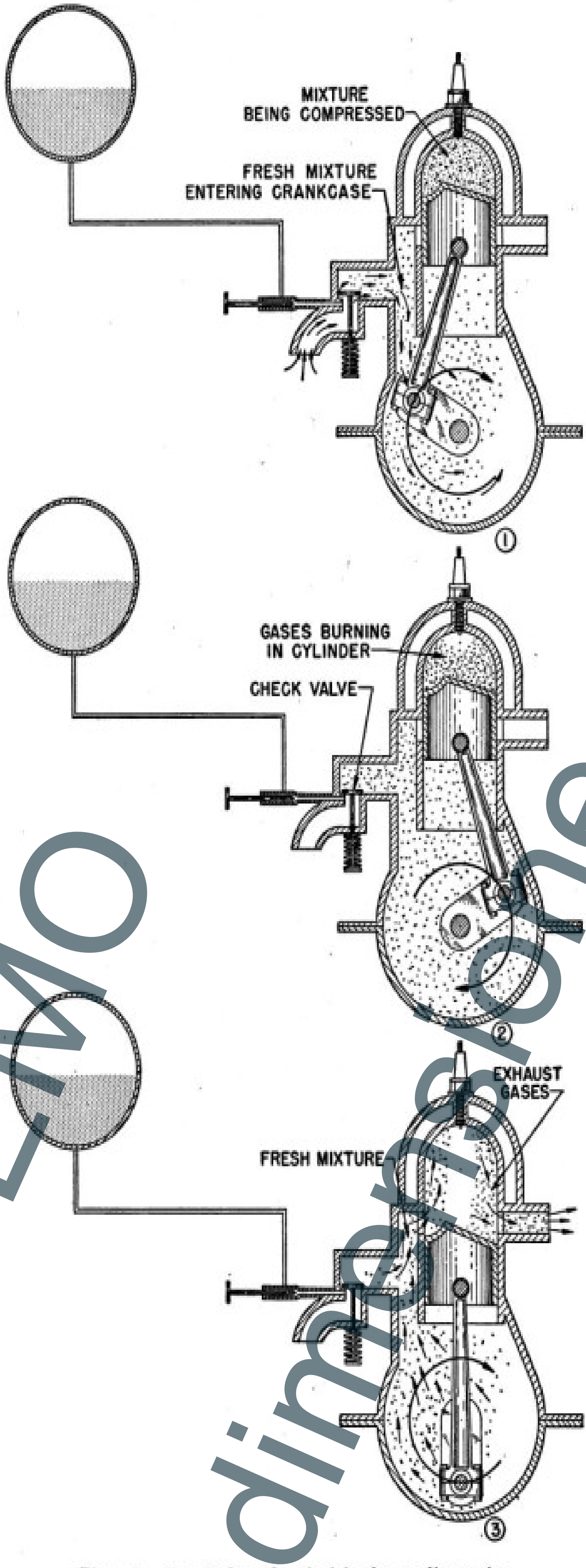


Figure 3. Two-stroke cycle principle of a gasoline engine.

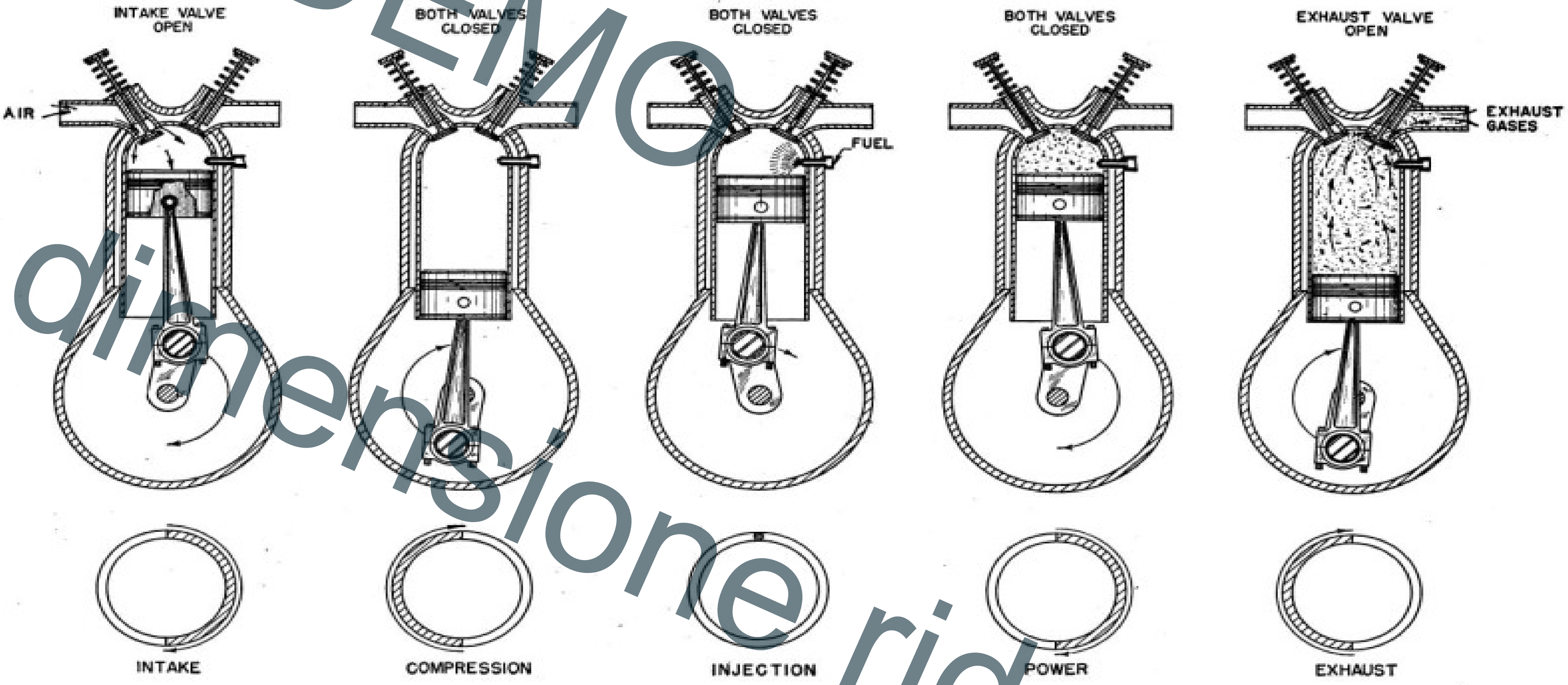


Figure 4. Diesel-engine principle.

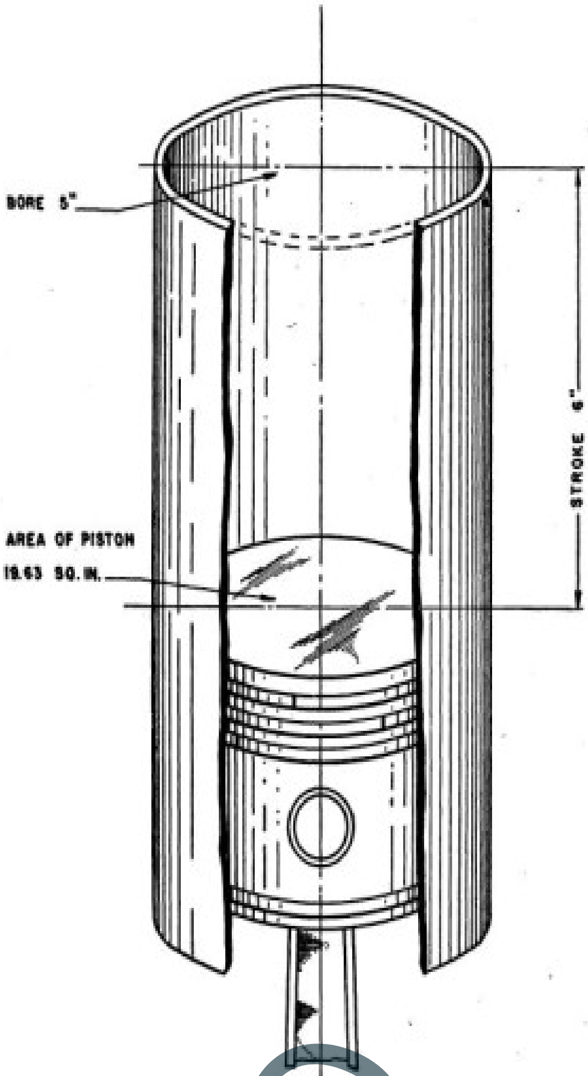


Figure 5. Piston displacement.

an engine will be capable of developing.

c. Compression ratio. The compression ratio of an engine is also a controlling factor of the maximum horsepower developed by the engine. The higher the compression ratio, within limits, the greater the maximum horsepower. The compression ratio is the ratio of the volume of space in a cylinder when the piston is at the bottom of its stroke to the volume when the piston is at the top of its stroke. For example, if there are 120 cubic inches of space when the piston is at the bottom of its stroke and there are 20 cubic inches of space when the piston is at the top of its stroke the compression ratio would be 120 to 20. (See fig. 6.) Both numbers are then divided by the smaller number and the compression ratio in this case is 6 to 1. It is generally written 6:1. As mentioned before, there is a maximum ratio which may be used in an internal-combustion gasoline engine. If too highly compressed, preignition (premature ignition of the fuel) will occur. This will result in overheating and loss of power.

d. Brake horsepower. The horsepower that an engine is capable of transmitting to a propeller or other mechanism is known as the brake horsepower. This is not the total horsepower developed by the engine, but is that part of the total which can be used to do work. It is usually between 85 and 90 percent of the total (indicated) horsepower of the engine.

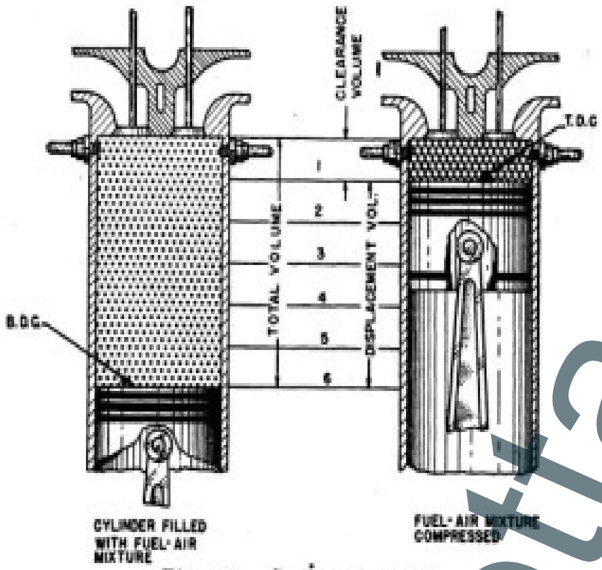


Figure 6. Compression ratio.

e. Friction horsepower. All the horsepower developed by an engine cannot be delivered as brake horsepower. A part of it is necessary to overcome the friction of the moving parts within the engine. This part is known as the friction horsepower. In modern aircraft engines, the friction horsepower is usually between 10 and 15 percent of the total horsepower developed by the engine. The friction horsepower (FHP) is determined by subtracting the brake horsepower (BHP) from the total indicated horsepower (IHP).

$$FHP = IHP - BHP$$

f. Indicated horsepower. The indicated horsepower is the total horsepower converted from heat energy to mechanical energy by the engine. The indicated horsepower is found by using an indicating device which records the combustion pressure within the cylinder. This reading of combustion pressure is then used in a formula to calculate the indicated horsepower. A combustion pressure card is shown in figure 7.

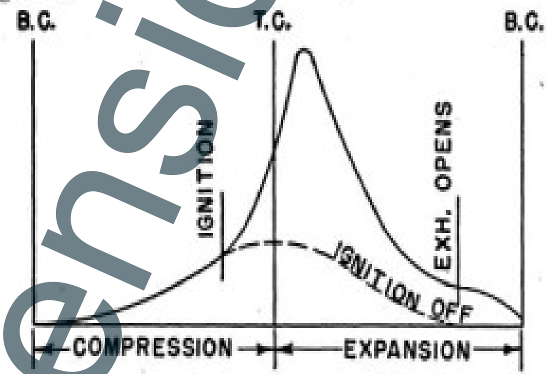


Figure 7. Pressure indicator card.

g. Heat losses and efficiency. Internal-combustion engines are only about 34 percent thermally efficient. That is, they transform only about 34 percent of the total heat produced by the burning fuel into mechanical energy. The remainder of the heat is lost through the cooling of the engine or exhausted through the exhaust manifold. This means that of every 100 gallons of fuel completely burned in an engine, only about 34 gallons are used to do work. It is ,of course, undesirable, but the heat must be removed to prevent damage to the engine.

CLASSIFICATION AND DESCRIPTION OF AIRCRAFT ENGINES

8. GENERAL. Many types of internal-combustion engines have been designed. However, the use and application of the powerplant unit has caused many manufacturers to develop some designs that are used more commonly than others and are recognized as conventional. Internal-combustion engines may be classified according to cylinder arrangement with respect to the crankshaft (in-line, **V**-type, etc. — see fig. 8) or according to the method of cooling (liquid-cooled or air-cooled). Actually, all engines are cooled by transferring excess heat to the surrounding air. In engines classed as air-cooled, this transfer is direct from the cylinders to the air. In liquid-cooled engines, the heat is transferred from the cylinders to the coolant which is then sent through piping and cooled within a radiator placed in the airstream. The radiator must be of sufficient size to cool the liquid efficiently. Heat is transferred to air

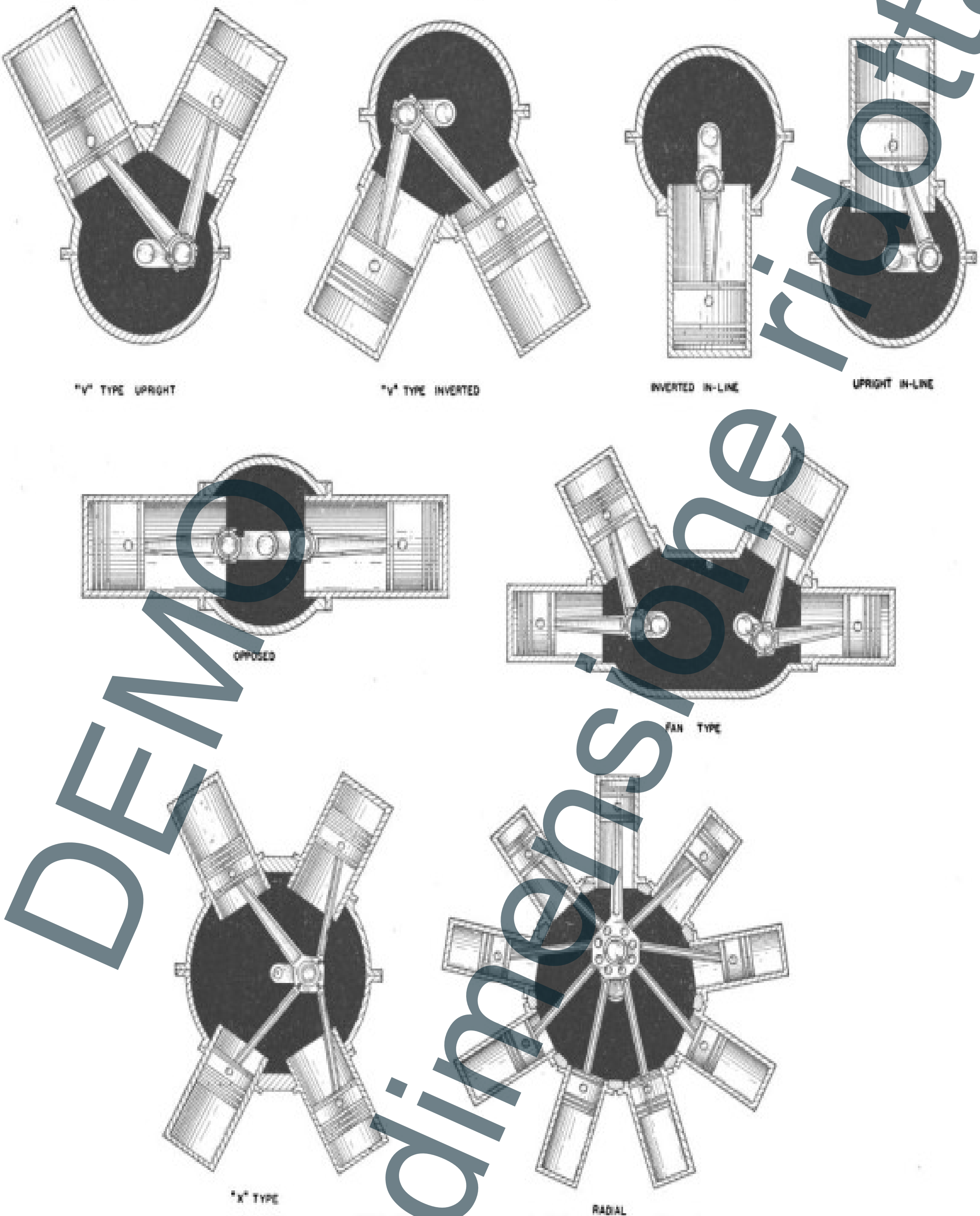


Figure 8. Cylinder arrangement of different types of engines.

trolled by the valve-operating mechanism. This mechanism should be simple and rugged in construction and should provide satisfactory service over long periods of time with little care or maintenance. The two types of valve-operating mechanisms in general use are the type used on in-line engines and the type used on radial engines.

a. In-line and V-type engine valve-operating mechanism. The valve mechanism consists of a number of rocker-arm assemblies operated by a camshaft either directly or through push rods. In some engines which have the camshaft on the top of the cylinder block, the shaft is driven from the crankshaft by bevel gears and other necessary shafts. (See fig. 39.) Other engines may incorporate the camshaft in the cylinder block, and use push rods to operate the rocker-arm assemblies. (See fig. 40.)

(1) *Camshaft.* A camshaft is a steel rod with cams or lobes machined at certain specified positions along its length. A cam or lobe is the raised portion on the shaft surface. The shaft extends from one end of a cylinder bank to the other and is parallel to the bank of cylinders. One camshaft is generally used for the operation of all inlet and exhaust valves of each bank. It is so located that, when it turns, the lobes operate the valve mechanism. As the camshaft rotates and a cam lobe moves the valve mechanism, the valve is

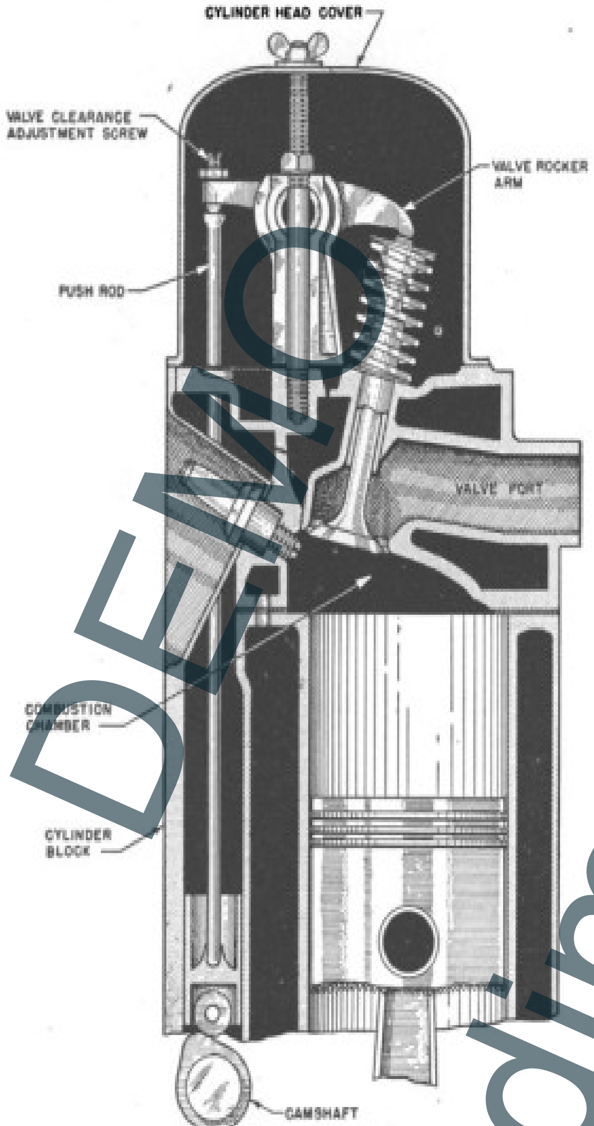


Figure 40. Camshaft located in the crankcase housing.

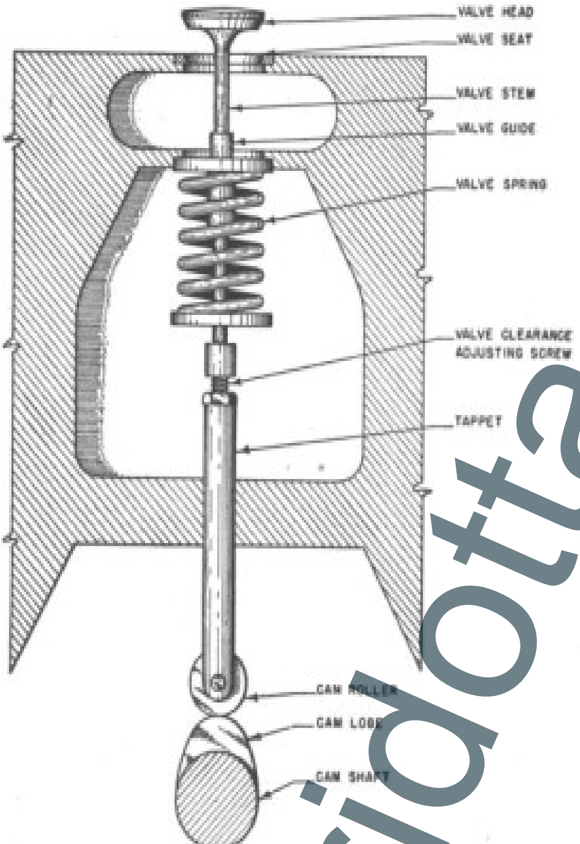


Figure 41. Camshaft valve-operation mechanism.

raised, opening the port in the cylinder, as shown in figure 41. As the camshaft continues its rotation, the cam lobe moves away from the valve mechanism, allowing the valve spring to force the valve closed. This closes the port in the cylinder.

(2) *Push rods.* On some types of engines using overhead valves the camshaft is installed in the crankcase. Push rods are incorporated on these engines to transmit the camshaft action to the rocker assembly. Push rods are usually made of aluminum-alloy tubing, steel rod, or seamless-steel tubing.

(3) *Rocker-arm assemblies.* The valve-actuating rocker used on some in-line and **V**-type engines is constructed with a stationary pivot at one end of the rocker lever. The camshaft bears on the center and the assembly on the other end of the lever bears on the valve stem. A typical arrangement of this kind is shown in figure 42 ①. The pivot end provides an oil passage to the assembly. The valve-stem end of the rocker lever is provided with a screw-type adjusting tappet for the proper adjustment of valve clearance. In some aircraft engines the rocker lever incorporates a plain, roller or ball bearing near the center and pivots from that point. (See fig. 42 ②.) One end of the rocker lever bears on the camshaft and receives the valve-operating force. The other end bears on the valve stem and transmits the camshaft movement to the valve. The camshaft end of the rocker-lever will generally be equipped with a roller. The valve end of the rocker arm incorporates an adjusting screw to permit the setting and adjustment of valve clearances. Many variations as to size and shape of rocker arm levers can be found. In one **V**-type engine a rocker-arm lever is forked to operate two valves per cylinder. (See fig. 39.)

b. Radial-engine valve-operating mechanism. The valve mechanism of a radial engine is operated by one or two cam plates or rings, depending upon the number of rows of cylinders. In a single-row radial engine, one plate or ring with a double cam track is used. One track operates the intake valves and the other the exhaust valves. The mechanism also includes the tappet assemblies, push rods, and rocker-arm assemblies

(1) *Cam ring or cam plate.* A cam ring or cam plate is used in a radial engine for the same purpose as a camshaft is used in a **V**-type or in-line engine. The cam ring is a circular piece of steel with a series of cams or lobes on the outer surface. The surface of these lobes and the spaces between them (on which the cam rollers ride) is known as the cam track. (See fig. 43.) The inner surface of the cam ring rides on a bronze bearing which is securely fastened to the crankcase. A set of gear teeth on one side of the cam ring provides the means for rotating it. As the cam ring revolves, the raised portions or lobes cause the cam roller to raise the tappet in the tappet guide, thereby transmitting the force through the push rod and rocker arm to open the valve. (See fig. 44.)

(2) *Tappet assemblies.* A valve tappet assembly consists of a short steel rod (called a tappet) inclosed in a tube called a tappet guide. (See fig. 44.) At one end of the tappet is mounted a hardened-steel roller which rides on a cam track. This roller is made of steel and is attached to the tappet which slides up and down in the tappet guide. At the other end of the tappet a hardened steel recess is found. This recess accommodates the ball end of a push rod. A hole is drilled through the tappet to allow engine oil to flow to the hollow push rods in order to lubricate the rocker assemblies.

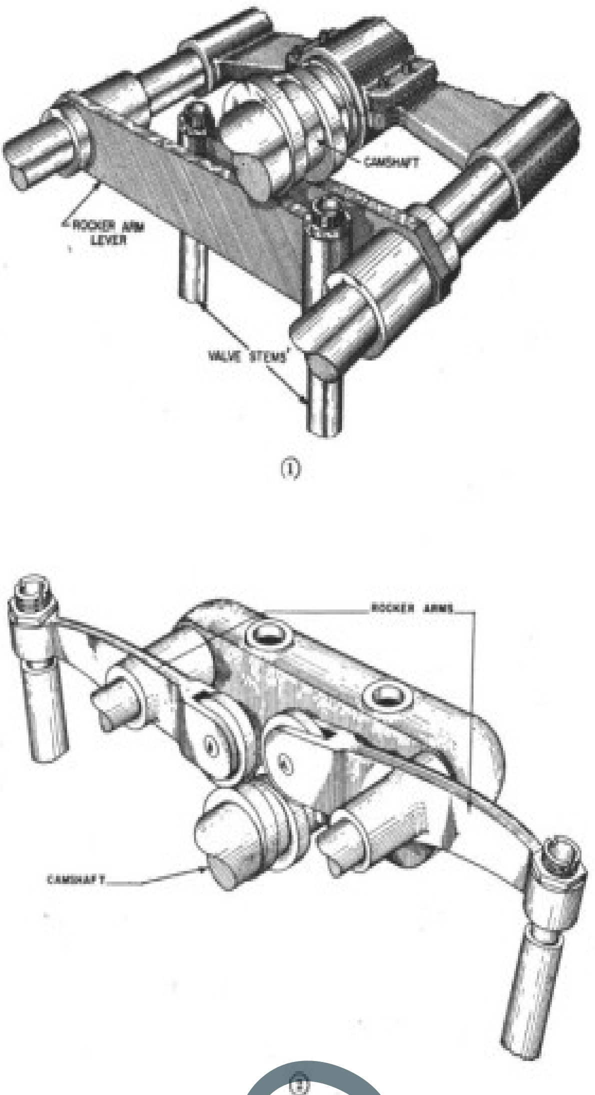
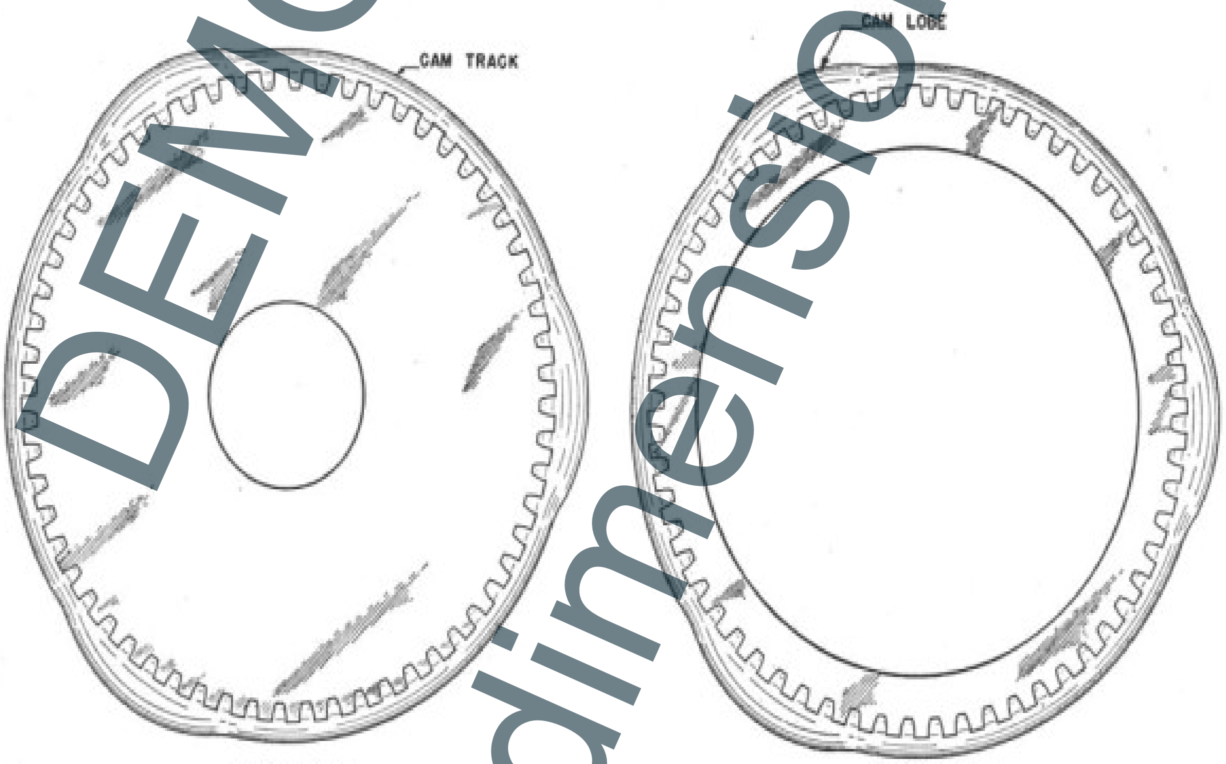


Figure 42. Rocker-arm assembly.



① *Cam plate.* ② *Cam Ring.*

Figure 43. Cam plate and cam ring.

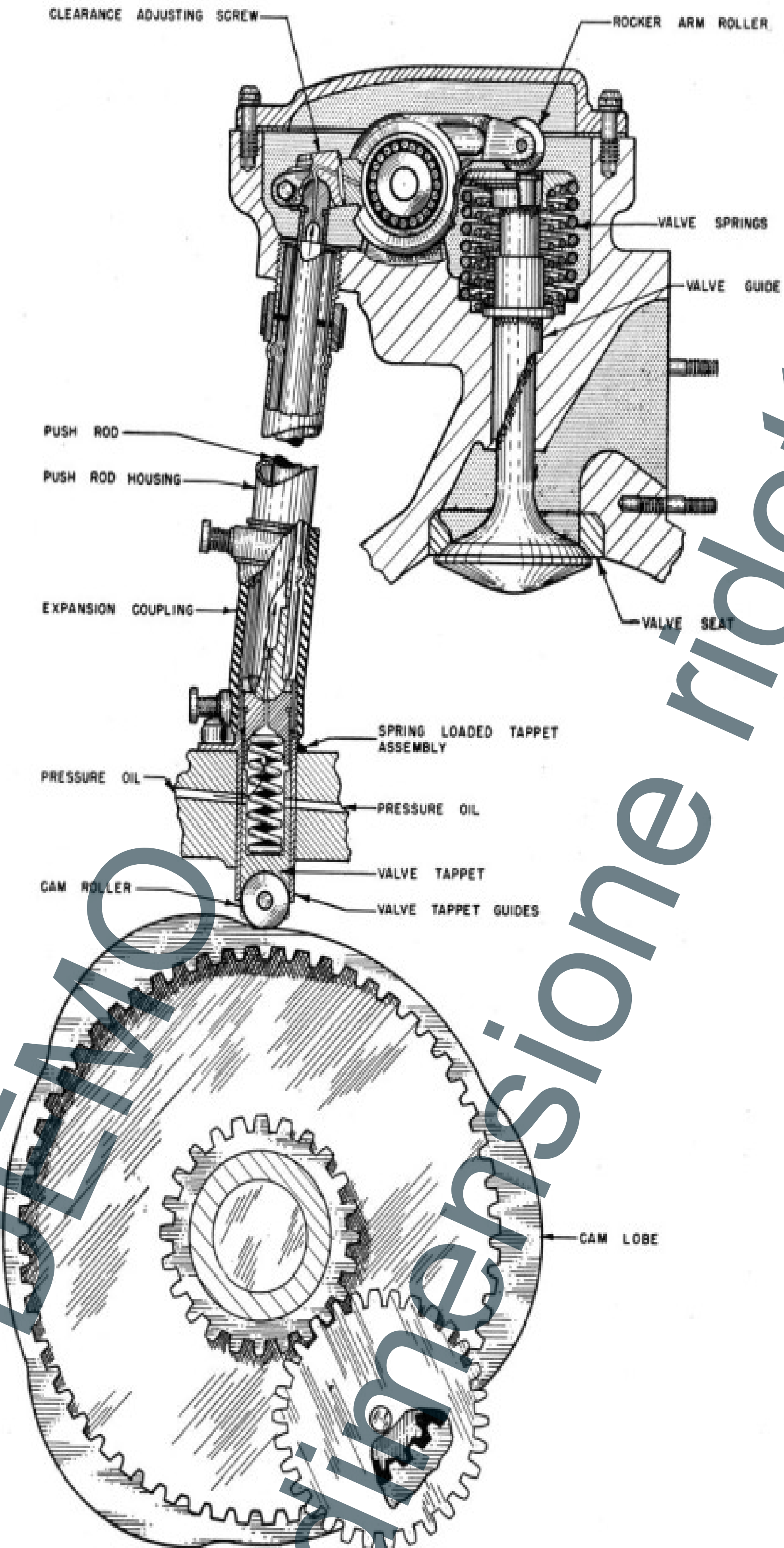


Figure 44. Valve-operating mechanism — radial engine.

(3) *Zero-lash hydraulic-valve lifter.* Another method of transmitting the force to operate the valves employs a column of oil which is confined between the cam follower and a plunger. (See fig. 45.) When the cam follower is pushed upward, the column of confined oil pushes the plunger upward. As the plunger bears against the valve stem, the valve will be moved upward against the spring. A very small leak is allowed to exist in a system of this type to compensate for temperature expansion. This slight loss is constantly being replaced by the engine-oiling system. No valve-clearance adjustments are necessary on engines using this system except at major overhaul. This device has so far been used only on the low-output engines.

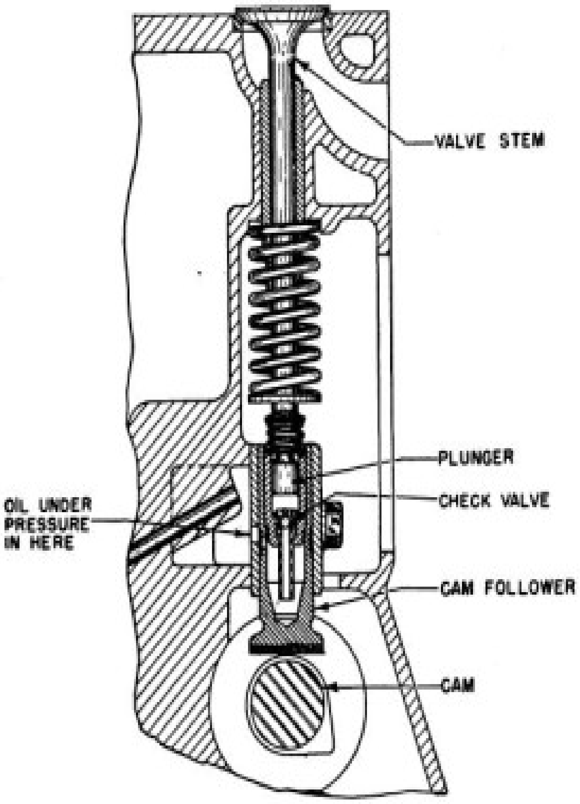


Figure 45. Hydraulic valve-lifting mechanism.

(4) *Push rods.* A push rod is used to transmit the lifting force from the valve tappet to the rocker arm. It is tubular in form and is made of either aluminum alloy or seamless steel. A hardened-steel ball is pressed over or into each end of the tube. One ball end fits into the socket of a tappet and the other into the socket of a rocker arm. In some instances the balls are on the tappet and rocker arm and the sockets are on the push rod. The tubular form is employed because of its lightness and strength. It permits the engine lubricating oil under pressure or gravity feed to pass through the hollow rod and the drilled ball ends to lubricate the ball ends, rocker-arm bearing and valve-stem guide. This circulating oil flow greatly reduces valve-mechanism wear. Frequent checking of the valve clearances has been practically eliminated in engines using automatic valve-gear lubrication. The length of each push rod is determined by the distance between the tappet and the rocker arm sockets. Each push rod is inclosed within an aluminum-alloy tube. The tube or housing provides a passage through which the lubricating oil returns to the crankcase. It also protects the push rod from damage and prevents dirt from coming in contact with the valve-operating mechanism.

(5) *Rocker-arm assemblies.* Rocker arms or levers are mechanical devices for transmitting the lifting force from the cams to the valves. (See fig. 44.) Rocker-arm assemblies are made of steel and are supported by a plain, roller, or ball bearing which serves as a pivot. Generally one end of the arm bears against the push rod and the other bears on the valve stem. One end of the rocker arm is sometimes slotted to accommodate a steel roller. The opposite end may be constructed with either a threaded split clamp and locking bolt (see fig. 46 ①) or a tapped hole (see fig. 46 ②). Adjustments of valve clearances are made at this point. After the clearance has been adjusted, the locking bolt (or the lock nut) locks the adjusting screw so that the proper clearance will be retained. On some engines, the adjusting ball socket is generally drilled to provide a passage for lubricating oil.

27. VALVE-TIMING DEVICES. Variations in valve timing will vary the power delivered at a given speed. To obtain the best performance at high speeds means a sacrifice at low speeds and vice versa. A compromise must be made to obtain the desired results. The valve timing on practically all modern engines is arranged in such a manner that it is almost impossible for it to change once the mechanism is properly connected. However, there are some valve mechanisms that are driven by certain types of drives in which the timing may change enough to cause eventual engine failure. In a few instances, the

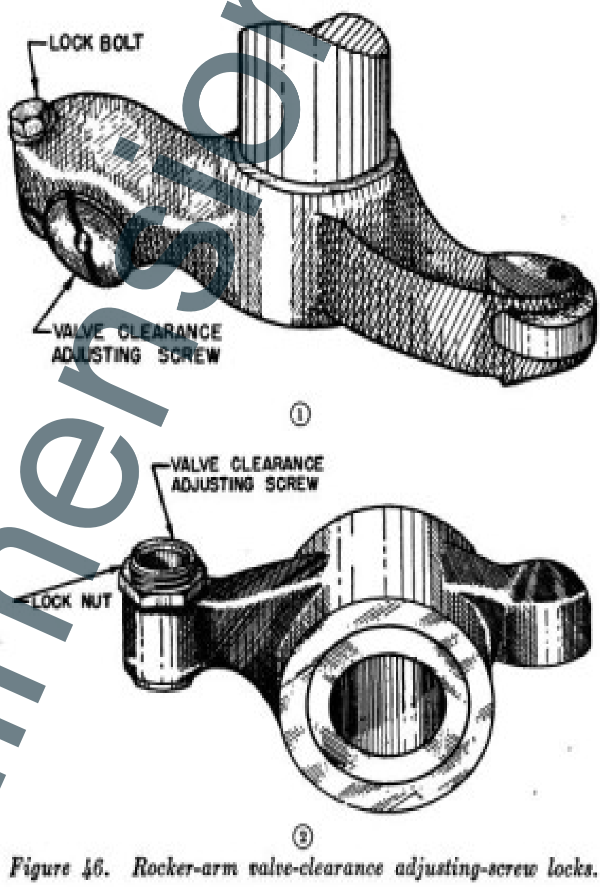


Figure 46. Rocker-arm valve-clearance adjusting-screw locks.

coupling devices have become disconnected and caused malfunction of the valves. In order to provide for ease of valve-timing operation, such special tools as the top-center indicator and the timing disk are used. The top-center indicator is a tool used to determine the top-dead-center position of a piston in a cylinder. The timing disk is a device which measures the crankshaft rotation in degrees and helps to determine when the crankshaft is in the correct position for timing the valves of the engine. These tools are also used in ignition timing. Several methods of adjusting valve timing follow.

a. Vernier coupling. One particular model of **V**-type engine incorporates a gear-coupling vernier. The gear which is bolted to the camshaft by means of 7 bolts, has 36 teeth. (See fig. 47.) Since there are 360° in the circumference of the gear and 36 teeth, adjacent gear teeth are 10° apart and the space between the centers of two adjacent bolt holes is 51.4° Therefore, if the gear is removed and turned the distance between two bolt holes and replaced, it will no longer mesh with the driving gear. (See fig. 48.) The camshaft will have to be turned 1.4° to allow the gears to mesh. This arrangement provides an adjustment by means of which the valves can be accurately timed. The number of teeth on the gear and the number of bolt holes could of course be different so long as the number of teeth is not evenly divisible by the number of holes.

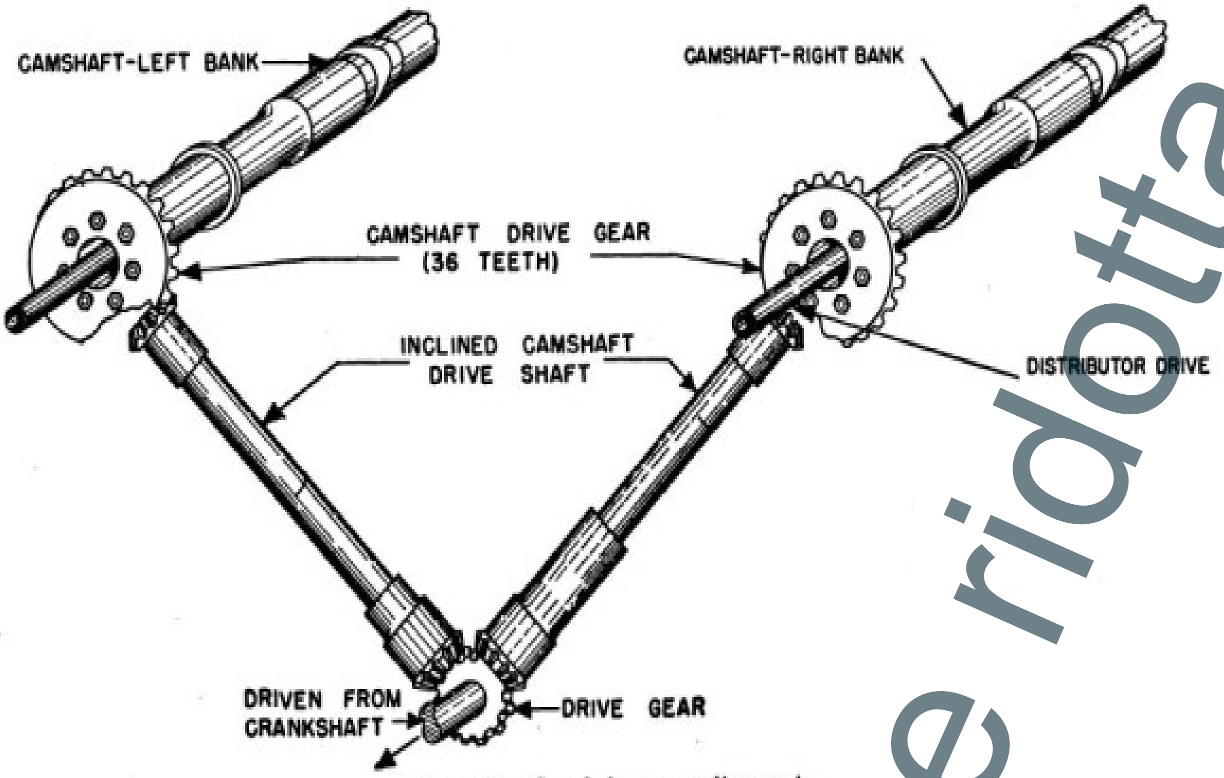


Figure 47. Camshaft gear-coupling vernier.

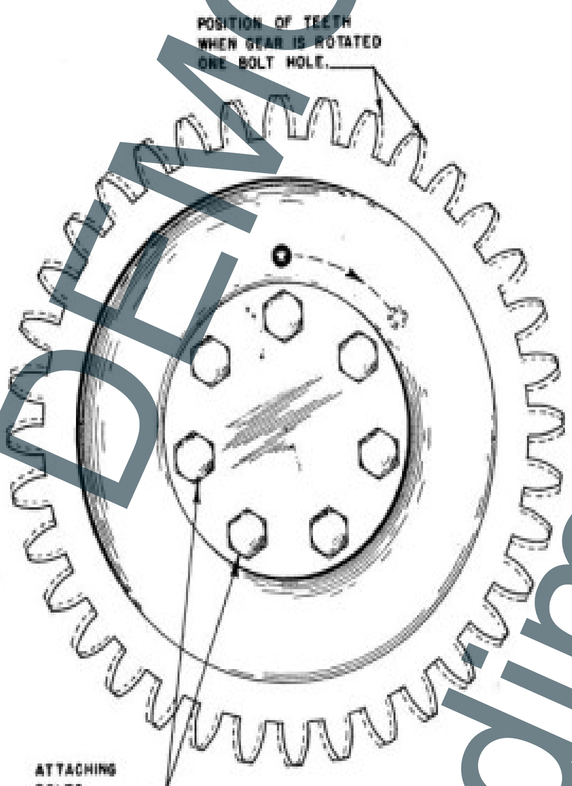


Figure 48. Vernier adjustment for valve timing.

b. Splined driveshaft. On some engines the force to drive the camshafts is transmitted from a driveshaft in the accessory section to each of two camshaft bevel gears by an inclined driveshaft. (See fig. 49.) Each of these inclined shafts has 19 external splines on one end and 21 on the other end. The splines at the lower end of the inclined shaft mesh with the internal splines of a bevel gear. The splines at the upper end of the inclined shaft mesh with the internal splines of another bevel gear that drives the camshaft gear. The uneven number of splines permits a vernier adjustment of the valve timing. When the valves are timed, the specified piston must be on its proper stroke (see Technical Orders). In other words, the crankshaft must be in a particular position. This position is usually indicated by markings on the propeller reduction gears. These markings may be

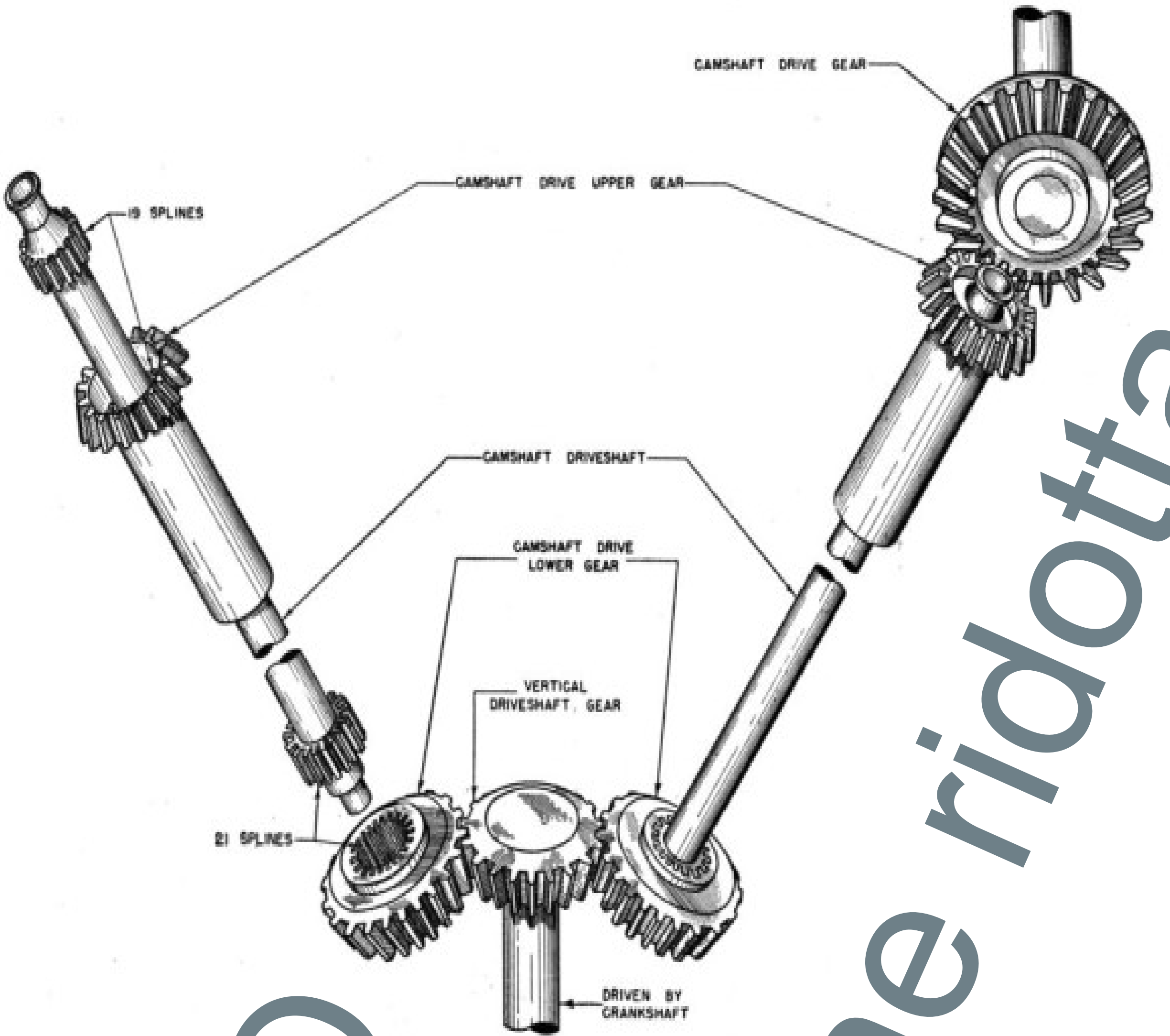


Figure 49. Camshaft splined drive shaft.

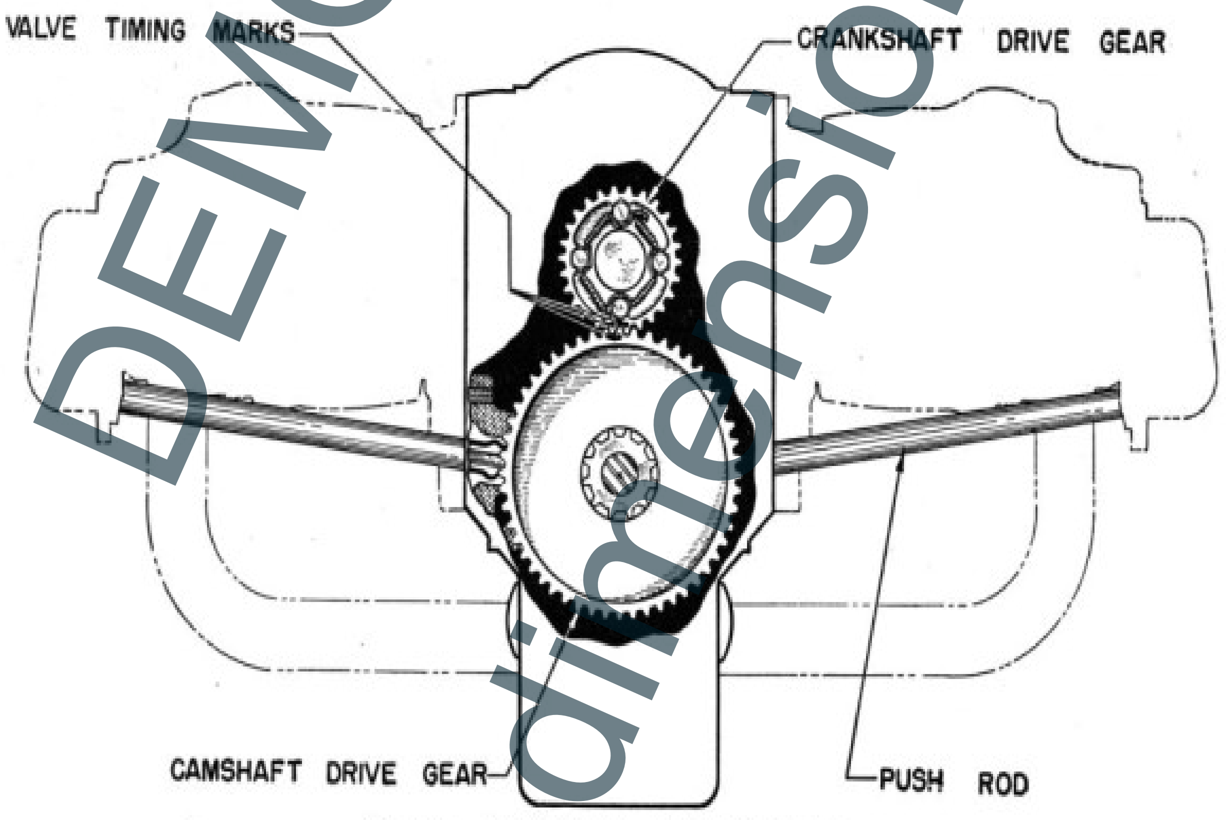


Figure 50. Camshaft drive — opposed-type engine.

seen by looking through the inspection hole located in the front- (nose-) section housing. Before timing the valves, a thrust cap must first be removed from the upper end of the splined drive-shaft bearing retainer. This permits the lifting of the shaft. When the inclined drive shaft is lifted, the upper bevel pinion remains meshed with the gear on the camshaft, but out of mesh with the lower-pinion drive gear. This allows the camshaft to be rotated independently of the crankshaft. The camshaft can then be placed in the proper position. The inclined shaft is then lowered, permitting the splines of the shaft to mesh with the internal splines of the bevel-pinion gear. If the splines do not mesh, the shaft is rotated until the proper mesh is secured. At times, slight movement of the camshaft is permitted, usually within a tolerance of 1°. The same operation is performed in timing the valves of the other bank.

c. Direct gearing. The valve-operating mechanism of some opposed-cylinder engines incorporates a rocker-arm assembly, push rods, and a camshaft driven directly through a set of gears. (See fig. 50.) The camshaft is located within the crankcase housing. This type of camshaft mechanism operates on the same principle as the overhead camshaft previously described. The only difference is that push rods are used to transmit the action of the cam lobe to the rocker-arm assembly. The camshaft is connected to the crankshaft by a gear arrangement that causes the camshaft to rotate one-half as fast as the crankshaft. During engine assembly the cam shaft is installed in its proper location. The crankshaft cam-drive gear is marked with center-punch marks on two adjacent teeth. The camshaft gear is marked with one center-punch mark on one tooth. This tooth is meshed between the two marked teeth on the crankshaft gear. When these gears are meshed according to the marks, the valves are properly timed.

d. Radial-engine valve timing. On most radial-type engines no external adjustments are incorporated to provide for valve timing after the engine has been assembled. During the time of engine assembly, after a major overhaul, the valve-timing operation is performed. The exact meshing of the marked teeth of the cam ring and the marked tooth of the cam-drive gear must be fixed as designated in the Technical Order for the specific engine. The operation of the valve mechanism is accomplished by the cam ring or cam plate. In some engines, the ring or the plate is supported on a journal which is mounted directly on the main crankcase. In other engines, the cam plate rides on a bushing which is mounted directly on the crankshaft. The gear teeth may be on the inside or the outside of the cam ring. These teeth mate with an intermediate cam-drive pinion gear and causes the cam ring (or plate) to rotate at a fraction of the crankshaft speed (depending upon the number of lobes).

28. IGNITION TIMING DEVICES. On nearly all of the present aircraft engines, dual high-tension ignition is supplied. The high voltage necessary for ignition is produced by two separate engine-driven high-tension magnetos. Some engines use two magnetos incorporated in one housing. The magneto is timed to deliver high voltage at certain specified intervals. Since this high voltage must reach each spark plug at the proper time, an arrangement is also provided for timing each magneto to the engine. The magneto has a distributor which directs the electric current to each of the cylinders in the proper sequence (firing order). Therefore, if the magneto is properly timed for one cylinder, it will be properly timed for all cylinders. Two general methods of timing the magneto to the engine are the vernier-coupling and splined-coupling methods.

a. Vernier coupling. Magneto timing may be accomplished by means of a hard synthetic-rubber coupling with gear teeth molded on each side of it. There is one more tooth on one side than on the other; therefore, turning the rubber plate one gear tooth in relation to the two gears that mesh with it will change the magneto timing by the difference in the size of the teeth on each side of the rubber plate. (See fig. 51.)

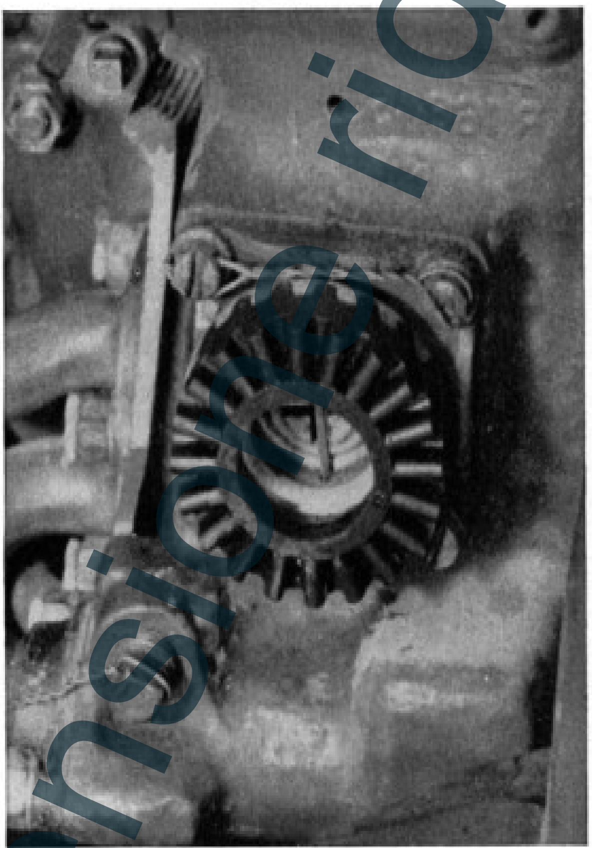


Figure 51. Vernier coupling — ignition timing.

b. Splined coupling. (1) On some types of engines, a splined coupling is used to connect the magneto drive shaft to the splined shaft protruding from the magneto housing. Before installing the magneto, remove the breaker cover and align the step cut with the marks on the edge of the housing with a straight edge. (See fig. 52.) Be certain that the position of the piston is as specified in the Technical Order for the particular engine. Place the splined coupling on the end of the drive shaft and then attempt to mesh the splined end of the magneto shaft with the coupling. If the magneto does not drop into the coupling spline within a specified tolerance, remove the magneto and try another mesh position with the coupling. When the magneto is meshed within the proper tolerance, proceed as explained in c (1) below.

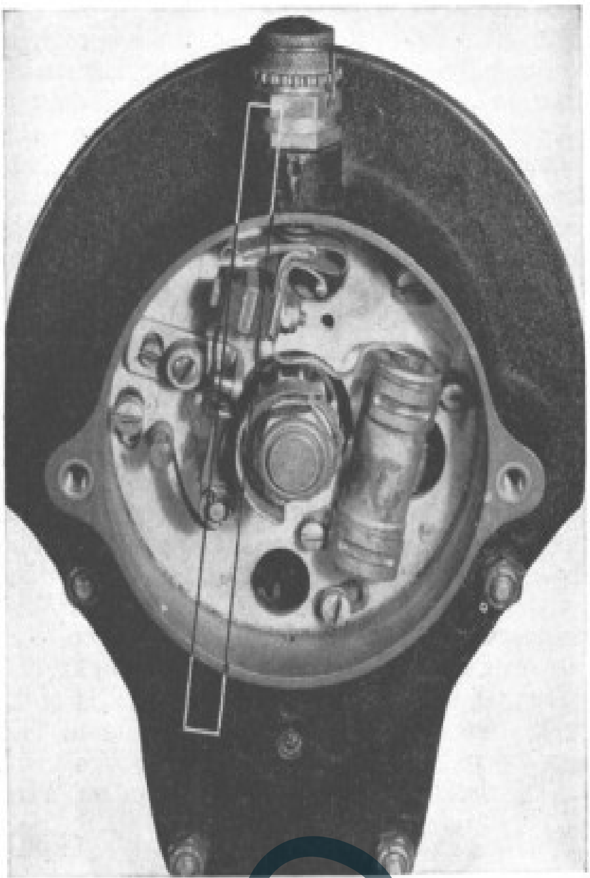


Figure 52. Setting magneto cam prior to installation.

(2) *Slotted magneto flange.* The mounting flanges of magnetos utilizing the splined-coupling method are slotted (See fig. 53.) These slots allow rotation of the magneto housing (within the length of the slots) and permit closer adjustment of engine timing. When the magneto is in the correct position after the splined coupling is correctly meshed, rotate the magneto housing until the magneto is exactly timed to the engine. The mounting bolts are then tightened to hold the magneto securely in place.

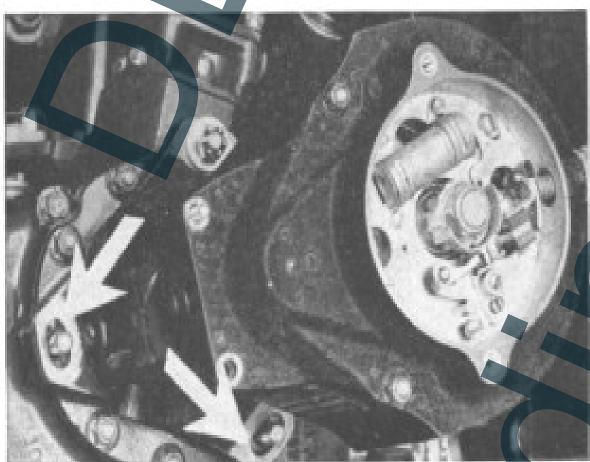


Figure 53. Slotted magneto-housing flange — ignition timing.

29. INTERNAL BLOWERS AND SUPERCHARGERS. The horsepower developed by an engine operating at a given speed depends upon the compression ratio, the piston displacement, and the volumetric efficiency of the engine. The compression ratio and the piston displacement are fixed and cannot be changed on any given engine. The volumetric efficiency however can be changed. The volumetric efficiency is the ratio of the volume (at normal atmospheric pressure and temperature) of the charge drawn into the cylinder to the piston displacement. For example, if the piston displacement in a given cylinder is 100 cubic inches, and 90 cubic inches of fuel-air mixture is drawn into the cylinder the volumetric efficiency would be 90 percent. As an airplane gains altitude, the air becomes thinner and the volumetric efficiency of the engine decreases. In order to increase the volumetric efficiency (and in turn the horsepower of the engine) especially at high altitudes, superchargers are used on most modern airplane powerplants.

a. Internal-blower assembly. The blower is a centrifugal-type air pump. The fuel-air charge is drawn directly into the supercharger, where it is subjected to the action of the rotating impeller. The purpose of the blower assembly is to atomize more thoroughly the fuel-air mixture and assure (as nearly as possible) equal distribution of the mixture to the various cylinders. It also improves the acceleration of an engine during operation.

(1) *Blower impeller.* Aircraft-engine blower impellers are of the centrifugal type and are forged of aluminum alloy. An impeller consists of a circular disk with blades extending radially from its surface. (See fig. 54.) It may be attached directly to the

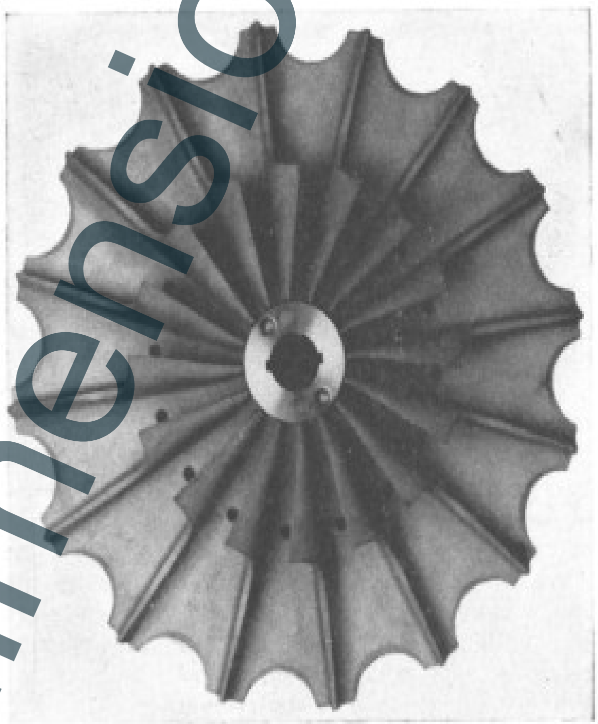


Figure 54. Impeller.

crankshaft or it may be driven through a gear train. If the impeller operates at approximately the same speed as the crankshaft, it does not boost or increase the pressure on the fuel-air charge. The speed is selected by the designer and it is mainly dependent upon the piston displacement of the engine, the octane rating of the fuel used, the diameter of the impeller and the strength of the engine structure. It is also important that the impeller be light, yet perfectly balanced and strong enough to withstand the high centrifugal forces.

(2) *Diffuser section.* The diffuser section is that part of the induction manifold that surrounds the blower impeller. The diffuser plate (fig. 55) is fitted closely around the impeller. The unit consists of a circular plate and curved vanes on one surface. The

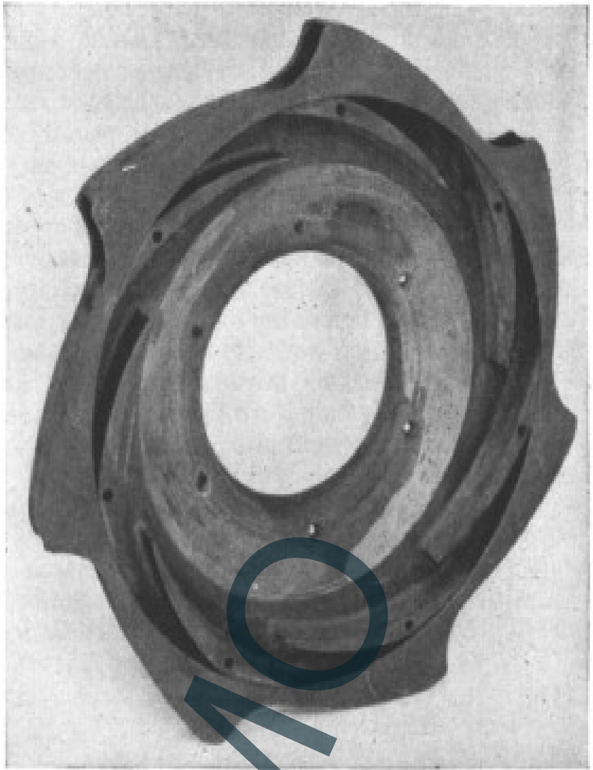


Figure 55. Diffuser plate.

vanes may be plain or shaped as airfoils. The action of the impeller on the fuel-air charge tends to create a swirling of the fuel-air flow. The purpose of the diffuser vanes is to eliminate this swirling of the fuel-air within the diffuser chamber in order to obtain efficient flow into the cylinders.

(3) *Distribution chamber.* This section may be called "the manifold ring," and incloses the entire blower assembly. In a radial-type engine, it forms part of the engine crankcase and is generally made of forged aluminum alloy. Individual intake pipes extend into openings on the ring and provide passageways through which the fuel-air charge reaches the engine cylinders. The pipes are held in the openings by synthetic-rubber packing rings and packing retaining nuts, which form slip joints to allow for cylinder expansion and contraction. In an in-line engine, the fuel-air charge passes from the diffuser vanes into a chamber. From here it is conducted through the main intake manifold to smaller branch manifolds and into the engine cylinders.

(4) An aftercooler unit is incorporated on some engines equipped with a two-stage internal supercharger. The purpose of this unit is to cool the fuel-air charge after it has been compressed by the supercharger. The assembly consists of a housing, a radiator core and the necessary units for a coolant system. It is located between the supercharger outlet and the main induction system. The fuel-air charge circulates around the core tubes in order to dissipate the heat produced during compression. A separate cooling system is maintained for this particular installation. It uses the same type of coolant mixture as used in the engine-cooling system. The liquid is forced through the core tubes by the aftercooler pump. A relief valve is incorporated in the system to prevent the development of excessive pressures.

(5) *Drain valves.* Each time an engine is started or stopped the fuel is not entirely vaporized and taken into the cylinders. This unburned gasoline gathers in the lowest part of the induction system and becomes a serious fire hazard. To remove this unvaporized gasoline from some systems, a drain hole (open to the atmosphere at all times) is provided in the induction system at its lowest point. More frequently, however, an automatically operated drain-valve assembly is incorporated. (See fig. 56.) When the engine is not operating, the weight of the valve causes it to fall away from the seat. This opens a passage to the atmosphere through which unvaporized fuel may drain from the system. When

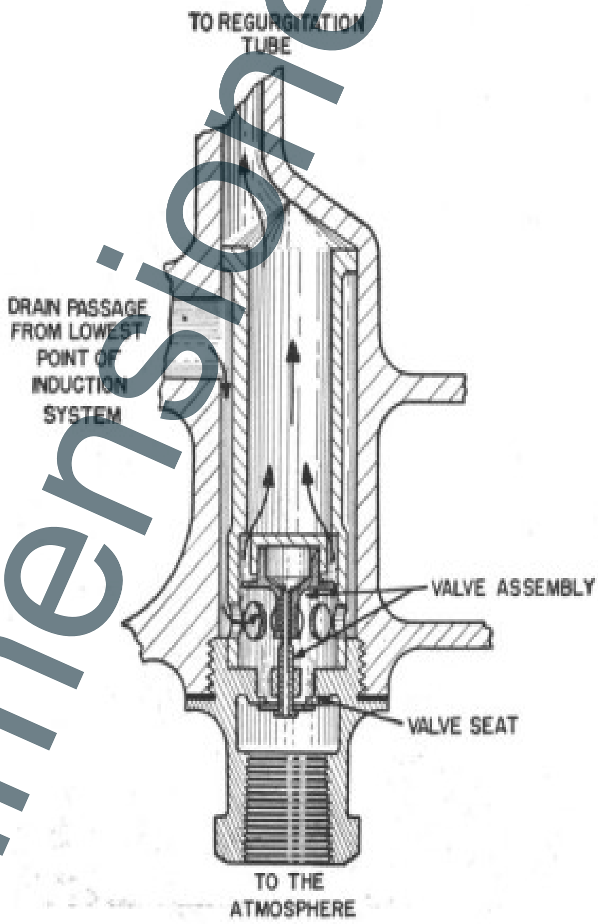


Figure 56. Supercharger drain valve.

the engine is operating, the pressure in the regurgitation or gurgle tube is below atmospheric pressure because the upper end of the tube is open to the inlet side of the impeller. The pressure on the valve will, therefore, be less than that on the bottom and the valve will be held on the seat by the differential pressure. This closes the opening and any gasoline-vapor condensate which forms in the induction system is piped-up to the inlet side of the whirling impeller through the regurgitation tube as shown by the arrows in figure 56. The piped-up action is brought about by the same differential pressure which closes the valve.

b. Superchargers. The supercharger of an internal-combustion engine is a mechanical unit that compresses the fuel-air charge in order to maintain the manifold pressure at or above atmospheric pressure. This unit provides a pressure greater than atmospheric whereas the internal blower does not. Internal superchargers are of several types such as: single-speed, two-speed with a mechanical or hydraulic clutch, and two-stage. External superchargers are of the variable-speed type and are generally turbine driven.

(1) *Internal superchargers.* An internal supercharger (shown in fig. 57) is a unit whose impeller is located in the induction system between the carburetor and the intake ports of the engine cylinders. This unit is designed and assembled as an intergral part of the engine, and is gear- or hydraulic-driven. The speed with which the impeller rotates is limited by the impeller-tip speed and the heating of the charge due to compression. Impeller speeds may be as high as 15 revolutions to one revolution of the crankshaft. The average impeller ratio ranges between ratios of 6:1 and 10:1. The internal supercharger consists of an impeller, a diffuser chamber, a distribution chamber (manifold

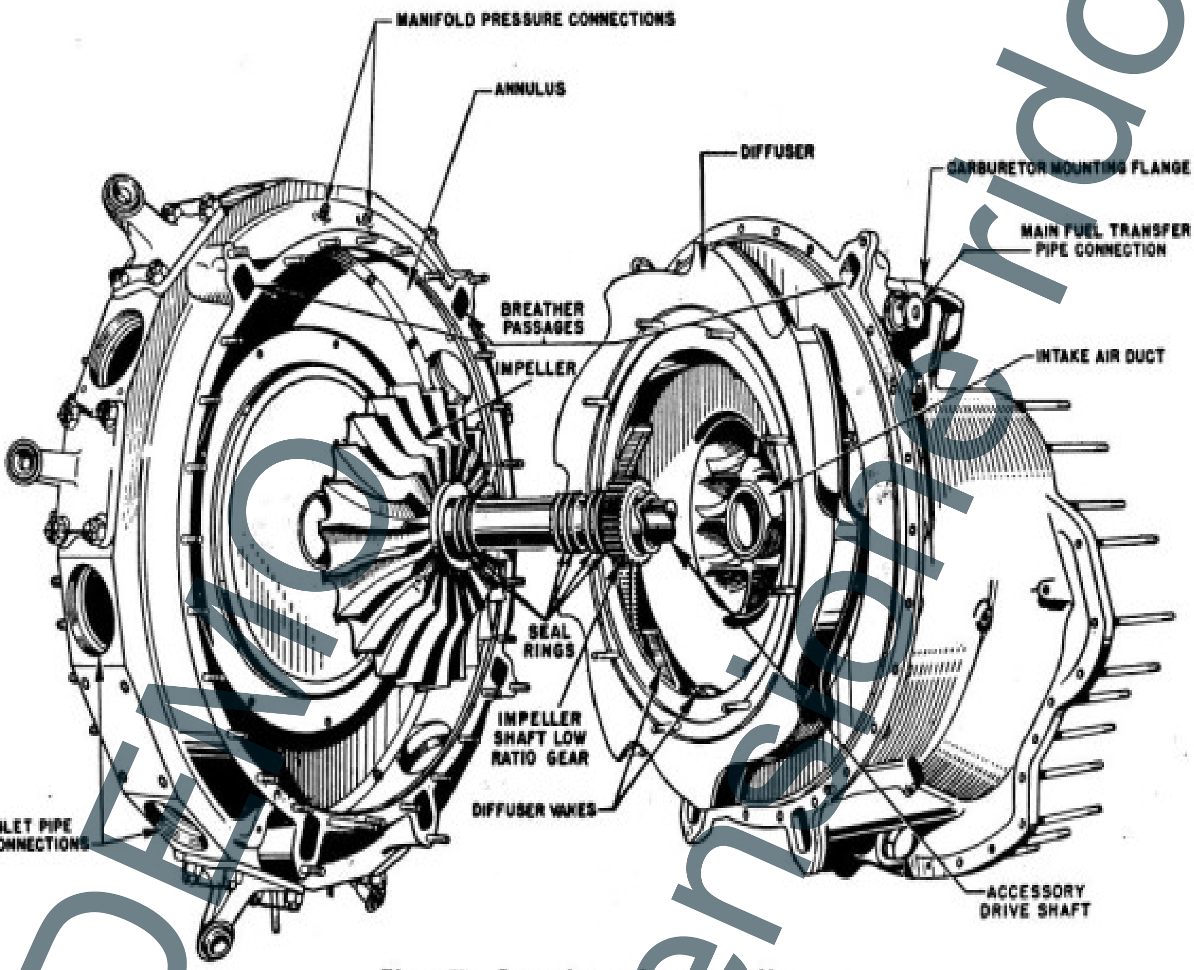


Figure 57. Internal-supercharger assembly.

ring) and an impeller-driving mechanism. It may have a single impeller-speed ratio, a two-speed ratio, or a variable-speed ratio. The *single-speed unit* has a fixed-gear ratio and is similar to the internal blower, although the single-speed unit rotates at a speed sufficient to maintain the manifold pressure at or above standard atmospheric pressure at certain engine speeds. The *two-speed drive mechanism* consists of gears and clutches. When the actuating control valve is moved, oil pressure is applied to one side of a clutch disk. There is no neutral position in which the clutches are disengaged. Selection of the gear ratio

High supercharger pressure (high manifold pressure) is used to obtain more engine power for take-off, or to maintain or increase engine power at high altitudes. As a plane equipped with an unsupercharged engine rises to a higher altitude, the carburetor-intake pressure will decrease because of the decrease in atmospheric pressure. This will result in a decrease of manifold pressure and power output. To prevent this, aircraft-engine designers have developed internal and external superchargers. Many variations in the methods of supercharging, each with its particular advantages, are used.

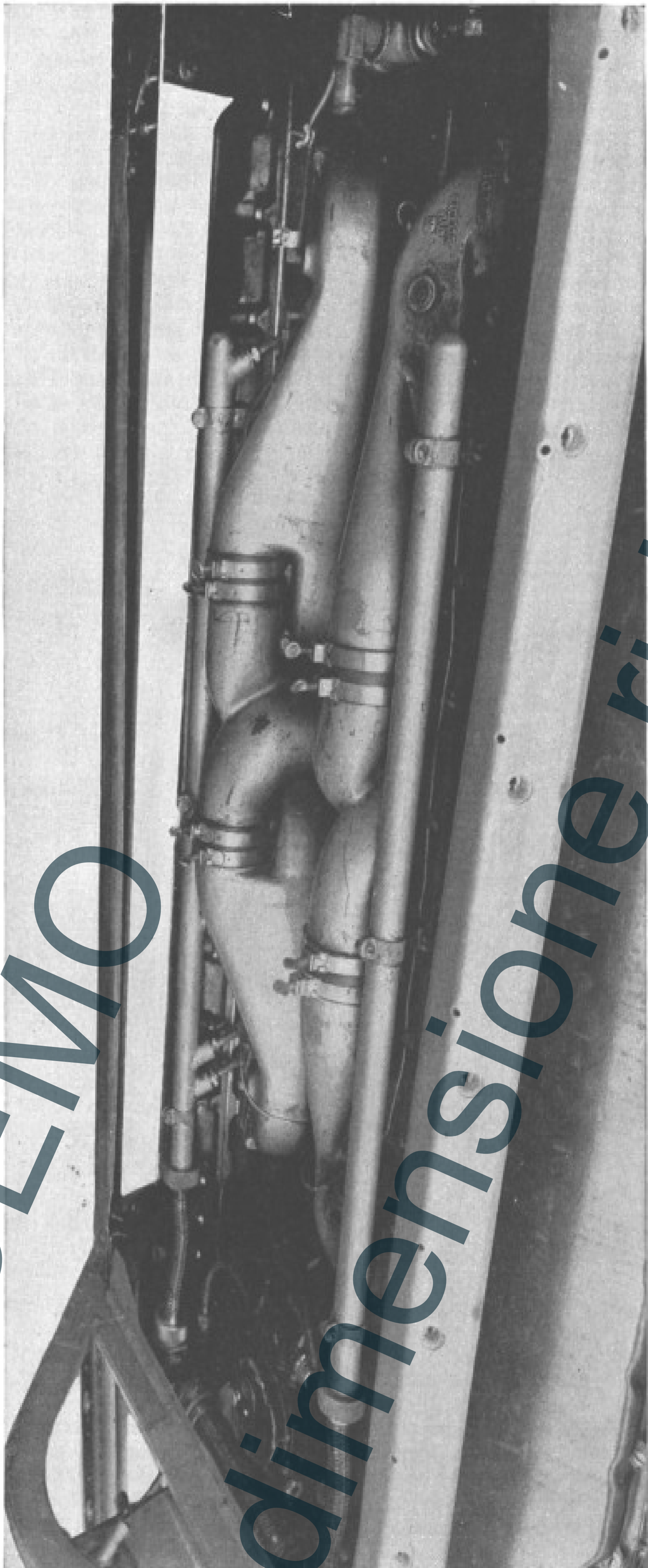


*Figure 58. Induction manifold.—***V***-type engine.*

is performed with a push-pull control. The control unit is a piston-type selector valve located in the supercharger rear cover. The setting for the lower-impeller ratio is called "the low-blower position;" that for the higher-impeller speed is called "the high-blowerposition." Low blower is generally used at take-off and during flight at low altitudes. As the airplane climbs to higher altitudes and engine power begins to decrease, the pilot will shift the control valve to the high-blower position for increased supercharger pressure and engine power.

(2) *External superchargers.* An external supercharger is not a component part of the engine and, therefore, will not be discussed in this manual (reference TM 1–407).

30. INTAKE MANIFOLD AND PIPES. Induction manifolds and pipes are the sealed passageways used to conduct air or fuel-air mixture from the distribution-chamber section to the intake-valve ports of the cylinders. The number and construction of manifolds or pipes depend on the engine type and the total number of cylinders to be supplied. The manifolds and pipes are light in weight and designed to offer the least possible resistance to the flow of the air or mixture.

a. Intake manifolds. An aircraft engine with in-line or multiple banks of cylinders distributes the fuel-air charge through a large main induction manifold into smaller branches attached to the cylinder intake ports. The other end of the main manifold is attached to the distribution chamber. The manifold assembly is generally made of aluminum or magnesium alloy, manufactured in one or two sections per bank. The single-section unit incorporates openings for all cylinders on one bank. The double-section assembly consists of two branches, each supplying the mixture charge to half of the cylinders. Tubular synthetic-rubber couplings are used in connecting the two branches to the main section. (See fig. 58.) This allows for expansion of the cylinder block due to heat of combustion. A gasket is placed between the manifold flange and the cylinder intake ports and the assembly is rigidly secured to the cylinder block by studs or bolts and nuts. Threaded holes are provided for cylinder-primer nozzle connections and for the manifold-pressure-gauge take-off line.

b. Intake pipes. Intake pipes are individual pipe connections between the distribution chamber (manifold ring) and the cylinder intake ports. The pipes are circular in cross section and are generally designed to eliminate sharp bends, thus providing a smooth flow of fuel-air mixture to each cylinder. Most radial-type engines and some in-line engines employ this system of induction instead of the manifold type. (See fig. 59.) In some in-line and double-row radial powerplants, **Y**- or **T**-type intake pipes may be employed. Each of these conducts the charge to two adjacent cylinders. The pipes are generally made of aluminum alloy or steel. Steel intake pipes are stronger and are less subject to dents or warping. A gas-tight connection is provided at the distribution chamber by a synthetic-rubber packing ring and a packing retaining nut. This forms a slip-joint seal allowing the intake pipes to slide in and out of the distribution-chamber opening during the expansion and contraction of the cylinder metal. At the cylinder intake port, a gasket is placed between the pipe flange and the cylinder port, and the flange is rigidly secured by bolts and nuts. Another method provides for attachment of the intake pipe by a packing ring and packing-retaining nut which screws into or over the intake-port opening. On other engines, short stacks protrude from the intake ports and incorporate rubber couplings to attach the pipes to the extensions. The upper intake pipes of some radial engines have threaded holes for the installation of primer nozzles.

31. EXHAUST MANIFOLD AND STACKS. The exhaust manifold is a unit specially designed to provide a passageway for the removal of exhaust gases and flames from the vicinity of the engine. The gases may be conducted directly to the atmosphere, or by-passed through special ducts and used to drive the turbosupercharger or to provide heat for the carburetor intake or the cockpit before being released to the atmosphere. The assembly must conduct the gases away from the engine with a minimum of back pressure. The metal used is generally stainless or inconel steel. Inconel steel is used because it expands very little when heated and is resistant to corrosion. An exhaust assembly may be made in any of the following types: short stacks, exhaust manifold, or a collector-ring assembly.

a. Short exhaust stacks. Short exhaust stacks are short pieces of piping, generally curved toward the rear of the airplane. They are attached to the exhaust-port openings. These stacks may be designed for each individual cylinder or they may combine two adjacent cylinders. (See fig. 60.) They minimize exhaust-gas back pressure and exhaust-valve temperature, and also reduce fire hazard in the event of a crash landing. Short stacks present certain disadvantages because of the possible sudden cooling of the exhaust valves during side-slip maneuvers of the airplane and they are not efficient in conducting the exhaust gases away from the airplane cockpit.

b. Exhaust manifold. On some in-line engines, exhaust manifolds may be attached to the cylinder banks as single units. The unit consists of a manifold housing with one closed end. Protruding from the housing are short stacks which are bolted over the exhaust ports. The manifold housing enlarges progressively toward the outlet. (See fig. 61.)

c. Collector ring. Radial-engine exhaust manifolds are generally known as collector rings. The unit consists of a large ring (usually the approximate diameter of the engine) to which are attached exhaust pipes from the exhaust port of each cylinder. (See fig. 62.) The exhaust-ring assembly is usually constructed in several sections and sliding joints are provided between sections to allow for cylinder and collector-ring expansion. Cases are collected and conducted from all cylinders to the collector ring and thence to the atmosphere through a common outlet.

Figure 59. Individual intake pipes — radial engines.

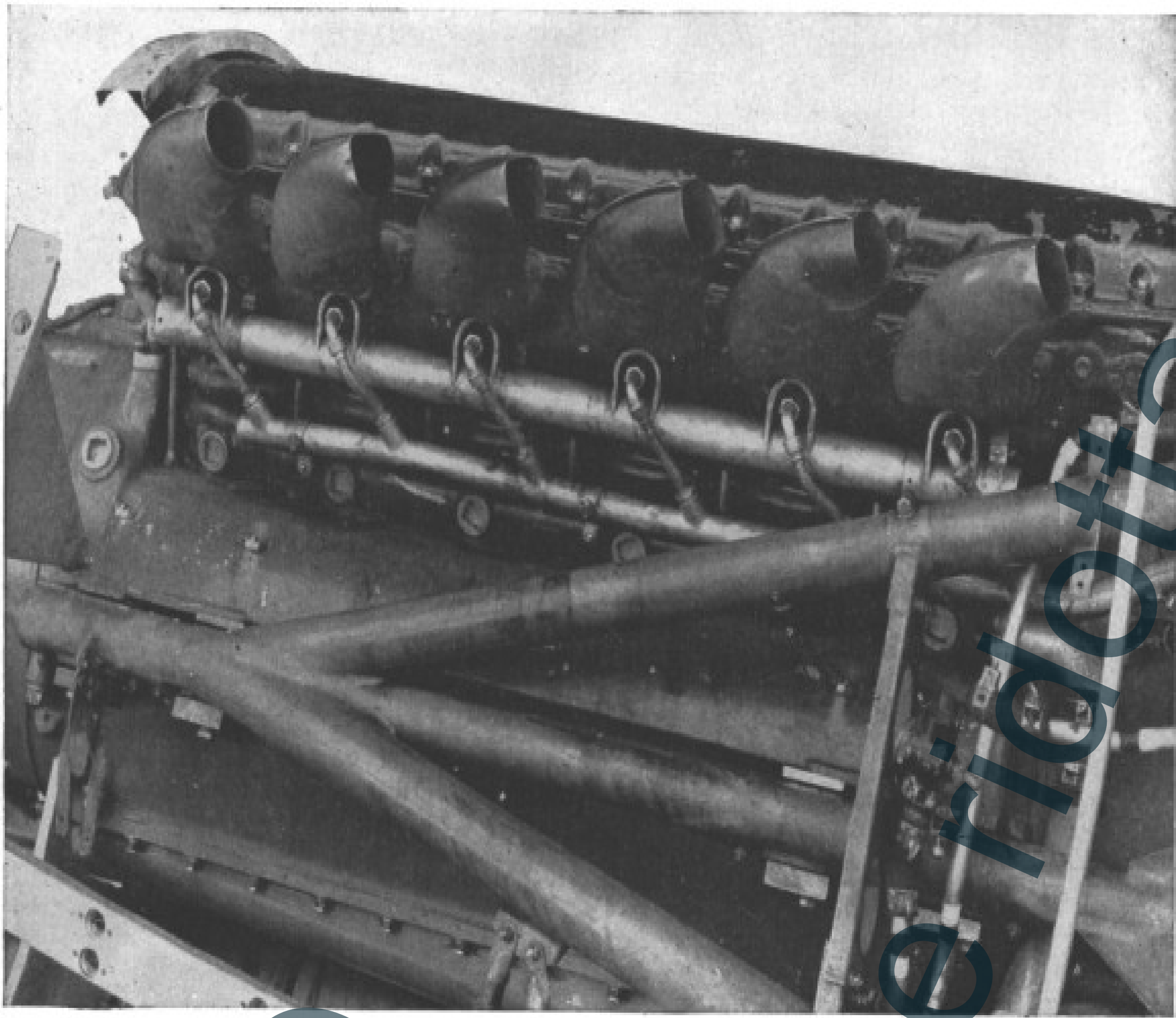


Figure 60. Exhaust manifold — short stacks.

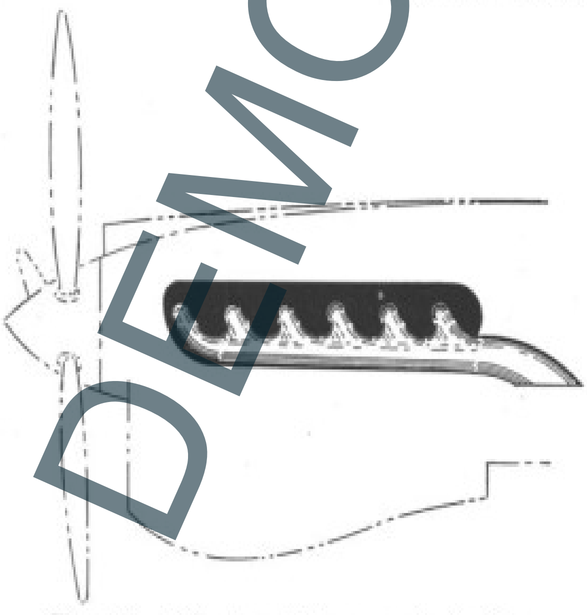


Figure 61. Exhaust manifold — one-piece housing.

The ring becomes progressively larger in cross-sectional diameter toward the common outlet. The outlet is streamlined toward the rear of the airplane. These collector rings may be installed on the front or the rear side of the engine cylinders. The front-type collector ring is not widely used because it tends to cause overheating of the engine.

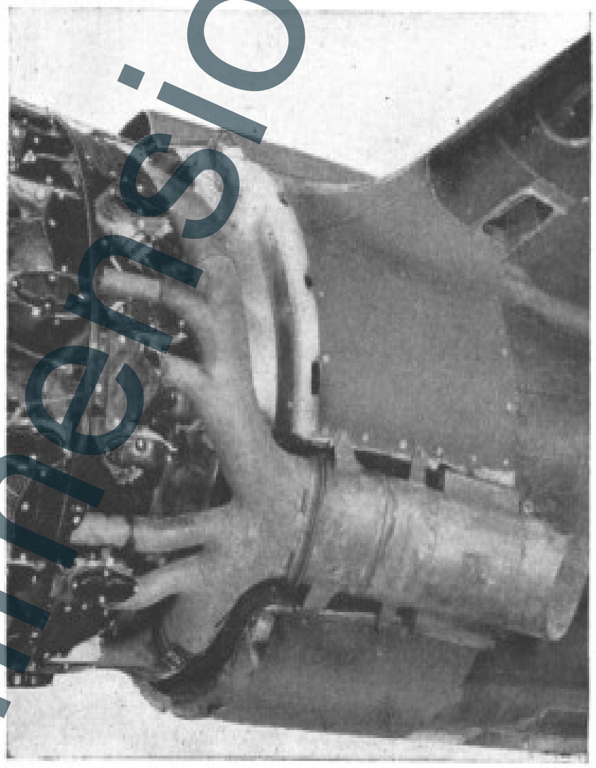


Figure 62. Exhaust collector-ring assembly.

32. PROPELLER REDUCTION GEARING.

Propellers used with low-horsepower engines are usually attached directly to the crankshaft. The increased brake horsepower delivered by a high-horsepower engine results partly from increased crankshaft speed. It is therefore necessary to provide reduction gearing to limit the speed of rotation of the propeller to a value at which efficient operation is obtained. The general practice has been to provide reduction gearing for propeller speeds above 2,000 rpm because it has been found that propeller efficiency decreases rapidly above this speed. As the reduction gearing must withstand extremely high stresses, the gears are machined from steel forgings. Many types of reduction gearing systems are in use. Four of these types will be discussed.

a. External spur-and-pinion reduction gearing. This assembly consists of an external spur gear mounted on the propeller shaft and an external pinion (driving) gear located on the crankshaft. (See fig. 63.) In some cases, this gear is mounted on an extension shaft which may be attached directly

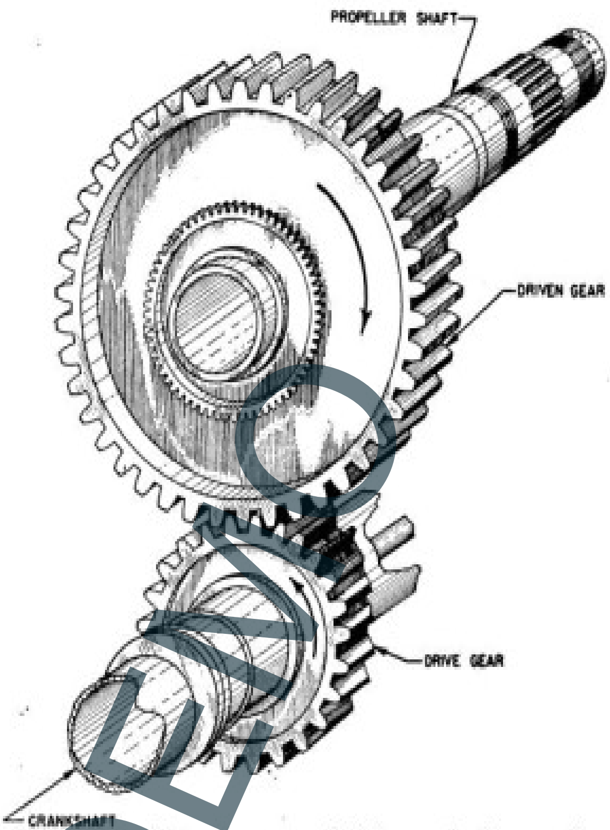


Figure 63. External spur-and-pinion reduction gearing.

to the crankshaft or may be driven through a flexible splined coupling. The propeller shaft is supported in the middle by a thrust bearing and at the rear by a roller bearing or a steel-backed, bronze bearing.

b. Spur planetary-system reduction gearing—rotating bell gear. The spur planetary reduction gearing consists of a large driving or bell gear that is splined (and sometimes shrunk) to the crankshaft, a large stationary gear (called a sun gear), and a set of small spur planetary pinion gears mounted on a carrier ring. (See fig. 64.) The ring is fastened to the propeller shaft and the planetary gears mesh with both the bell gear and the stationary gear. The stationary gear is bolted or splined to the

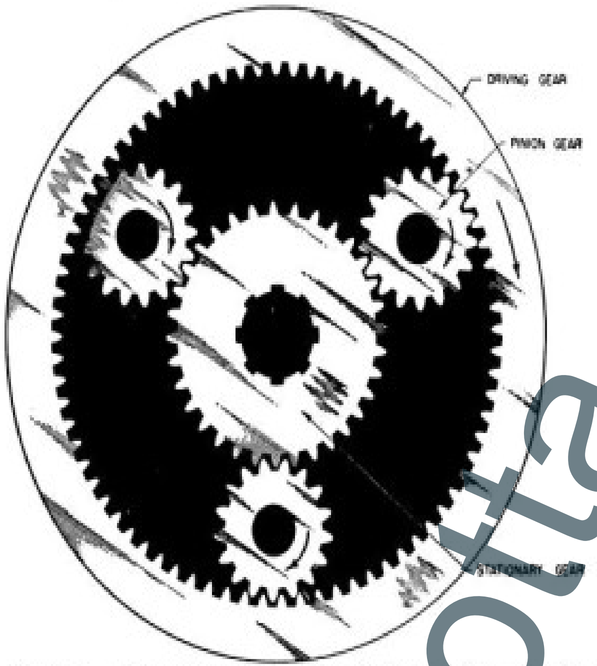


Figure 64. Spur planetary-system reduction gearing — rotating bell gear.

front-section housing. When the engine is operating, the bell gear rotates. As the planetary gears are meshed with this ring, they also must rotate. Since they also mesh with the stationary gear, they will walk or roll around it as they rotate; the ring in which they are mounted will rotate the propeller shaft in the same direction as the crankshaft but at a reduced speed.

c. Spur planetary-system reduction gearing—stationary bell gear. In some engines, the bell gear is mounted as the stationary gear in the front-section housing. The planetary pinion gears walk around inside of it. The sun gear acts as a driving gear because it is splined to the crankshaft.

d. Bevel planetary-system reduction gearing. In this system, the driving gear is machined with beveled external gear teeth and is attached to the crankshaft. A set of mating bevel pinion gears is mounted in a cage which is attached to the end of the propeller shaft. The pinion gears are driven by the driving gear and walk around the stationary gear which is bolted or splined to the front-section housing. (See fig. 65.) The thrust of the bevel pinion gears is absorbed by a thrust ball bearing of special design. The drive and the fixed gears are generally supported by heavy-duty ball bearings.

33. PROPELLER SHAFTS.

The types of propeller shafts are the tapered-end and the splined-end. The correct propeller assembly must be used with each type of shaft. Tapered shafts are identified by taper numbers and the splined shafts by SAE number sizes.

a. Tapered ends. In many low-power-output engines, the propeller shaft is forged or cast as a part of the crankshaft. (See fig. 66.) The shaft is tapered and a milled slot is provided so that the propeller hub may be keyed to the shaft. The end of the shaft is threaded to receive the propeller retaining nut.

b. Splined ends. (1) On a high-output engine the propeller shaft is splined. (See fig. 65.) It is

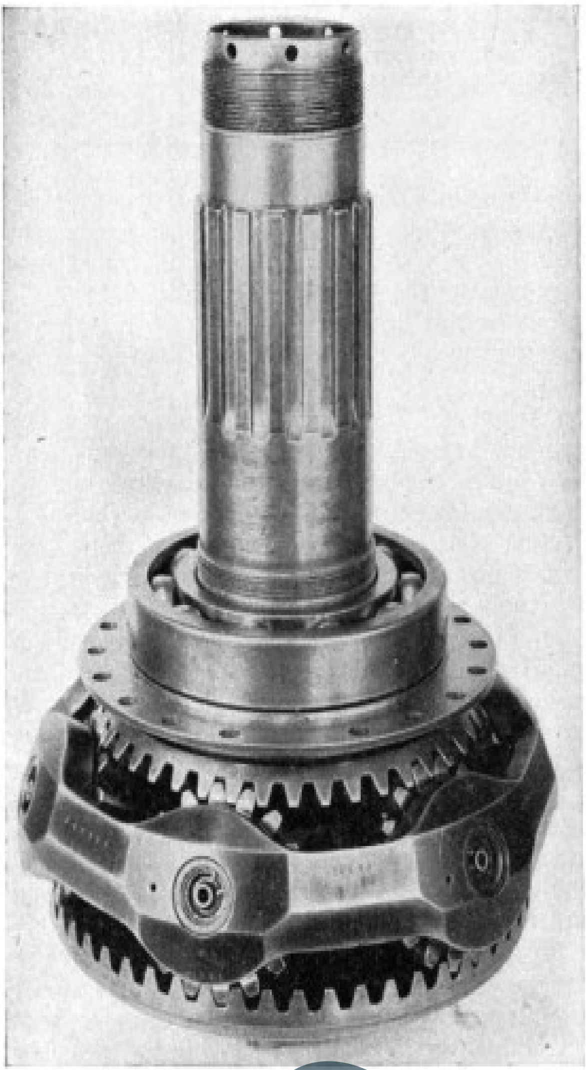


Figure 65. Bevel planetary-system reduction gearing.

threaded on one end for a propeller hub nut. The thrust bearing, which absorbs propeller thrust, is

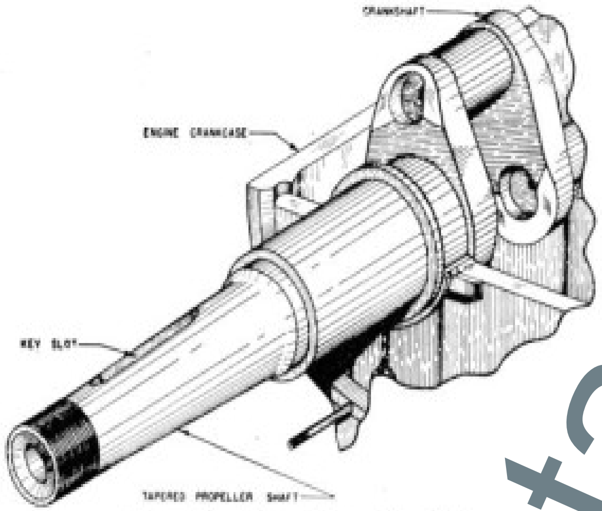


Figure 66. Tapered propeller shaft.

located near the middle of the shaft and transmits the thrust to the front-section housing. The shaft is threaded near the middle to provide a location for the thrust-bearing retaining nut. On the portion protruding from the housing (between the two sets of threads) are located splines to receive the splined propeller hub. The shaft is generally machined from a steel-alloy forging and is hollow throughout its length.

(2) *Propeller shaft-crankcase breathers.* In one type of installation a breather tube is installed inside the hollow propeller shaft and extends into the crankshaft front extension. On an engine equipped with a hydromatic propeller, the tube is so constructed and installed that it also provides a passage for high-pressure oil to operate the propeller unit. These methods eliminate the breather unit generally located in the oil sump or front supercharger housing.

V-TYPE AIRCRAFT ENGINES

39. GENERAL. a. Cylinder arrangements. One of the most common types of engines used to power airplanes is the **V**-type engine. The cylinders of this type of engine are arranged in two rows or banks. The centerlines of the banks of cylinders form the letter V. (See fig. 68.) This type of engine may be

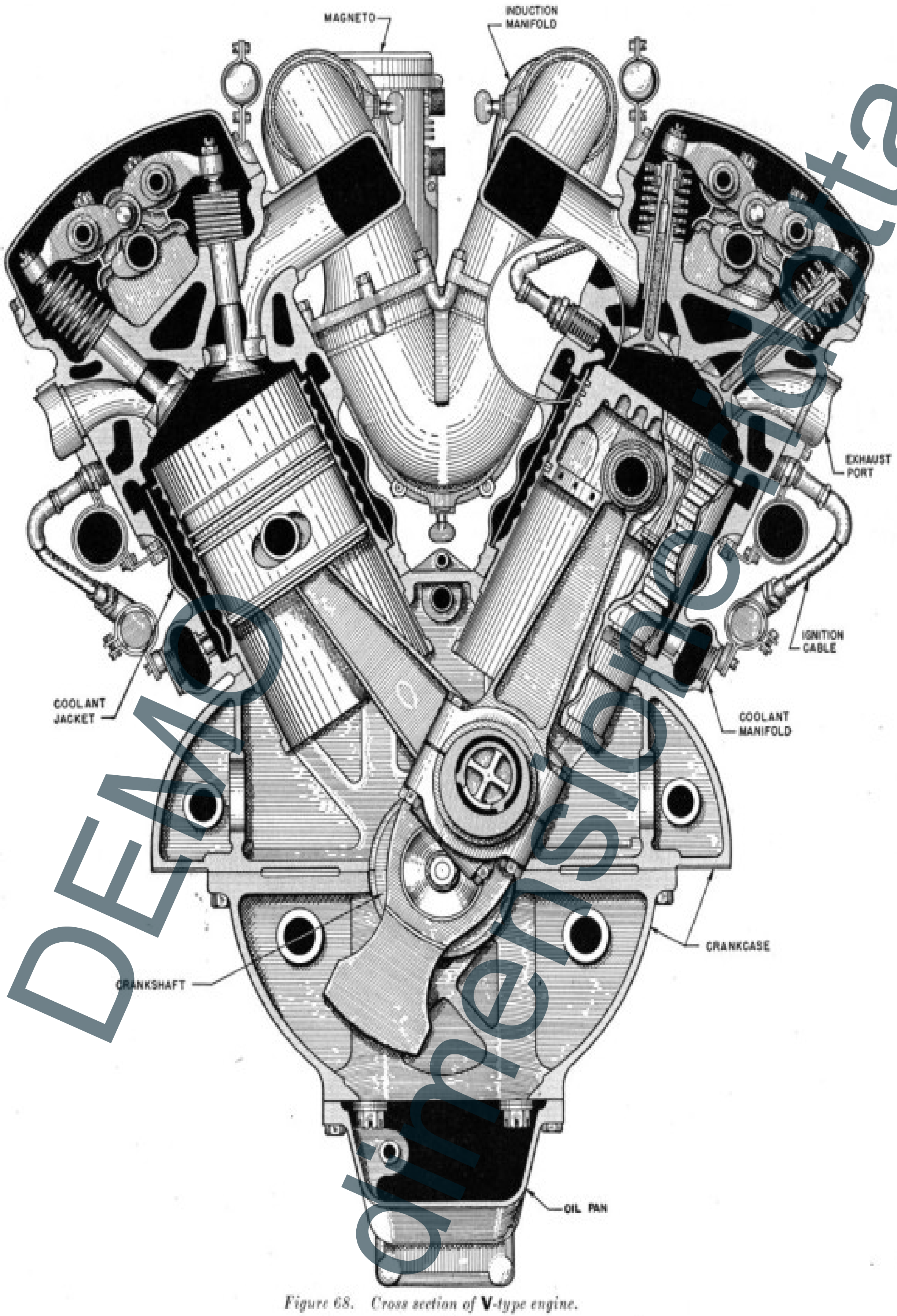


Figure 68. Cross section of **V**-*type engine.*

mounted in the inverted position, but it is generally mounted upright.

b. Firing order. The firing order is the sequence in which the power events occur in the cylinders of the engine. It is determined by the direction of crankshaft rotation. A common firing order of a **V**-12 engine, the crankshaft of which rotates counterclockwise, is 1L–6R–5L–2R–3L–4R–6L–1R–2L–5R–4L–3R. (See fig. 69.) A **V**-12 engine, with a clock-

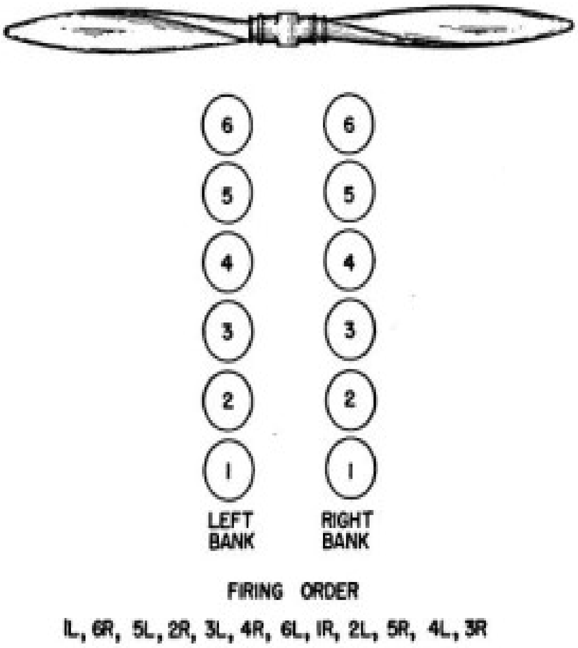


Figure 69. Firing order of ***V****-type engine.*

wise-rotating (right-hand-rotating) crankshaft, may fire 1–L, 2–R, 5–L, 4–R, 3–L, 1–R, 6–L, 5–R, 2–L, 3–R, 4–L and 6–R. An eight-cylinder **V**-type engine with a left-hand-rotating crankshaft will fire 1–L, 4–R, 2–L, 3–R, 4–L, 1–R, 3–L, and 2–R. A **V**-8 type engine with a right-hand-rotating crankshaft will fire 1–R, 4–L, 2–R, 3–L, 4–R, 1–L, 3–R, and 2–L.

40. CONSTRUCTION CHARACTERISTICS.

a. General. The various parts and units of a **V**-type engine accomplish the same purpose as the parts of the other type engines, though they may often differ in shape and size. The mechanic should familiarize himself with these differences.

b. Power section. The power section of a **V**-type engine consists of the upper and lower main section of the crankcase, the crankshaft, the cylinders, the connecting rods and pistons, the valves and valve-operating mechanisms, and the necessary bearings.

(1) *Crankcase.* On some **V**-type engines, the crankcases are divided into two halves at the center of the crankshaft. Each half contains web partitions which support the main bearing inserts. The two halves of some crankcases are held together with long stud bolts, one on each side of each main bearing. Numerous short bolts around the parting flanges hold the two halves rigidly together. The lower half of the crankcase usually has a small oil pan bolted to it. Other **V**-type engines have crankcases which are split well below the centerlines. The upper halves have heavy web partitions. The upper portions of the main bearings are installed in these webs. Individual bearing caps are fastened to the webs by means of studs and nuts. A small dowel prevents the bearing insert from turning. The lower part of the crankcase is held to the upper part by means of closely spaced studs. The engine-mounting pads are located on the upper half of the main crankcase section.

(2) *Crankshaft.* The crankshaft of a **V**-type airplane engine is forged of steel and is machined and polished on all surfaces. A **V**-12 type engine has six crankpins and seven main bearing journals. The **V**-8 type engine has four crankpins and five main bearing journals. The crankshaft must be statically and dynamically balanced. The main and crankpin journals and the crankcheeks are drilled to provide passages for lubricating oil. This also makes the crankshaft lighter in weight.

(3) *Cylinders.* The cylinders are made of steel barrels shrunk into aluminum-alloy heads. The barrels are made as individual units while the six heads of each cylinder bank may be cast or forged in a single unit. The barrels of each bank are inclosed in an aluminum coolant jacket which is secured to the head by studs and nuts. Space through which the cooling liquid flows is provided between the cylinder barrels and the cylinder block. Intraconnected passages for the cooling liquid are provided in the cylinder head. The entire assembly of the cylinder barrels and cylinder block of each bank is held to the crankcase by means of long stud bolts. On some **V**-type engines the cylinder barrels are held to the cylinder block by means of large lock nuts. On other types, the barrels are pressed into the block. In each type a gasket is provided to seal the cooling system from the crankcase. Aluminum gaskets seal the joints between the cylinder blocks and cylinder heads. The bronze spark-plug bushings and steel valve seats are shrunk, or screwed and shrunk, into place.

(4) *Connecting rods.* The connecting rods of this type engine are of I cross section and are forged of steel. They are machined on all surfaces to remove any small scratches which might cause failure during operation. The fork-and-blade type is generally used and each rod is marked by the manufacturer so that it can be replaced in the cylinder from which it was removed. The bearing on the big end of the connecting rod is an insert while the bearing on the piston-pin end is a bronze bushing pressed in place and reamed to size.

(5) *Piston assembly.* The connecting rod is attached to the piston by means of a hardened-steel, full-floating piston pin. The pin is retained in the piston by two circlets which are fitted in the piston at each end of the pin. The piston is made of forged aluminum alloy and is machined on all external surfaces. Three grooves are provided above the piston pin for the three compression rings. On some types of piston, a groove is provided for one oil ring above the pin and another below the pin. Other models have both oil rings in a single groove located below the piston pin.

c. Nose section. (1) The nose section of the crankcase of a **V**-type engine houses the propeller thrust bearing and the propeller reduction gears. On some models it also contains an oil pump which scavenges the oil used to lubricate the nose-section gears and bearings.

(2) The nose-section crankcase is usually forged of aluminum alloy and is bolted to the main crankcase section by means of studs and nuts. The propeller thrust bearing, located in the forward end of the nose section, receives the forward thrust of the propeller and transmits it to the nose section and to the main crankcase section.

d. Valve mechanism. The valves of **V**-type engines are operated by two camshafts—one on each bank of cylinders. Rocker arms are also located above each cylinder to transmit the lifting motion from the cam to the valve stems.

(1) *Camshaft.* One camshaft is located on top of each cylinder bank and extends from one end of the bank to the other. The camshaft is mounted in plain bearings which are located between each two cylinders. Some models have flanged plain bearings near the drive gear to take care of thrust loads while other models have ball bearings for this purpose. A separate cam is provided for each rocker arm.

(2) *Rocker arm.* The rocker arms used on this type engine may be pivoted on the end or in the middle. They bear directly on the camshaft. (See par. 26b (3).)

(3) *Valve springs.* Each valve is held on its seat by means of multiple compression springs, one inside of the other. The springs are held in place by means of a cone plate and split locks. Some **V**-type engines have one intake and one exhaust valve for each cylinder. Other models have two valves of each kind for each cylinder. This facilitates cool operation of the valves.

(4) *Valves.* The valves are of the poppet type, made of steel, and faced with Stellite or bright-ray. The end of the valve stems are hardened to minimize wear. The stems of the exhaust valves of all models and of the intake valves of some models are partly filled with sodium to aid in dissipating heat from the valve head. The valve guides are made of cast iron or phosphor-bronze and pressed into place in the head.

e. Intake systems. The induction system of a modern **V**-type engine consists of a carburetor, an internal blower or supercharger, and the necessary manifold to conduct the fuel-air mixture to the cylinders. On some models, the internal blowers are of the single-speed centrifugal type. On other models, internal superchargers of the two-speed contrifugal type are used. In either case, the impeller is driven by a gear train from the engine crankshaft. An engine that has a single-speed internal blower is sometimes equipped with an exhaust-driven turbosupercharger. Whether or not a turbosupercharger is incorporated depends upon the type and use of the airplane on which the engine is installed. The intake manifold is made of cast aluminum or magnesium alloy. It is designed to conduct the fuel-air mixture to the cylinders with a minimum of turbulence.

f. Exhaust systems. The type of exhaust manifold used depends on the type of the airplane rather than the type of engine. If a turbosupercharger is used, the exhaust manifold will collect the exhaust gases from all cylinders and direct them to the supercharger turbine. If the turbosupercharger is not employed, the exhaust system will be merely short stacks leading from each cylinder to the atmosphere or to a common exhaust outlet for each bank. In either case corrosion-resistant steel is used for all parts of the exhaust system.

g. Cooling. (1) *Air cooling.* Pressure-type cylinder baffles are standard equipment on an air-cooled engine. Pressure baffling forces the cooling air at high velocity around the finned surfaces of the cylinder. This type of engine does not differ greatly in construction from the liquid-cooled powerplant. The cylinder assemblies of this type of engine are usually cast or forged individually.

(2) *Liquid cooling.* On some models, the liquid used is a mixture of ethylene glycol and water. Systems of this type are sealed to prevent the water from boiling away at high altitudes. Other models use ethylene glycol as the cooling liquid and do not need to be sealed since ethylene glycol has a higher boiling point than the mixture of ethylene glycol and water previously mentioned. The pressure system is a closed system which has a relief valve to prevent excessive pressures. The system using pure ethylene glycol is an open system which is vented to the atmosphere. A centrifugal coolant pump supplies coolant to each cylinder block at two inlets, one located at the coolant jacket and the other at the rear of the cylinder head. An integrally cast, inlet manifold extends the full length of each jacket and distributes the coolant to each cylinder through metering holes. The inlet at the rear of the cylinder head provides an opening through which the coolant flows to the passages surrounding the combustion chambers.

h. Lubrication. Oil is circulated to the moving parts of the engine through a pressure system. Circulation is maintained by a pressure pump and one or two scavenger pumps. A constant desired pressure is maintained by use of the pump and an oil-pressure relief valve. The oil is supplied to the pump from an external supply tank. An oil-inlet check valve (which prevents the flow of oil from the tank into the engine when the engine is stopped) is installed in the main oil-pressure line from the pump. A pressure of approximately 1 to 3 pounds per square inch is sufficient to open the valve. The relief valve may be located in the oil-pressure line from the Cuno or screen filter or it may be incorporated at the discharge side of the pump. The oil is delivered to the Cuno filter where all foreign matter is removed. Oil from the filter outlet is then distributed to the moving parts of the engine.

(1) *Engine oil-pressure control.* Oil pressures must be sufficiently high to provide adequate lubrication of the engine and its accessories during maximum output. They must not be too high or leakage and damage to the oil system may result. To regulate the oil pressure in a **V**-type engine, one of the following types of oil-pressure relief valves is used.

(*a*) *Dual pressure type.* In this type valve, two pressure-regulating valves are built into the same housing. (See fig. 70.) Oil from the pump enters the

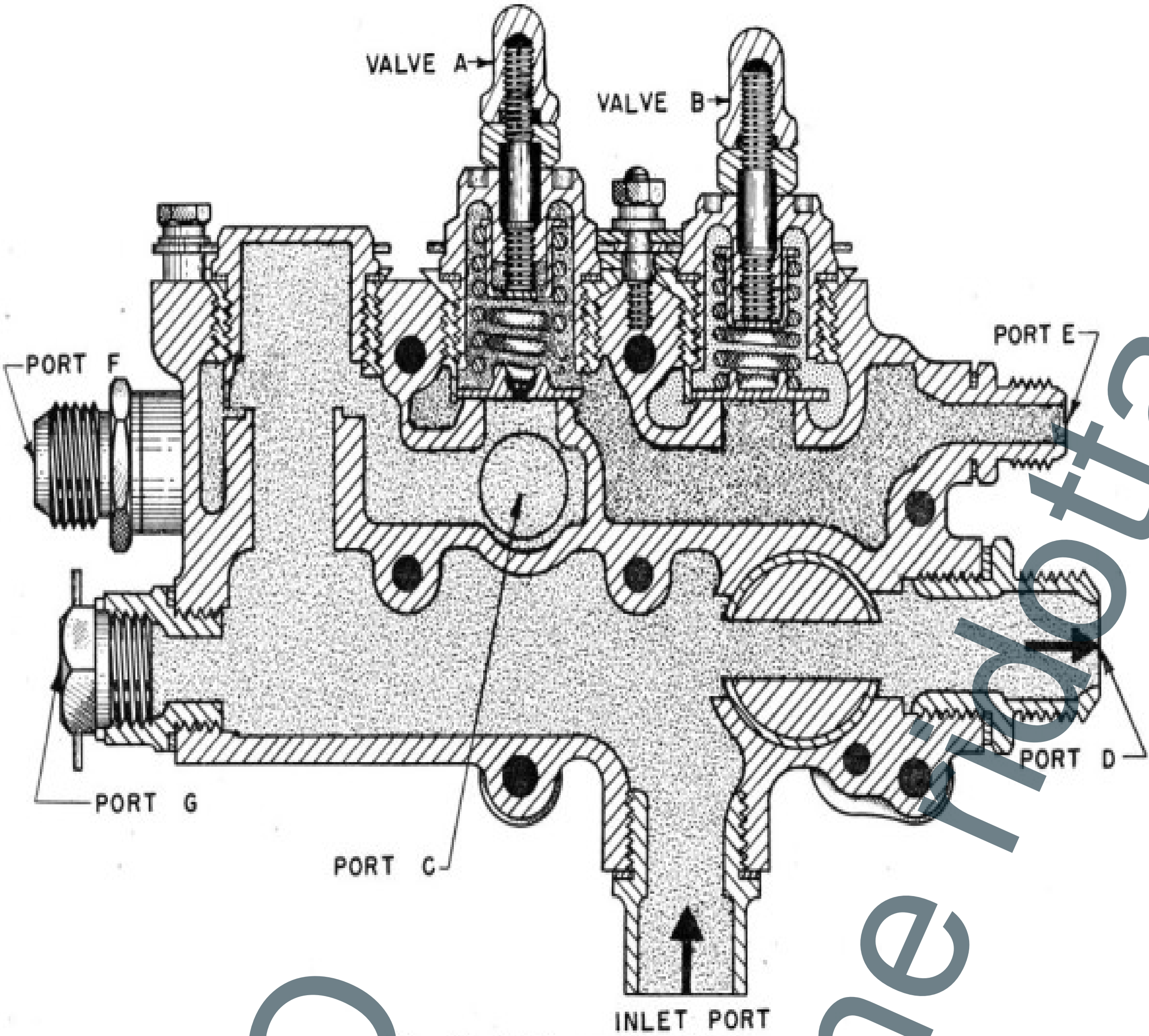


Figure 70. Dual pressure-type relief valve.

high-pressure chamber of the relief valve through the inlet port. Valve *A* limits the pressure of the oil delivered by the pump. If the pressure exceeds the value for which this valve is set (usually 60 to 90 pounds per square inch) the valve unseats and surplus oil is bypassed to the inlet side of valve *B*. This valve is set to open at 4 to 8 pounds per square inch. If pressure in the low-pressure chamber exceeds the value for which valve *B* is set, the valve opens and by-passes oil to the crankcase. A small bleed hole in valve *A* assures flow of oil into the low-pressure chamber at any pump pressure. High-pressure oil is supplied to the crankshaft and bearings through port *C* (located on the back face of the unit). High-pressure oil is also conducted from port *D* to the propeller governor. Low-pressure oil for lubrication of the reduction gearing is supplied through port *E*. Port *F*, which is also connected to the low-pressure chamber, supplies oil to the camshaft and the accessories. Port *G* is an oil-thermometer connection. A pressure-gauge connection (not shown in the figure) is provided on the front of the unit.

(*b*) *Spring-opposed balanced relief valve*. An installation incorporating this type of relief valve is shown in figure 71. The valve consists of a three-port housing which contains a spring-loaded piston. Port *A* is connected (through the check valve) to the

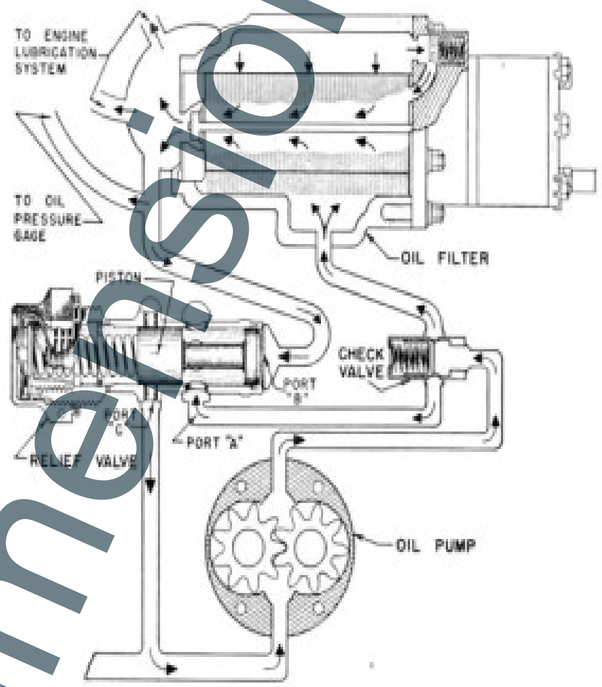


Figure 71. Installation incorporating a spring-loaded balanced relief valve.

discharge side of the pump. Engine-oil pressure is applied to the end of the piston through port *B*. This tends to move the piston to the left. The spring located on the opposite end of the piston opposes this movement. If engine-oil pressure exceeds the value for which the valve is set, the piston will be moved to the left. Port *A* will then be connected to port *C* by the cut-away part of the piston, and the output of the pump will be bypassed to the inlet port of the pump. When the pressure drops below the value for which the valve is set, the spring will move the piston to the right and the output of the pump will again be directed through the oil filter to the engine lubrication system.

(2) *Oil sumps.* Oil sumps are located in the lowest part of the engine. There are usually two sumps in each engine. The housing of the sump may be cast as part of the main crankcase or it may be a separate unit. The primary purpose of the sump is to provide a well for collecting the engine oil so that the scavenger pump (located in the sump) may return the oil to the supply tank.

(3) *Scavenger pumps.* The number of scavenger pumps in an engine may vary from one to three, depending on the size and type of the engine. The usual practice has been to locate one scavenger pump at the rear of the engine and one at the forward end of the crankcase or in the nose-section housing. The pumps are located in such a way as to permit positive scavenging of the oil at all times during normal flight maneuvers.

(4) *Main-bearing lubrication.* A large tube in the crankcase delivers oil to a drilled passage in each web partition support and lubricates the main bearings.

(5) *Connecting-rod lubrication.* Connecting passages are drilled in the crankshaft to allow oil to flow to each connecting-rod bearing. Oil spray, thrown from the connecting-rod bearings, lubricates the cylinder walls and piston pins.

(6) *Sludge sumps.* In some engines the main bearings and the crankpin journals are hollow and fitted with special aluminum-alloy plugs. (See fig. 72.) These provide passages for the lubricating oil yet permit the collection of foreign matter and oil sludge.

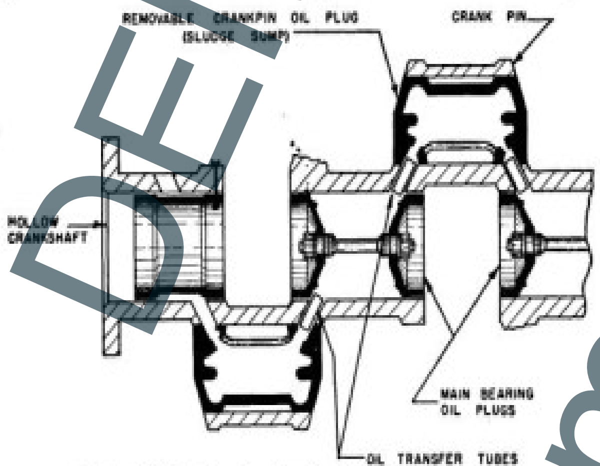


Figure 72. Crankpin oil plugs (sludge sumps).

(7) *Reduction-gearing lubrication.* Oil to lubricate the reduction-gear bushings and bearings flows through passages and hollow shafts to the nose section. The reduction gears are lubricated by spray from these units.

(8) *Propeller operation.* Oil under pressure is directed to the propeller-governor pad and carried through the propeller shaft to provide the operating pressure for hydraulically operated propellers.

(9) *Camshaft lubrication.* A branch lead from the crankcase tube carries the oil to the inclined hollow shafts of the camshaft drive. From there, it passes into the hollow camshaft. At the heel of each cam lobe, a hole is located to lubricate the lobe and rocker-arm mechanism.

(10) *Blower-impeller lubrication.* Drilled passages are usually provided from the Cuno or screen-filter outlet to the supercharger bearings.

(11) *Accessory lubrication.* Other drilled passages are incorporated to provide lubrication from the filter outlet to each accessory-unit bearing.

(12) *Internal oil drains.* Oil drains are provided at every lubricated part of the engine. Oil passages at both ends of the camshaft housing allow the oil to drain to the crankcase sumps. The pumps draw the oil from the sumps and return it through passages and lines to the oil-supply tank.

i. Accessories. Most accessories are located at the rear of **V**-type engines. They are gear-driven by power from the crankshaft. A spring or fluid coupling located between the crankshaft and the accessories absorbs crankshaft vibration and prevents accelerating shock from shearing the gear teeth. The accessories include the generator; magnetos; fuel-oil, coolant and vacuum pumps; tachometer generator; etc.

41. VALVE CLEARANCE. Clearance between the valve stem end and the valve-actuating mechanism is necessary to permit positive valve seating. If cold clearance is inadequate, the intake valve will be held off its seat, causing a loss in compression and power output. This condition also causes backfiring in the induction system. If the exhaust valve is held off of its seat it also causes a loss in compression and power, and "after-firing" will occur in the exhaust manifold. Burning and warping of the valve head and stem results from the escape of the hot flames through the small opening between the valve face and valve seat.

a. Checking valve clearance.

(1) Remove cylinder valve cover.

(2) Rotate the propeller shaft until the cam roller is on the heel (low point) of the cam lobe for the valve being checked.

(3) Insert the correct feeler gauge between the end of the valve stem and the adjusting screw. (The correct clearance may be found in Technical Orders.) The gauge should just slip into the opening and the next larger gauge should not.

(4) If the valve clearance is not correct, adjust according to the procedure given below.

b. Adjusting valve clearance. This adjustment must be made when the engine is cold. It is neither safe nor practical to adjust valve clearances when the engine is operating. Valves should be adjusted at temperatures between 10° C. and 50° C. (50° F. and 122° F.).

(1) Loosen the lock nut on the valve-clearance adjusting screw.

(2) If the clearance is too small, back out on the adjusting screw until the specified feeler gauge can be inserted between the end of the valve stem and the adjusting screw. (See fig. 73.) Tighten adjusting

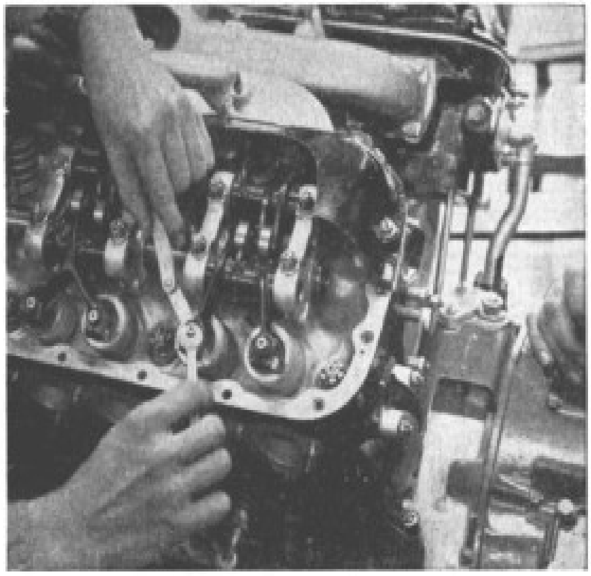


Figure 73. Adjusting valve clearance.

screw until it bears lightly on the feeler gauge. Remove the gauge, hold the adjusting screw and tighten the lock nut. The clearance should be rechecked after the lock nut is tightened.

(3) If the clearance is too large, loosen the adjusting screw and proceed as in (2) above.

(4) Care should be exercised to keep the adjusting screw from turning when the lock nut is being tightened.

42. VALVE AND IGNITION TIMING. After a new engine is designed, and the first model produced, it is installed on a test stand and operated. During operation it is operated at different speeds, on different grades of fuels, and the valve and ignition timing are varied. During these tests an accurate record is kept of the brake horsepower developed by the engine. From these data, the design engineers select the best timing for the valves and ignition. It is important, therefore, that the mechanic time the engine exactly as specified in Technical Orders. For timing the valves and ignition of a **V**-type engine, a top-center indicator and a timing disk are used. The top-center indicator is used to locate the top-dead-center (TDC) position of the piston. The pointer and the timing disk are used to indicate the amount of rotation of the crankshaft. The method of using these devices is described in the timing procedures which follow.

a. Checking valve timing. Valves are opened by movement of a cam and closed by spring tension. The shape of the cam lobe determines the opening and closing speed of the valve and the length of time it stays open (in degrees of crankshaft rotation). The crankshaft is always turned in the direction of rotation during timing operations to eliminate errors that might be caused by gear lash (clearance between gear teeth). One purpose in checking valve-opening and valve-closing positions (in relation to piston position) is to determine the amount of wear that exists in the valve-operating mechanism. A few degrees of tolerance are generally permitted for continued operation. Any tolerance greater than that specified in Technical Orders requires that the valves be retimed. If this does not correct the condition the engine must be overhauled.

(1) *Checking valve timing of an engine with right-hand propeller rotation.*

Step 1. Remove the cylinder valve covers and check the valve clearances. If necessary, adjust to that specified by Technical Orders. (See par. 41.)

Step 2. Install the top-center indicator in the No. 6L intake spark-plug opening.

Step 3. Remove the magneto cover and cam screw. Install the timing disk and the pointer on the magneto housing. Be sure that the step of the pointer is properly placed with the step on the magneto cam and secured with the special screw.

Step 4. Rotate the propeller shaft until the top-center indicator shows that No. 6L piston is at TDC. The relative position of No. 1L piston is the same as the position of No. 6L piston because both pistons are connected to crankpins which are of the same angle on the crankshaft.

Step 5. *Checking valves of the left bank.* Rotate the propeller in the normal direction of rotation until the exhaust valves of *No. 6L* cylinder are closed. The pressure must be removed from the rocker-arm rollers. Check the reading on the inner scale of the timing disk. This reading should be that specified in the Technical Order of that engine (for example, 26° ± 2° ATC).

Step 6. *Checking the valves of the right bank.* The next valve to operate is No. 5R (right bank). Rotate the propeller in the normal direction of rotation until the exhaust valves of No. 5R are closed (pressure is off the rocker-arm roller). Check the reading on the *outer scale* of the timing disk. The reading should be that specified in Technical Orders (for example, 26° ± 2° ATC).

(2) *Checking valve timing of an engine with left-hand propeller rotation.*

Step 1. The first six steps of this procedure are the same as Steps 1 through 6, (1) above.

Step 2. *Checking valves of the right bank.* Rotate the propeller in the normal

OPPOSED- OR FLAT-TYPE AIRCRAFT ENGINES

44. GENERAL. The opposed- or flat-type aircraft engine is sometimes referred to as the "pancake" type. The term "pancake" is generally used to refer to an opposed engine with a greater number of cylinders than those used in the Army Air Forces at the present time. Opposed engines of low horsepower have been used for some time, but high-horsepower engines of this type are being developed for horizontal mounting in the wings of large airplanes.

a. Cylinder arrangements. The cylinders of an opposed-type engine are arranged in two banks. The banks are 180° apart with the crankshaft between them. On low-power engines, the cylinders in each bank are not directly opposite each other. Instead, the cylinders of one bank are slightly in front of the cylinders of the other bank. Cylinders arranged in this order are said to be *staggered* as shown in figure 74. The cylinders of an opposed engine are usually numbered with the odd numbers on the left side of the powerplant when observed from the rear of the engine. The cylinder on the left side nearest the rear of the engine is usually designated as No. 1.

b. Firing order. The firing order is the sequence in which the power events occur in the cylinders of an engine. On six-cylinder opposed engines, the firing order is 1–4–5–2–3–6. The firing order of one model four-cylinder opposed engine is 1–4–2–3, while on another it is 1–3–2–4.

45. CONSTRUCTION CHARACTERISTICS. a. General. While all aircraft engines are made up of parts that serve similar purposes, these parts may differ in shape on the different types of engines. The mechanic should be familiar with these differences.

b. Power section. The power section on an opposed engine is made up of the main crankcase, the crankshaft, the connecting rods and pistons, the cylinders, the camshaft and other valve operating mechanisms, and the necessary bearings.

(1) *Crankcase.* The crankcase is made of two halves of cast aluminum alloy which are bolted together with long bolts. These two halves have ribs in them which hold the main crankshaft bearing inserts. The camshaft bearings are also in the main crankcase. In some engines, babbitt lined inserts are used for the camshaft, while in others the aluminum alloy itself is the bearing material. The oil sump is located in the lower part of the main crankcase section.

(2) *Crankshaft.* The crankshaft is made of forged steel and the main and crankpin journals have a ground finish. It has passages drilled through it to decrease weight and to provide for transmitting the lubricating oil. The crankshaft of a four-cylinder opposed engine has three main bearings while that of the six-cylinder engine has four. In each model there are two crankshaft throws between each two main bearings. The front main bearing may be a plain bearing with a flange to take the thrust of the propeller. In some cases, the front main bearing is a thrust-type ball bearing.

(3) *Connecting rods.* The connecting rods are forged of steel and are generally of an **H** cross-section. The big-end bearing is an insert-type bearing. The piston-pin bearing is a bronze bushing which is pressed in and then reamed to size.

(4) *Pistons.* The pistons are made of aluminum alloy and are provided with three piston rings on some models and four on others. The piston pins are made of hardened steel and are of the full-floating type. They are prevented from rubbing against the cylinder wall by aluminum-alloy plugs fitted into each end of the piston pin.

(5) *Cylinders.* The cylinder assembly of an opposed engine is composed of a steel barrel and an aluminum-alloy head. The head is screwed and shrunk onto the barrel. In air-cooled opposed engines, the outside surfaces of the cylinder head and barrel are provided with the cooling fins. The valve seats and valve guides are made of bonze or steel and are shrunk (or shrunk and rolled) into place. The spark-plug holes are also lined with bronze bushings. The liquid-cooled type of opposed engine has a cooling system similar to that used in other liquid-cooled engines.

(6) *Valves.* The valves are of the conventional poppet type and are made of steel. They are closed by coil springs which are held in place by cone washers and split locks.

c. Nose section. The nose or front section of this type of engine is generally cast or forged as a part of the power section. It incloses the propeller shaft and a thrust bearing.

d. Valve mechanism. The valves are operated by a camshaft and a hydraulic valve-lifting mechanism. The hydraulic valve-lifting mechanism automatically compensates for any changes in the length of the cylinders due to combustion heat, so that valve-clearance adjustment is not necessary. The valve-lifting force originates at the camshaft which is driven at one-half crankshaft speed.

e. Induction and exhaust systems. (1) The induction system has an individual pipe leading to each cylinder. On some models these pipes are connected to the manifold by short sections of rubber hose held by clamps. On other models, one end of each pipe is bolted to the cylinder by means of a flange and the other fits into a slip joint in the manifold. On another type, the carburetor is mounted on the oil sump. In this type, the fuel-air mixture flows from the carburetor through passages in the oil sump and out through individual pipes to the cylinders. (See fig. 75.) As the mixture travels

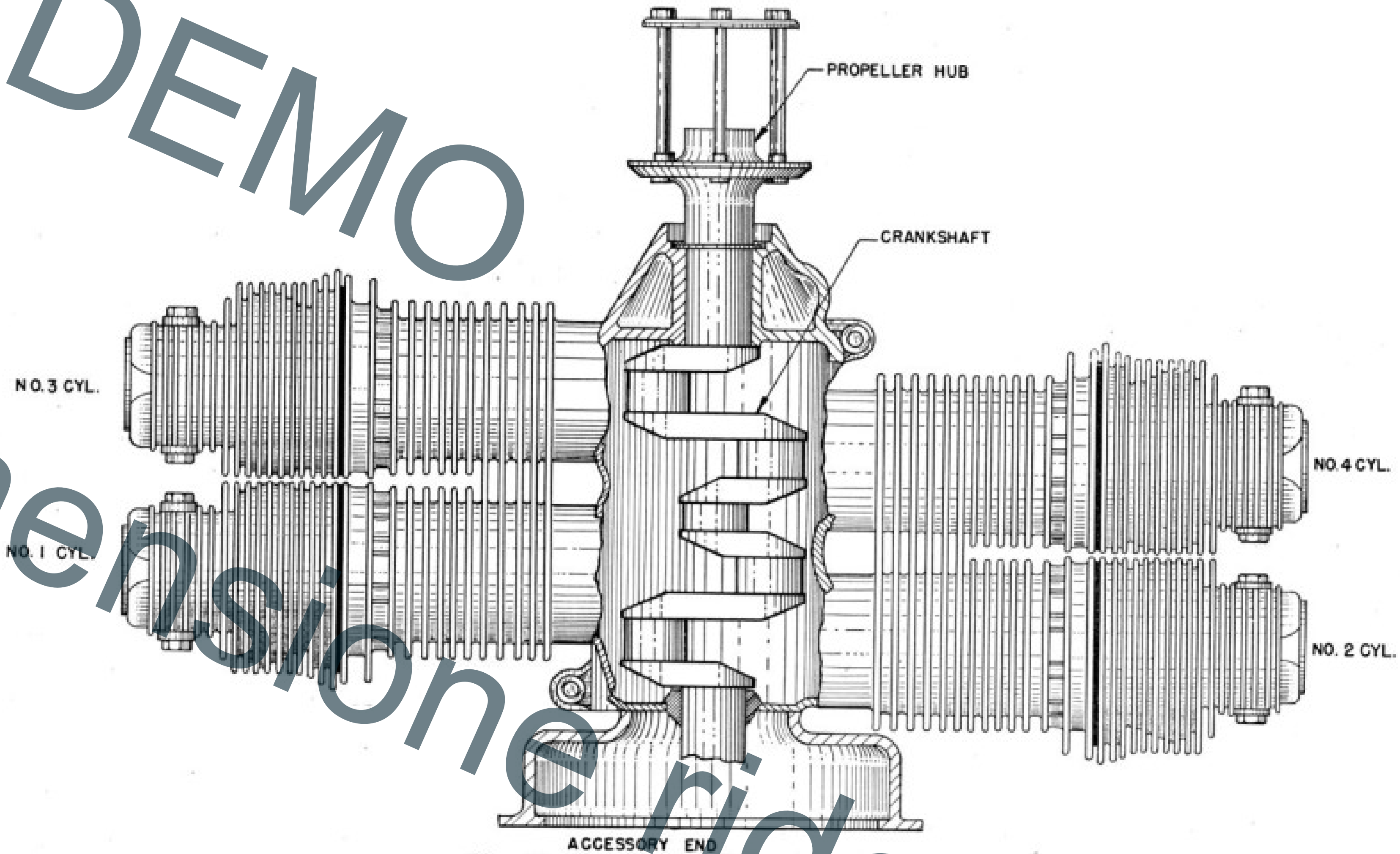


Figure 74. Staggered engine cylinders — opposed engine.

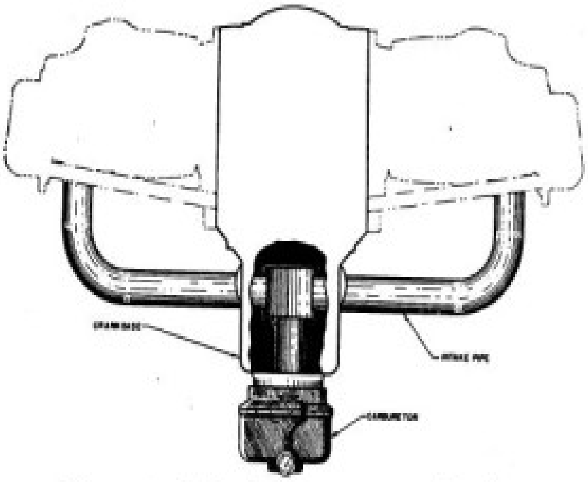


Figure 75. Induction system — opposed engine.

through the passages, heat is transferred from the oil to the fuel-air mixture. This cools the oil to some extent and provides some heat for better vaporization of the fuel.

(2) Exhaust gases are conducted through pipes to a noise-damping unit (muffler) and then to the side of the airplane where they are released. The exhaust-system pipes are made of welded, corrosion-resistant steel.

f. Cooling. On present-day air-cooled opposed engines, a baffle located above each bank of cylinders directs the air between and around the cylinder cooling fins.

g. Lubrication. The oil reservoir is in the lower part of the crankcase. This arrangement is called a wet-sump-type oil system. The oil pump draws oil from this reservoir and forces it through a screen and out through the lubricating system. The crankshaft main and crankpin journals, the camshaft bearings and the valve push rods are lubricated by oil under pressure. The piston pins, pistons, cylinder walls, valve guides, valve tappets, and gears are splash- or spray-lubricated. The oil then drains back to the reservoir in the bottom of the crankcase to be recirculated by the pump.

h. Accessories. The accessory housing is made of aluminum alloy and is bolted on the rear of the main crankcase section. The accessories, such as the generator, magnetos, and tachometer drive, are bolted to the accessory section and driven by the crankshaft through a gear train.

46. VALVE AND IGNITION TIMING. a. Importance of proper timing. After a new engine is designed and the first model is completed, it is installed on a test stand and operated. During operation, various grades of fuels are used, the engine is operated at various speeds, and the valve and ignition timing is varied to achieve the best performance. An accurate record is kept of the brake horsepower developed throughout these tests. The design engineers, with these records at hand, decide on the best timing for the valves and ignition. It is important, therefore, that the mechanic time an engine exactly as specified in Technical Orders.

b. Timing methods. The opening and closing of the intake and exhaust valves at the proper time, and the proper timing of ignition are essential to the efficient performance of the four-stroke-cycle engine.

(1) *Valve timing.* The valves of an opposed engine are timed by meshing the marked tooth of the crankshaft gear between the two marked teeth on the camshaft gear. This can be performed only when the nose section has been removed.

(2) *Ignition timing.* To time the ignition, a timing disk is placed on the crankshaft so that the marks on the disk and on the crankshaft are in line. The timing disk is then fastened securely to the crankshaft—usually by means of a clamp nut. The crankshaft is rotated until the No. 1 piston is at the top-center of the compression stroke. The compression stroke may be identified by placing a thumb over the spark-plug hole while the crankshaft is rotated. The No. 1 piston will be at top center when the mark on the timing pointer is in line with the upper joint of the main crankcase section. The crankshaft is then turned backward 15° to 30° depending on the model which is being timed. The engine is now in firing position and ready for the installation of the magnetos. Rotate the magneto drive shaft until the marks on the gears which show through the inspection window are in line. Place the magneto on its mounting pad so that its drive gear meshes with the drive gear from the engine and tighten the mounting bolts finger tight. Place a 0.0015-inch thickness gauge between the breaker points and rotate the magneto back and forth until the point at which the breaker contacts are just separating is found. This point will be indicated by the release of the thickness gauge. Tighten the bolts to hold the magneto securely in place.

c. Timing specifications. The intake valve of one model of an opposed engine is timed to open at 10° before top-center, the exhaust valve opens at 50° before bottom-center, and the ignition spark occurs at 30° before top-center. On another model, the intake valve opens at 20° before top-center, the exhaust valve opens at 65° before bottom-center, and the ignition spark occurs at 15° before top-center. On another model, the intake valve opens at 20° before top-center, the exhaust valve opens at 65° before bottom-center, and the ignition spark occurs, at 15° before top-center.

47. VALVE-CLEARANCE ADJUSTMENT. On engines using hydraulic valve lifters, no valve-clearance adjustments are necessary between engine overhauls.

48. INSPECTION AND MAINTENANCE. Inspections are performed on an airplane to find and correct minor troubles before they become serious. The inspection should be performed in a systematic manner and the parts being inspected should be thoroughly cleaned. Careful inspection will prevent accidents.

a. Maintenance requirements. It is the duty of an airplane mechanic to keep the airplane in flying condition as much of the time as possible.

His job is to repair and maintain. By periodic inspection he can locate and correct minor failures. If some part cannot be repaired, or if more highly trained personnel is required to repair it, he should replace the unit.

b. Minor repair of subassemblies. Some of the repair work that an airplane mechanic must perform on opposed-type engines is listed below.

(1) Fouled spark plugs must be cleaned. When a spark-plug cleaning machine is available the spark plugs will be cleaned and re-gapped according to the directions specified in Technical Orders. If this unit is not available, replace the spark plugs. In many cases, if only oil fouling is present, clean the electrodes by dipping the lower part into gasoline and blowing it out with compressed air.

(2) Dirty magneto points must be cleaned as specified in the particular Technical Order of the engine.

(3) Faulty ignition connections must be repaired. Cleaning and resoldering of the brass clips is generally necessary.

(4) The fuel system must be cleaned of any accumulated water and foreign matter. Examine the screens, clean them with gasoline and blow them out with compressed air. Be careful not to damage the screen with the compressed air.

(5) The hydraulic valve-operating mechanism must be cleaned only after consulting the specific Technical Order for directions. After the cleaning operation is performed check the valve-tappet clearance.

(6) The oil-relief valve will be cleaned and adjusted when necessary.

(7) All backlash and free play must be removed from the engine controls.

(8) Broken air-cooled engine-cylinder head fins can be repaired if the damage is not excessive. Sharp edges will be removed by filing. In cases where excessive overheating is encountered, the cylinder may be replaced.

(9) Adjust the engine idling speed by adjusting the set screw in the throttle-operating control. Set the screw in order to obtain an engine speed as specified by the particular Technical Order.

(10) Generally, when a leak is present, it is permissible to replace the faulty gasket or seal without replacing the complete unit.

c. Replacements. Some of the replacements that may be made by an airplane mechanic follow:

(1) Faulty spark plugs that cannot be reconditioned by cleaning.

(2) Ignition wiring that has had the insulation burned or worn off.

(3) Cracked, kinked, or broken oil or fuel lines.

(4) Leaking manifold gaskets.

(5) Faulty accessories.

RADIAL AIRCRAFT ENGINES

49. GENERAL. The radial engine supplies power to a wide variety of airplanes, from light trainers to the heaviest bombers. This type of engine has passed rapidly through many stages of development to its present high-power output and low weight per horsepower. The unit is a precision product and will give excellent performance and continued high-power output during operation only when it is treated with the care it deserves. Special tools and fixtures are provided for use in maintenance, and maximum engine life will be secured only by following the procedures recommended in the Technical Order for the particular engine.

a. Cylinder arrangements. The cylinders on an engine of this type are arranged radially in one or more rows around the crankshaft. Engines with all the cylinders in one row are called single-row radial engines while those which have the cylinders arranged in two rows are known as twin-row or double-row radial engines. There is always an odd number of cylinders in each row of a radial engine, because it is impossible to secure even distribution of firing impulses when using an even number of cylinders in one row.

b. Firing order. The firing order of an engine is the sequence in which the power event occurs in the different cylinders.

(1) *Single-row radial engines.* On a single-row radial engine, all the odd-numbered cylinders fire in numerical succession while the even-numbered cylinders fire in numerical succession. For example, on a five-cylinder radial engine the firing order is 1-3-5-2-4, and on a seven-cylinder radial it is 1-3-5-7-2-4-6. The firing order of a nine-cylinder radial is 1-3-5-7-9-2-4-6-8, as shown in figure 76.

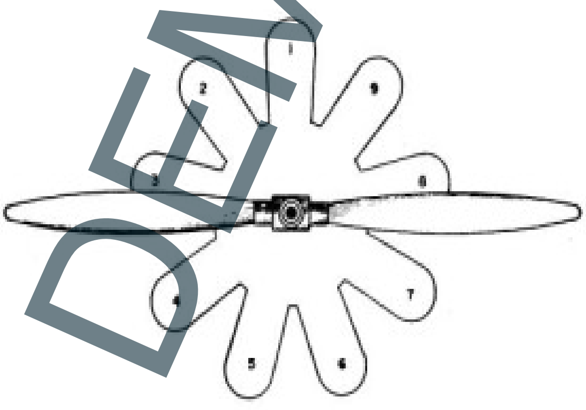


Figure 76. Firing order — nine-cylinder radial engine.

(2) *Twin-row radial engine.* On a twin-row radial engine the firing order is more complicated. The firing order is arranged with the firing impulse occuring in a cylinder in one row and then in a cylinder in the other row; therefore, two cylinders in the same row never fire in succession. The cylinders in a twin-row radial engine are numbered consecutively so that all the cylinders in the rear row will have odd numbers and those in the front row will have even numbers. On a 14-cylinder radial engine the cylinders in the rear row are

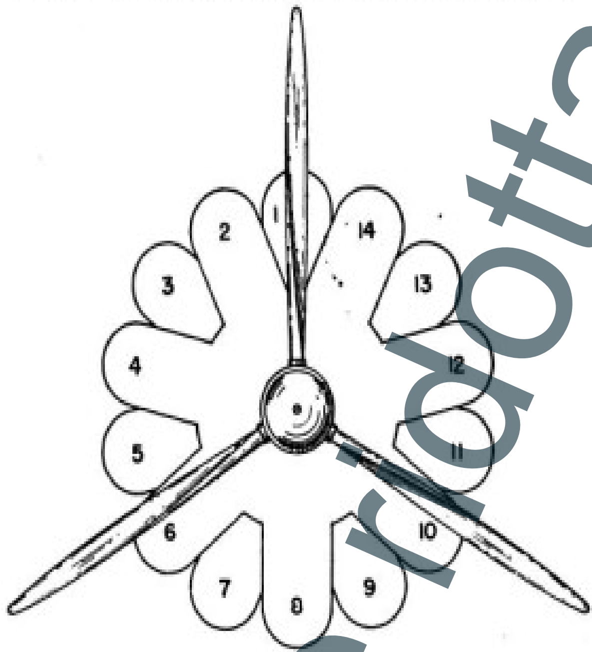


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Figure 77. Firing order of 14- and 18-cylinder radial engines.

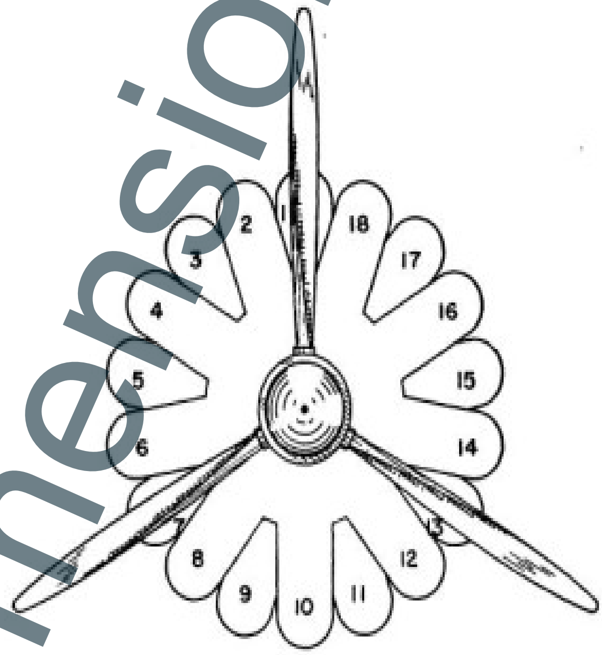

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Figure 77.

compressed air is available it will be introduced through the filler opening (drain plug removed) to dry out the system as much as possible. If the airplane is stored without removing the engine, the entire coolant system will be filled with the oil specified in Technical Orders. Red tape must be

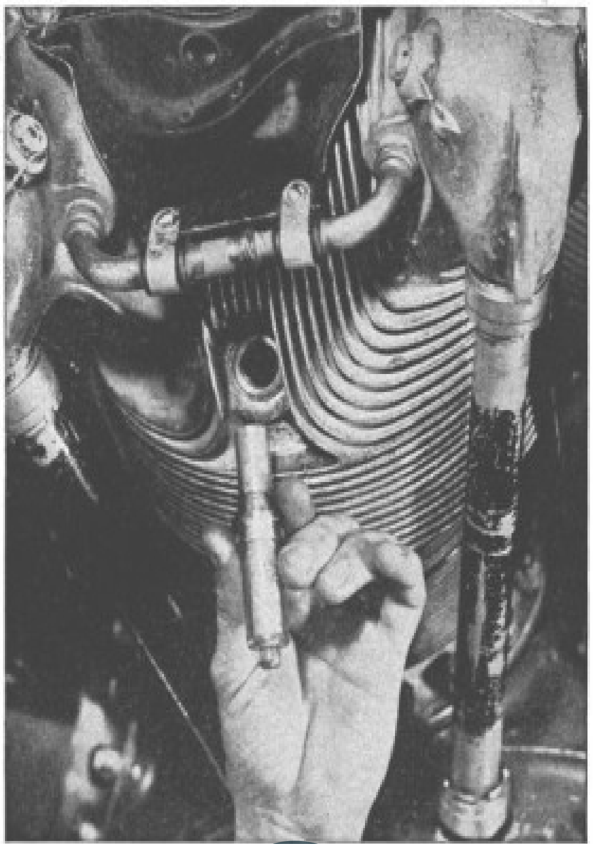

Figure 85. Installing dehydrating plug in the engine cylinder.

attached to the throttle-control lever of the airplane so treated. This is a reminder to maintenance and operating personnel that the engine is not to be operated until the oil is removed and cleaned from the system. The system is cleaned by removing the drain plug and introducing steam into the filler opening.

(6) *Vents and breathers.* All distributor vents, engine and supercharger breathers, and all other openings will be sealed with tape as specified in Technical Orders.

c. Inspection. All engine dehydrator plugs will be inspected weekly and replaced when their color indicates an unsafe condition for storage. If more than one-half of the dehydrator plugs are replaced, the dehydrator bags in the air-intake and exhaust manifolds must be replaced. Replacement of the dehydrator plugs or bags should not be made on highly humid or rainy days.

d. Preparation for service. When aircraft are removed from the temporary-storage status, they will be prepared for service as follows:

(1) *Engine openings.* Remove all dehydrator plugs, silica gel bags, cover plates, nipples, tape, and other means used to plug various openings.

(2) *Cylinders and spark plugs.* First remove any excessive corrosion-preventive mixture by draining or by using a hand suction pump. Rotate the propeller shaft by means of a propeller-shaft wrench to check for sticking valves. Lubricate the sticking valves with a gasoline and engine-oil mixture. If the valves continue to stick, perform the necessary maintenance to eliminate this condition. Install the proper spark plugs.

(3) *Preoiling.* Preoil the engine as directed in the specific Technical Order.

(4) *Engine starting.* Before starting the engine, rotate the crankshaft by hand four or five revolutions, as a final check, to determine that liquid lock has been eliminated.

60. EXTENDED STORAGE.

a. Length of time. Extended storage is used for engines that are to be idle for more than 30 days.

b. Treatment. The treatment of the aircraft treated in extended storage follows:

(1) *Oil system.* The engine oil system will be serviced and given a ground run-up as described in paragraph 59b(1).

(2) *Coolant system.* The coolant system of liquid-cooled engines will be serviced according to paragraph 59b(5).

(3) *Oil coolers.* Oil cooler must be blanked off or by-passed to produce the mixture *outlet* temperature specified in Technical Orders.

(4) *Oil sump.* Drain the mixture from the engine-oil sump while the sump is still warm. Do not drain the mixture from the oil tank. Replace the sump plug with properly specified dehydrator plug. (See fig. 86.)

(5) *Carburetor.* Drain the fuel from the carburetor. Reinstall the drain plugs and remove the pipe plugs from the top of the regulator. Pour the specified oil into the opening until the oil runs out of the front chamber or from the discharge nozzle. Reinstall the plugs and safety them. Carburetor openings will be sealed with suitable pipe plugs and the throttle valves will be locked in the open position. A bag of silica gel is placed in the carburetor intake and the opening is then sealed with a moisture-resisting film and taped securely.

(6) *Fuel pumps.* Fuel must be drained from all fuel pumps and the specified lubricating oil injected into the pumps while the propeller shaft is being rotated. The lines of the fuel system will be disconnected and the lines will be sealed with suitable plugs or tape.

(7) *Exhaust ports and manifolds.* With the exhaust valves open each exhaust port is sprayed with corrosion-preventive mixture. A bag of silica gel will be placed in the exhaust outlets. The openings are then covered with moisture-resisting film and taped securely.

(8) *Cylinder walls.* Treat as specified in paragraph 59b(3).

(9) *Vents, openings, and breathers.* Seal all openings, vents, and breathers with the properly specified tape.

(10) *Propeller shaft.* Spray the interior of the propeller shaft. The exterior of the shaft must be covered with the compound as specified in Technical Orders. Install a propeller-shaft thread protector.

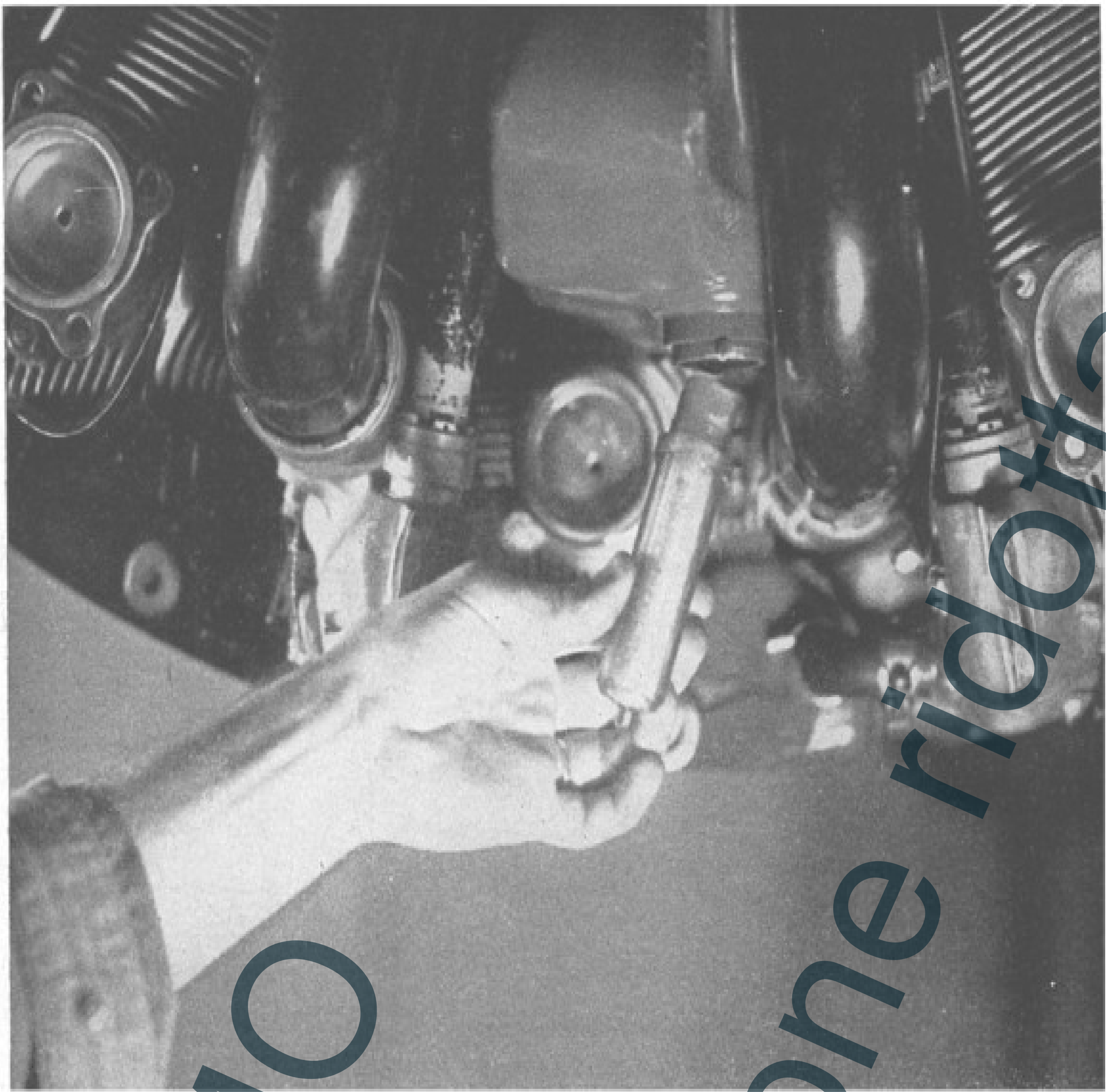

Figure 86. Installing dehydrating plug in the oil sump.

These instructions are followed only when the propeller is stored separately.

(11) *Magnetos.* All openings in the magneto will be sealed with tape.

(12) *Entire engine.* Install covers on all openings in the engine and fasten them securely.

c. Inspection. Inspect according to paragraph 59c.

d. Preparation for service.

(1) *Engine openings.* Remove all dehydrator plugs, silica-gel bags, plates, tape, nipples, plugs, and other such items which have been used to seal the openings.

(2) *Oil and fuel lines.* Properly install all oil and fuel lines.

(3) *Engine cylinders.* Follow instructions listed in paragraph 59d(2).

(4) *Propeller and propeller shaft.* Clean the propeller shaft and the propeller. Mount the propeller on the propeller shaft.

(5) *Cuno oil filter.* The Cuno oil filter will be removed and cleaned by washing it in a solvent such as kerosene, gasoline or a half-and-half mixture of carbon tetrachloride and benzol. Rotate the filter while it is immersed in the cleaning solvent to make certain that all foreign material is removed. Do not use any hard tool to scrape or pick the material from the cartridge. An air jet must not be used in cleaning the cartridge. After washing, immediately lubricate the cartridge by immersing it into clean engine oil.

(6) *Screens.* All oil screens shall be removed, cleaned in gasoline, dried, reoiled and reinstalled.

(7) *Preoiling.* Prior to ground testing the engine preoil the engine as directed in the specific Technical Order.

(8) *Spark plugs.* Before installing the spark plugs rotate the propeller four or five times to make certain that liquid lock (due to excessive corrosion-preventive mixture in the cylinders) has been eliminated. Install the spark plugs and tighten them to the correct torque.

61. STORAGE TREATMENT OF REPARABLE ENGINES. The preparation of reparable engines includes those that can be operated without further damage and those which cannot be operated.

a. Operable engines. An engine in this class can be operated without damage to the engine itself or any of its parts. The procedure for storage treatment of operable engines is specifically outlined in Technical Orders.

(1) *Oil system.* Treat as specified in paragraph 58b(1).

(2) *Coolant system.* Drain the coolant out of liquid-cooled engines.

(3) *Rocker boxes.* Remove the rocker-box covers and clean and spray each rocker box with corrosion-preventive mixture. Replace the covers and gaskets to form an airtight seal.

(4) *Exhaust ports and manifolds.* With the exhaust valve open spray the exhaust valves and exhaust ports. Seal the openings with the properly specified plates and tape.

(5) *Accessory drive.* Remove the accessory-drive cover plates, spray the drives, and reinstall the cover plates securely.

(6) *Propeller.* The propeller will be removed. The thrust-bearing propeller plates, if provided, will be removed and the thrust bearing will be thoroughly sprayed. The cover plate must be reinstalled.

(7) *Carburetor.* Treat as specified in paragraph 60b(5).

(8) *Oil inlet, outlet, and breathers.* The oil inlet and outlet will be sealed with locally manufactured oil-resistant or moisture-resistant blank caps or tape.

(9) *Crankcase.* Remove the oil-sump plug and replace it with the properly specified dehydrator plug. Attach the sump plug to the sump with safety wire.

(10) *Magnetos.* Seal all external openings with the properly specified tape. Coat the cam breaker mechanism with oil, as specified in Technical Orders.

(11) *Propeller shaft.* Treat as specified in paragraph 60b(10).

(12) *Cylinder bores.* Treat as specified in paragraph 59b(3).

(13) *Other engine openings.* Seal all openings with tape or other suitable moisture-resistant seals as specified in Technical Orders.

(14) *Packing procedure.* Silica gel and the engine envelope will be applied as described in the particular Technical Order.

b. Engines that cannot be operated. Engines which cannot have their crankshafts rotated will be treated as near to the procedure listed in a above as practicable. Utmost care must be applied to make certain that all interior surfaces are sprayed or covered with corrosion-preventive mixture. These engines will not have the run-out protection of the engines that can be operated.

62. PREPARING SERVICEABLE ENGINES FOR SERVICE. Serviceable engines to be installed in aircraft will be prepared for service according to the detailed procedure listed in Technical Orders. A brief outline of the procedure follows:

a. Engine envelope. Carefully open the engine envelope without unnecessary tearing and fold the envelope down over the sides of the engine. Remove the engine from the mounting plate. After removing the engine, the envelope will be carefully cleaned and folded for reuse.

b. Silica-gel bags, seals, and dehydrator plugs. Remove all silica-gel bags, all seals and inclosures, and all dehydrator plugs.

c. Cuno oil strainer. See paragraph 60d(5).

d. Supercharger fuel-drain valve. If the unit is installed, clean and check it for proper operation. Lubricate with engine oil and reinstall.

e. Engine cylinders and valves. Service as specified in paragraph 59d(2).

f. Blower (impeller) section. When installing a radial engine, the corrosion-preventive compound is allowed to drain into the lower intake pipes for at least 24 hours with the engine in a flying position. This may be done by placing it in position on the airplane, suspending it, or by laying the packing box or crate on its side. After draining, remove the intake pipes, remove the liquid, and reinstall the pipes.

g. Spark plugs. See paragraph 60d (8).

h. Preoiling the engine. Before ground testing, preoil the engine according to instructions in Technical Orders.

63. AIRCRAFT SUBJECTED TO SEA-WEATHER CONDITIONS DURING SHIPMENT. Engines installed in aircraft that are loaded aboard ships and subjected to sea-weather conditions will be treated for extended storage status. In addition, the following procedures must also be included.

a. Exterior engine surfaces. All exterior engine surfaces, parting lines of the crankcase, clamps, studs, and nuts will be sprayed with the properly specified solvent. (See Technical Orders.)

b. Oil regulators and radiators. The oil regulators and radiators must be sprayed with a light coat of corrosion-preventive mixture to prevent corrosion from salt spray.

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