

**manual for the
SAE 17.6 CUBIC INCH
SPARK PLUG RATING ENGINE
including maintenance and overhaul**

prepared under the auspices of the
SAE Ignition Research Committee
by the
Spark Plug Rating Engine Standardization Panel
of the
Aircraft Piston Engine Ignition Subcommittee

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I. FOREWORD

This manual was prepared under the auspices of the SAE Ignition Research Committee by the Spark Plug Rating Engine Standardization Panel of the Aircraft Piston Engine Ignition Subcommittee. It defines the standard engine to be used in determining spark plug preignition ratings. The engine is known as the SAE 17.6 Cubic Inch Spark Plug Rating Engine. The background of its design, development, and applications is contained in SAE publication SP-243.

In addition to describing the engine, this manual deals with maintenance and overhaul instructions for the engine. Appendices providing engine manufacturing tolerances and replacement limits and engine bill of materials are also included. The manual does not, however, include the procedure for rating spark plugs; this material is covered in the current SAE Handbook.

The 17.6 engine has been used for many years in the spark plug industry to classify spark plugs by their preignition rating. Correlation of these ratings among the various test agencies has been accomplished with limited success primarily due to engine variations. This correlation difficulty prompted the Aircraft Piston Engine Ignition Subcommittee of the SAE Ignition Research Committee to investigate the possibility of standardizing and improving this engine. The Ethyl Corp. (which originated and now owns the patterns for the 17.6 engine) consented to the effecting of improvements in the engine, by SAE, with the provision that the Ethyl Corp. patterns not be changed.

The Spark Plug Rating Engine Standardization Panel, which was established to standardize and improve the engine, consists of men who are closely associated with the use or manufacture of the engine. The sum of their individual experience and the many special projects conducted by the panel have been gathered into this manual.

Conformance with the engine description included in this manual and the diligent following of the Maintenance and Overhaul instructions, will result in more uniform spark plug rating data from each engine and a closer rating correlation between engines.

The manual will be revised periodically to reflect engine improvements which have been developed and thoroughly evaluated. Comments, advice, or recommendations concerning the manual, or the engine it defines, will be welcomed by this committee and should be sent to SAE Headquarters for consideration.

An engine of this type may be obtained from the Laboratory Equipment Corp., (Labeco), Mooresville, Ind., and all part numbers herein mentioned are those of Labeco, unless otherwise specifically stated.

Two classifications of the 17.6 engine are described in this manual: the 5000 and 5750 engines. The 5000 engine (Fig. 1) is similar to the 5750 engine (Fig. 2), except that the latter is provided with the Lanchester balancing system, consisting of two counter-rotating, chain driven counter-balance shafts, rotating at crankshaft speed, to dampen the unbalanced forces generated by the upper portion of the rod and piston assembly.

II. CYLINDER ASSEMBLY

The cylinder assembly consists of a cast iron barrel assembly and a detachable cast iron cylinder head assembly; the latter including integral rocker arm housings and covers completely enclosing the valve gear. The barrel assembly has a removable, centrifugally cast, iron cylinder sleeve mounted in the cylinder housing, and is attached to the head by ten 1/2 in. dia bolts which extend the length of the barrel. Coolant transfer from barrel jacket to head is through ten holes drilled in the head and communicating with water passages between the cylinder sleeve and the jacket. The head is located on the upper end of the barrel by a pilot extension on the barrel. The combustion chamber is sealed by a copper asbestos ring gasket which is compressed to a predetermined thickness when the ten bolts are tightened.

The combustion chamber is hemispherical in shape with the axis of the two valves intersecting at the center of the sphere. The included angle between the valves is 72 deg. Valve seat inserts for both valves are expanded in the head. Two tapped holes, for spark plugs, are provided on opposite sides of the dome and in a plane at right angles to the plane through the valves. The included angle between the holes is 110 deg. Standard combinations of spark plug thread diameters and reaches are shown on Labeco Drawing No. 16100. (Note: The thermal plug used during spark plug rating is installed in one of the spark plug holes and contains a chromel - alumel thermocouple having a response rate of 7 1/2 sec for a change from ambient room temperature to 1150 ± 50 F when dipped in a molten tin bath at 1500 ± 10 F. The thermal plug temperature indicator has a 4.5 sec (max) travel time for the range of 0-1600 F.)

The cylinder sleeve is of generally uniform thickness from

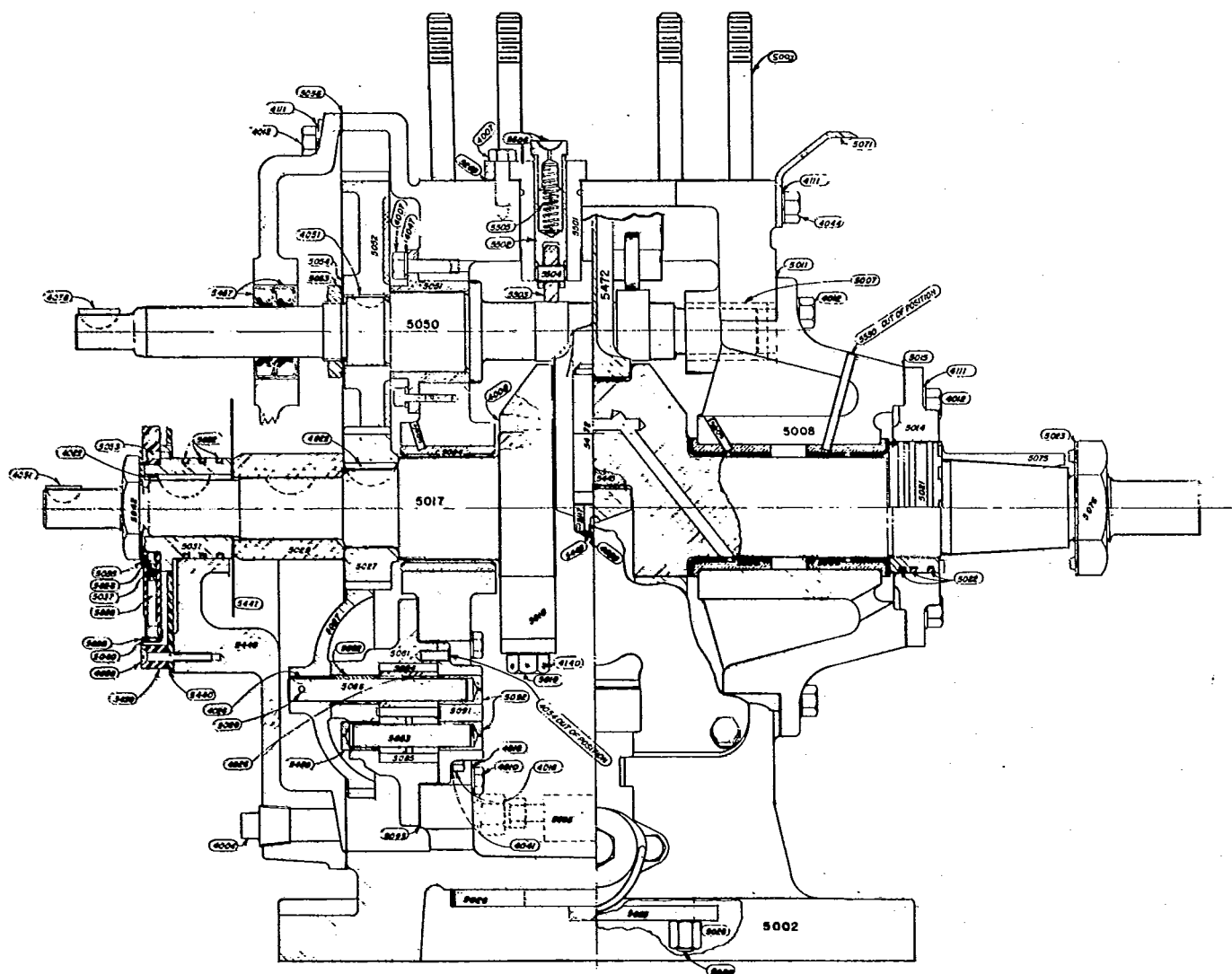


Fig. 1B - The 5000 engine

NOTE: Shown for illustrative purposes only. Detailed drawings may be obtained from Laboratory Equipment Corp., Mooresville, Indiana

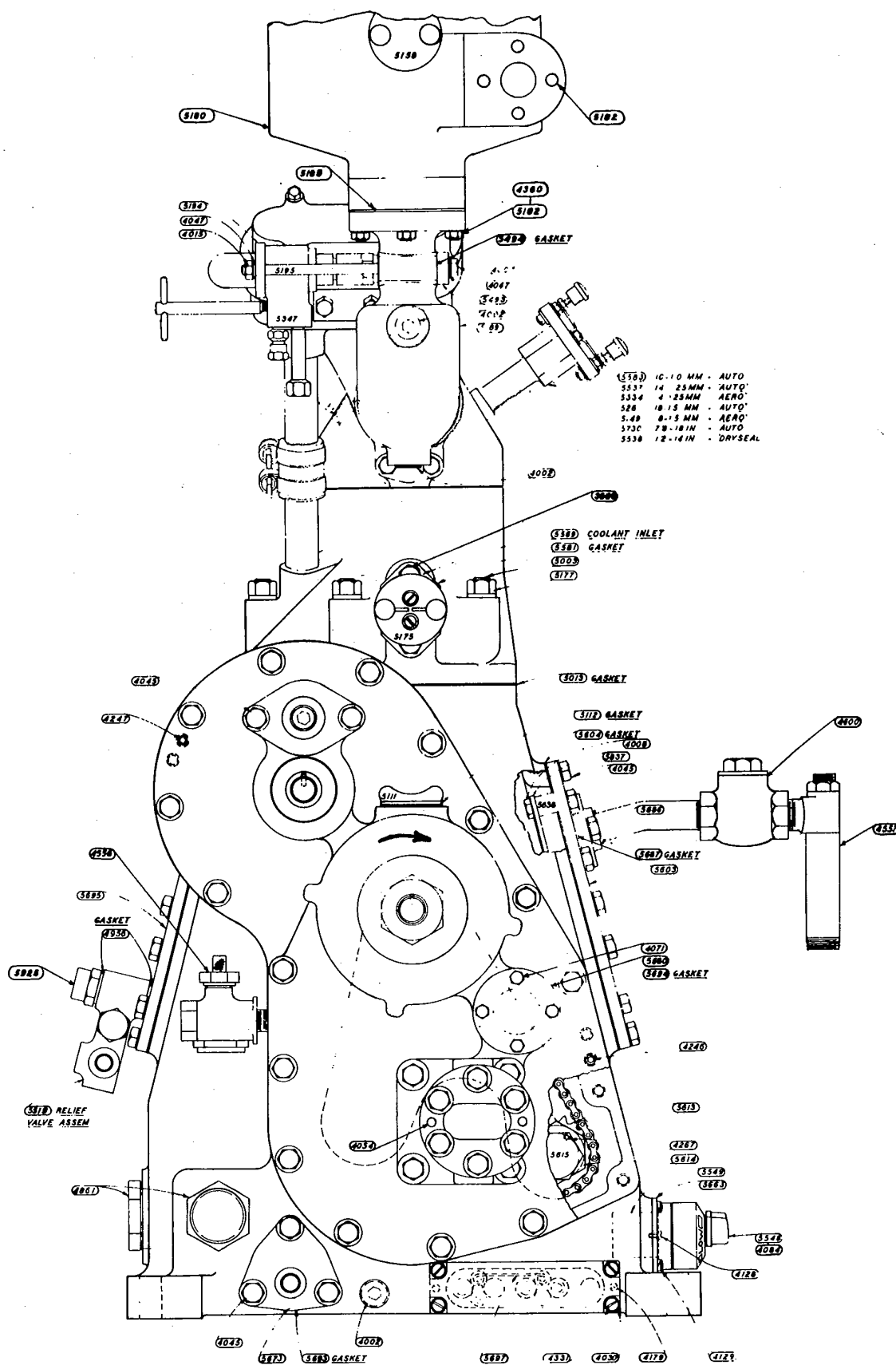


Fig. 2A - The 5750 engine

NOTE: Shown for illustrative purposes only. Detailed drawings may be obtained from Laboratory Equipment Corp., Mooresville, Indiana

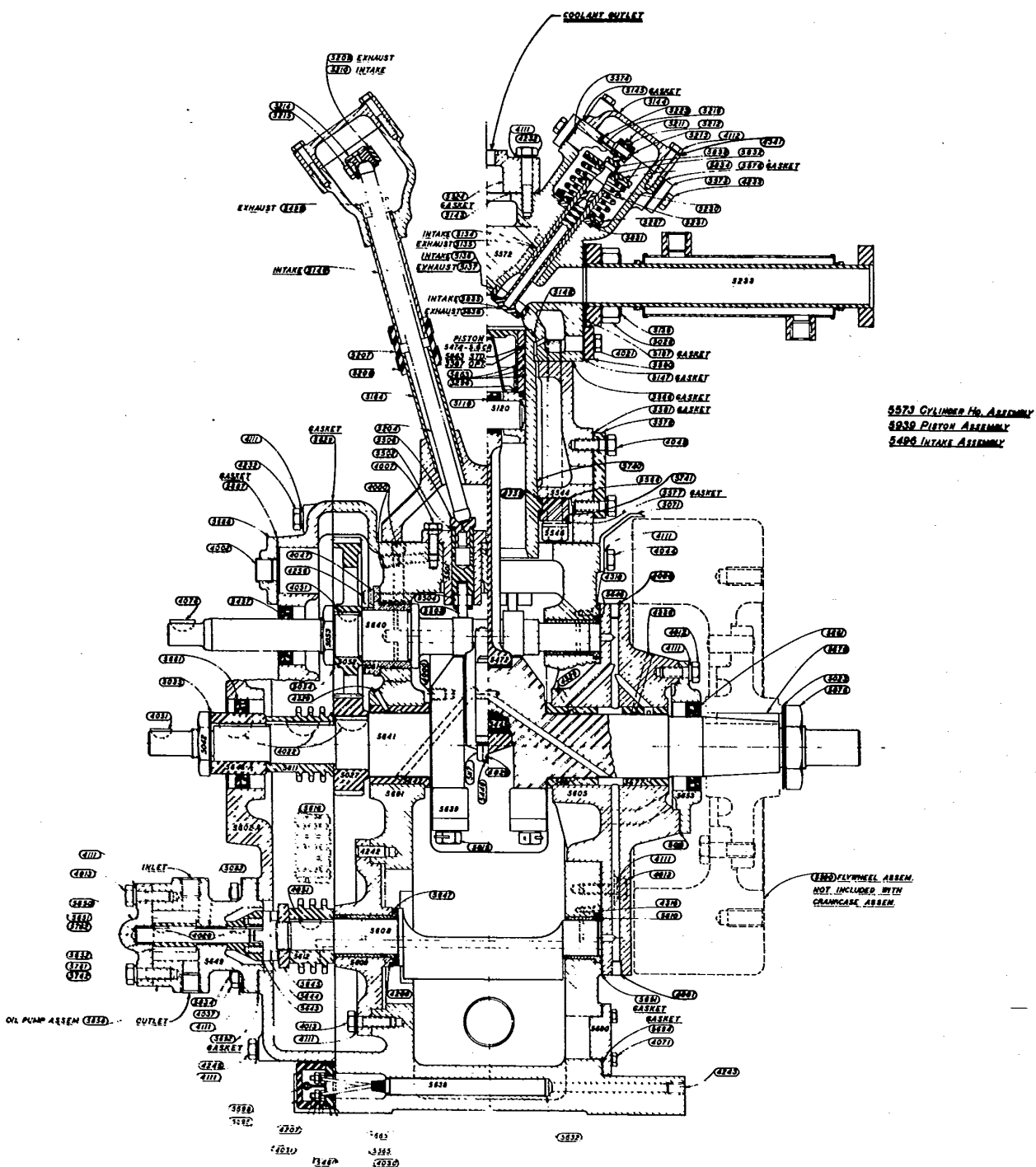


Fig. 2B - The 5750 engine

NOTE: Shown for illustrative purposes only. Detailed drawings may be obtained from Laboratory Equipment Corp., Mooresville, Indiana

top to bottom, except for a small outer flange near the lower end of the sleeve. This flange engages a steel ring flange which seals the sleeve to the cylinder housing and the head by gaskets and the same ten bolts which hold the barrel assembly to the head. The inner surface of the cylinder is knurled before finish honing and after final honing the surface is Parco Lubrize treated.

The coolant is brought in the lower end of the cylinder housing at the timing gear end and leaves the assembly at the top of the head between the rocker boxes.

The cast steel rocker arms (providing a 5/16 in. valve lift for a 1/4 in. lift of the camshaft) are equipped with needle bearings operating on floating case hardened solid steel rocker shafts, secured by cover plates bolted to the rocker box housings. Each rocker has a roller at the valve end and an adjusting screw at the push rod end. The valve gear is lubricated by pressure oil from the valve tappets, through a hole in the adjusting screw which affords splash lubrication, supplemented by additional exhaust valve lubrication effected by projecting the push rod housing 1/2 in. into the exhaust rocker box.

The valves, one intake and one exhaust, have valve stem diameters and lengths considerably greater than those generally provided for the valve head diameters used. Each valve is operated by two valve springs which provide satisfactory operation up to, and including 3200 rpm.

III. CRANKCASE ASSEMBLY

A. 5000 Engine - The gear end is considered the front end of the crankcase and the flywheel end, the rear of the crankcase. The crankcase consists of an extremely rigid iron casting with drilled oil passages allowing pressure lubrication to all bearing surfaces. Located by dowels and bolted to the front of the crankcase, a cast iron timing gear case cover encloses the timing gears and oil pump. Bolted to the rear of the crankcase is a cast iron adapter which serves as the rear main bearing support. A shoulder on this adapter pilots in a hole in the rear supporting section to the crankcase deck assuring positive alignment. Bolted to this adapter and located by dowels and a shoulder is a small casting which serves as the outer race for the crankshaft rear oil seal rings. Two large covers bolted to the sides of the crankcase provide means for inspection of the crankcase interior.

There are three main bearings: the front main bearing is pressed into the front supporting section of the crankcase deck and the rear two main bearings are pressed into the removable adapter mentioned earlier; all three are locked in place by taper pins. All main bearings are of the one-piece, steel backed silver grid type and are precision bored in place; no adjustment is provided to compensate for wear. End play is adjustable by means of the crankshaft rear oil retainer nut which screws on the crankshaft with a left hand thread. The rear of this race is slotted and locked in position by the fly-wheel key. End thrust is absorbed by the shoulder on the rear crankshaft cheek, by the crankshaft rear oil retainer nut, and by shoulders on the rear main bearings.

The crankshaft is a very rigid steel forging, has hardened bearing journals to insure minimum wear, and is counter-weighted to balance one-half the reciprocating weights as well as all the centrifugal weight in accordance with standard practice. Keyways are provided for flywheel, timing gear, timing disc spacer sleeve, and accessory drives. Threads are provided for the crankshaft front lock nut and the crankshaft rear oil retainer nut. The cast flywheel bears directly on a tapered and hardened section at the rear of the crankshaft and is held by key and lock nut. At those points where the crankshaft extends through the crankcase, piston ring type oil seals are used.

The camshaft, driven through helical gears, is carburized steel with case hardened bearing journals and cams, the gear being held to the camshaft by Woodruff key and lock nut. The front of the camshaft extends through the timing gear case for an auxiliary drive, leather or Victoprene oil seals being used at this point.

There are two bronze camshaft bearings: the front bearing, which absorbs the camshaft end thrust, is bolted by a flange to the front supporting section of the crankcase; the rear bearing is a bushing which is pressed into the rear crankcase supporting section. End play can be adjusted by removing metal from the inner face of the front bearing.

The valve lifters are of the roller type. The guides are iron castings and are held to the top deck of the crankcase by capscrews, positive vertical alignment being assured by shoulders which fit in piloting holes drilled in the crankcase deck.

The connecting rod is a steel forging which has a precision shell type split bearing, the cap being held by two bolts of

generous proportions. The bearings are precision bored steel backed silver grid and no adjustment is possible for wear. The wrist pin bushing is a press fit in the rod and is a hard cast bronze.

The piston pin is hardened carburized steel, is solid and employs a full diameter end having 1-9/32 in. spherical radii.

The piston is cast iron, has four compression rings and one oil control ring, all located above the piston pin boss and incorporates a sodium filled capsule in the head. This capsule, cooled by an oil spray from the small end of the connecting rod, is used to prevent localized overheating of the piston by more uniformly dissipating the heat to the cylinder wall through the rings and skirt and to the oil. The capsule consists of a two-piece, copper brazed chamber which totally encloses the sodium and is shrunk into the outer casting. Pressure on the middle of the piston head is directly transmitted to the piston bosses by the inner member of the capsule. The compression ratio of the engine is 5.6:1.

B. 5750 Engine - The crankcase of the 5750 engine from the cylinder mounting surface to the crankshaft main bearing is basically the same as that of the 5000 engine. The crankcase from the main bearing to the base is extended to house two counter-rotating, chain driven counterbalance shafts. The timing gear case cover is enlarged to enclose the timing gears, the chain drive for the counterbalance shafts, and the chain tension idler sprocket. An increased capacity oil pump is mounted on the outside of the timing gear case cover and is driven through an Oldham coupling by the left hand counterbalance shaft.

The crankcase has three main bearings, similar to the 5000 engine. However, the end play of the crankshaft is controlled by dimensional machining of the thrust faces of the two inner main bearings, with the adapter secured in place on the crankcase with the proper gasket.

The crankshaft is machined from the same forging as used for the 5000 engine. The only difference is that it is longer and the rear end is machined to use a radial lip seal instead of the ring seal. The front ring seal is also replaced with a radial lip seal, sealing against the timing disc spacersleeve.

The lead weighted counterbalance shafts are mounted in the lower part of the case. Their unbalance weight dampens out the unbalanced forces generated by the upper portion of the rod and piston assembly.

The shafts are mounted on bronze bushings pressed into

the rear of the case and front bushings pressed into a piloted bearing adapter. They are driven in opposite directions at crankshaft speed by a triple chain drive. The tension of the chain is adjusted by an idler sprocket mounted on an eccentric bushing which may be locked in the position giving the desired tension.

The timing gears, camshaft, valve lifters, connecting rod and piston assembly are the same for both engines.

IV. INDUCTION SYSTEM

The induction system consists of an air receiver assembly and an intake pipe (see Fig. 3). The air receiver, a cylindrical aluminum casting, is mounted at the top of the intake pipe and functions as an equalizing chamber to provide a constant pressure at the entrance to the induction system. It contains a standpipe whose inside diameter (7/8 in.) is equal to the pipe passage diameter and an air filter consisting of four layers of bronze screen (two of 110 mesh, and two of 22 mesh) to prevent pipe scale and the like from entering the cylinder. The air enters the receiver tangentially and is drawn off at the standpipe entrance near the top of the receiver. Two thermocouples are located in the air receiver, one is connected to a controller to maintain the air inlet temperature at $225 \pm 5F$ (see Section XI), and the other is used for indicating the temperature.

The intake pipe is an iron casting in the form of a 90 deg bend and is held to the cylinder head by four studs. Surrounding the pipe is a coolant jacket which not only gives a great rigidity to the section, but also serves as a means by which mixture temperature may be controlled. Provisions are made for the mounting of the fuel injection nozzle on either side of the intake pipe between the coolant jacket and the flange to which the air receiver is bolted.

V. IGNITION SYSTEM

The ignition system consists of a low tension magneto, one high tension coil, magneto drive coupling assembly.

The magneto, mounted independently of the engine on a mounting bracket, is driven at engine speed through a drive coupling assembly connected to the front extension of the crankshaft. The magneto rotation is counterclockwise as viewed from the magneto drive end. The magneto generates

and distributes low voltage current through low tension cables to the high tension coil. The low voltage current is transformed to high voltage by this coil and is conducted through a short length of high tension cable to the spark plug in the engine. Negative polarity impulses shall be delivered to the spark plug. An alternate, high tension, magneto, part No. 5310, Scintilla Types CR4/1 or CBR4/2, may be used.

The magneto drive coupling assembly consists of one adjustable coupling flange assembly, two flexible couplings, and a driving coupling flange which is keyed to the crankshaft. The adjustable coupling flange assembly, two versions of which have been supplied, is provided for ease of ignition timing. The original assembly was of the split disc type, alignment being assured by a shoulder on one half fitting into a hole on the other half. The driving half of the assembly is bolted to the flexible coupling, the driven half is positioned on the magneto shaft by a Woodruff key and secured with a lock nut. Both discs have a series of holes drilled through their faces on identical circumferential diameters, one with 24 holes and the other with 26. Adjustment of the magneto rotor timing in relation to the crankshaft, within 1 deg, is possible by aligning holes in the discs and bolting the discs together. The later version of the adjustable coupling flange assembly differs in that one disc has two fixed screws which can be positioned in the two circumferential slots in the other disc.

In timing the low tension magneto to the engine, remove the breaker cover and the timing inspection plug from the magneto. With the crankshaft set at 40 deg btc (or 30 btc, if required by test) on the compression stroke, position the adjustable coupling flange assembly so that the white dot on the chamfered tooth of the large distributor gear lines up with the pointer as seen through the inspection hole. In this position the breaker points of the magneto are just opening. In timing the alternate, high tension magneto to the engine, the adjustable coupling flange assembly is set so that the timing screw marked "L" on the distributor gear of the magneto is in line with the timing pointer on the magneto cover. In this position the breaker points are just opening.

VI. FUEL SYSTEM

The fuel system consists of a fuel supply pump, fuel cooler, filter, fuel injection pump assembly, injection nozzle, and fuel tank as shown on Fig. 3.

The gear type, positive displacement, fuel supply pump, is driven at 600 rpm and has a capacity of $1/2 \pm 1/4$ gpm at this speed.

The fuel cooler maintains the fuel temperature to the engine within the desirable range of 60-90 F.

The filter is a multiple disc edge type with 0.0015 in.

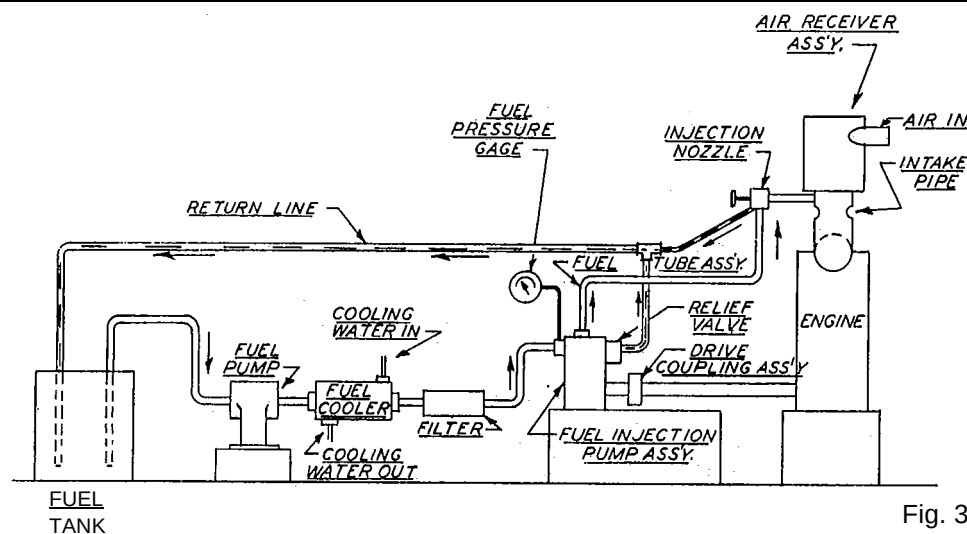


Fig. 3 - Suggested fuel system

spacing. To reduce difficulty during engine operation due to fuel contamination, it is suggested that the fuel be filtered before delivery to the fuel system. This may be accomplished by recirculating the fuel in the drum through a two-micron filter during the mixing operation employed to assure thorough mixing of the fuel constituents.

The fuel injection pump assembly, a single cylinder American Bosch type APEIB-70P 300/3 is mounted independently of the engine on the same mounting bracket that supports the magneto. The pump has a variable delivery rate and is driven at half engine speed through a drive coupling assembly (similar to that used for the magneto) connected to the front extension of the engine camshaft. The pump outlet connection contains a spring loaded relief valve to maintain a pressure in the pump gallery of 15 ± 2 psi to reduce vapor locking. A portion of the fuel, determined by the injection pump control rod setting, is passed to the injection nozzle and the balance is returned to the fuel tank. The injection pump lubricant, SAE 30 oil or castor oil, should be changed at least every 50 hr. The timing of the injection pump is accomplished by setting the engine flywheel at 60 deg atc on the intake stroke, and coupling the injection pump to the engine camshaft with the scribed line on the tapered

shaft of the pump aligned with the "R" line on the pump endplate, for clockwise rotation, of the pump as viewed from the drive end. When aligned, the bypass port of the pump is closed and fuel delivery to the nozzle begins.

The injection nozzle is mounted on the upper end of the intake pipe and sprays fuel directly across the passage at right angles to the air flow direction.

VII. COOLING SYSTEM

The cooling system is a pressure water cooling system (Fig. 4), consisting of a coolant pump, a cooling tower assembly, two optional pressure gages and controls for maintaining the jacket inlet temperature at 265 ± 5 F. The coolant pump, mounted independent of the engine, is of the centrifugal type and is driven by an electric motor at 3450 rpm. Its rated capacity is approximately 5 gal. per minute under operating conditions.

The heat exchanger of the cooling-tower assembly (Fig. 5) consists of a core weldment having 1/4 in. threads on its OD, mounted in an intermediate tube weldment.

The complete assembly is so constructed that

1. It is completely accessible for inspection and cleaning.

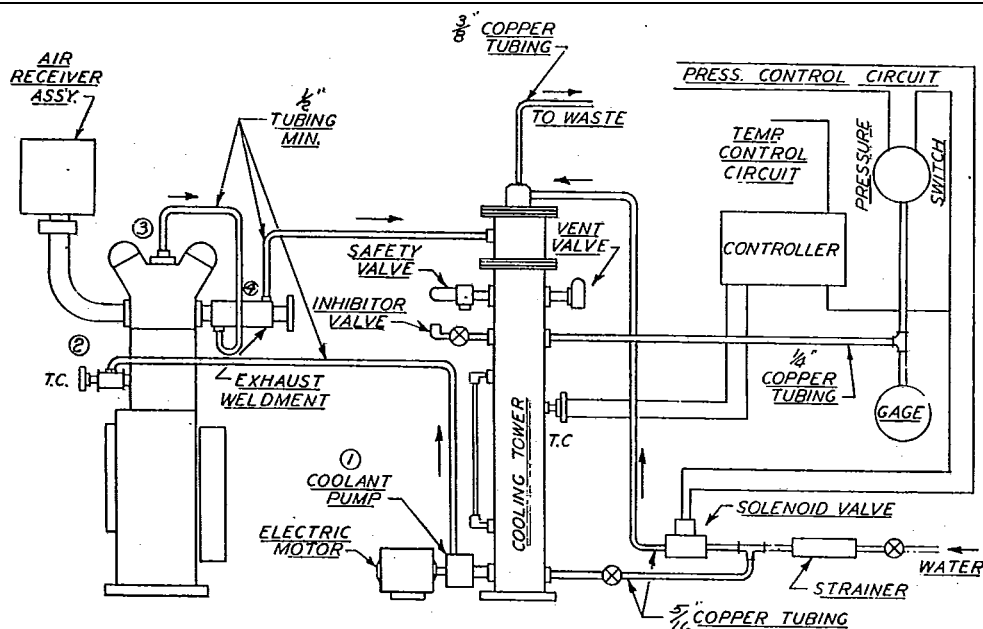


Fig. 4 - Cooling system

2. The various concentric tubes may expand or contract longitudinally without producing axial stresses.

3. It is able to safely withstand 100 psi static pressure without danger of rupture, although pressures above 52 psi gage (bp water -- 300 F) are not recommended.

Two optional pressure gages may be used for indicating pressure in the cooling tower and in the cylinder barrel, respectively, the latter being used to denote failure of the pump or formation of steam pockets either in the pump suction line or in the pump itself. An air vent valve is attached to the cooling tower and is essential if the heat exchanger is controlled by pressure since it minimizes dissolved air in the water and is desirable, although not essential, if the control

is by temperature. A safety valve is also mounted on the cooling tower to prevent rupture in the event of malfunctioning of the controls.

As can be seen from the schematic layout of the cooling system (Fig. 4) the coolant is drawn from the cooling tower base by the coolant pump (1) and forced through the barrel jacket (2), cylinder head (3) and exhaust weldment (4), before returning to the top of the cooling tower. The coolant then flows down the threaded OD of the core weldment (Fig. 5) in a long helical path at high velocity and into the intermediate tube weldment whose outlet is below the coolant level in the lower section of the tower.

Jacket inlet temperature control is effected by allowing city water to enter the core weldment through a normally closed solenoid valve. This valve can be actuated by means of either a suitable temperature or pressure control (see Fig. 4). When the control temperature or pressure has dropped to the preset value, the solenoid valve closes and the cooling water contained in the core weldment boils and sufficient pressure is developed to rapidly eject the water through the center tube extending almost to the bottom of the core weldment. When the temperature or pressure again rises, the cycle is repeated. Consequently, the jacket inlet temperature does not remain constant but fluctuates between 260 - 270 F, and the outlet temperature fluctuates between 270-275 F. However, this cycle is quite rapid and no appreciable change in engine operating temperature is noticeable, the head temperature varying perhaps 2 F.

The coolant pump is either mounted on an adapter at the bottom of the cooling tower, or a short 1 in. min dia pipe is used as a suction line from the pump to the base of the tower. It should be emphasized that this line must be free of elbows

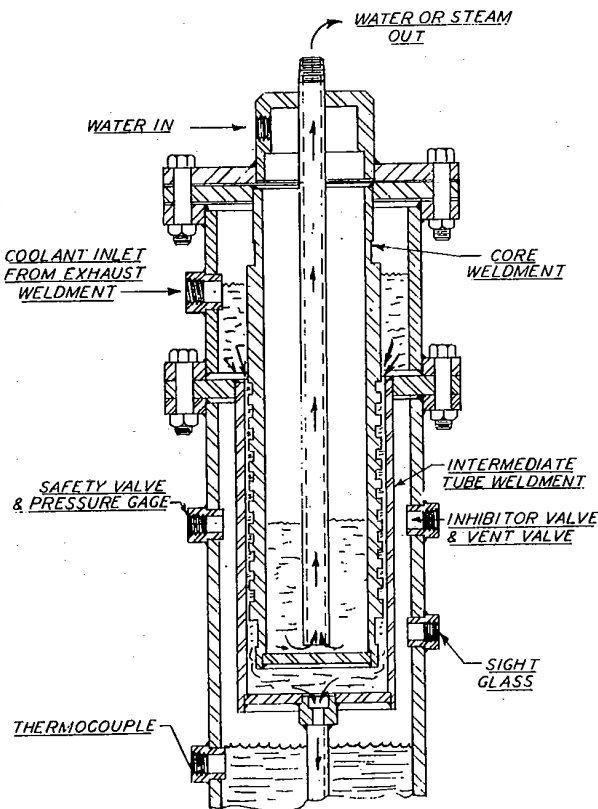


Fig. 5 - Section through coolant heat exchanger in cooling tower

or restrictions and must not require the pump to lift any head. Violating these items can, and readily does, cause steam pockets in the lines or cavitation in the pump. The discharge lines from the pump to the barrel jacket, from the cylinder head to the exhaust weldment, and from the exhaust weldment to the top of the cooling tower are all 1/2 in. (min) OD X 0.030 in. wall copper tubing. The restriction effected by these lines and exhaust weldment results in pressures approximately 25 psi higher in the cylinder head than in the cooling tower.

Distilled or treated water is used for the coolant to prevent the formation of lime or deposits in the cooling system. Such deposits, if allowed to accumulate in the engine, result in progressively higher metal temperatures of all surfaces exposed to combustion gases and in time may completely fill the cooling jackets. City water may be used, however, if the dissolved and suspended solids do not exceed 120 parts per million. One gram of 20 Mule Team Borax or Calgon per gallon, or 1/2 oz sodium chromate per gallon may be used as an inhibitor. The coolant capacity is approximately 3-1/2 gal. When the short cooling tower, No. 5010, is used, the capacity is approximately 2 gal.

VIII. LUBRICATION SYSTEM

A. 5000 Engine - The schematic layout of the complete lubrication system for the 5000 engine is shown in Fig. 6. The oil is drawn from the crankcase sump by the oil pump and is fed through the external oil cooler and oil filter, and the two external oil pressure regulator assemblies mounted on the side cover plate. From here the oil is distributed through the engine and returned to the oil sump.

The oil pump is of the gear type and has a capacity of approximately 5 gal./minute at 100 psi at 2700 rpm engine speed. The pump is located in the oil sump and bolted to the outer face of the front crankcase supporting section and is driven by helical gears from the crankshaft.

The oil cooler is fabricated with steel tubing and is identical in detail to the coolant heat exchanger (Fig. 5) with the exception of length.

The oil filter is a heavy duty edge type design (0.0035 in. spacing between discs) to withstand high pressures and so made that the disc edges may be cleaned without disassembly. Three taps are provided for oil drain, oil entrance and oil exit, respectively.

The two oil pressure regulator assemblies are of the spring loaded cone seat type. One of the regulators is used for maintaining a pressure of 100 ± 5 psi to all bearings in the crankcase, the other for maintaining a pressure of 25 ± 5 psi to the valve gear. Short lengths of copper tubing lead from the high and low pressure regulators to drilled passages in the crankcase which lubricate the crankshaft bearings, and the valve gear, respectively. A thermocouple is attached to the drilled passage of the high pressure oil and this temperature is maintained at 190 ± 10 F by regulating the oil cooler and oil heater. Bypass, or bleed oil, is returned through the side cover plate to the sump. A steel

plate attached to the inner side of the cover plate prevents this oil being thrown on crankshaft throw and reduces any foaming tendencies.

Since there are two regulators delivering differing pressures from a constant pressure source, an orifice restriction is embodied in the valve gear regulator which limits the oil fed to the assembly. The crankcase oil heater is of the calrod type and is bolted to the bottom of the crankcase immediately below the oil sump. Three heating capacities (250, 500, and 1000 w) are available by means of three taps which lead to a switch attached to the front of the crankcase.

B. 5750 Engine - The schematic layout of the complete lubrication system for the 5750 engine is shown in Fig. 7. The oil pump, of increased capacity, is mounted externally on the front timing gear case cover and driven through an Oldham coupling by the left hand counterbalance shaft. All bearings are pressure lubricated through a single pressure relief valve set to 100 ± 5 psi. The timing gears and the counterbalance drive chain are lubricated by splash from a metered hole in the right hand counterbalance drive shaft sprocket. The valves and rocker arms are lubricated by bleedoff oil which comes through the camshaft to the valve lifters and through the push rod to the rocker arms. The pressure to the valve gear is 10-15 psi, depending on the clearance in the camshaft bearings and between the valve lifter and valve lifter guide.

Four tubular cartridge type oil heaters are located on the front of the crankcase and extend into the base of the crankcase. Three crankcase heating capacities (285, 570, and 1140 w) are available.

The lubricating oil is a non-additive aviation SAE 60 type. Twenty cc of DAG Dispersion No. 2404 to each gallon of oil may be used to reduce varnish formation on moving engine parts. The crankcase oil filler and level indicator

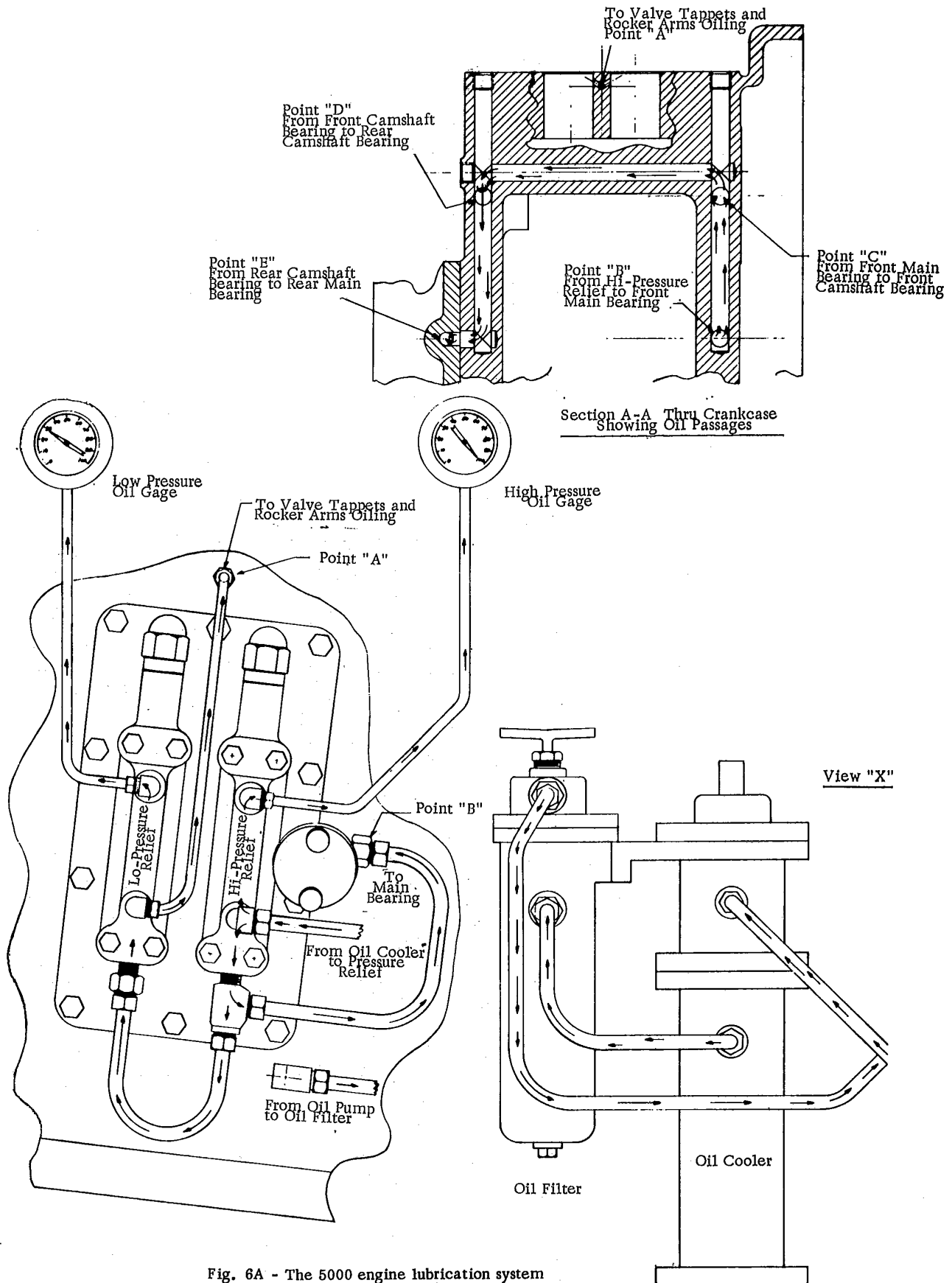


Fig. 6A - The 5000 engine lubrication system

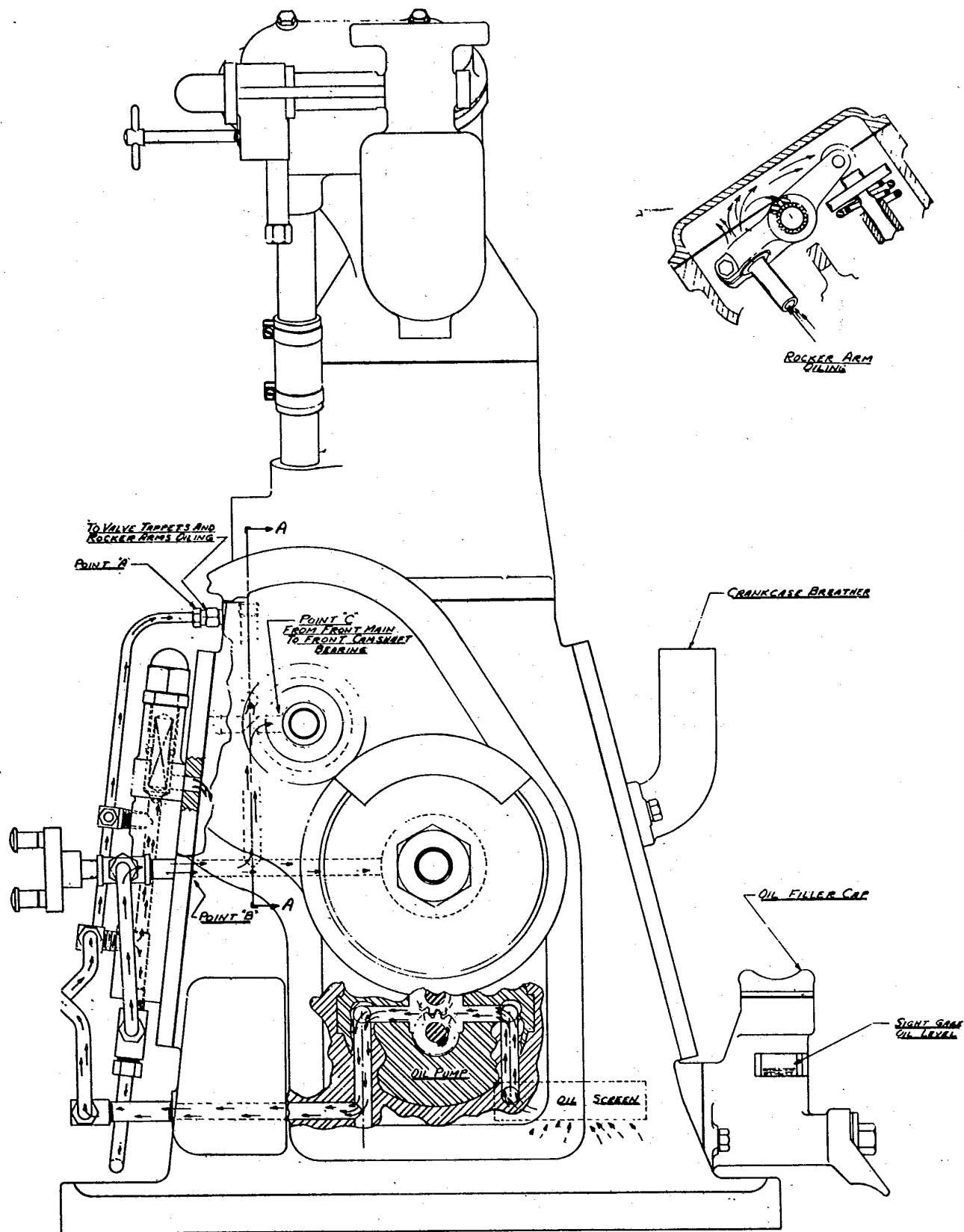


Fig. 6B - The 5000 engine lubrication system