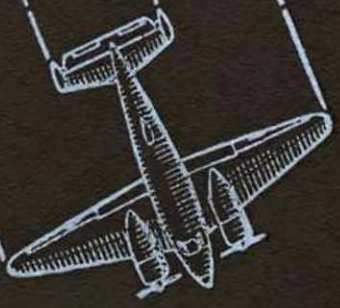
R-1830

S1C3G

PRATT & WHITNEY AIRCRAFT

DEPENDABLE ENGINES

Twin Wasp

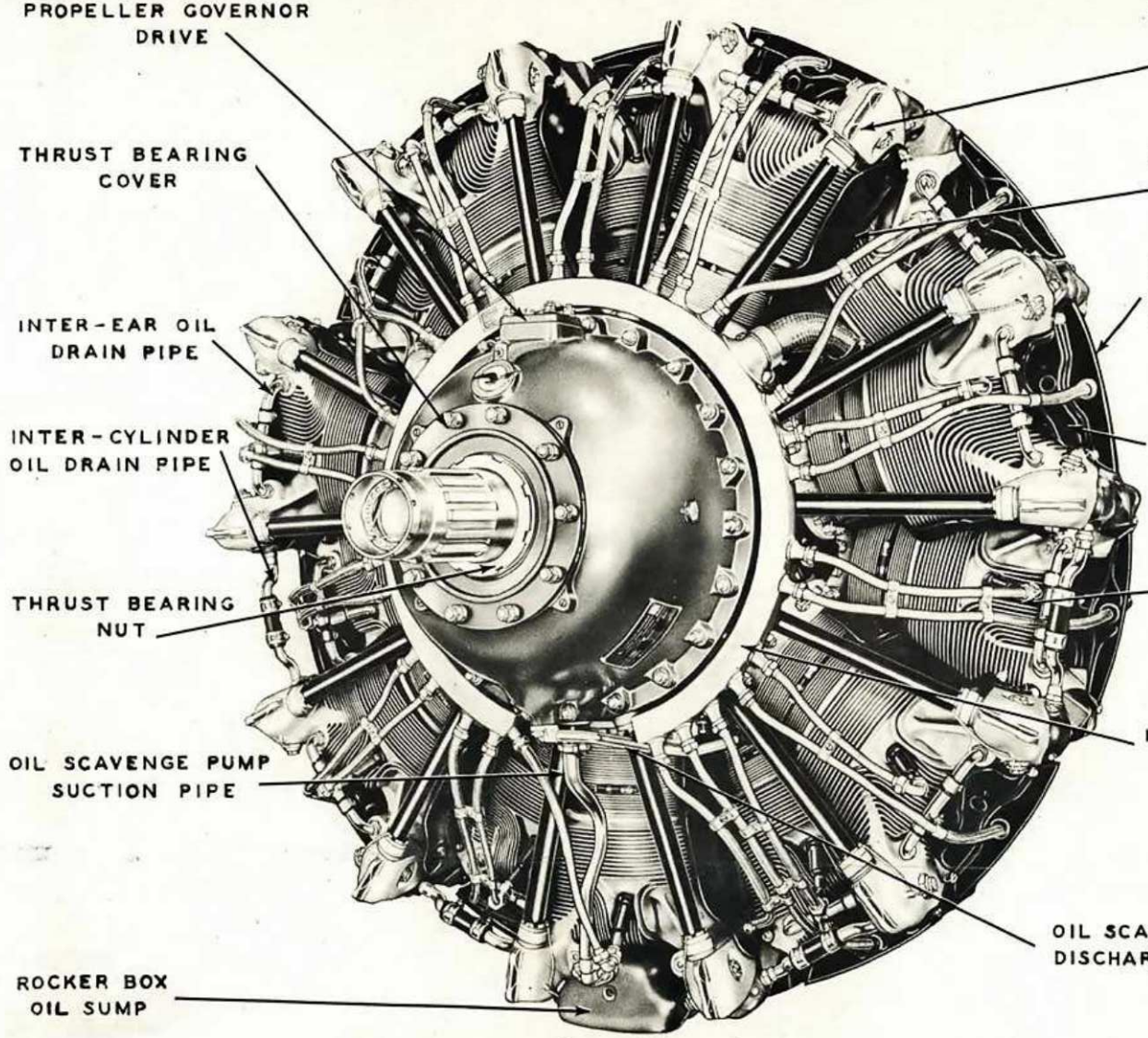


MAINTENANCE MANUAL

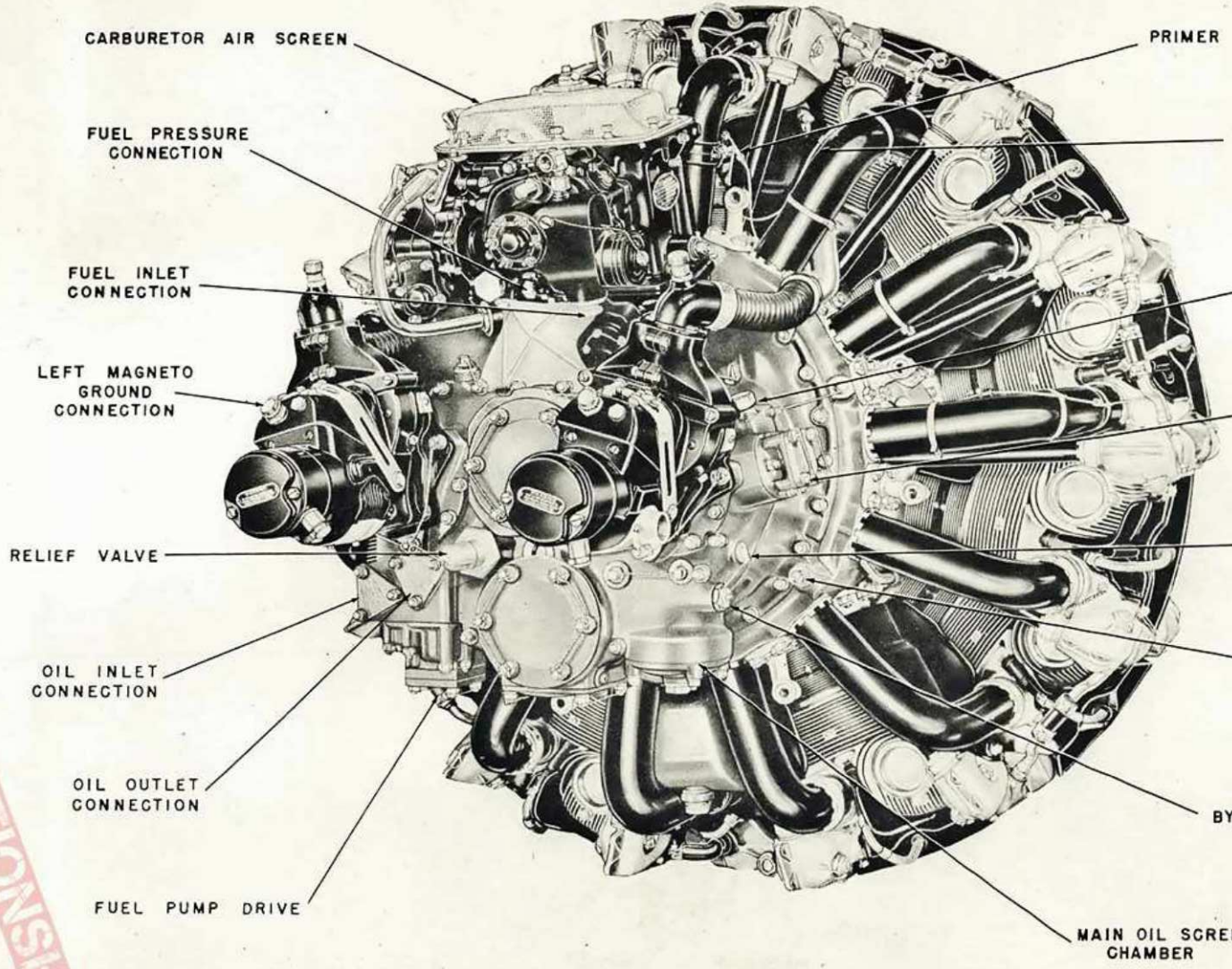
Notes

THIS PAGE INTENTIONALLY LEFT BLANK

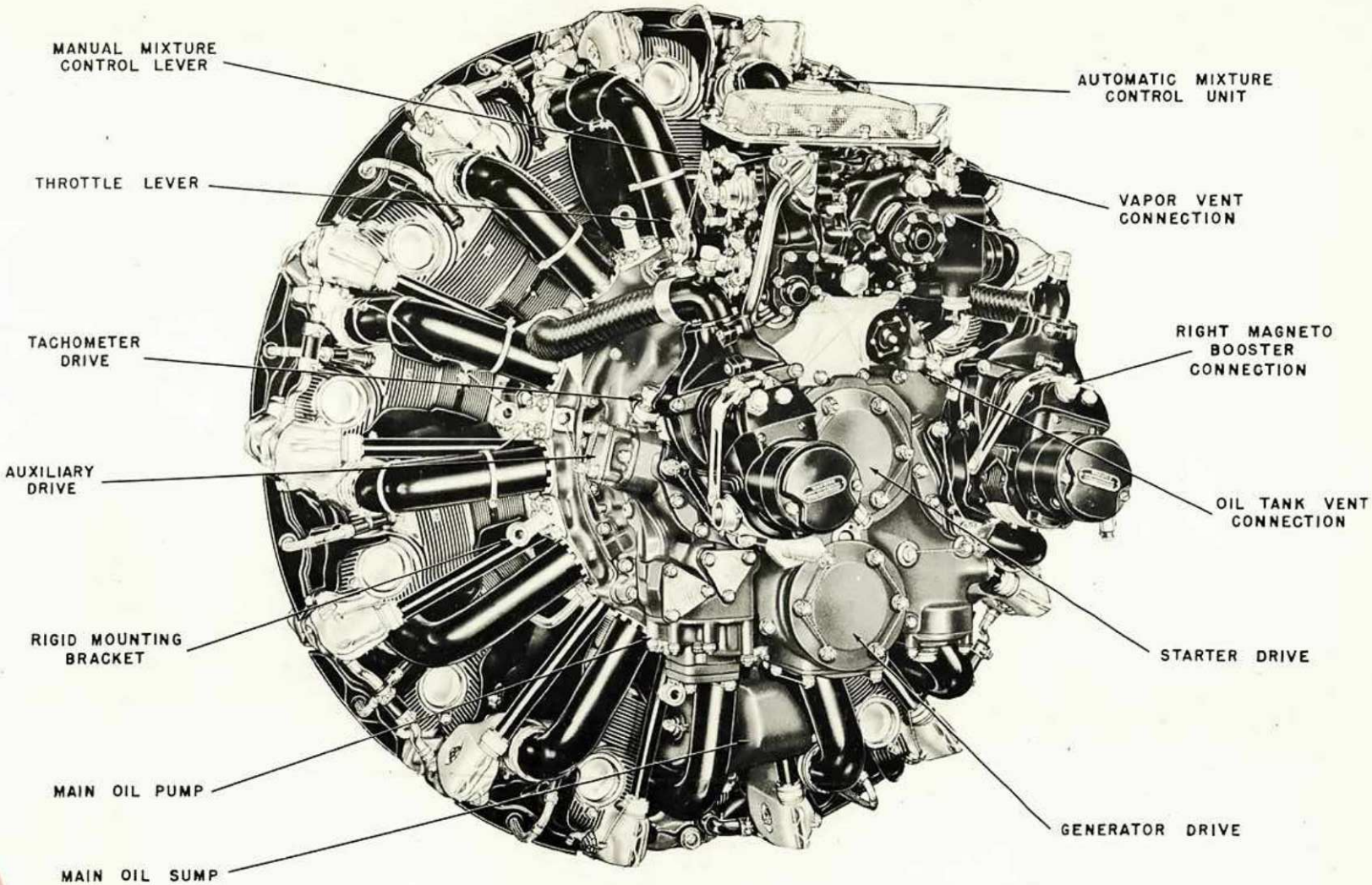
TABLE OF CONTENTS



Front View of Engine



Right Rear View of Engine



Left Rear View of Engine

INTRODUCTION

This publication is compiled and issued by the Service Department of Pratt & Whitney Aircraft. It includes approved and recommended engine maintenance and service procedures. The instructions contained herein are based upon actual experience acquired under varied and exacting conditions. The utmost in dependable engine performance will be gained by conforming to these instructions.

Unusual problems concerned with engine maintenance should be presented to the Service Department either through its field representatives or by direct contact. All possible assistance will be provided.

For complete overhaul procedures, please refer to the Overhaul Manual, Part No. 86405. When necessary, replacement engine parts should be ordered from a Pratt & Whitney Aircraft Engine Parts Catalog, Part No. 111464.

Suggestions for the amplification or modification of these instructions will be gladly received and considered by the Service Department.

At six month intervals this publication will be revised as necessary to incorporate latest maintenance data

SPECIFICATIONS

GENERAL

Model	Twin Wasp (R-1830) S1C3-G
Type	Two Row, Radial, Air Cooled
Number of Cylinders	14
Bore	5.5 inches
Stroke	5.5 inches
Piston Displacement in Cubic Inches	1830
Compression Ratio	6.70:1
Blower Gear Ratio	7.15:1
Diameter of Impeller	11 inches
Crankshaft Rotation	Clockwise
Propeller Rotation	Clockwise
Propeller Reduction Gear Ratio	.5625:1 (16:9) Spline Coupled
Propeller Shaft Spline Size	50
Diameter of Mounting Bolt Circle	27 inches
Number of Mounting Bolts	8
Average Dry Weight of Engine	1467 pounds
Overall Diameter of Engine	48.19 inches
Overall Length of Engine	61.67 inches
Position of Center of Gravity:	
Distance Below Crankshaft Centerline	9/64 inch
Distance Above Crankshaft Centerline	0
Distance Forward of Rear Face of Mounting Bosses	10-55/64 inches

IGNITION

Magneto Type	SF14LN-3
Rotation of Magneto Drive	Clockwise
Magneto Speed in Multiples of Crankshaft Speed	.875:1
Spark Plug Gap	.011-.014 inch
Spark Plug Type	RC-34S, RC-35S, 7KLS2, RB19R
Spark Advance	25 degrees

VALVES AND TIMING

Intake Opens Before Top Center	20 degrees
Intake Closes After Bottom Center	76 degrees
Exhaust Opens Before Bottom Center	76 degrees
Exhaust Closes After Top Center	20 degrees
Intake Remains Open	276 degrees
Exhaust Remains Open	276 degrees
Valve Adjusting Clearance (cold)	.020 inch
Valve Timing Clearance (cold)	.060 inch

FUEL SYSTEM

Carburetor Type	PD-12H4
Fuel	Grade 91/96

LUBRICATION SYSTEM

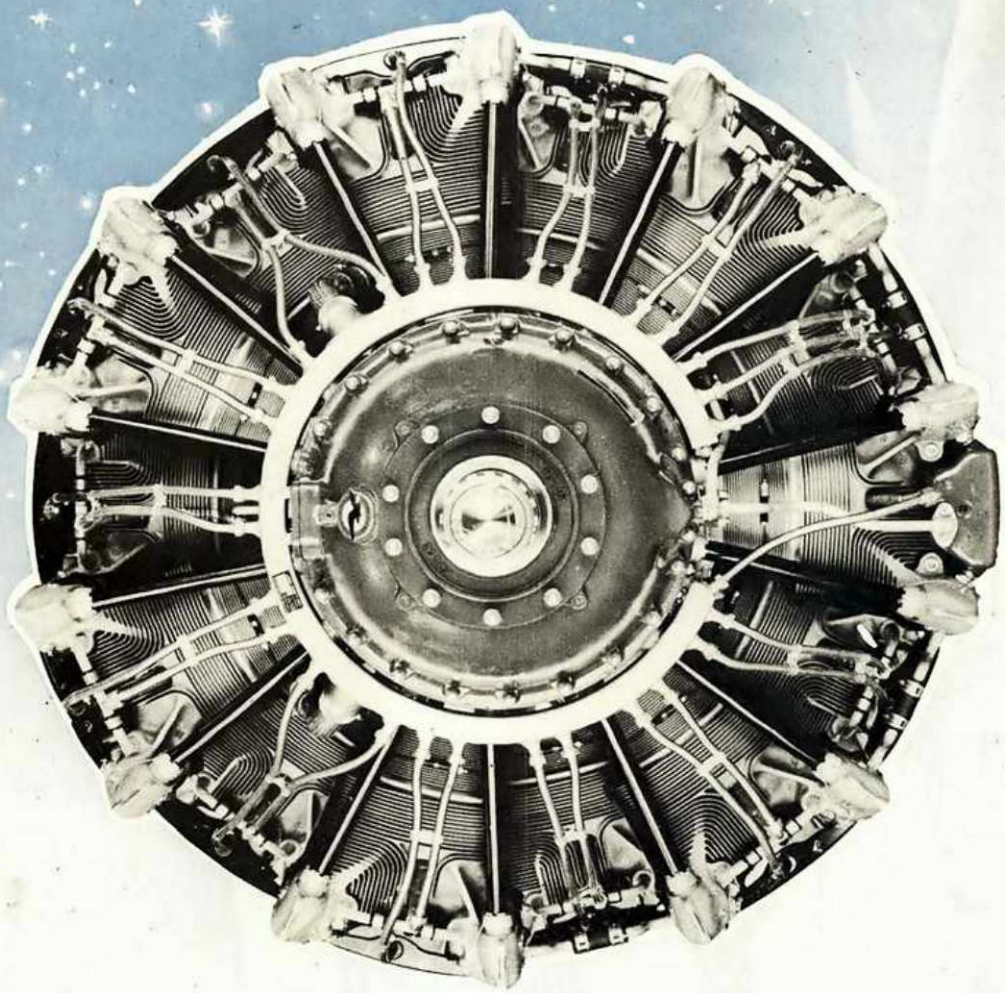
Grade of Oil	100 (Oil Grade S. U. S. at 210°F.)
Oil Pump Speed in Multiples of Crankshaft Speed	.875:1

ACCESSORY DRIVES

Generator Drive	16 Int. Inv. Splines, 1.40:1 Clockwise
Generator Pad	5 in. Dia. Bolt Circle
Starter Drive	3 Tooth Jaw, 1.00:1 Clockwise
Starter Pad	5 in. Dia. Bolt Circle
Fuel Pump Drive	11 Int. Inv. Splines, .875:1 Counterclockwise
Fuel Pump Pad	2 in. x 2 in.
Tachometer Drive	7/8 in.—18NS-3 Coupling, .500:1 Clockwise (Right Side), Counterclockwise (Left Side)
Vacuum Pump Drive	12 Int. Inv. Splines, 1.40:1 Clockwise
Vacuum Pump Pad	1 7/8 in. x 1 7/8 in. Sq. Pad
Propeller Governor Drive	12 Int. Inv. Splines, .958:1 Clockwise
Propeller Governor Pad	2 1/8 in. x 2 1/8 in.

ACCESSORY AND INSTRUMENT CONNECTIONS

Manifold Pressure Gage	1/8-27 NPT
Oil Pressure Gage	1/8-27 NPT
Oil Tank Vent	3/8-18 NPT
Oil Inlet Thermometer	5/8-18 NF-3
Vacuum Pump Oil Separator Discharge	3/8-18 NPT
Fuel Drain	3/8-18 NPT
Accessory Oil Return	3/8-18 NPT
Air Blast Covers	3/4-14 NPT



DESCRIPTION

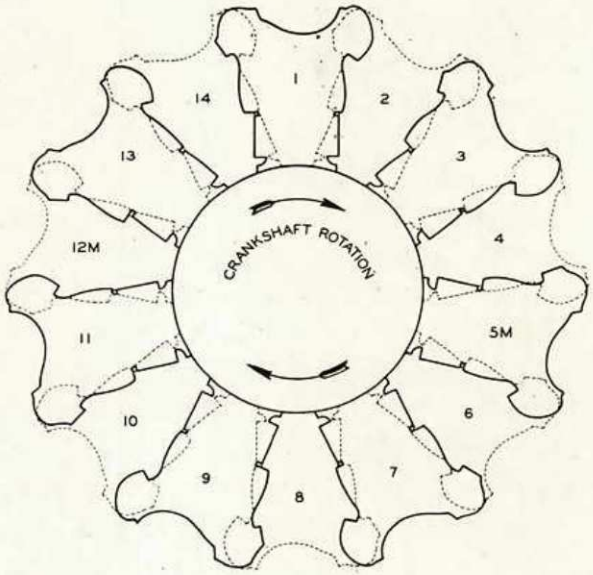
The Pratt & Whitney model S1C3-G engines are two row, radial, air-cooled engines. For descriptive purposes, the engine is divided into the following major assembly groups: front section, main crankcase section, cylinders, blower section, intermediate rear section, and rear section. A combination of the main crankcase section and cylinders is generally regarded as the power section, and the blower, intermediate rear, and rear sections, when combined, are termed the accessory section.

Right and left, clockwise and counterclockwise, upper and lower, and similar directional phrases apply to the engine as viewed from the rear with the crankshaft in the horizontal position and with No. 1 cylinder at the top of the engine. The normal direction of rotation of the crankshaft and propeller shaft is clockwise. For the accessory drives, the direction of rotation is specified as it appears to an observer facing the accessory mounting pad.

Cylinder numbering and firing order and the position of the master rods are illustrated in the adjoining column. Beginning with the top cylinder, the cylinders are numbered consecutively in the direction of crankshaft rotation.

FRONT SECTION

Reduction Gear Housing. The reduction gear housing supports and houses the propeller reduction gear assembly and has provision for mounting and driving a propeller governor to control the operation of a hydraulically operated propeller. It also houses a two section oil pump which is driven by the front cam through an intermediate gear.



VIEWED FROM REAR OF ENGINE

FIRING ORDER
1-10-5-14-9-4-13-8-3-12-7-2-11-6
M=MASTER CYLINDER

DOTTED LINES DESIGNATE FRONT ROW OF CYLINDERS

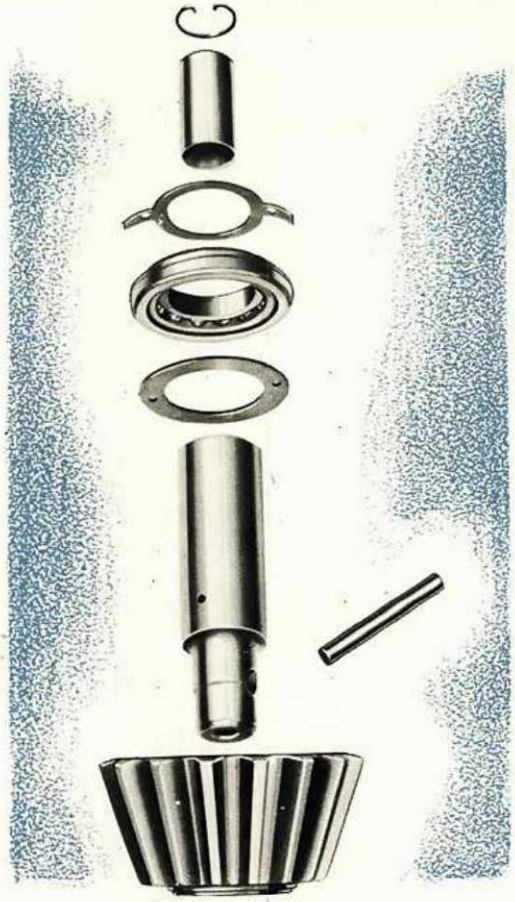
Cylinder Numbering Diagram

This pump scavenges oil from the rocker box sump and from the front part of the engine. A ball bearing mounted in the front of the reduction gear housing transmits the thrust from the propeller shaft to the housing and thence through the crankcase to the engine mount.

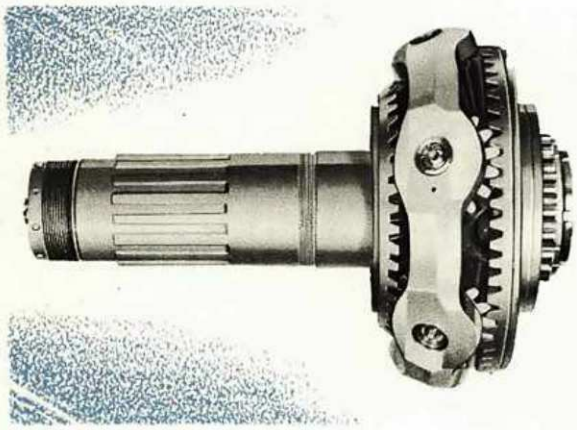
Reduction Gearing. The engines covered by this handbook are equipped with a .5625:1 propeller reduction gear ratio. This ratio is commonly referred to as 16:9.

The reduction gearing is of the bevel planetary type. The drive gear meshes with six bevel type pinions which mesh with a fixed gear that is splined to the fixed gear anchor in the front end of the reduction gear housing. The bevel pinions incorporate steel backed, lead bronze bushings and are supported by shafts in the pinion cage, which is integral with the propeller shaft. The outward thrust of the pinions is taken by ball bearings located between the pinion cage and the outer face of the pinions. The drive and fixed gears are supported by ball bearings which seat on the propeller shaft. The drive gear is coupled to the front end of the crankshaft by a series of three couplings. The front coupling is splined to the reduction drive gear and the intermediate coupling, the intermediate coupling is splined to the rear coupling, and the rear coupling is splined to the front end of the crankshaft.

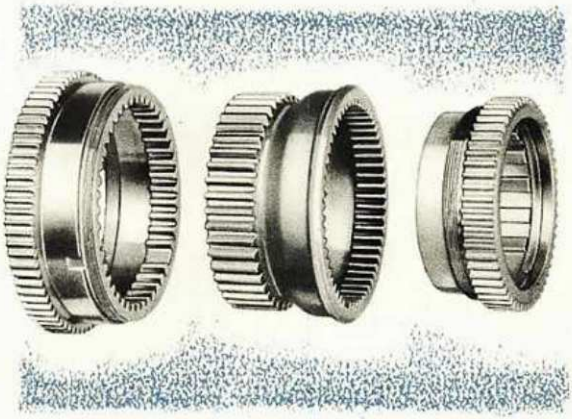
With the spline coupled type of drive, the propeller shaft is supported at the forward end by the thrust bearing and at the rear by two roller bearings. One of the two roller bearings is fitted over the end of the propeller shaft and the other is mounted in a liner



Reduction Pinion Shaft



Propeller Shaft and Reduction Gearing

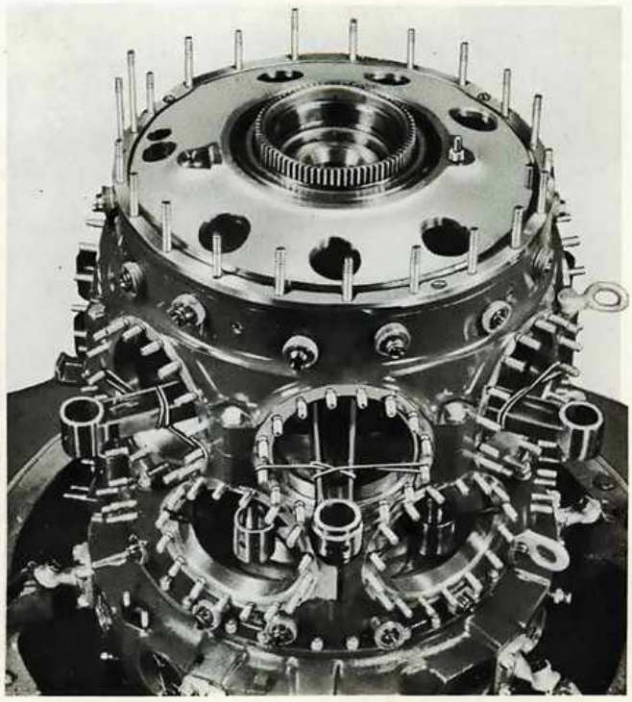


Coupling Gears

in the support plate. The reduction drive front coupling is supported between the two roller bearings.

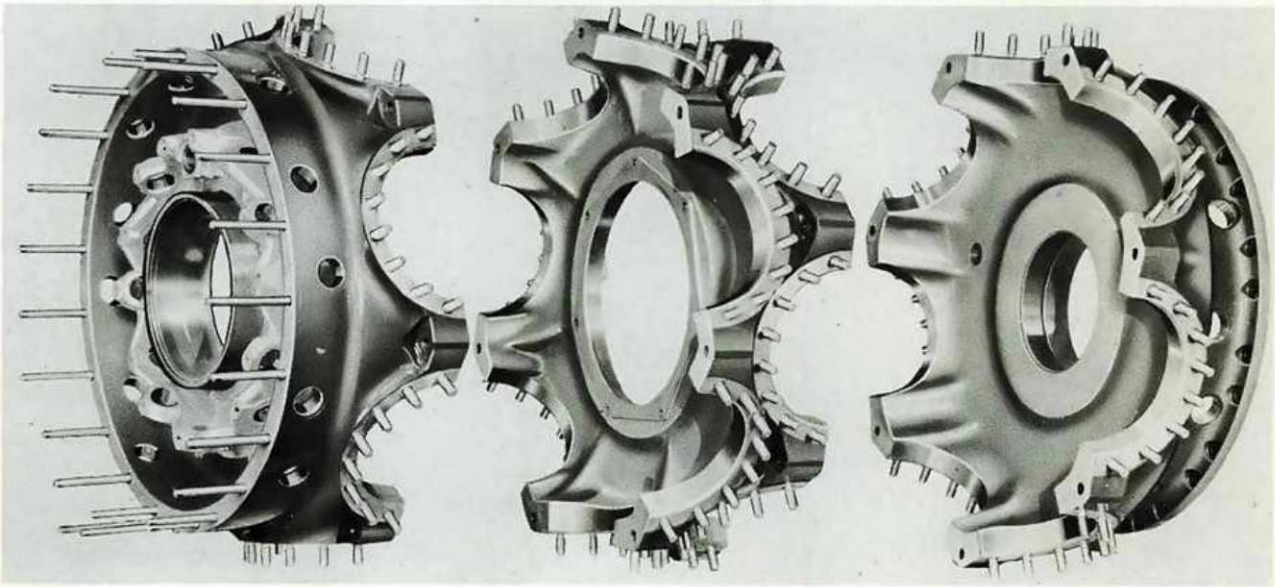
MAIN CRANKCASE SECTION

Support Plate Assembly. The support plate is secured between the front main crankcase and the reduction gear housing. It supports the rear end of the propeller shaft and the governor and front oil pump intermediate drive gears. A hole in the bottom of the support plate retains the rear end of the front oil pump housing, thus affording additional support to the drive shaft of the pump. A steel liner in the bore of the plate supports the roller bearing for the reduction drive gear or coupling.



Crankcase Sections and Support Plate

Front, Center, and Rear Main Crankcases. The main crankcase of these engines is composed of three sections which are held together by bolts. Around the outer circumference of the crankcase assembly, two rows of cylinder mounting pads are arranged. Sixteen studs hold each cylinder to its pad. Hardened steel liners in the front and rear main cases support the crankshaft front and rear bearings. A bronze liner, which is held in place in the center main crankcase by bolts, supports the crankshaft center bearing. The front cam bearing is supported on an extension of the crankshaft front bearing

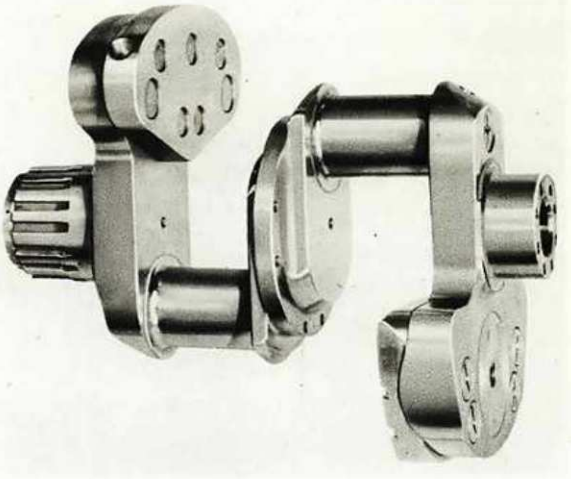


Front, Center, and Rear Crankcase Sections

liner, and the rear cam bearing is supported on a boss on the rear main crankcase. The front cam reduction gear is supported by bronze bushings in the front main crankcase and support plate, and the rear cam reduction gear is supported by bronze bushings in the rear main crankcase and blower case. The valve tappets and tappet guides are housed in the front and rear main crankcase.

Valve Timing Gears. The valves are operated by two single piece double track cams having external teeth. The front cam actuates the valves for the front row cylinders, and the rear cam actuates the valves for the rear row cylinders. In spline coupled type drive engines, the front cam is driven through the cam reduction gear by the reduction drive intermediate coupling. The rear cam is driven through the rear cam reduction gear by the crankshaft rear gear which is secured to the rear end of the crankshaft by cap screws.

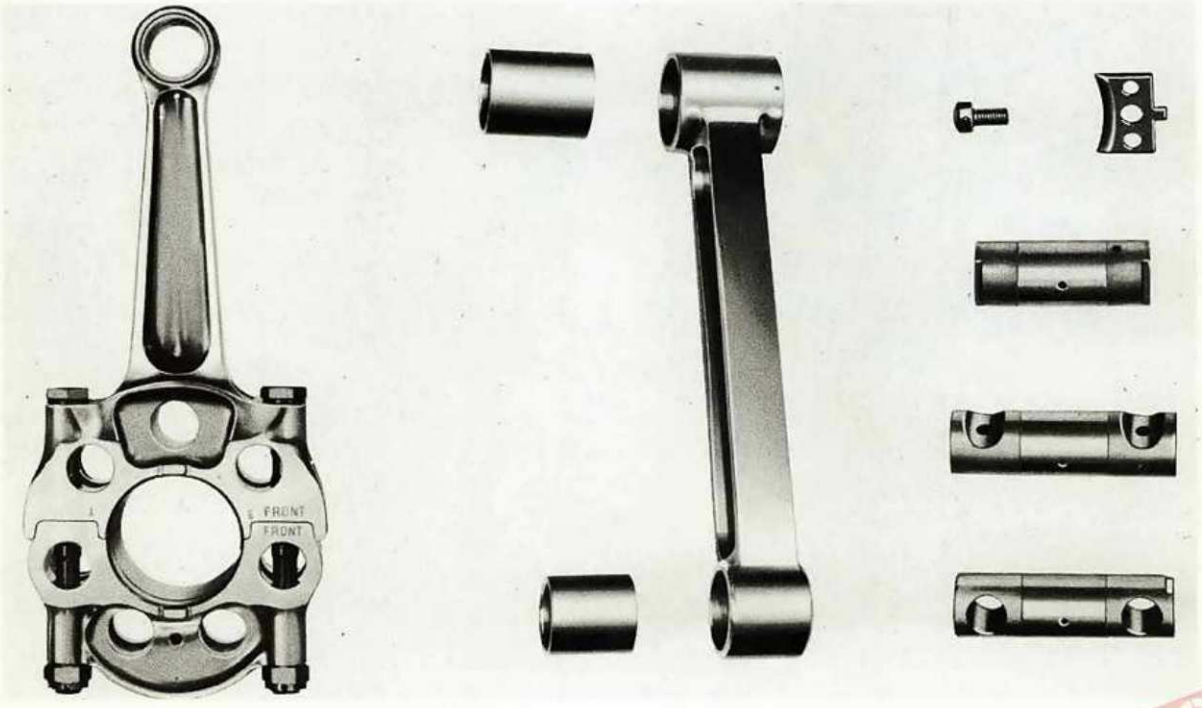
Crankshaft. The crankshaft has its main support in three roller bearings which are



Crankshaft

mounted in the front, center, and rear main crankcases. The weights of reciprocating and rotating parts connected to the crankpins are counterbalanced by weights secured to the cheeks of the crankshaft. A flyweight, incorporated in a steel liner in the rear counterweight, acts as a torsional vibration damper.

Master and Articulated Rods. The master rods are of the two piece type and are lo-



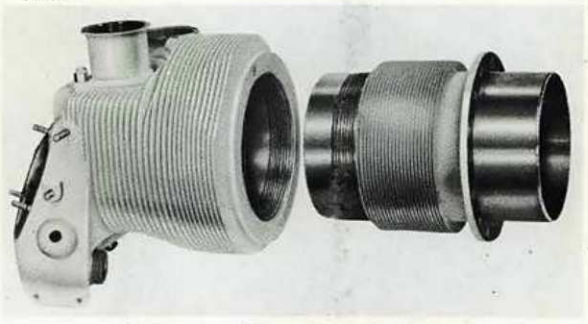
Master Rod and Cap, Articulated Rod, and Knuckle Pins

cated in cylinders No. 5 and No. 12. A steel backed, leaded silver master rod bearing is incorporated in the bore of the master rod which has a detachable cap that is held in place by four bolts. Silver plated steel shims are installed between the parting surfaces of the rod and cap to prevent galling. Six "I" section articulated rods are attached to the master rod assembly by knuckle pins. The cylinder end of each master and articulated rod is provided with a bronze bushing for the piston pin, and the opposite end of each articulated rod has a bronze bushing for the knuckle pin.

CYLINDERS

Cylinder Heads and Barrels. The cylinder barrels are steel and have integral cooling fins. The head is aluminum and has integral cooling fins and rocker boxes. The aluminum head is screwed and shrunk onto the cylinder barrel, thus forming a semi-permanent assembly. Each cylinder has one inlet and one exhaust valve. The inlet valve seats on a bronze insert and the exhaust valve on a steel insert, both of which are shrunk into the cylinder head. The cylinder also incorporates bronze inlet and exhaust valve guides, bushings for two spark plugs, and four steel bushings for supporting the two rocker shafts. Fins of extreme depth are concentrated on the top and exhaust side of the head and around the exhaust port where the greatest heat dissipation is required. Shallow fins are incorporated on the inlet side. The oil drain line between the exhaust and inlet rocker boxes is permanently installed on the front side of the head and supports the front of the inter-ear deflector. The inter-ear deflector incorporates a blast tube directing cooling air on the rear spark plug lead elbow. An integral cowl mounting lug is provided on each rocker box.

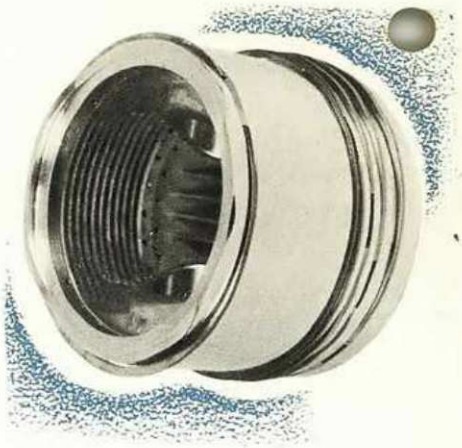
Valve Mechanism. All valve operating parts are enclosed. The rockers incorporate double row ball bearings. A valve clearance adjusting screw and lock nut are incorporated in each rocker. A steel insert in the adjusting screw is used as a contact between the adjusting screw and the valve stem to minimize friction at this point. The tappets actuate the rockers through tubular push rods having hardened steel ball ends which mate with hardened steel sockets in the tappets and the valve rockers. These rods are enclosed by removable covers which are held in place by a nut at each end. A cover is secured to each rocker box.



Cylinder Head and Barrel

Valve Mechanism

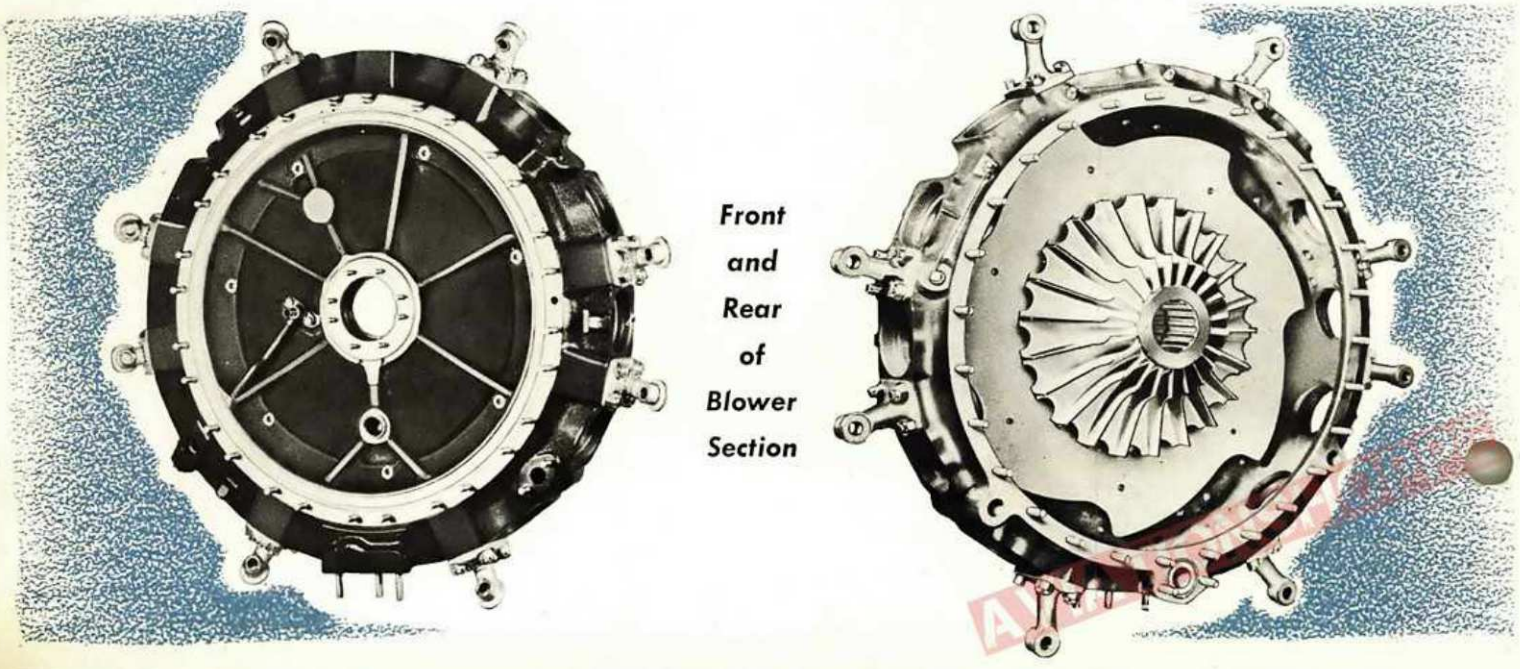
Two concentric valve springs are secured to each valve stem by a split cone and washer. Inlet and exhaust valve springs are interchangeable. The exhaust valve is hollow and is sodium cooled. A stellite face prolongs the life of the seating surface of the exhaust valve.



Pistons. The aluminum pistons are of the flat head type. Each piston has five ring grooves and is fitted with compression rings in the first three grooves, dual oil control rings in the fourth groove, and an oil scraper or plain compression ring in the bottom groove. The top compression ring is chromium plated on the face which bears against the cylinder wall. Steel piston pins link the pistons to the articulated rods.

BLOWER SECTION

Blower Case and Impeller. The blower case attaches to the rear of the main crankcase and supports the engine in the airplane. Engine mounting bracket pads on the outer circumference accommodate mounting brackets which are secured by studs and nuts. The rear of the rear cam reduction gear shaft is supported by a bronze bushing in the front face of this case. A steel liner in the center of the case accommodates oil seal rings which are held in a carrier at the front of the impeller shaft. The blower case houses the impeller, which is driven by intermediate drive gears at 7.15 times crankshaft speed. The impeller delivers the fuel and air mixture to 14 ports in the outside circumference of the case. Attached to each port is an intake pipe leading directly to its own cylinder.



Front and Rear of Blower Section

INTERMEDIATE REAR SECTION

Intermediate Rear Case and Diffuser. The intermediate rear case is attached to the rear of the blower case. It houses the impeller drive gear train and supports a vaned diffuser at its forward face. A flange at the top of the case provides a mounting surface for a down draft carburetor. Leading from the flange is a duct which carries the intake air to the impeller through a series of distributor vanes at its throat. An "X" bar type nozzle, attached to the carburetor adapter at the top of the intake duct, injects fuel into the air stream, and the mixture is carried from there to the impeller. A steel liner in the center rear face of the intermediate rear case accommodates the oil seal rings carried by a ring carrier on the rear of the impeller shaft. At the lowest point in the carburetor air duct, drain passages are drilled down to an automatic fuel drain valve that drains gasoline which may accumulate while the engine is being started.

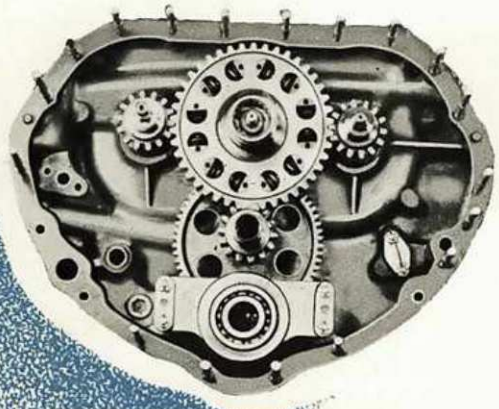
Long studs extend from the rear flange of the intermediate rear case to secure the rear case. Bronze bushings in the rear side of the intermediate rear case support the front ends of the two impeller intermediate drive gears, the generator intermediate drive gear, and the generator drive gear.

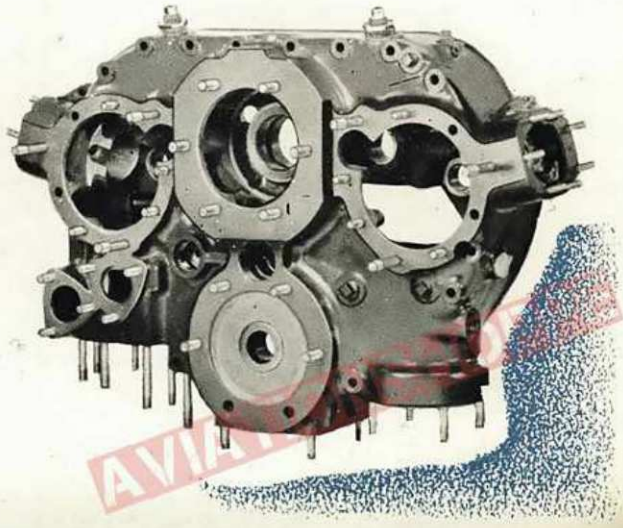
Impeller Shaft. The impeller shaft, to which the impeller is splined, is hollow and is supported at each end by a ball bearing. An integral spur gear on the rear end of the shaft meshes with and is driven by the impeller intermediate drive gears which are driven by the accessory drive gear.

REAR SECTION

Rear Case. The rear case incorporates bronze bushings which support the rear ends of the accessory, impeller intermediate, generator intermediate, and generator drive gears. A housing in each side of the rear case supports a tachometer intermediate drive gear which drives a tachometer drive gear and an auxiliary drive gear. Other bushings in the rear case support the vacuum pump drive gear and the front ends of the magneto drive gears. This case houses the rear oil pump and an oil pressure relief valve, and incorporates flanges for mounting a starter, generator, two magnetos, a vacuum pump, two tachometers, and two auxiliary accessories. With the exception of the generator and vacuum pump, all accessories are driven through two impeller intermediate drive pinions which are driven by the accessory drive gear. The two impeller intermediate drive pinions are splined to the impeller intermediate drive spider and drive the two impeller intermediate drive gears through spring couplings. The impeller intermediate drive gears, in turn, drive the impeller shaft.

Accessory Drive Shaft. This shaft extends through the blower and intermediate rear cases, passing through the impeller shaft.





Intermediate Rear and Rear Sections

It is supported at the front end by an adapter which splines into the crankshaft rear gear. The accessory drive gear is splined to the rear of the shaft. The hub of the drive gear is internally splined to accommodate the starter jaw which is secured to the shaft by a nut screwed onto a stud anchored in the rear of the shaft.

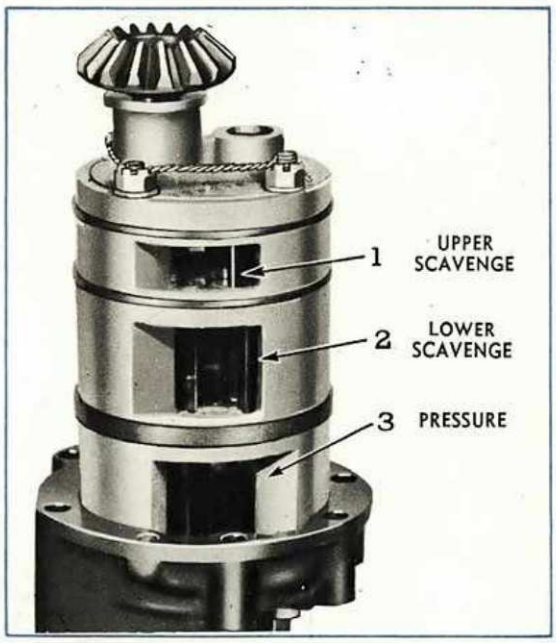
Generator Drive Gear and Vacuum Pump Drive Gear. The spur gear of the generator drive gear meshes with and is driven by the generator intermediate drive gear which is driven by the accessory drive gear. The vacuum pump drive gear is situated directly below the generator drive gear and meshes with the bevel gear of the generator drive gear.

Magneto Drive Gears. These gears drive the right and left magnetos. The spur gear of each gear meshes with and is driven by its respective pinion on the impeller intermediate drive shaft. The bevel gears mesh with and drive the two tachometer intermediate drive gears, one at either side of the rear case. The bevel gear of the left magneto drive gear also drives the rear oil pump drive gear which is equipped with a coupling for driving the fuel pump.

Auxiliary Drives. The tachometer intermediate drive gears are mounted in housings at the right and left sides of the rear case. Each of these gears incorporates an integral bevel gear, an integral spiral gear, and a spur gear. The spur gear is splined to the shaft and drives an auxiliary drive gear. The integral bevel gear meshes with and is driven by the corresponding magneto drive gear, while the integral spiral gear drives the corresponding tachometer drive gear.

Tachometer Drive Gears. Two of these gears are mounted in the rear case, and are driven by the spiral gears of the tachometer intermediate drive gears.

Rear Oil Pump Drive Gear. This gear is supported by the oil pump body and cover. An integral bevel drive gear and three spur type pumping gears are incorporated on the shaft. The three pumping gears, located in their respective sections of the oil pump body, are secured to the shaft by keys. The lower end of the shaft is designed to accommodate a coupling for driving the fuel pump which is mounted on the bottom of the oil pump. The integral bevel gear on the oil pump drive shaft meshes with and is driven by the bevel gear on the left magneto drive gear.



Rear Oil Pump

LUBRICATION SYSTEM

(For complete illustrations of the engine's lubrication, see the charts on pages 72, 73, and 74.)

Oil is circulated through the engine by means of two oil pumps. The rear oil pump, located in the lower left side of the rear case, has one pressure section and two scavenging sections. The front oil pump, located in the lower rear of the reduction gear housing, has two scavenging sections.

Oil from the tank enters the engine rear section through an inlet port situated above the rear oil pump mounting pad, and is directed to the pressure section of the oil pump. After passing through the pressure section of the pump, the oil flows under pressure to the oil screen chamber via a cored passage in the rear case. The oil screen chamber, located at the lower right side of the rear case, contains an assembly comprised of two oil screens, one located within the other, and a check valve. Upon entering the oil screen chamber, the oil passes through the screen assembly and upward through the spring loaded check valve located at the top of the screen assembly. When the engine is not running, the check valve prevents oil in the tank from draining into the system of lubricating passages. A by-pass valve is provided in the outer wall of the oil screen chamber to allow oil to by-pass the screens in the event they become clogged, thus preventing any possibility that the oil flow through the engine will be impeded.

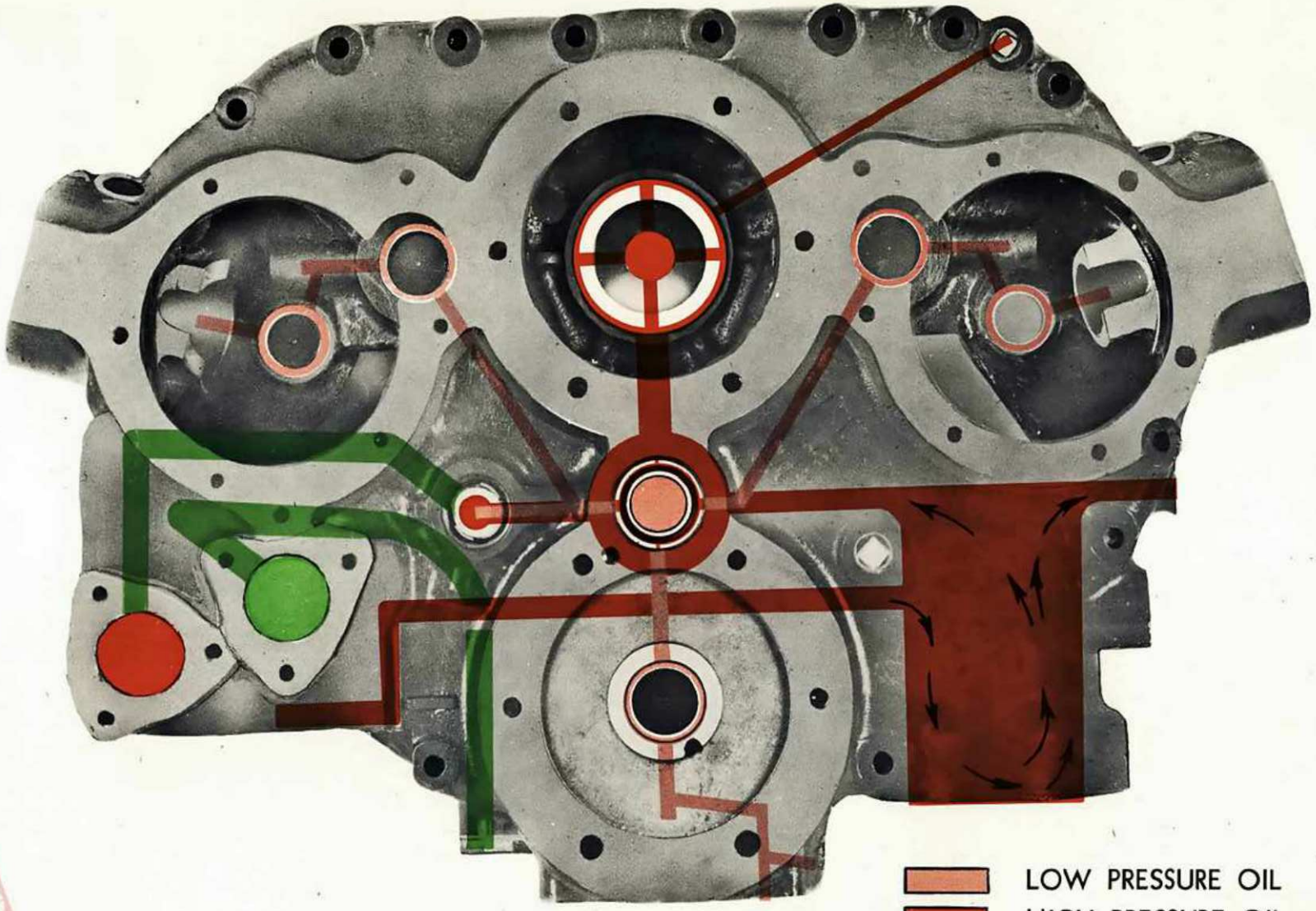
The oil from the screen chamber passes through the check valve and is diverted into two main branches. The flow of oil through each branch is described separately below.

First Branch. The oil leaves the oil screen chamber and is directed to an annulus which encircles the generator intermediate drive gear bushing. At this point, part of the oil is reduced to low pressure oil as it passes through metering holes in the generator intermediate drive gear bushing and shaft. These holes register as the shaft rotates in the bushing, thereby permitting the oil to enter the hollow shaft of the generator intermediate drive gear. This low pressure oil is then carried through drilled passages to the bushings and gears in the accessory section, and to the relief valve. This oil is also directed through drilled passages to the impeller shaft rear bearing.

The remaining pressure oil is diverted into two channels, one of which leads to the relief valve. The other channel directs pressure oil upward to an annular groove located between the two accessory drive gear bushings. From this point, a portion of the oil is directed to the upper right side of the rear case, where it may be utilized as a source of external pressure oil supply. The main quantity of oil is transferred from the annular groove through the inside of the accessory drive shaft to where it enters the rear end of the crankshaft. A series of drilled passages in the crankshaft directs the oil through both crankpins and thence to the master rod bearings. Each bearing is provided with holes which convey the pressure oil to an annular distributing groove in the master rod bore. This groove distributes the oil through a series of drilled passages in the master rod and knuckle pins to furnish lubrication to the knuckle pin bushings.

Spray lubrication is afforded the crankshaft bearings, the cylinder walls, and the piston pins by oil which is thrown from the master rod bearings and knuckle pin bushings. Additional lubrication is furnished to moving parts within the power section by oil which is discharged from two jets in the crankshaft. One jet is located in the rear cheek, just forward of the accessory drive shaft; the other is located on the crankshaft horizontal axis at the front side of the crankshaft center bearing web.

From the crankpins, the oil continues into the front end of the crankshaft, where it is transferred to the propeller shaft. With spline coupled reduction gearing a transfer pipe is provided to carry the oil from the crankshaft to the propeller shaft. Oil thus supplied to the interior of the propeller shaft is guided through the reduction drive pinion



Rear Section Oil Flow

shafts to lubricate the pinion bushings and ball bearings. The teeth of the propeller reduction gears are splash-lubricated by oil emitted from the pinion bushings and bearings. Oil is discharged from three jets in the propeller shaft to provide additional lubrication to the teeth of these gears.

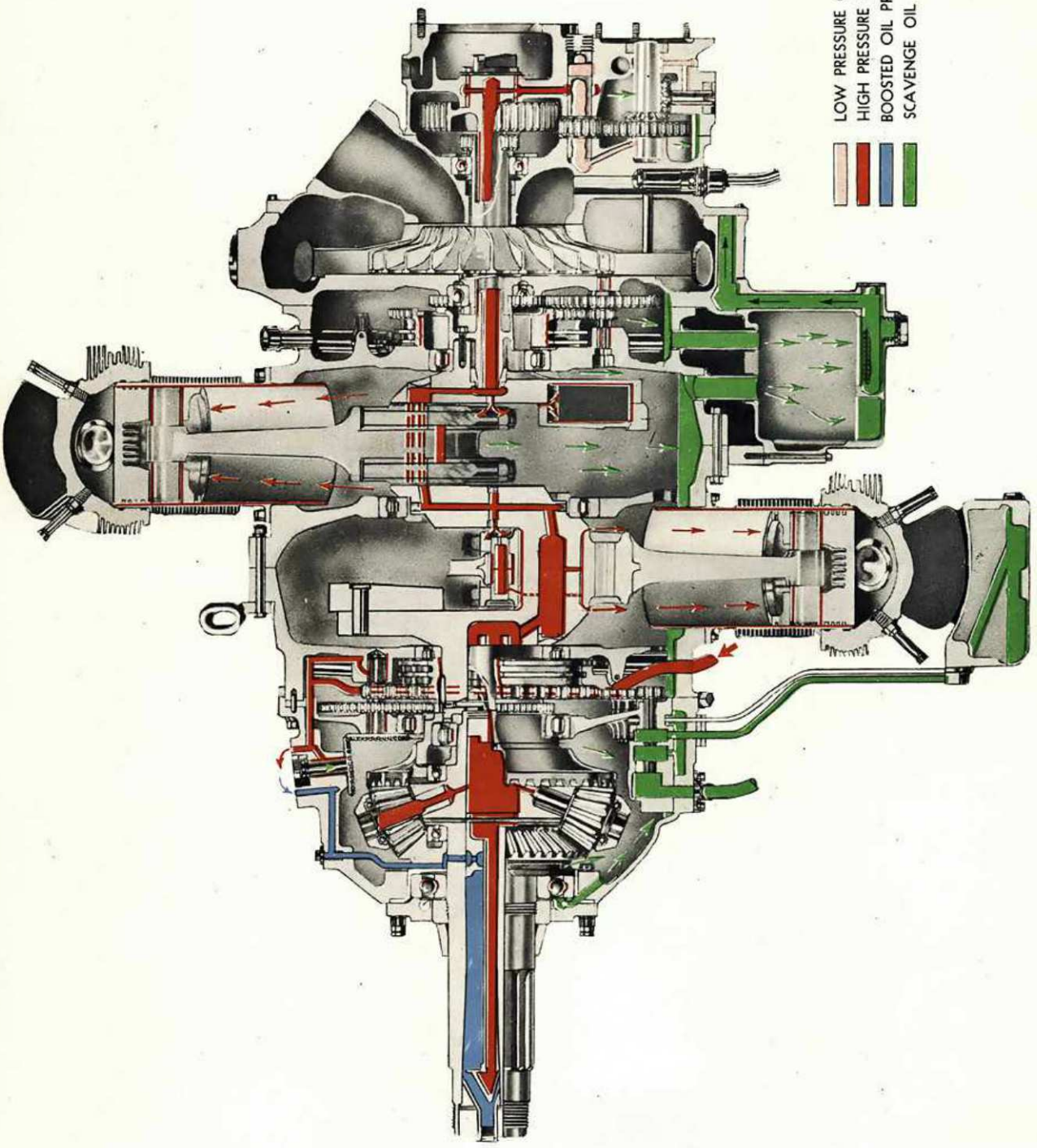
Second Branch. This branch extends through the right side of the accessory section and directs oil into the three principal routes.

In the first route, an oil pipe and bracket carry the oil from the front of the blower case to an opening in the rear cam bearing where the oil is transferred into a system of internal passages in the rear main crankcase. The internal passages are drilled through the rear tappet guide bosses and receive their supply of oil through a drilled hole in the circular boss which supports the rear cam bearing. A portion of the oil supplied to the internal passages is directed to the rim of the cam bearing boss where it is distributed to the rear cam bearing from an annular groove. The oil which flows through the internal passages of the tappet guide bosses is transferred into the hollow tappets via holes in the tappet guides. Oil thus admitted into the interior of the tappets is conducted through the tubular push rods and thence to the rocker boxes to lubricate the valve mechanisms in the rear row cylinders. An auxiliary oil channel conveys oil from the internal passages of the tappet guide bosses to the front end of the rear cam reduction gear. As the flow progresses through the hollow gear shaft, it lubricates both the front and rear bushings of this gear, and proceeds through drilled passages in the blower case to the impeller shaft front bearing.

In the second route, an external oil pipe carries the oil from the front face of the blower case to the lower part of the front main crankcase where an internal pipe transfers the oil to the upper part of the front main crankcase. At this point, the oil diverges into two auxiliary passages. One of these passages directs oil through the support plate to the propeller governor and the governor drive gear bushing. Oil from the governor passes through drilled passages and a pipe in the reduction gear housing and then enters the propeller shaft via an oil transfer ring carrier. This oil is kept separate from the other oil in the propeller shaft, and it may be used for operating a hydraulically controlled propeller. The other passage directs the oil to a series of internal passages in the front main crankcase. The internal passages lead the oil through the front tappet guide bosses and furnish lubrication to the front cam bearing and the bushings which support the front cam reduction gear. Oil within the front tappet guide bosses passes on to lubricate the valve operating mechanisms in the front row cylinders.

Scavenge System. Drain oil from the valve operating parts contained in the rocker boxes is collected in a small sump attached to No. 8 cylinder head. The oil reaches this sump through a series of external pipes which are connected to the rocker box covers. There is also provision for oil from the upper rocker boxes to drain into the main crankcase section through the push rod covers and holes in the tappet guides. This oil aids in lubricating parts at the front and rear of the main crankcase section.

Oil draining into the rocker box sump and the bottom of the front section is scavenged by the front oil pump. This pump, located in the reduction gear housing, incorporates two scavenging sections. One section removes oil as it drains into the bottom of the front section, and the other draws oil from the rocker box sump via an external pipe. Both sections of the pump force oil through an external pipe which extends from the bottom of the reduction gear housing to the forward left side of the blower case. The flow



Engine Oil Flow

of oil proceeds through passages in the accessory section and is discharged into an opening just ahead of the oil outlet port. A portion of the oil discharged from the pump serves to lubricate the front oil pump drive gear and the bushing which supports the intermediate drive gear.

Oil discharged from moving parts within the main crankcase and rear cam compartment drains through separate pipes to the main sump located between No. 7 and No. 9 cylinders. The drain oil which collects in this sump is scavenged by the middle section of the rear oil pump through an oil screen, a vertical pipe in the sump, and a series of passages in the accessory section, and is then delivered to the oil outlet port. Drain oil which accumulates in the bottom of the rear section is scavenged through an oil strainer and pipe and is delivered to the oil outlet port by the top section of the rear oil pump.

CARBURETOR

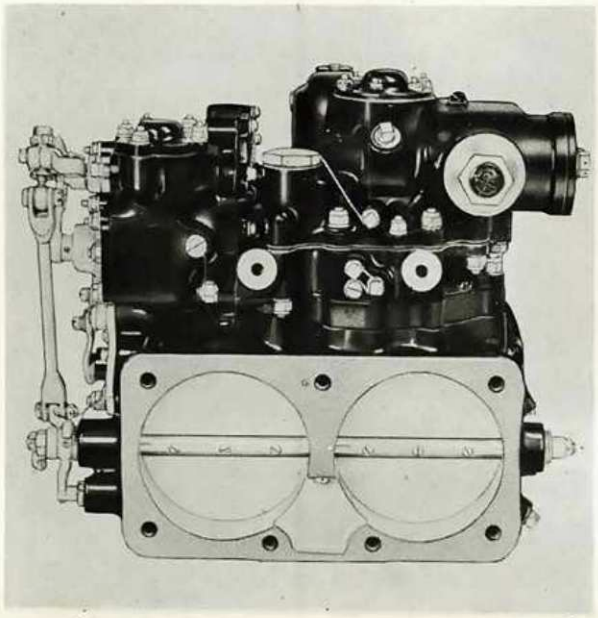
These engines are equipped with injection type carburetors. These carburetors meter fuel in proportion to the mass airflow to the engine. The mass airflow to the engine is determined by the throttle opening. After being metered by the carburetor, the fuel is discharged at the blower throat where it is taken up by the impeller, mixed with the air, vaporized, and then delivered to the cylinders through the intake pipes and inlet valves.

IGNITION

Ignition is furnished by two Scintilla magnetos located at the rear of the engine. The right magneto fires the front spark plug and the left magneto fires the rear spark plug in each cylinder, thus giving two independent sources of ignition. The ignition harness and spark plugs are of shielded types to prevent radio interference.

PROPELLERS

These engines are equipped to mount constant speed and full feathering propellers of the hydraulically controlled type. The reduction gear housing of the engine contains the oil passages for introducing the oil into the propeller shaft and connections to the propeller. The governor for constant speed operation is mounted on the top of the reduction gear housing. The addition of special propeller control parts at the thrust bearing cover readily adapts the engine for the use of mechanically or electrically operated variable pitch or constant speed propellers.



Carburetor

PREPARATION FOR SERVICE

Unpacking the Engine

All Pratt & Whitney Twin Wasp Engines are prepared for shipment in accordance with the most exacting packing and preservation procedures. Each engine is contained in a sealed, moisture-resistant envelope and is rigidly secured to the base of the packing case. During the removal of the protective envelope from the engine, the room temperature should be above 20°C (68°F) as the envelope tends to stiffen at lower temperatures, thereby becoming vulnerable to rupture.

CAUTION

When raising or lowering the packing case, use a chain hoist with a minimum capacity of 2 tons. Support the bottom of the case by passing a double sling underneath. Use the lifting rings on the cover only for lifting the cover from the case.

Loosen the turnbuckles, remove the metal straps and attach a sling to the lifting rings on the cover. Raise the cover carefully so that the carburetor and other accessories fastened inside will not be damaged. Lift the four sides out of the base. Unfasten the tape and cut off the sealed portion of the envelope. Unscrew the protector cap and spanner nut; then remove the protective envelope and spacer from the propeller shaft.

Unfasten the nuts holding the mounting plate to the support cone screw PWA-1333 Lifting Eye on the propeller shaft, attach a hoist, and raise the engine carefully out of the cone. Unfasten the mounting plate, and remove it from the engine. Carefully roll down the protective envelope. Remove, clean, and store it for future use.

Remove the paper from around the power section, remove the humidity indicator, and the bags of dehydrating agent.

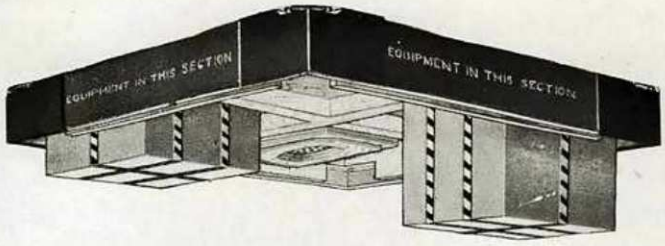
If the engine is to be installed in an airplane, remove the bent bolts from the rigid brackets and install the flexible mounting brackets. If the engine is to be placed in an engine stand, remove the bent bolt and rigid bracket assemblies from the blower case, install the rigid mounting brackets, carefully lower the engine into the engine stand and secure it to the mounting plate.

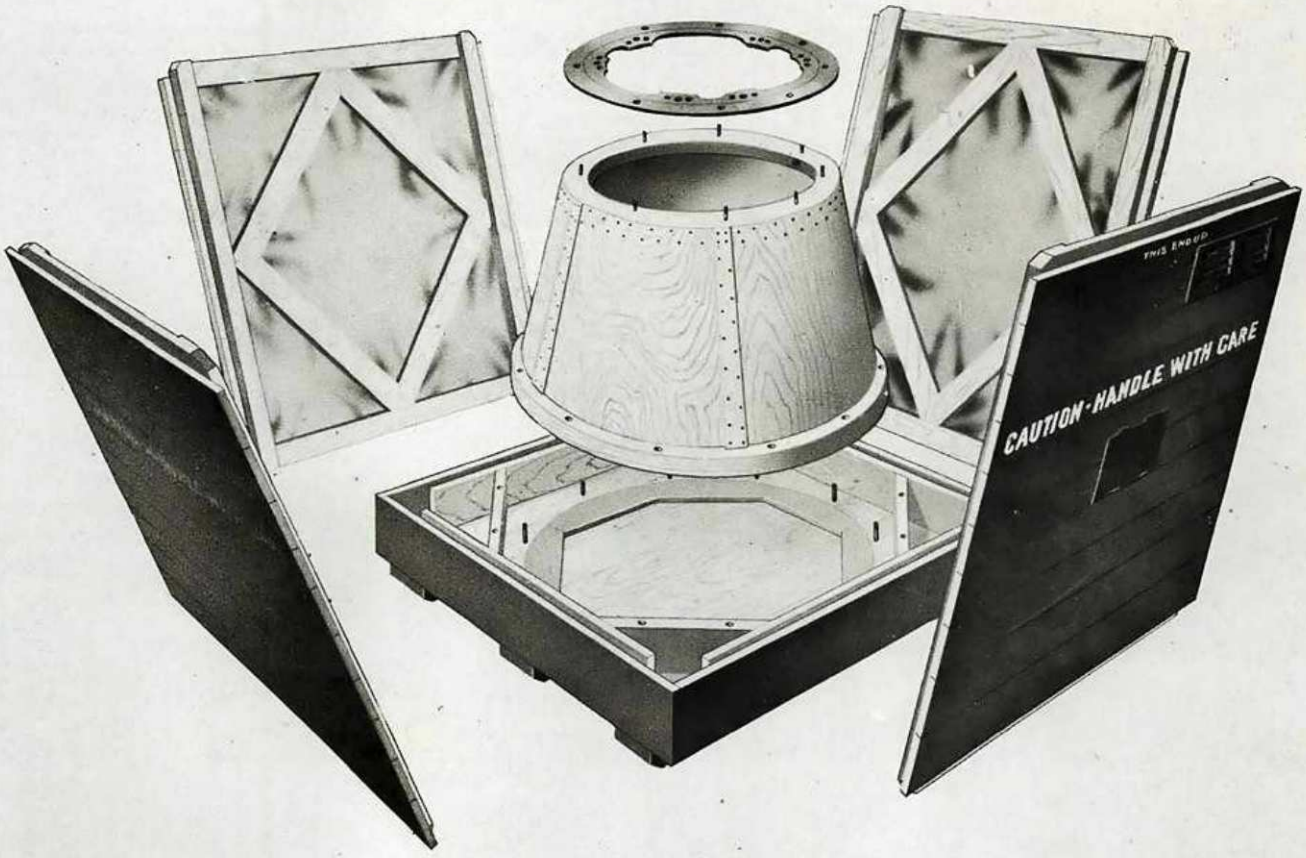
Cut the straps and remove the carburetor and accessory packing cartons from the packing case cover.

Drainage

After unpacking and prior to operation, the engine must be completely drained of all corrosion preventive mixture. Remove the moisture proof coverings from the breathers, exhaust ports, and other engine openings. Remove the dehydrator plugs from the cylinders, the sump, governor pad, and from the rear case. Remove the scavenge strainer, the main oil screen assembly, and the drain plug from the rocker box sump [1].

To facilitate the drainage of corrosion preventive mixture, rotate the propeller shaft several times in the normal direction





Engine Packing Case

of rotation. Using a small inspection light, inspect the inside of each cylinder through the spark plug hole to make sure excess mixture is not present. Remove any remaining mixture with a hand pump.

CAUTION

Prior to operation of the engine, determine that the lower cylinders and intake pipes are completely free of corrosion preventive mixture.

Cleaning of Parts

Remove the automatic fuel drain valve from the blower case and flush with unleaded gasoline. Check its operation, determining that the plate is not sticking and falls free of its seat when the upper valve assembly drops to its lowest position [2].

Wash the main oil screen and scavenge oil strainer thoroughly in unleaded gasoline. Install the screen and strainer [3]. Install the drain plugs in the main sump and rocker box sump.

Clean the spark plugs with a suitable solvent; dry and bomb test them. Apply a small amount of Champion No. 119 graphite anti-seize compound, or a 50-50 mixture of graphite and petrolatum, to the first two or three threads of each plug [4]. Install the spark plugs with PWA-3168 Wrench to a torque of 300 to 360 inch-pounds.

CAUTION

Because of high electrical conductivity, graphite compounds must be handled carefully. Traces of the compound on terminal sleeves or electrodes will result in flash-over or shorting.

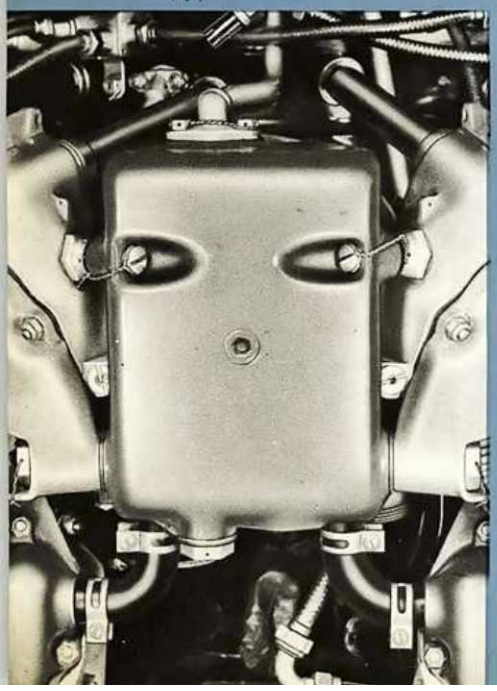
Make certain that the insides of the spark plug barrels are clean and dry. Using a brush, apply a thin coating of Dow Corning No. 4 compound to the spark plug lead terminal sleeve.

CAUTION

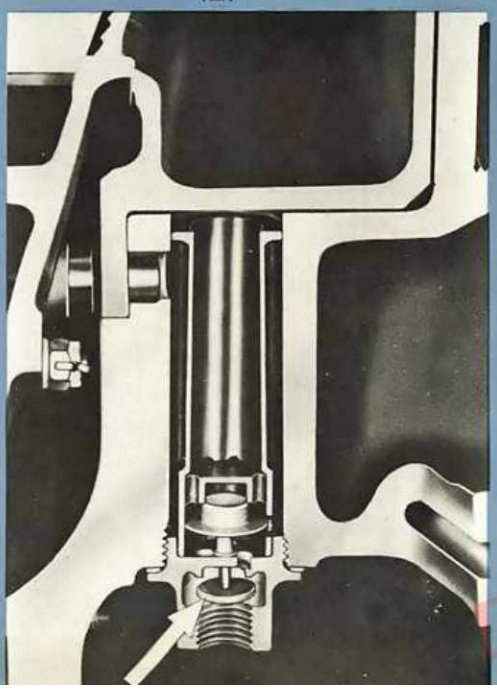
Do not apply the compound with fingers, because any moisture from the hands tends to make the compound inefficient.

Carefully insert each connector into its spark plug barrel. Before tightening the nuts, remove any compound which may have been deposited on the threads of the spark plug barrels [5]. Tighten the spark plug lead nuts finger tight and then a half turn more with PWA-1683 Wrench.

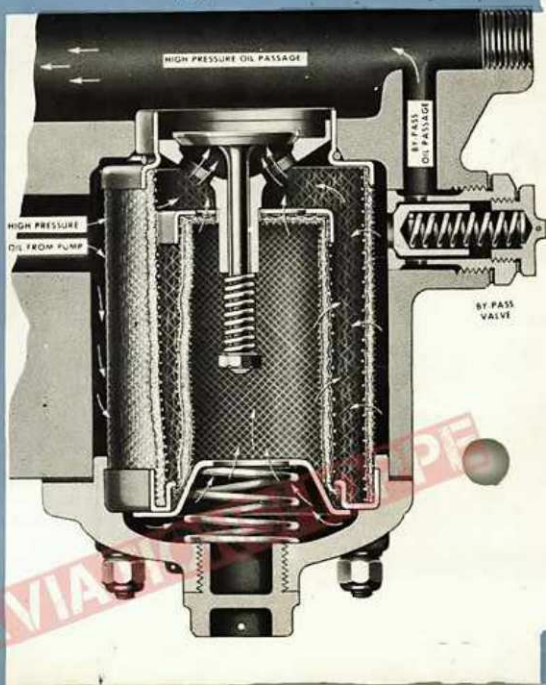
(1)

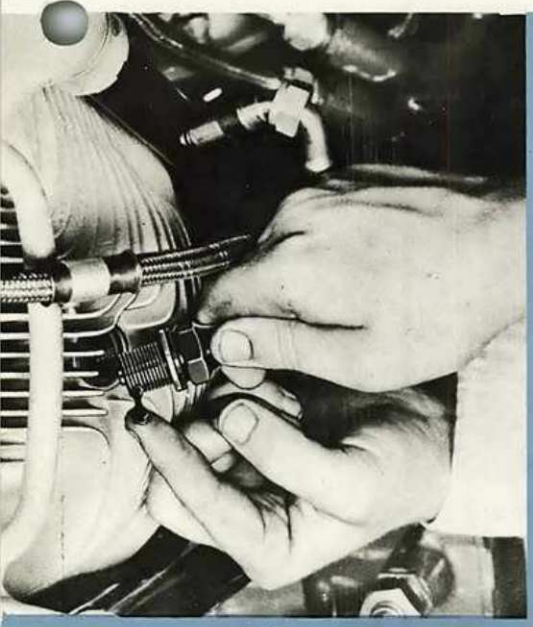


(2)



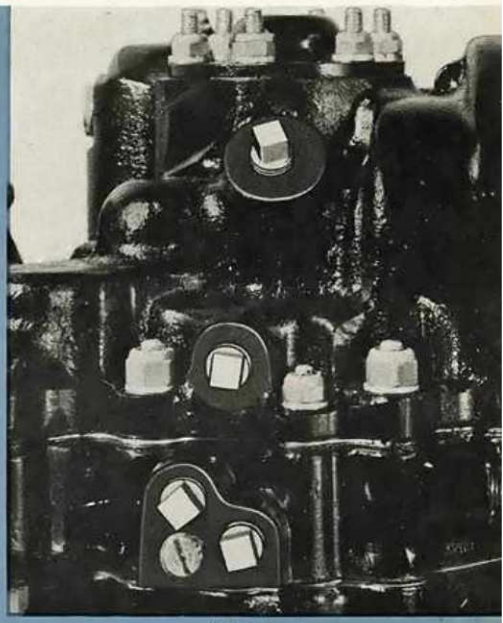
(3)





(4)

(5)



(6)

Flush the carburetor through the fuel inlet opening with clean unleaded gasoline or naphtha and allow the cleaning fluid to drain from the carburetor **[6]**. Repeat this operation until the storage oil has been completely washed out. Fill the carburetor with fuel and allow it to stand at least eight hours before draining it, to insure flexibility of the diaphragms.

Installation of Engine

Raise the engine carefully by means of a chain hoist and guide the engine and mount into position in the airplane. Bolt the engine mount to the airplane. Attach all fuel, oil, and control lines to their connections. For specific instructions, refer to the Airplane Manufacturer's Handbook.

Installation of Propeller

Complete instructions for the installation of the propeller are given in the service manual issued by the manufacturer of the propeller and should be referred to before the propeller is installed.

GROUND CHECKS

Pratt & Whitney Engines are given thorough run-in tests for several hours before they leave the factory. In spite of the extended running to which the new engine has been subjected, the engine will benefit from careful treatment during its first hours of service. For complete information, refer to the specific operating instructions on the S1C3-G engines published by Pratt & Whitney Aircraft.

Preliminary Starting Information

For the first start after installation, filling of the carburetor will be facilitated by temporary removal of the fuel discharge nozzle pressure gage connection plug. With the mixture control in auto rich, pump fuel at 2 or 3 pounds pressure until fuel appears at the plug hole. Install and rewire the plug.

The run-in should be made with no cowling over the engine accessory compartments to permit inspection of installation details and their operation. The main engine cowling should be in place, however, with cowl flaps open to insure proper cooling of the cylinders.

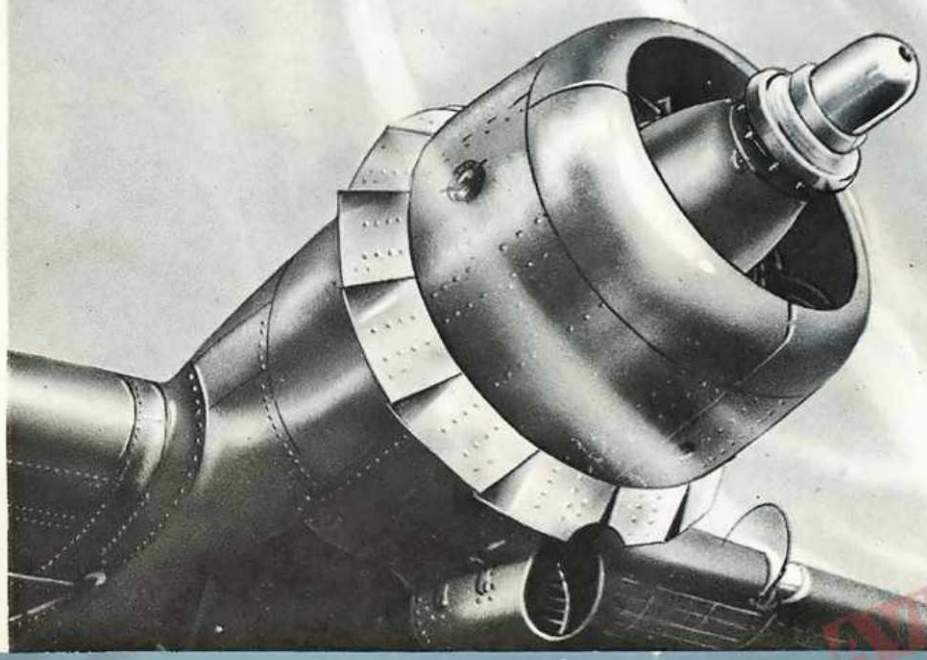
Engine Starting Instructions

Before starting the engine, consult the Airplane Manufacturer's Handbook for the starting sequence and for specific ground operating procedures. The following sequence of operations may then be followed.

Control Position Check

Ignition ..... Off
Mixture ..... Idle Cut-off
Propeller ..... High rpm (low pitch)
Carburetor Heat ..... Cold (Off)
Filtered Air ..... Unfiltered (Off)
Cowl Flaps ..... Full Open
Oil Cooler Shutters
Closed (or Automatic)

Throttle
1/10 to ¼ Open (to give 800-1000 rpm after engine starts)



1. Note the manifold pressure at zero rpm as a reference for the power and magneto checks.
2. Pull the propeller through 4 or 5 revolutions. Always pull the propeller through in the direction of engine rotation. Do not back up the propeller as this may force fluid through the intake valves and allow for the possibility of fluid lock when the engine is started.
3. Turn the fuel supply on.
4. Turn the auxiliary fuel pump on.
5. Open primer switch for 2 seconds. (This is to fill primer lines, and is not a priming operation.)
6. Energize the starter (if inertia type).
7. Turn ignition switch to "Both On."
8. Engage starter.
9. Simultaneously close primer switch.
10. When the engine fires, immediately move the mixture control to the auto rich position.
11. After the engine starts, adjust the throttle to obtain 600 to 800 rpm and watch for a rise in oil pressure.

CAUTION

If oil pressure does not register on the gage almost immediately, STOP the engine and investigate.

12. When oil pressure is indicated, readjust the throttle to obtain 1000 rpm.
13. If the engine does not fire almost immediately, continue cranking and move mixture control to auto rich for not more than 3 seconds.
14. Return mixture control to idle cut-off for at least 5 seconds (unless the engine fires meanwhile).
15 If necessary, repeat steps 13 and 14 above, one to three times.

Note: If a start is not effected within a reasonable time, an investigation should be made to ascertain the cause.

Warm-Up Control Position Check

Mixture	Auto Rich
Propeller	High rpm
Carburetor Heat	As needed
Filtered Air	As needed
Cowl Flaps	Full Open
Oil Cooler Shutters	Closed
Throttle	1000 rpm

Ignition Safety Check

At approximately 1000 rpm, turn the ignition switch from Both to Right and back to Both. Switch from Both to Left and back to Both. Switch to Off momentarily and back to Both. A slight drop-off in rpm on separate magneto operation, and complete cutting out of the engine at Off position indicates proper connection of ignition leads. This operation may be performed during engine warm-up.

The following tests must be made with minimum oil-in temperature of 100°F (approx. 40°C) and carburetor heat in cold position.

Propeller Governor Check

Check propeller governor according to manufacturer's recommendations.

Magneto Check

With the propeller in low pitch (high rpm) position and the mixture control in auto rich, operate the engine on both magnetos using a manifold pressure equal to the field barometric pressure (indicated by the manifold pressure gage before the engine is started). Switch from operation on Both to Left and note the drop-off in rpm. The normal drop-off is 50 to 75 rpm and should not exceed 100 rpm. Switch back and operate on Both to clear the plugs which have been inoperative. Now switch to Right and observe drop-off. Switch back to Both. The difference between operation on L and R should not exceed 30 to 40 rpm. If the drop-off is excess, the ignition system must be checked and the cause for the excess determined.

Cockpit Check for Fuel Leakage

It is suggested that the following check for leakage of the fuel system be made during the daily engine check. The check is made from the cockpit and is based on the principle of trapping fuel under pressure between the fuel selector valve and the carburetor vapor vent valve.

With the ignition switch off and the carburetor mixture control in idle cut-off,

(a) open the fuel selector valve,

(b) start the booster pump,

(c) when the fuel pressure gage indicates that the fuel pressure is stabilized, close the fuel selector valve,

(d) stop the booster pump.

If the fuel pressure again stabilizes at a point higher than zero, the portion of the fuel system between the fuel selector valve and the carburetor vapor vent valve is tight.

If the pressure drops rapidly to zero when the pump is turned off, the system is not tight and the usual checks should be made, starting with the vapor vent valve.

Power Output Check

With the mixture control in auto rich, propeller in low pitch, check manifold pressure and rpm relationship. Open the throttle until the manifold pressure is equal to the field barometric pressure (indicated by the manifold pressure gage reading before the engine is started). The rpm obtained will be 2000 to 2200 rpm, depending on the low pitch setting of the propeller. When the rpm is once established for the installation, variation in altitude of various fields will not change this rpm when the throttle is opened to the manifold pressure equal to the field barometric pressure. If the approximate check rpm cannot be secured when the throttle is opened to the proper manifold pressure, the engine is not delivering the proper power and an investigation should be made to determine the cause for the improper engine functioning.

Instrument Readings

Check oil pressure, oil temperature, fuel pressure and other items at 2000 rpm, propeller in low pitch (high rpm.)

Cylinder Head Temperature

Do not exceed 450°F (232°C) cylinder head temperature during ground operation.

Oil Pressure Limits	**Psi**
Desired at 2000 rpm at 140°F	85 ± 5
Minimum at 2550 rpm at 200°F	80
Minimum at 2230 rpm at 185°F	65
Minimum at 1200 rpm at 185°F	45
Minimum Idle	15

Fuel Pressure Limits

14 to 16 pounds per square inch.

Carburetor Idling Mixture Strength Check (450 to 500 rpm)

While observing the tachometer, place the mixture control in idle cut-off. Return the mixture control to auto rich before the engine dies. If a momentary rise of not more than 20 rpm is observed before normal drop-off, the mixture strength is correct. If a greater rise in rpm is noted, the mixture is too rich. If no rise in rpm is noted, the mixture is too lean. This check should be made in relatively still air. A strong wind affects the propeller loading and the rpm change may be different from that noted above. Refer to page 46 for specific adjustment instructions.

Engine Equipment or Accessories Check

Consult the Airplane Manufacturer's Handbook for instructions.

PERIODIC INSPECTION

Service inspection and associated maintenance include periodic inspection, cleaning, lubricating, adjusting, and all maintenance work associated with the routine inspection of the engine.

When an engine is new or has just been overhauled, it should be given a thorough check no later than 30 hours after it has been installed in the airplane. In the following periodic inspection schedule, it is suggested that "A" represent a 50 hour inspection period, "B" 100 hour, "C" 200 hour, and "D" the midpoint period between overhauls. Experience and the type and condition of operation should establish an actual hourly inspection period breakdown similar to that given above, for each operator. Any periodic inspection should be performed each time the interval established for that inspection has elapsed.

PERIODIC INSPECTION SCHEDULE

NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
GENERAL							
Remove sufficient cowling to check engine section for leaks and failure.		✓					
Check engine ring cowling for security of attachment.		✓					Not excessively tight when engine is cold.
Check propeller governor for oil leaks.		✓					
Check engine section for oil throwing.		✓					

PERIODIC INSPECTION SCHEDULE

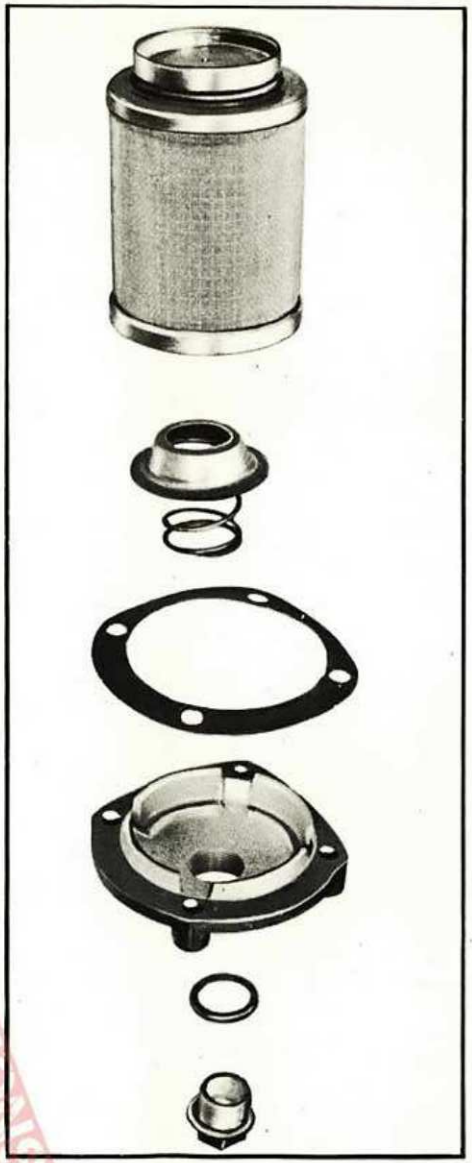
NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
Inspect breather screens and clean if necessary.		✓					
Check for loose nuts and broken safety wire.		✓					Frequently indicated by signs of oil or fuel leakage.
Inspect drain plugs and covers for proper safetying.			✓				
Check cowl flap operation and general condition.			✓				
Check deflectors for security and fin clearance.			✓				
Inspect cylinder for general condition.			✓				Refer to page 66.
Check cylinder studs and hold down nuts for tightness.			✓				Recommended torque: 350 inch-pounds for nuts.
Check push rod cover nuts for tightness and safetying.			✓				Recommended torque: 125 to 150 inch-pounds.
Check thermocouple leads and connections for tightness.			✓				
Check exhaust piping for cracks and signs of burning.			✓				Slipjoints should be free, and all connections tight.
Examine all engine control linkages; remove excess play. Oil points and bearings if necessary.			✓				

NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
Check accessory pumps for security of mounting.			✓				
Check clamps, bonding, rods, and lines.				✓			
Check mounting brackets for condition and security.					✓		
Check engine mount for cracks, tightness, and safetying.					✓		
Inspect fuel, oil and pressure gage lines for brittleness.							At engine change. Anneal copper or brass lines that are brittle.
LUBRICATION SYSTEM							
Remove and clean main oil screen				✓			Examine strainer, screen, and sump plugs for metal particles or other foreign matter. If metal chips are found, they may be an indication of trouble within the engine and further investigation should be made to discover their source. In a new installation, the oil system has not always been entirely cleaned of metal particles and it is not necessarily cause for alarm when particles appear. If nothing wrong can be discovered after foreign matter has been found in the strainer, screen, or plugs,
	CAUTION **The introduction of gasoline into the engine oil system tends to loosen carbon and sludge deposits within the system. This carbon and sludge may collect in the engine oil screen in sufficient quantity to cause the screen to collapse. Therefore, if gasoline is used to dilute the engine oil during cold weather operation, the engine oil screen must be removed for inspection and cleaning within an hour or two after the dilution is first used in the season. This inspection and cleaning must be repeated at short intervals until sludge and carbon no longer collect.**						
Remove and clean scavenge oil strainer.				✓			

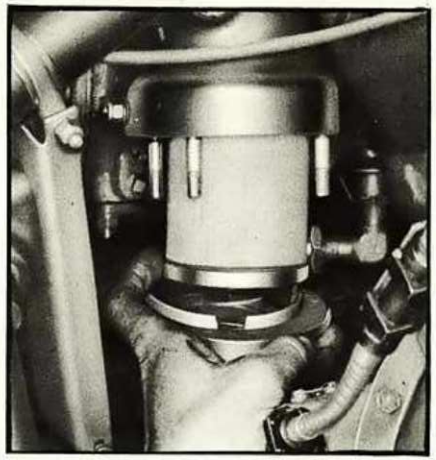
PERIODIC INSPECTION SCHEDULE

NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
Remove sump plug and examine cavity for metal particles.				✓			check these parts again after the engine has been given a ground test using new oil. If the quantity of metal chips found after a second ground test is sufficient to warrant removal of the engine, the oil tanks and lines should be thoroughly cleaned and the oil cooler replaced before installing a new engine.
Remove rocker box drain plug and inspect plug cavity for metal particles.				✓			
Inspect oil for sludge and carbon.				✓			The presence of carbon and sludge indicates the need for an oil change.
Inspect all oil lines and connections for leaks, dents, cracks, chafing, and security.				✓			
Inspect connections and clamps for general condition, location, and tightness.				✓			
Change oil.							The time between oil change should be determined by the type and conditions of operation to which the engine is subjected. When the oil tank has been refilled, turn over the propeller several times in order to prime the oil lines and oil pump.

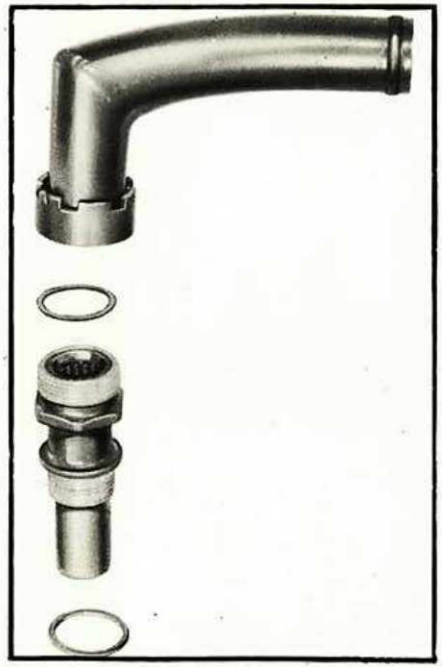
NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
IGNITION SYSTEM							
Remove spark plugs for general inspection.				✓			When using plugs of the approved type, operating conditions may establish a longer period before inspection.
Check ceramic insulation in spark plugs for chipping or cracks.				✓			Never disassemble a ceramic plug.
Clean spark plugs with unleaded gasoline or equivalent.				✓			
Check spark plug gap clearance.				✓			Gap = .012 in. (+ .002 in. — .001 inch.)
Give spark plugs bomb and leakage tests.							
Inspect ignition harness for loose connections, damaged spark plug leads, chafing, and security of mounting.				✓			
Check spark plug lead ceramic connectors, for presence of oil, dirt, cracks, or chips.				✓			Remove dirt and oil with a clean lint-free cloth. If necessary dampen with unleaded gasoline or Stoddard Solvent.
Inspect the induction vibrator terminals and cables for security and broken insulation. Check magneto mounting and ground wires for security.				✓			



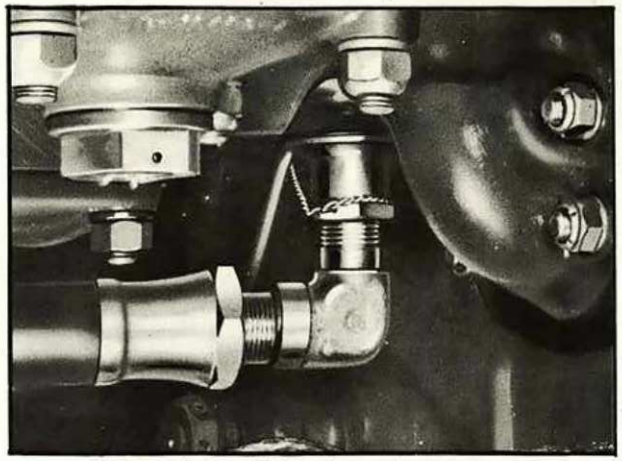
Main Oil Screen



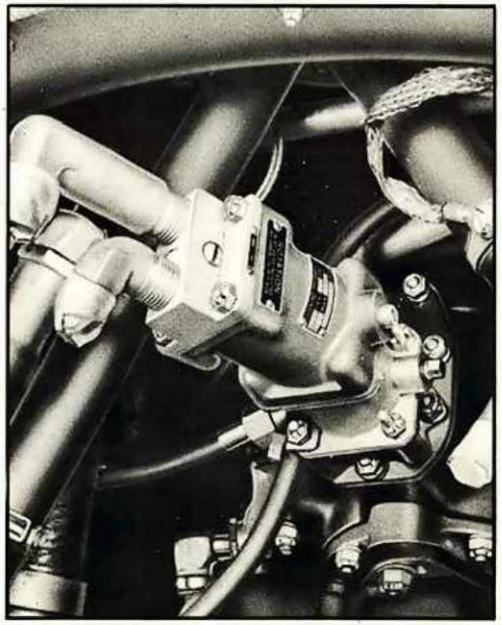
Removing Main Oil Screen



Main Crankcase Breather



Location of Fuel Drain Valve



Hydraulic Pump

NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
Clean threads on high tension leads, nuts, and coupling bushings, and terminal blocks.				✓			Use a lint-free clean cloth dampened with acetone or unleaded gasoline. Wipe with a dry, clean cloth. Allow sufficient time for traces of acetone to evaporate before replacing.
Check spark plug lead elbow nuts for tightness and security. Check starter, generator, and magnetos for security of mounting and for condition.				✓			Do not tighten excessively.
FUEL AND INDUCTION SYSTEM							
Drain fuel strainers and tank drains. Inspect for water and foreign matter.		✓					
Check operation of fuel drain valve.		✓					Using a piece of hose or the bare tube end itself, blow into the fuel drain line. If, after a few seconds of blowing, there is a sudden stoppage or restriction in the air passage, the fuel drain valve is operating. If the valve is stuck open, there will be no automatic closing of the valve, as indicated by the results of the above check. If the valve is stuck closed, pressure will be built up immediately in the drain line and prevent any fur-

PERIODIC INSPECTION SCHEDULE

NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
							ther blowing in the line. If the drain valve is stuck in either position, it should be removed and cleaned. Refer to page 20. The fuel booster pump should not be used to check the operation of the valve.
Check carburetor and fuel lines for leaks with pressure up.			✓				Fuel booster pump on.
Check fuel line supports and clamps for security, chafing, and looseness.			✓				
Check all fuel lines and connections for bends, cracks, leaks, and signs of abrasion or interference with other parts.			✓				
Inspect all shut-off cocks for leakage in open and closed positions.			✓				
Inspect throttle and mixture controls for tightness and safetying.			✓				
Check carburetor air screen. Clean if necessary.			✓				
Check fuel strainers. Check carburetor float chamber for air lock.			✓				Carburetor — Clean the fuel strainers and install in the strainer body. Replace plugs, drain valves, and covers and

NATURE OF INSPECTION	Preflight	Daily	A	B	C	D	REMARKS
							safety them. Disconnect the vapor vent return line at the carburetor and pump gasoline to the carburetor with the booster pump. Proper operation will be indicated by the outrush of air from the vent as the gasoline enters the float chamber and by the cessation of air flow when the floats are raised sufficiently.
Clean all screens and strainers.			✓				
Remove and clean the fuel drain valve. Check for free movement of plate.			✓				Refer to page 20
Check intake pipe nuts for tightness.			✓				Look for evidence of leakage at intake pipe nuts and seats. Excessive tightening of the nuts will tend to nick the pipes.

TROUBLE SHOOTING

This section outlines the most common symptoms of engine troubles, their possible causes, and remedies. It is intended to guide and expedite the work of the trouble shooter. Locating and correcting engine troubles should be accomplished by first studying the symptoms carefully and then checking each possible cause, beginning with the most probable, until the exact cause of the trouble is determined. Because some engine troubles are evident in only one range of engine speed, the engine's operation should be observed at low, medium, and high speeds, whenever possible.

Before attempting to work on an engine which has been reported as faulty in flight, consult the pilot's flight report and all other available sources for any pertinent information which might give a clue to the cause of the trouble.

TROUBLE SHOOTING TABLE

CAUSES	TROUBLES										REMEDIES
	Failure to Start	Rough Running	Low Power	Improper Idling	Improper Acceleration	High Oil Pressure	Low Oil Pressure	Oil Foaming	High Oil Temperature	Low Oil Temperature	
FUEL SYSTEM											
Insufficient or fluctuating fuel pressure.	✓	✓	✓								Check fuel gage to make sure fuel tanks are full. Check operation of engine fuel and booster pumps.
Fuel leaks.	✓	✓									Check fuel lines, connections, joints, and clamps for tightness.

CAUSES	TROUBLES										REMEDIES
	Failure to Start	Rough Running	Low Power	Improper Idling	Improper Acceleration	High Oil Pressure	Low Oil Pressure	Oil Foaming	High Oil Temperature	Low Oil Temperature	
Underpriming.	✓										Increase priming. Check fuel booster pump pressure. If prime is still insufficient, check for clogged lines and leaks in system.
Overpriming.	✓										With ignition off and carburetor mixture control in idle cut-off, open the throttle fully and rotate propeller several times. Repeat starting procedure, maintaining priming to minimum.
Defective priming solenoid valve.	✓	✓	✓								If prime fuel to cylinders is excessive, check priming solenoid valve for leakage and sticking. If prime fuel is insufficient, check booster pump. Repair or replace solenoid valve or pump if necessary.
Vapor in fuel system.	✓	✓									Operate booster pump, allowing vapor to vent from lines. Remove vent plug from carburetor, place mixture control in auto rich, and operate booster pump until fuel spurts from vent; then reinstall vent plug.
Excessive fuel pressure.		✓									Adjust fuel pump. Turn the adjustment screw to right to increase pressure, and to left to decrease pressure.
Incorrectly adjusted carburetor control linkage.		✓	✓								Adjust linkage so that movement of cockpit controls results in corresponding correct movement of throttle and mixture control levers.

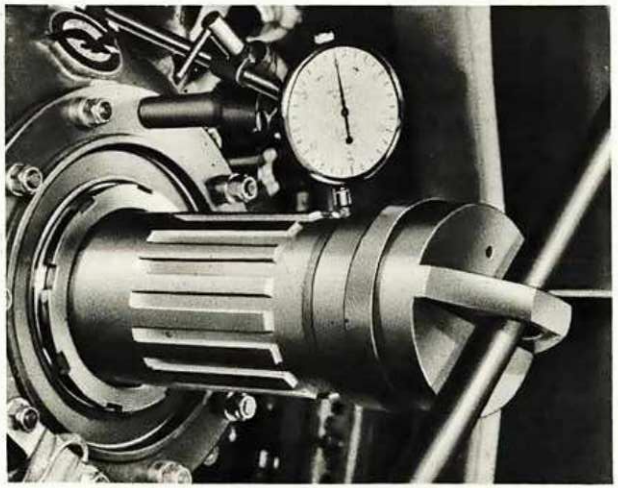
TROUBLE SHOOTING TABLE

CAUSES	TROUBLES										REMEDIES
	Failure to Start	Rough Running	Low Power	Improper Idling	Improper Acceleration	High Oil Pressure	Low Oil Pressure	Oil Foaming	High Oil Temperature	Low Oil Temperature	
Internal carburetor trouble.	✓	✓	✓	✓	✓						Replace carburetor.
Incorrect carburetor idle adjustment.				✓							Adjust carburetor idle mixture as described on page 46.
Improper grade of fuel.			✓		✓						Drain fuel system. Fill tanks with fuel Grade 91/96.
IGNITION SYSTEM											
Loose or defective spark plugs.	✓	✓	✓	✓							Tighten loose plugs to torque of 300 to 360 inch-pounds. Check for fouled plugs, plugs improperly gapped, or plugs having cracked insulation. Install reconditioned plugs.
Defective spark plug lead connectors.	✓	✓		✓							Clean dirty or oily connectors with a dry, clean cloth. If necessary, unleaded gasoline or Stoddard Solvent may be used. Replace cracked connectors.
Moisture or oil in magnetos.	✓	✓									Clean distributor terminal blocks, and distributor rotor with acetone or unleaded gasoline. Use lint-free cloths.
Defective ignition wires.	✓	✓		✓							To determine that an ignition wire is defective, apply continuity and high voltage tests. Replace wire where possible.
Internal magneto trouble.	✓	✓									Disconnect spark plug lead connector, turn engine over by starter and hold connector 1/4 to 3/8 inch from grounded surface. If there

CAUSES	TROUBLES										REMEDIES
	Failure to Start	Rough Running	Low Power	Improper Idling	Improper Acceleration	High Oil Pressure	Low Oil Pressure	Oil Foaming	High Oil Temperature	Low Oil Temperature	
											is no spark or if spark is weak, install new magneto.
Inoperative induction vibrator.	✓										If no buzzing sound is heard when starter engaging switch is on, replace vibrator.
Defective magneto timing.		✓	✓								Check the magneto timing.
LUBRICATION SYSTEM											
Inadequate oil supply.							✓		✓		Fill tank with oil.
Water or impurities in oil.							✓	✓	✓		Drain engine and oil system.
Excessive oil dilution.							✓	✓	✓		Drain oil from engine. Check oil dilution valve operation. If valve leaks check for dirt under valve seat and clean If seat is worn or misaligned, or if valve spring is broken, replace unit.
Clogged main oil screen.							✓		✓		Remove and clean screen.
Defective oil pressure relief valve.						✓	✓				Remove, clean, and inspect relief valve. If spring is defective, replace spring. When relief valve has once been set correctly, do not readjust to remedy variations in engine oil pressure.
Improper operation of oil cooler.									✓	✓	Check oil cooler shutter control operation. Check for obstructions in cooler. Replace cooler or control unit if necessary.
Obstructions or leaks in oil lines.							✓		✓		Check all oil lines and remove any obstructions.

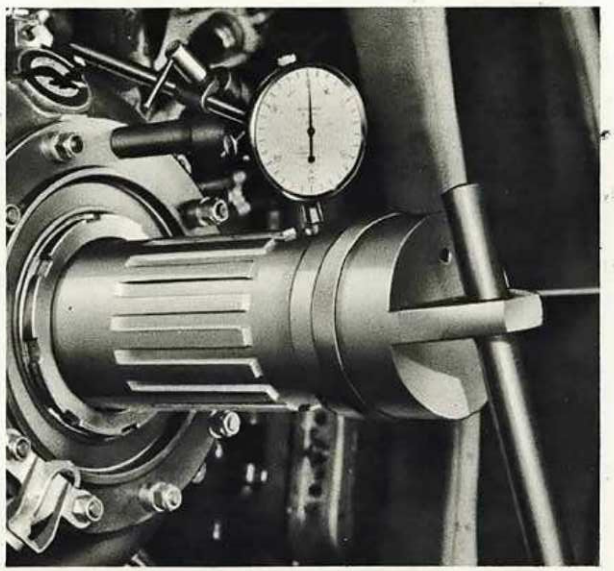
TROUBLE SHOOTING TABLE

CAUSES	TROUBLES										REMEDIES
	Failure to Start	Rough Running	Low Power	Improper Idling	Improper Acceleration	High Oil Pressure	Low Oil Pressure	Oil Foaming	High Oil Temperature	Low Oil Temperature	
PROPELLER											
Faulty operation of propeller or governor.		✓	✓								Refer to applicable technical publications.
Loose propeller retaining nut.		✓									Tighten nut.
Propeller not tracking evenly.		✓									Replace propeller.
Propeller out of balance.		✓									Replace propeller.
Excessive propeller shaft runout.		✓									Remove propeller from engine. Remove a spark plug from each cylinder and install a PWA-3252 Vent Plug in its place. Install a dial indicator on a convenient thrust bearing cover stud so that indicator plunger rests on rear cone seat. Install PWA-1333 Eye on propeller shaft; then place a bar through eye and turn propeller shaft in normal direction of rotation. The runout on rear cone should not exceed .005 inch full indicator reading. Readjust dial indicator and check runout on front cone seat. The runout on front cone seat should not exceed .015 inch full indicator reading. If propeller shaft runout exceeds these limits, withdraw engine from service until a new shaft is installed.



Checking Propeller Shaft Runout

CAUSES	TROUBLES										REMEDIES
	Failure to Start	Rough Running	Low Power	Improper Idling	Improper Acceleration	High Oil Pressure	Low Oil Pressure	Oil Foaming	High Oil Temperature	Low Oil Temperature	
Excessive propeller shaft radial clearance.		✓									Remove propeller from engine. Install a dial indicator on a convenient thrust bearing cover nut and set the dial on the front cone seat 7 inches forward of the thrust bearing cover plate. Lift the propeller shaft up and read the dial. Repeat this movement several times and take the readings. The amount of radial movement permitted is not to exceed .030 inch. If it is more, the front section should be removed and the radial play restored to a lesser value by replacing parts in the assembly which show the greatest wear. If it is noticed that the outer race of either of propeller shaft rear bearings has shown a tendency to spin, it is recommended that the support plate liner or the front reduction drive coupling be replaced. If another front coupling is not readily obtainable, it may be desirable to copper plate the recess which accommodates the bearing. The plating should not exceed .001 inch thickness.
INDUCTION SYSTEM											
Restrictions or leaks.	✓	✓	✓	✓							Remove air scoop from carburetor. Check air screen for foreign matter. Make sure that air scoop is clean. Check security of carburetor



Checking Propeller Shaft Radial Looseness

TROUBLE SHOOTING TABLE

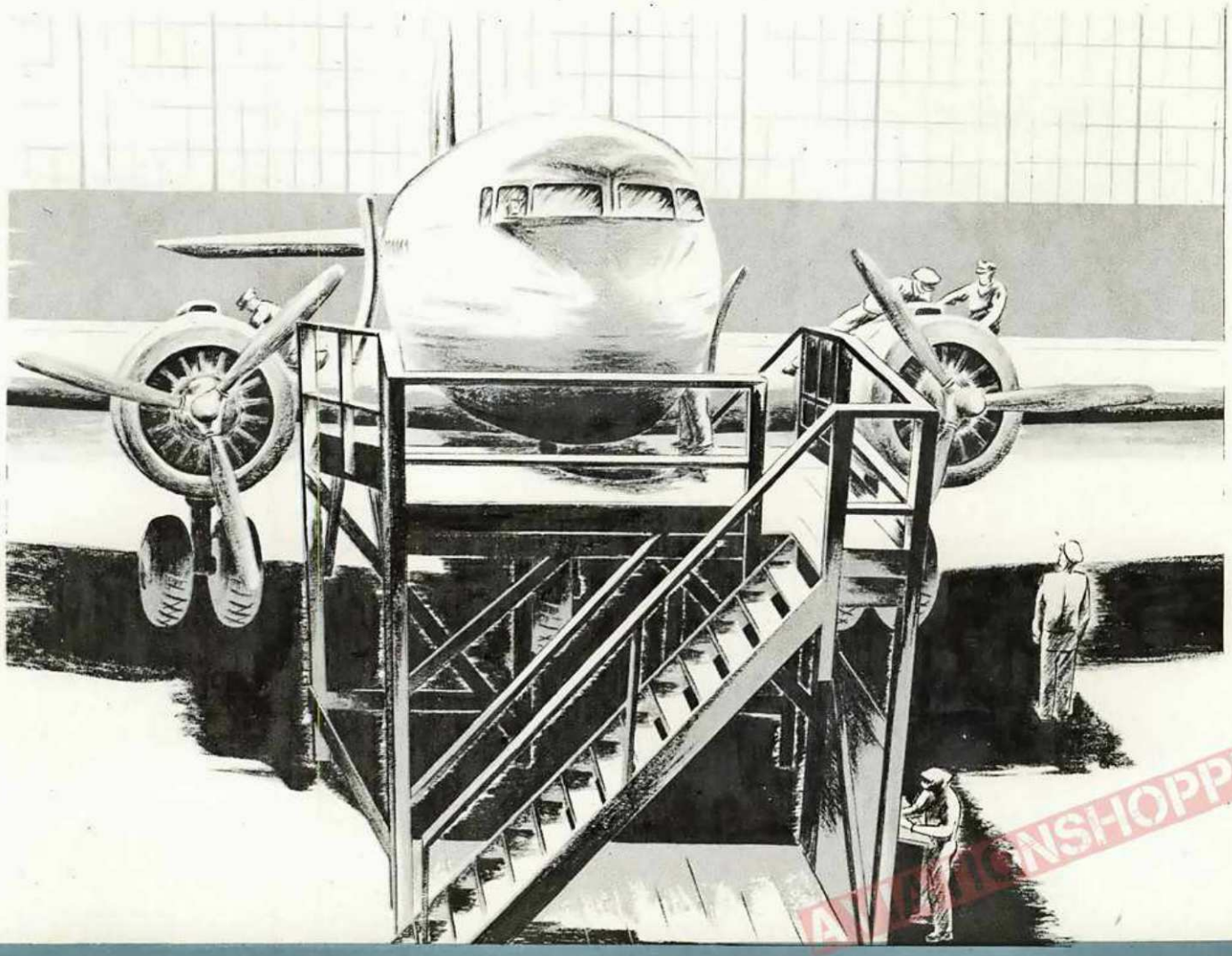
CAUSES	TROUBLES										REMEDIES
	Failure to Start	Rough Running	Low Power	Improper Idling	Improper Acceleration	High Oil Pressure	Low Oil Pressure	Oil Foaming	High Oil Temperature	Low Oil Temperature	
											on engine and see that all intake nuts are tight. Check intake pipes for cracks.
Improper valve clearances.		✓	✓	✓	✓						Adjust valve clearances.
Sticking valves.	✓	✓		✓	✓						Lubricate sticking valves. Replace cylinder if necessary.
Broken valve springs.		✓	✓		✓						Install new springs.
MISCELLANEOUS											
Loose air ducts.		✓									Check all air duct connections and supports. Tighten where necessary.
Loose exhaust manifolds.		✓									Check the exhaust manifolds and tighten loose nuts.
Loose cowling supports.		✓									Check all cowling supports.
Insufficient cranking speed.	✓										Check for weak batteries and condition of starter.
Loose or broken engine mounting brackets.		✓									Check all core stem nuts and engine mount ring nuts to see that they are tightened to correct torque. Replace broken bracket assemblies. Recommended torque for core stem nuts; 300 to 800 inch-pounds; for engine mount ring nuts: 400 to 800 inch-pounds.
Loose thrust nut.		✓									Tighten thrust nut.
Improper starting procedure.	✓										Warm up engine thoroughly before permitting it to idle.

LINE MAINTENANCE

Pratt & Whitney engines give dependable and maximum performance provided, they are properly serviced, periodically inspected, and overhauled at regular intervals. Between periods of overhaul, the replacement of valves, pistons, cylinders, or ignition system is not recommended except in cases of emergency.

Should internal engine trouble be indicated at any time, remove the scavenge oil strainer and the main oil screen allowing the oil to drain through a clean cloth into a suitable receptacle. Inspect the cloth, plugs, and screen for foreign material, such as metal chips. A careful examination of this material may offer a clue for the course of further investigation.

If, for some reason, it is necessary to adjust the valve clearances, retime and synchronize the magnetos, or to remove a cylinder prior to the time of engine overhaul, the following pages describe the correct procedure.



CHECKS AND ADJUSTMENTS

The magnetos seldom need attention between overhauls. Under normal conditions the wear or burning of the breaker points offsets the wear of the fiber cam follower, and the spark timing tends to remain approximately at its original setting. However, a faulty condenser or the presence of oil, grease, or cleaning fluid on the breaker points may cause excessive burning of the points, or lack of lubrication may lead to excessive wear of the cam follower. If the wear at one of these locations exceeds the wear at the other, a change in spark timing results. If the points require attention beyond cleaning or adjustment, replace the breaker assembly with a new or reconditioned unit.

CLEANING BREAKER POINTS

Remove the two breaker compartment cover screws and remove the cover. Do not disturb the breaker points unless they are oily, dirty, badly pitted, or require adjustment. Remove the breaker assembly by removing the locking screws, and clean the points with acetone or any other suitable cleaning fluid. Replace badly pitted points with a new or reconditioned breaker assembly. Install the breaker assembly in the magneto.

CAUTION

When inspecting the breaker points, do not raise the breaker main spring beyond a point giving 1/16 inch clearance between the contact points. Any further tension on the main spring caused by raising it beyond this point will weaken it, thereby causing unsatisfactory magneto performance.

ADJUSTING BREAKER POINTS

Do not disturb the adjustment of the breaker points unless the following check indicates the necessity. Connect PWA-2417 Timing Indicator, or equivalent, to the ground lead of the magneto and connect the ground lead of the indicator to the engine. Turn the propeller very slowly in the normal direction of rotation until the lobe of the breaker cam which is marked with a dot is adjacent to the cam follower and until the timing light just flashes on. At this point, place PWA-2446 Straightedge against the step of the cam or timing collar. It should line up with the timing marks on the housing. If the straightedge is more than 1/32 inch out of alignment, the breaker points are improperly timed and should be adjusted.

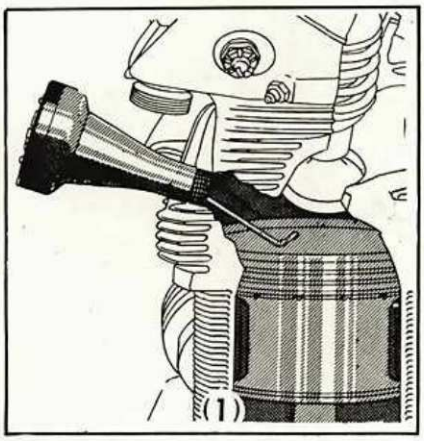
With the timing indicator still connected and the straightedge still in position, turn the propeller in the normal direction of rotation until the straightedge is in exact alignment with the timing marks on the housing. Being careful to keep the straightedge in exact alignment, loosen the adjustment locking screws and adjust the breaker points by means of the eccentric screw until the timing light flashes on, indicating the points are just starting to open. Lock the points in this position by tightening the adjustment locking screws. After the adjustment has been made, check it as described above.

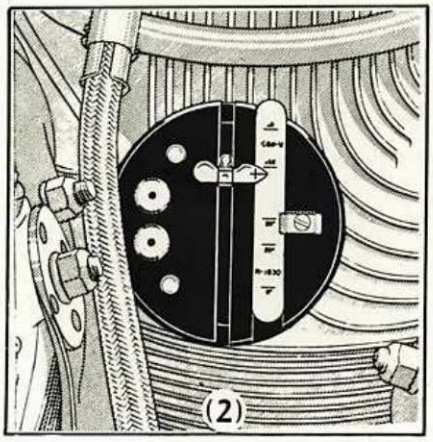
TIMING AND SYNCHRONIZING MAGNETOS

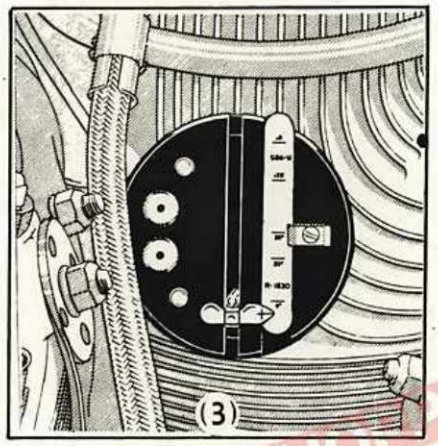
To determine whether the magnetos are properly timed to the engine and synchronized with each other, the following check should be made Turn the propeller in the normal direction of rotation until No. 1 piston is at top center of its compression stroke. Attach PWA-2420 Magneto Timing Template or a similar type of template to two convenient thrust bearing cover studs on the front case. Install a timing pointer, which may be improvised by fastening a piece of stiff wire securely to the propeller shaft or propeller hub, lining it up with the top center mark on the template. Turn the propeller about 90 degrees opposite the normal direction of rotation; then connect PWA-2417 Timing Indicator, or equivalent, to each magneto and connect the ground lead of the indicator to the engine. Turn the propeller very slowly in the normal direction of rotation until the timing pointer comes into alignment with the proper spark advance mark on the template, and note when the lights of the indicator just flash on. If the lights flash on simultaneously just as the pointer comes into alignment with the proper. spark advance mark, the magnetos are properly timed and synchronized; otherwise, an adjustment will be necessary.

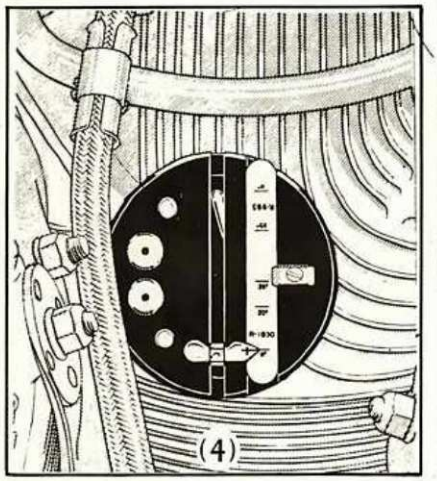
Loosen the nuts which secure the magnetos to the engine so that an adjustment may be made by turning the magneto through the range allowed by the slots in the flange. Turning the magneto counterclockwise as viewed from the rear will cause the points to open later, and turning it clockwise will cause the points to open sooner. Adjust either one of the magnetos so that the corresponding light of the ndicator just flashes on when the timing pointer comes into alignment with the proper spark advance mark on the template; then adjust the other magneto so that both lights of the indicator will flash on at the same instant. Secure the magnetos to the engine, taking care not to disturb the timing, then check the timing and synchronization to insure that both sets of breaker points are opening at the same time and just as the timing pointer comes into alignment with the proper spark advance mark.

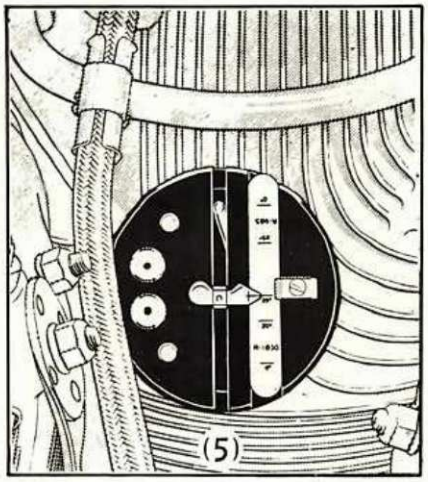
As an alternate method for positioning the No. 1 piston 25 degrees before top center, turn the propeller shaft in the normal direction of rotation to bring the No. 1 piston at the beginning of the compression stroke; then install PWA-4142 Indicator (Time-Rite) in the front spark plug hole of No. 1 cylinder [1]. Align the cap of the indicator so that the slide slot lines up with the vertical axis of the cylinder and the pivot arm is

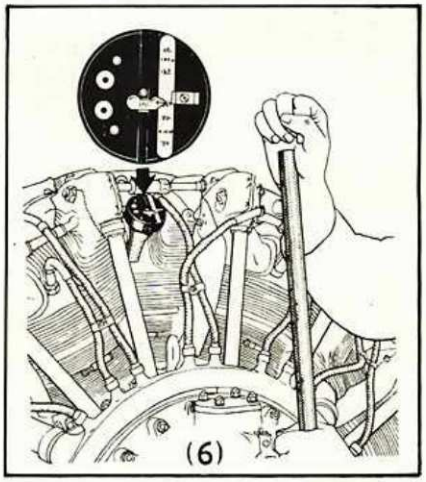

(1)


(2)


(3)


(4)


(5)


(6)

at the top of the slot. Push the slide pointer up close to the pivot arm [2].

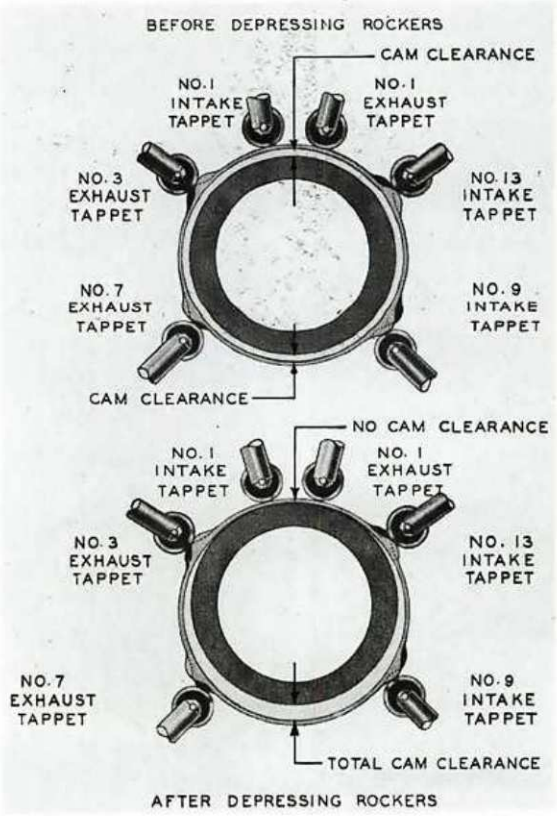
Turn the propeller shaft in the normal direction of rotation until the pivot arm pushes the slide pointer to its farthest point [3]. Turn the propeller shaft about 90 degrees in the opposite direction. This will return the pivot arm to the top of the slot.

Adjust the proper engine scale (the scale marked R-1830) so that the zero degree mark on the scale aligns with the reference mark on the slide pointer [4]. Move the slide pointer up to align with the 25 degree mark on the scale [5].

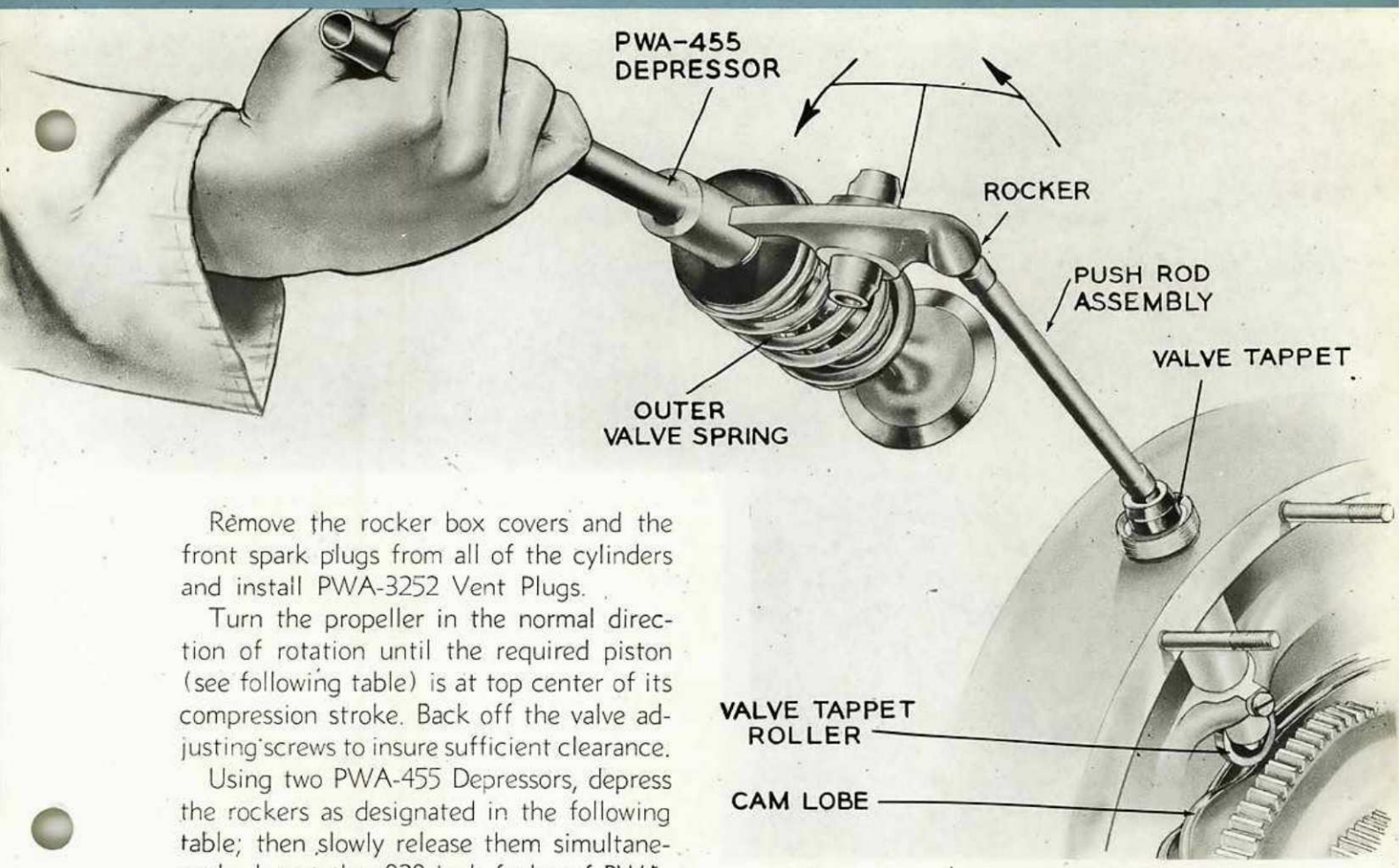
Turn the propeller shaft in the normal direction of rotation until the pivot arm just contacts the slide. At this point the lower light on the indicator should flash on [6] The No. 1 piston is now positioned 25 degrees before top center

VALVE CLEARANCE ADJUSTMENT

Proper valve clearance adjustment is obtained by the use of the Positive Method which eliminates cam float. The elimination of cam float is necessary to prevent valve clearances of wide variation on an engine. So that all of the valves will have uniform clearances, the intake and exhaust valve of each cylinder must be adjusted while the cam rests as nearly as possible against the cam bearing at that cylinder. To move the cam into such a position and to adjust the clearance of each valve, it will be necessary to use the following method. Adjust the valves only when the engine is cold.



Cam Position



Depressing Rocker

Remove the rocker box covers and the front spark plugs from all of the cylinders and install PWA-3252 Vent Plugs.

Turn the propeller in the normal direction of rotation until the required piston (see following table) is at top center of its compression stroke. Back off the valve adjusting screws to insure sufficient clearance.

Using two PWA-455 Depressors, depress the rockers as designated in the following table; then slowly release them simultaneously. Insert the .020 inch feeler of PWA-672 Gage between the adjusting screw insert and the valve stem, and turn down the adjusting screw, using PWA-2835 Wrench, until there is a slight drag on the feeler. Tighten the lock nut to a torque of 300 to 350 inch pounds.

Adjusting Valve Clearance

Set Piston at Top Center of its Compression Stroke	Depress Valves		Adjust Valve Clearances	
	Inlet	Exhaust	Inlet	Exhaust
1	9	7	1	1
10	4	2	10	10
5	13	11	5	5
14	8	6	14	14
9	3	1	9	9
4	12	10	4	4
13	7	5	13	13
8	2	14	8	8
3	11	9	3	3
12	6	4	12	12
7	1	13	7	7
2	10	8	2	2
11	5	3	11	11
6	14	12	6	6

CAUTION

Follow the valve adjusting chart with extreme care to see that the proper valves are depressed. The valves listed will be open due to normal cam action and may be fully depressed without the push rod ball ends falling free of their sockets. A push rod ball end may fall out of its socket if a closed valve is fully depressed.

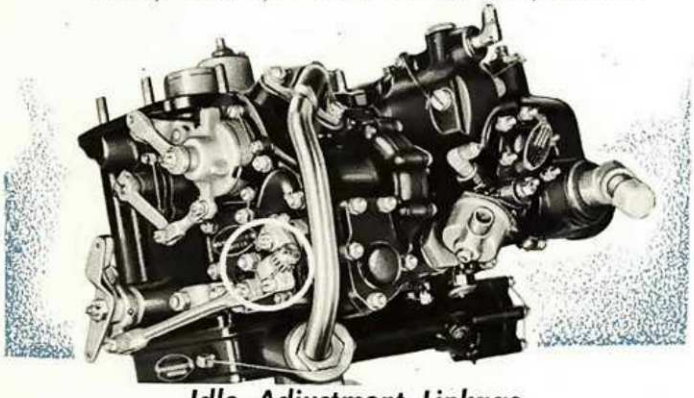
When the rocker box covers are reinstalled, examine the gaskets and replace any that are not in good condition. If any covers have become distorted, reface them on a lapping plate. Tighten the rocker box cover nuts to a torque of 60 to 75 inch-pounds.

Remove the vent plugs from the cylinders and reinstall the spark plugs to a torque of 300 to 360 inch-pounds.

CARBURETOR IDLING ADJUSTMENT

When a carburetor is once set for proper idling, it does not ordinarily require adjustment except to correct it for wide variations in weather conditions. An idling adjustment should not be changed until all other possible causes of unsatisfactory idling have been investigated. Use the following procedure when necessary.

Start the engine and run it at approximately 1000 rpm until the oil temperature reaches 140°F to 158°F and the cylinder head temperatures are normal.



Idle Adjustment Linkage

Run the engine up to 2000 rpm and check the spark plugs by operating on each magneto separately. If the drop-off in rpm is excessive, check for fouled plugs.

Slow down to closed throttle, 450 to 500 rpm. Adjust the throttle stop if the engine does not idle at approximately this rpm.

Move the control into idle cut-off and observe the rise or fall in rpm. Move the control back into auto rich before the engine stops. If the idling adjustment is properly set at 450 to 500 rpm, there will be a slight rise not in excess of 20 rpm.

If the engine rpm **decreased** immediately when the control was moved to idle cut-off, turn the knurled adjusting screw one or two notches in a clockwise direction to richen the mixture and again check the rpm.

If the engine rpm **increased** momentarily by more than 20 rpm when the mixture control was moved to idle cut-off, lean the mixture slightly by turning the knurled adjusting screw one or two notches in a counterclockwise direction, then move the control to idle cut-off and check the rpm.

Each time the adjustment is changed, run the engine up to 2000 rpm to clear the spark plugs before proceeding with the check.

To dissipate the heat caused by repeatedly running up the engine, allow the engine to idle (450 to 500 rpm) for 5 minutes before making the final adjustment or decision on adjustment. Make the check in relatively still air. A strong wind affects propeller loading and the rpm change may be different from that noted above.

Repeat the foregoing procedure until a momentary increase not in excess of 20 rpm is noted when the mixture control is moved to idle cut-off. When this condition exists, the idling adjustment is satisfactory.

When the idling has been properly adjusted, tighten and safety the lock screw.

PARTS REMOVAL AND INSTALLATION

These instructions are written with the understanding that all safety wiring, cotter pins, palnuts, nuts, washers, bolts, and screws will be removed where necessary in disassembly procedures and that new gaskets, packings, safety wiring, and cotter pins will be used at assembly. Fiber insert nuts may be continued in service as long as they are free from mutilation and provide an effective lock. Rubber oil seal rings may be reused, provided that they are in good condition.

Care should be taken to prevent dirt, dust, and other foreign matter from entering the engine during assembly and disassembly operations. Use suitable plugs and coverings over all the openings in the engine.

Cowling

Removal. Remove sufficent cowling sections to have easy accessibility during the removal of any parts.

Installation. Install the cowling sections that were removed.

Exhaust Piping

Removal. Unfasten the nuts and bolts which fasten the exhaust piping to the engine. Loosen the exhaust manifold and move it to the rear as far as possible so that the cylinders and related parts will be more accessible.

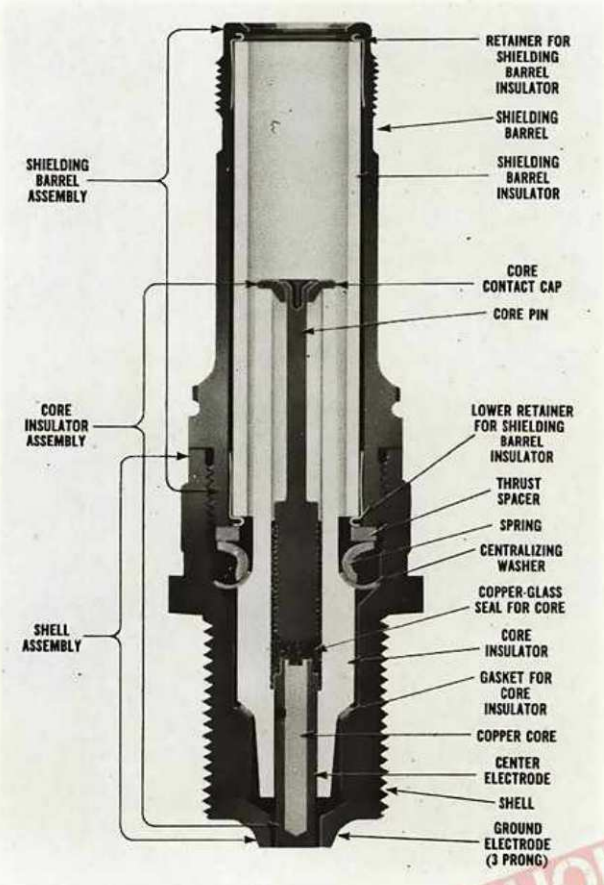
Installation. Move the exhaust manifold forward and fasten the exhaust pipes to the engine with nuts and bolts.

Spark Plugs and Spark Plug Leads

Removal. Unfasten the spark plug leads from the spark plugs, using PWA-1683 Wrench. Withdraw the ceramic connector from each spark plug and install a suitable protector cap over it; then remove the spark plug, using PWA-3168 Wrench.

Installation. Examine the spark plugs to be certain they are of approved type and in serviceable condition.

Install a serviceable solid copper gasket.



Lightly lubricate the first two threads of the spark plug shell with Champion No. 119 graphite antisieze compound or a 50-50 graphite and petrolatum compound.

Insert the spark plug in its bushing and screw it down with the fingers until the gasket is seated. If this cannot be done use an 18 by 1.5 millimeter tap, to clean the bushing threads.

CAUTION

Do not use a tap if the cylinder is equipped with Heli-coil or stainless steel spark plug inserts.

Heli-coil and stainless steel spark plug inserts may be cleaned with a wire brush moistened with a cleaning solvent. The wire brush may be used in conjunction with a power tool if the following precautions are taken. The brush used should be of a type which does not disintegrate while being used so that no bristles will fall into the combustion chamber. The diameter of the brush and the technique used should be such as to preclude the removal of material from the insert proper or, in the case of Heli-coil inserts, from the cylinder head surrounding the insert. Special care should be taken on the spark plug gasket seating surface, since removing material from this location could cause combustion leakage with subsequent damage to the cylinder head. Generally speaking, only a light application of a revolving brush will be required.

Using PWA-3168 Wrench, tighten the spark plug to a torque of 300 to 360 inch-pounds.

Make certain that the inside of each spark plug barrel is clean and dry. Wipe the connector clean; then apply a thin coating of Dow Cowning No. 4 Compound with a brush to the connector. Do not place any compound in the spark plug barrel.

CAUTION

Do not apply the compound with the fingers because moisture from the hands tends to make the compound inefficient.

Remove any compound from the threads of the spark plug to insure an electrical bond between the spark plug and its lead and to prevent radio interference from this source. Tighten the lead nut fingertight and then a half turn using PWA-1683 Wrench.

Deflectors

Removal. Remove the screw which secures the clamp on each rear spark plug lead to the inter-ear oil drain pipe; then withdraw the rear spark plug lead and rubber grommet from the slots in each inter-ear deflector and top plate. Remove the two screws which secure the inter-ear deflector top plate to each cylinder head; then remove the top plate. Unfasten and remove the intercylinder deflectors.

Installation. Install the intercylinder deflectors on each cylinder, securing them to the cylinder head with washers, nuts, and, in the case of rear row cylinders, a fillister head screw. Fasten the tabbed ends at the front of each cylinder with the long bolt, spring, washers, and nut, and secure the tabbed ends at the rear of each cylinder with the short bolt, washers, and nut.

With the rubber sleeves installed on the inter-ear oil drain pipes, assemble the deflector clamps to the pipes and to the inter-ear deflectors. Install the inter-ear deflector top plates and fillister head screws.

Magnetos and Ignition Harness

Removal of Distributor Blocks. Loosen the knurled coupling which secures each flexible harness conduit to its distributor block cover elbow Remove the two screws which secure each elbow to its distributor block

cover. Disengage the coil cover strap fastening screw and remove the cover. Remove the two screws which secure the distributor block cover to the front end plate, and lift the assembly from the magneto by tilting the distributor block toward the rear of the magneto and then lifting upward. Loosen the two screws near the bottom of the distributor block cover. Remove the clamp screws which hold the cover halves together at the top and lift off the cover. Cover each distributor block to keep it clean and dry.

Removal of Magnetos. Unscrew the three nuts which secure each magneto in place and remove the magneto. Insert a suitable dummy block in place of each distributor block to prevent any internal damage to the magneto. Secure the breaker compartment cover in place if it was removed.

Removal of Ignition Harness Assembly. It will be necessary to remove No. 2 and No. 12 cylinders before the ignition harness assembly can be removed from the engine. Remove No. 2 cylinder first, then the No. 12, and secure the master rod in the center of the crankcase opening so it cannot move sideways.

Unfasten the clamps holding the conduit to the blower case and the cylinder pads of No. 14, No. 4, No. 11, and No. 1 cylinders. Unfasten the two clamps which hold the harness to the front main crankcase. Loosen the knurled nut holding the conduit to the manifold and lift the harness from the engine, turning the conduit as it passes between the cylinders.

Installation of Ignition Harness Assembly. Install the ignition harness manifold before No. 2 and No. 12 cylinders are installed.

Place the assembly in position on the engine by lowering the left harness conduit between No. 11 and No. 13 rear row cylinders and No. 14 cylinder and No. 12 cylinder pad of the front row. Lower the right conduit between No. 1 and No. 3 rear row cylinders and No. 4 cylinder and No. 2 cylinder pad of the front row.

Attach the left harness conduit brackets to the first cylinder hold down stud above the crankcase parting surface on No. 12 cylinder, to the first cylinder hold down stud below the crankcase surface on No. 14 cylinder, and to the first cylinder hold down stud below the parting surface on No. 11 cylinder. Attach the right harness conduit brackets to No. 2, No. 4, and No. 1 cylinders in the manner prescribed for the left harness conduit brackets.

Install the No. 12 cylinder, then the No. 2 cylinder on the engine. Install the spark plug leads. Install the distributor blocks as described below.

Installation of Magnetos.

Turn the propeller until the piston of No. 1 cylinder is 25 degrees before top center.

Remove the coil cover, dummy distributor block, and breaker compartment cover. Place a straightedge against the step on the breaker cam or breaker collar. Turn the magneto drive shaft in the normal direction of rotation, as indicated by the arrow on the cam, until the straightedge aligns with the timing marks on the magneto housing.

Without disturbing the alignment of the straightedge, install the magneto on its mounting studs on the rear of the engine. It is important that the studs be located approximately in the center of the magneto mounting flange slots. If the studs are not in this position, remove the magneto, turn the magneto drive shaft one complete revolution, and reinstall the magneto on the engine. This procedure may be repeated four times if necessary, until the studs are approximately centralized in their slots when the straightedge is properly aligned.

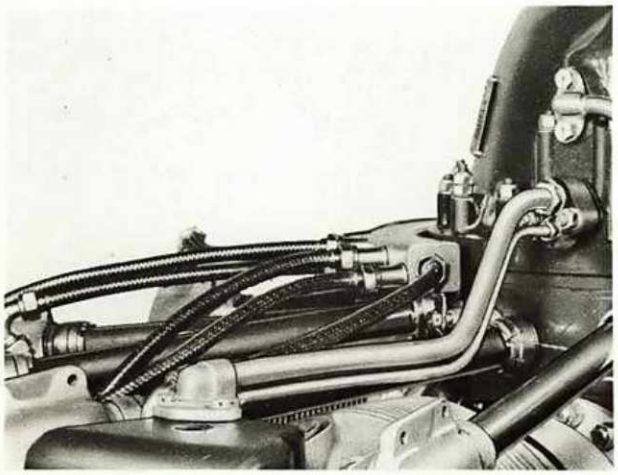
If the desired relationship between the mounting studs and the flange slots cannot be obtained in this manner, change the position of the coupling on the magneto drive shaft by mating different splines. Again mount the magneto on the engine and note the position of the studs in their slots. If necessary, the position of the coupling on the shaft may be changed six times. One of these positions will give the proper relationship between the mounting studs and the flange slots. After determining this position, remove the magneto and secure the coupling with the washers, castellated nut, and a new cotter pin.

Reinstall the magneto on the engine and install the washers and castellated nuts. Do not tighten the nuts enough to prevent further adjustment of the magneto. Install the second magneto on the engine in the same manner.

After installation, time and synchronize the magnetos in accordance with the instructions on page 43.

CAUTION

Be sure the magnetos are properly timed before finally secured to the engine.



Sump Suction and Vent Pipes

Installation of Distributor Blocks. Remove the covering from the distributor block and install the distributor block cover halves on the block. Secure the cover halves to the block with the two screws placed near the bottom of the cover halves; then secure the cover halves together with the clamp screws. Install the distributor block in the magneto. Place the coil cover in position on the magneto and secure it with the coil cover strap and its fastening screw. Secure the distributor block elbows to the block with two screws. Tighten the knurled coupling on the flexible harness conduit.

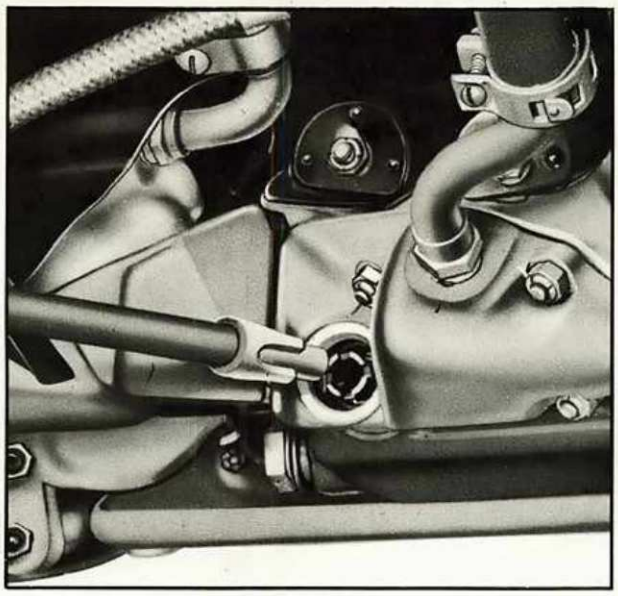
Rocker Box Covers

Removal. Unscrew the elastic stop nuts which secure the rocker box covers to the cylinder heads and remove the covers and gaskets. When removing No. 7 inlet and No. 9 exhaust rocker box covers, loosen the clamps which secure the rubber elbows to the pipe fittings in the rocker sump. To remove the covers from No. 8 cylinder, it is necessary to unscrew the plugs which are installed in the rear ends of the covers; then remove the hollow support screws which extend into the rocker covers and rocker sump.

Installation. Place a gasket on each rocker box, install the rocker box covers, tightening the elastic stop nuts to a torque of 60 to 75 inch-pounds. The Nos. 7 inlet and 9 exhaust rocker box covers are connected to the rocker box sump by special rubber hose connections and should be installed in conjunction with the assembly of the sump. Take particular care not to twist or bend the rubber elbows.

Rocker Box Oil Sump

Removal. Remove the nuts and cap screws which secure the oil suction and breather pipe assembly to the front section and rocker box oil sump respectively; then lift off the pipe assembly. Withdraw the pipe



Removing Sump Support Pipe

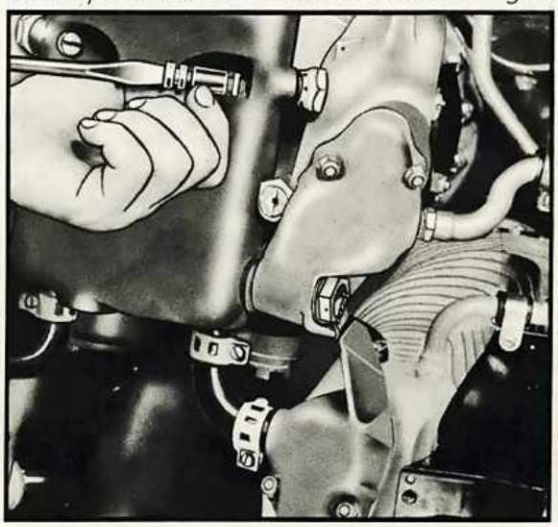
Removing Rocker Box Sump

assembly adapter from the reduction gear housing.

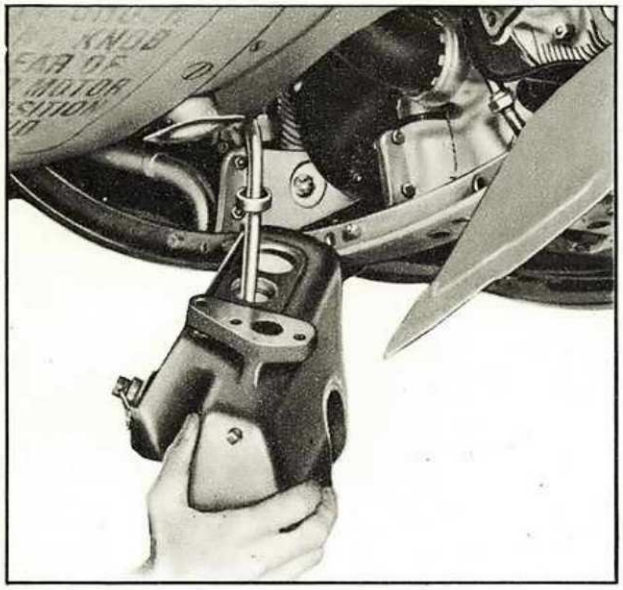
Remove the two plugs from the rear of the rocker box covers on No. 8 cylinder and unscrew the two hollow supports with PWA-2210 Wrench. Unfasten the nuts which secure the rocker box covers to No. 7 inlet and No. 9 exhaust rocker housings. Remove the two fillister head screws which fasten the sump to the rocker shafts of No. 8 cylinder. Lift the sump from the engine together with the attached No. 7 inlet and No. 9 exhaust rocker covers.

Installation. Install the rocker box sump, together with the No. 7 inlet and No. 9 exhaust rocker box covers to No. 8 cylinder head. Install a star lock washer, rubber packing, and copper gasket on each hollow sump support. Screw the two sump supports into position through the rocker box covers of No. 8 cylinder, using PWA-2210 Wrench. Install a cover plug and gasket in each rocker box cover of No. 8 cylinder. Assemble a washer, rubber packing, and another washer, respectively, on each sump support screw; then secure the sump to each rocker shaft of No. 8 cylinder with the two sump support screws.

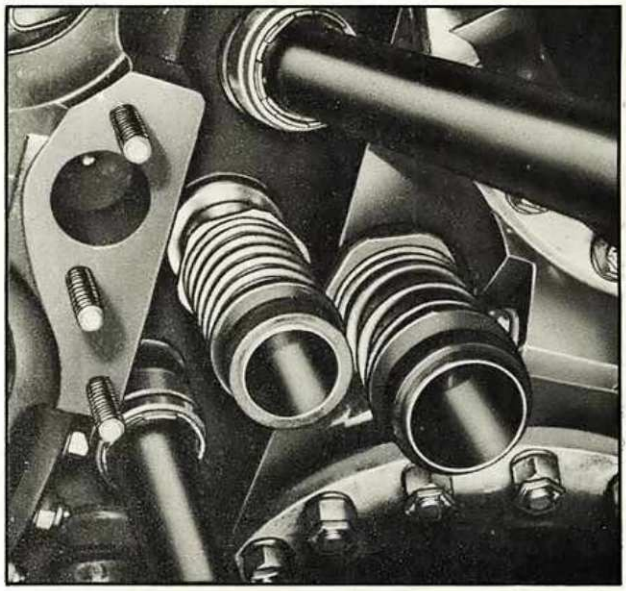
With a new gasket in place on the reduction gear housing, install the suction and breather pipe assembly adapter. Place new gaskets in position on the rocker box sump and on the adapter. Install the suction and breather pipe assembly, fitting the small dowel pin into its hole in the sump. Secure the pipe assembly to the sump with cap screws, and secure it to the reduction gear



Installing Rocker Box Sump



Removing Main Oil Sump



Sump Connections and Packing

housing with the washers and nuts. Install the oil drain plug in the rear of the rocker box oil sump, placing a gasket between the plug and the sump.

Main Oil Sump

Removal. Remove the cap screw and nuts which secure the sump in place. Loosen the sump, using PWA-1686 Puller; then remove the puller and the three nuts and lift out the sump. Exercise care in removing the sump to prevent cramping of the two oil pipes. Hold on to the rubber seals, inserts, and springs on the pipes; otherwise they will slide off when the sump is removed.

Installation. Install the oil screen and plug assembly into the front of the sump with a new gasket under the plug. Install a spring, spacer, and a new rubber seal on each main crankcase oil drain pipe. Place a new gasket on the blower section mounting pad and install the main oil sump in position, securing it to the blower section with the three washers and nuts. Install the washer and long cap screw which secure the sump to the support bracket on the center crankcase. Screw the oil drain plug into its insert in the bottom of the sump.

Primer Lines

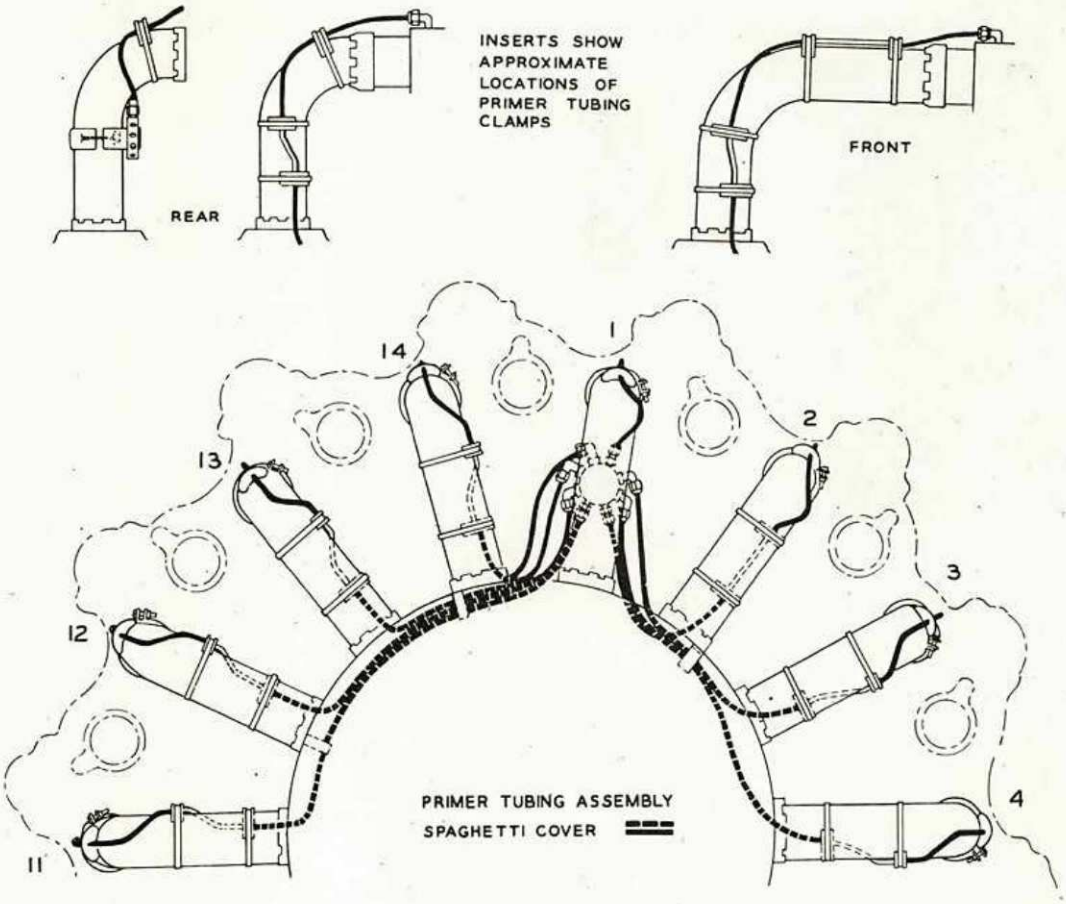
Removal. Disconnect all primer lines at the primer distributor and at the cylinders to which they are attached. Unfasten the clamps holding them to the intake pipes and blower section and remove the lines.

Installation. Connect all primer lines at the primer distributor and at the cylinders to which they are attached. Fasten the clamps to the intake pipes and blower section.

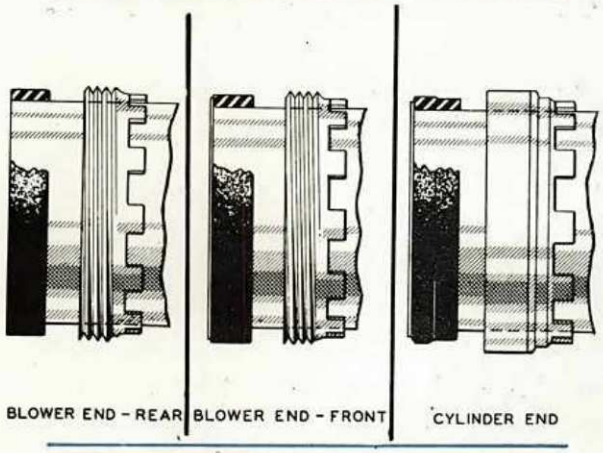
Intake Pipes

Removal. Loosen the nuts at the blower section and at the cylinder ends with PWA-1399 Wrench, then remove the intake pipes.

Installation. Install a flat rubber seal at the blower end and a small rubber seal at the cylinder end of each intake pipe after first coating the seals with a thin even coat of Dow Corning Compound No. 4. Place each pipe in position on the engine, installing the blower end of each pipe first; then install the cylinder end. Start the nuts by hand and tighten, first at the cylinder end and then at the blower end.

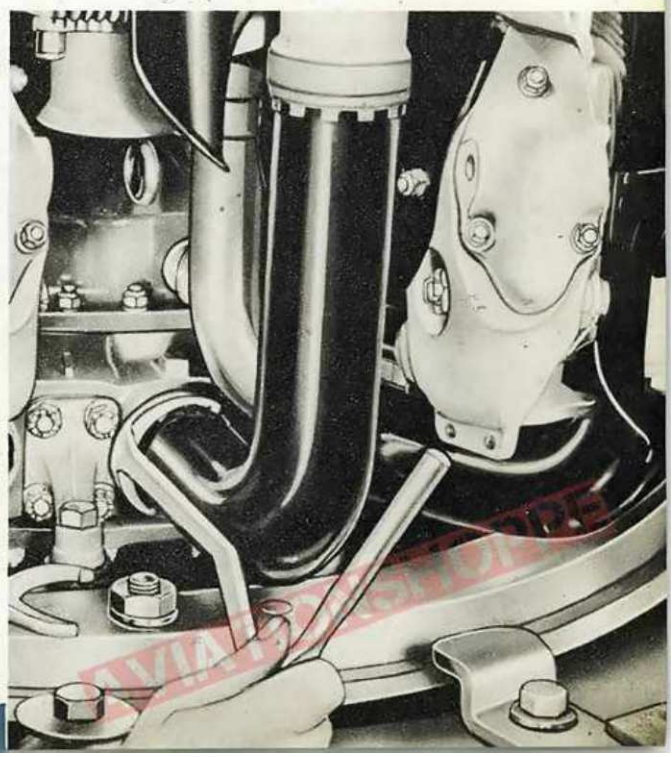


Primer Line Diagram



Intake Pipe Packings

Tightening Intake Pipe Nut →

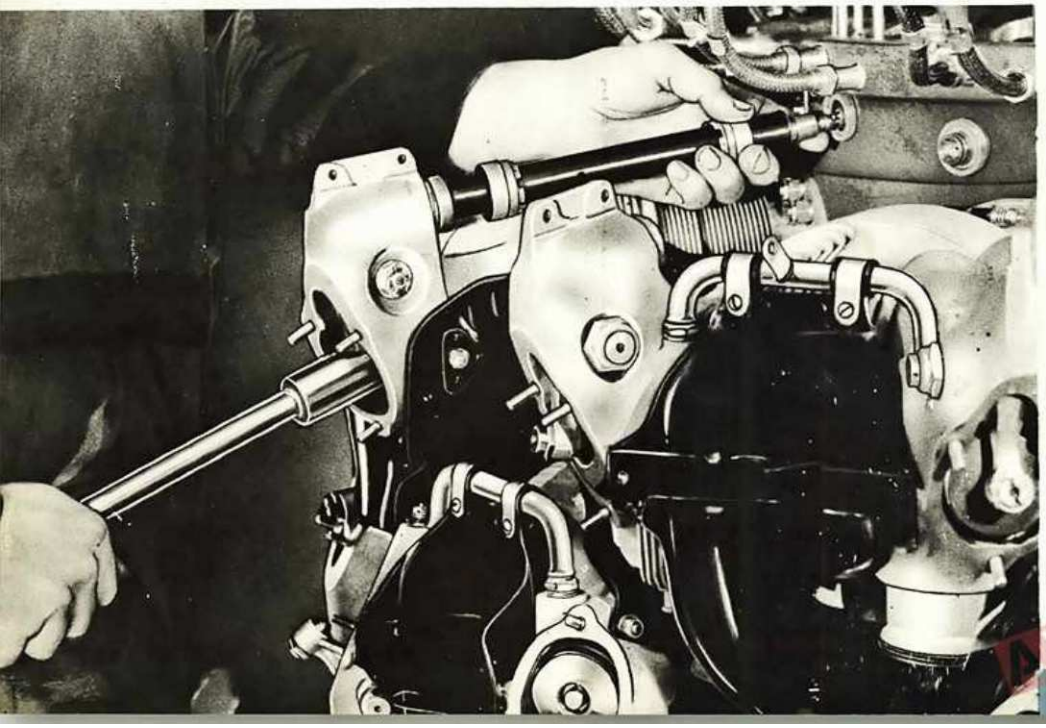


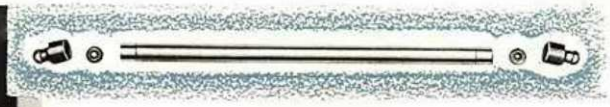
Loosening Push Rod Cover Nuts

Push Rods and Covers

Removal. Loosen all push rod cover nuts at the cylinder ends first; then at the crankcase ends using PWA-1424 Wrench. Turn the propeller until the piston in the cylinder from which the push rods are to be removed is at the top of its compression stroke (both valves closed). Depress the rockers with PWA-1392 Depressor and remove the push rods and covers.

Depressing Rocker to Remove Push Rod





Push Rod Disassembled

Installation. Before installing the push rods and covers, apply a thin even coat of Dow Corning Compound No 4 to the oil seal packing rings. Install the packing rings in place in each gland nut. Assemble the push rod and cover assembly with the marked end of the push rod and the flared end of the cover tube toward the crankcase. Depress each rocker with PWA-455 Depressor and fit the corresponding push rod and cover into position. If the valve tappet protrudes too far to allow installation of its push rod, turn the propeller until the tappet has receded sufficiently to permit installation. After the push rod and cover assembly are in place on the engine with the gland nuts secured finger tight, push the cover tube firmly against its seat on the tappet guide, turn down the gland nut, and tighten it to a torque of 125 to 150 inch-pounds, using PWA-3013 Wrench. Next tighten the gland nut on the cylinder head end of the cover tube to the same torque, and safety wire both nuts.

CAUTION

Never reverse the above sequence of operations as the packing on the tappet guide end might be pushed into the tappet compartment and be mutilated during engine operation.

If the push rod cover was not removed from

the crankcase, install the marked end of the push rod toward the crankcase and guide the push rod into the rocker socket while the cylinder is being installed on its pad.

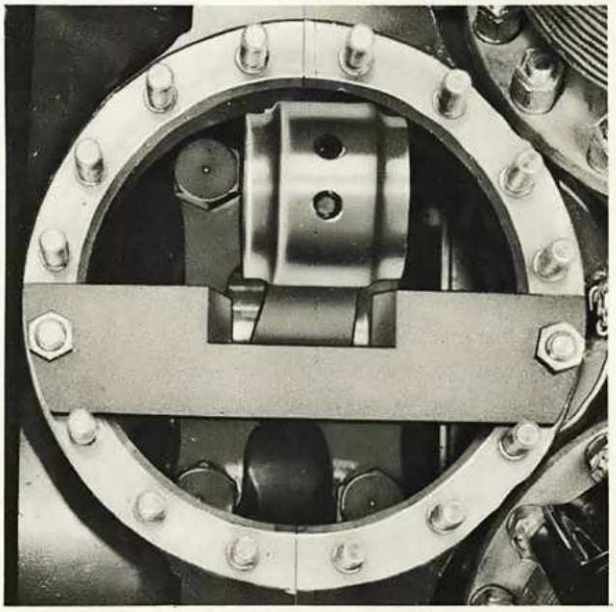
Cylinders

Preliminary Instructions. Remove the master rod cylinders (Nos. 5 and 12) last if their removal with one or more front or rear cylinders becomes necessary.

Upon removal of a master rod cylinder, the master rod should be centered rigidly in the crankcase opening by suitable blocking or wiring, and rotation of the propeller should be avoided. If the master rod is permitted to move sideways, the oil scraper rings on some of the other pistons will come out of the cylinders and seriously damage the pistons and the skirts of these cylinders.

It will be necessary to remove the main oil sump before number 7 and number 9 cylinders can be removed.

Removal of External Oil Pipes. The oil scavenge pipe which extends from the bottom of the front section to the blower section will interfere with the removal of some of the cylinder hold down nuts on Nos. 8, 9, and 10 cylinders. Consequently, this pipe must be removed before any of the specified cylinders can be pulled from the crankcase. Unscrew the cap screws which connect the pipe to the front section and remove the long cap screw and nuts which secure the lower end of the pipe to the blower section; then remove the clamp which secures the pipe to a hold down stud

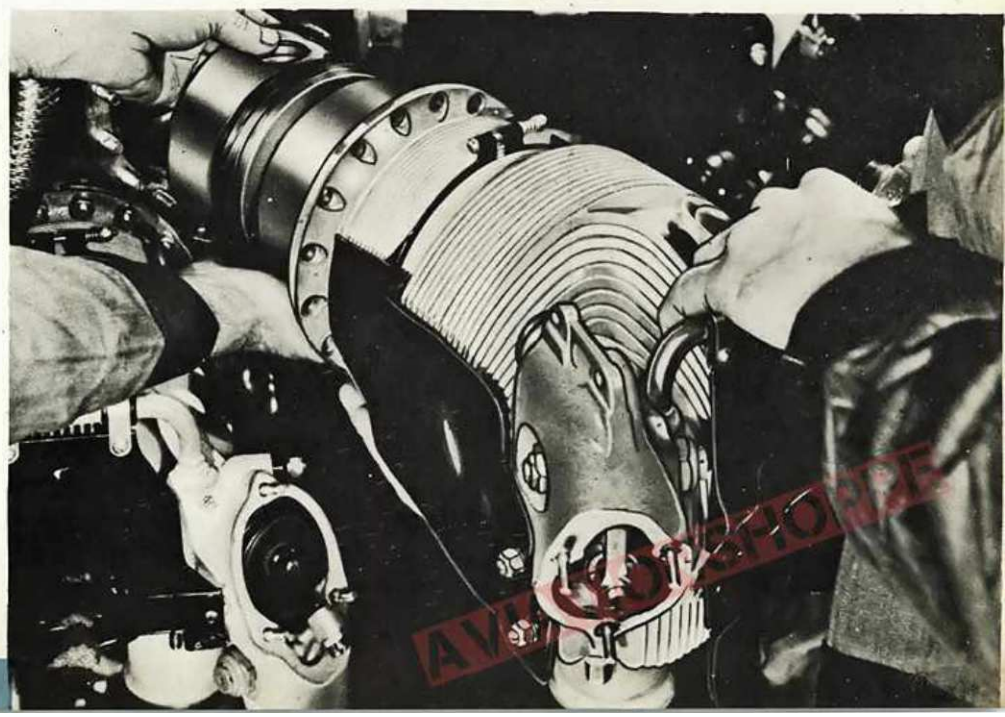


Master Rod Centered

on No. 10 cylinder flange and withdraw the pipe.

The oil pressure pipe which extends from the bottom of the front main crankcase section to the blower section will interfere with certain hold down nuts for Nos. 6, 7, and 8 cylinders. Therefore, this pipe must be removed before any of the specified cylinders can be pulled from the crankcase. Remove the nuts which fasten the upper end of the pipe to the front main crankcase section, and unscrew the oil transfer pipe which fas-

Removing Cylinder



tens the lower end of the pipe to the right side of the blower section. Remove the clamp which fastens the pipe at No. 7 and No. 8 cylinders and withdraw the pipe.

Removal of Cylinder. Remove the cylinder hold down nuts, excepting one nut on each cylinder, with PWA-2724 Wrench and extension handle. Turn the propeller until the piston of the cylinder to be removed is at the top of its compression stroke; then remove the remaining hold down nut and pull off the cylinder, making certain that the piston pin does not drop out. After removal, place the cylinder on wood or in an appropriate carrier to prevent damage to the cooling fins and the bottom edge of the barrel. The cylinder opening should be covered to prevent foreign matter from entering the crankcase. Remove the piston pin and piston immediately after the cylinder is removed. If difficulty is experienced in pushing out the piston pin, use PWA-2302 Pusher.

Remove the nuts, washers, screws, and spring loaded bolts which fasten the inter-cylinder deflector halves to the cylinder and to each other. Unfasten the screws which secure the inter-ear deflector clamps and rubber grommets. The deflectors should be stored in a separate box to prevent damage.

Removal of Valve Springs. Place the cylinder over a wooden mounting block shaped to fit the dome of the cylinder head. Compress the valve springs with PWA-459 Compressor and remove the split locks. Withdraw the upper valve spring washer, valve springs, and lower valve spring washer.

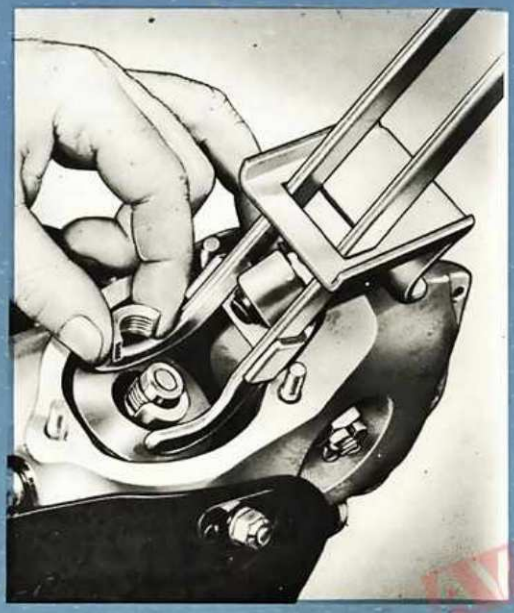
Removal of Valves. Lift the cylinder from the wooden block, remove the safety circlets on the valve stems, and lift out the valves.

Removal of Rockers. Remove the rocker shaft cap and gasket; then, holding the shaft with the proper wrench, remove the nut from the opposite end of the shaft. Lift off the washer, push the rocker shaft out of the housing, and withdraw the rocker. If the valve springs and rockers are to be removed from a cylinder on the engine, the propeller should be turned until the piston in the cylinder from which the springs and rockers are to be removed is at top center position. This will prevent the valves from falling out of their guides into the cylinder when the split locks, washers, and valve springs are being removed.

Installation of Valves. Clean and oil the

Placing Cylinder on Block

Removing Valve Locks



Removing Rocker Shaft Nut

valve guides and stems. Insert the valve stems in their guides and place the cylinder over a domed wooden block to prevent the valves from falling.

Installation of Rockers and Valve Springs. Place the rockers in position in their respective housings and insert the shaft through the bushings and rockers Install the rubber oil seal, washer, and nut on the small end of the rocker shaft. Hold the shaft at the large end with the proper wrench and tighten the nut to a torque of 175 to 200 inch-pounds. Place a copper sealing gasket on each rocker shaft bushing; then tighten the inner nut to a torque of 200 to 250 inch-pounds. Insert the lower valve spring washers and valve springs in the rocker housings and place the upper valve spring washers in position. Compress the valve springs with PWA-459 Compressor and install the split locks.

Installation of Cylinder.

> **Note:** When replacing cylinders with lapped cylinders, a ½ hour ground runup is required at 1200 to 1400 rpm. (The cylinder assembly will include piston and rings.)

Coat the cylinder walls, piston pins, pistons, and piston rings with a generous amount of oil. Stagger the ring gaps around the circumference of the piston. Fit the rubber seal ring under the cylinder hold down flange of each cylinder.

Rotate the propeller until the articulated or master rod of the cylinder to be installed is at its full outward position. Install the rear row cylinders first. The master rod cylinder should be the first in each row to be installed. The master rod cylinders are No. 5 and No. 12 for the rear and front rows, respectively.

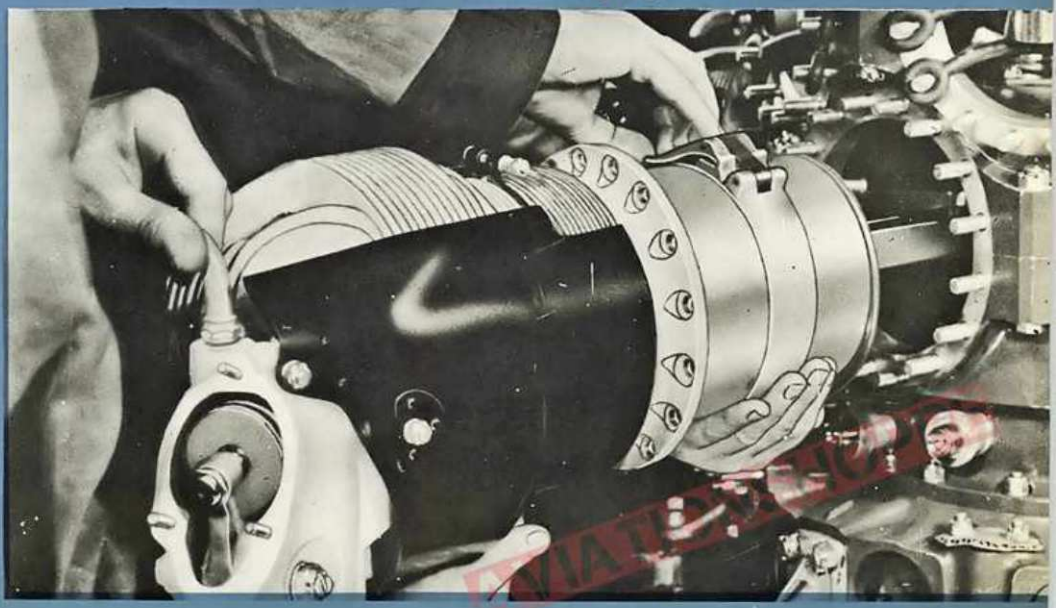
Hold the piston in position over the end of the rod and slide the piston pin into position in the piston pin bushing. Each piston, piston pin, and cylinder is marked with a number denoting its proper position; at installation the numbers should correspond. Install the piston and pin with their numbered sides toward the front of the engine.

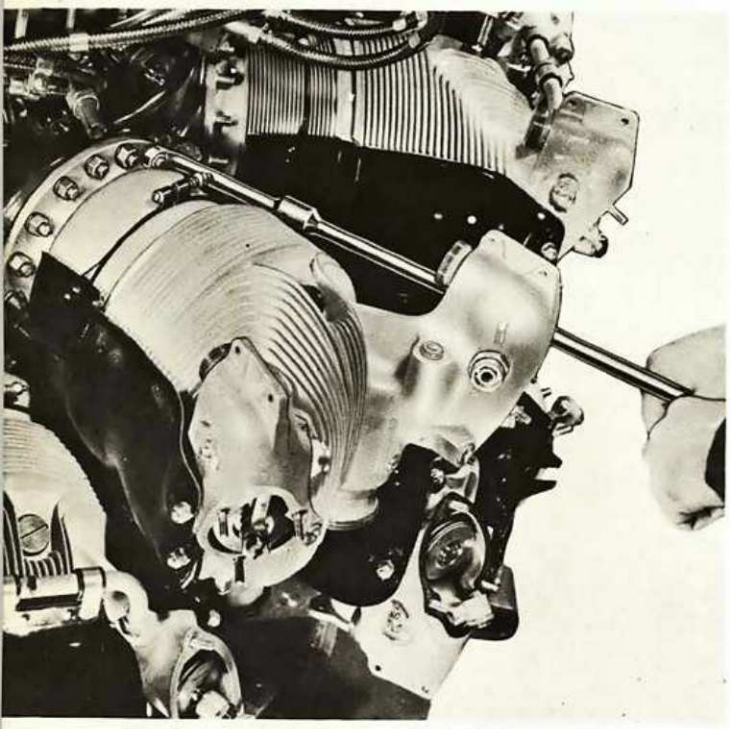
Compress the outer piston rings, using PWA-489 Clamp; then slide the cylinder over the outer rings. Compress the scraper ring with the clamp; slide the cylinder over this ring and into place against its mounting pad.

Center the cylinder on its studs immediately after assembly, using two PWA-3197

Removing Rocker

Installing Cylinder

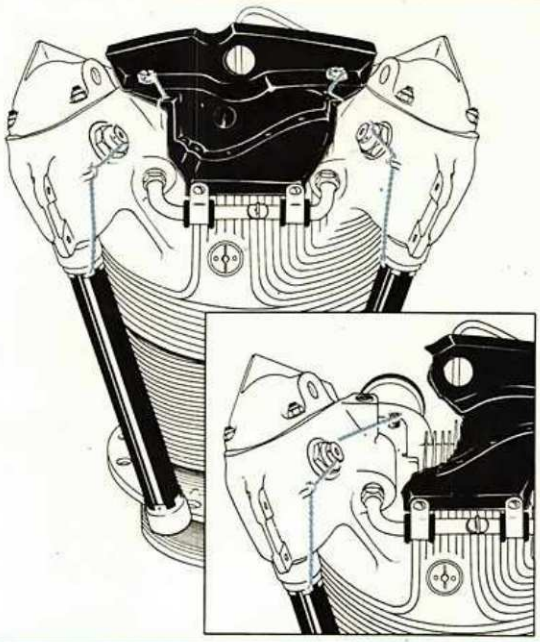




Tightening Cylinder Hold Down Nuts

Locating Nuts at opposite sides of the cylinder. Jar the cylinder with one hand and turn down the locating nuts gradually with the other hand until they are firmly seated in the cylinder flange. When the locating nuts cannot be screwed on further by hand despite continued jarring of the cylinder, tighten them firmly with an open end wrench.

Before securing the cylinder, make sure the nuts, the spherical washers, and the seats in the cylinder flange are clean and free of burrs. Install the washers, flat side out, over the remaining studs, making sure they are not cocked in their seats. Install the hold down nuts, using kerosene or engine oil as a lubricant if desired, and tighten the nuts to a torque of 300 to 350 inch pounds, using PWA-2724 Wrench. Replace the locating nuts with the regular nuts and washers and tighten them to the same torque. Secure all the nuts with palnuts.



Cylinder Assembly Safety Wired

Note: Do not tighten the nuts above the recommended torque. The studs may be stretched or broken if too much force is used.

Installation of External Oil Pipes. Install the oil scavenge pipe between Nos. 9 and 10 cylinders; install a new gasket and attach the rear end of the pipe to the blower section. Secure the pipe with the washers and nuts; then clamp the pipe to a cylinder hold down stud on No. 10 cylinder flange.

Install the oil pressure pipe between Nos. 6 and 7 cylinders; install a new gasket and attach the pipe to the blower section. Clamp the pipe to a No. 7 cylinder hold down stud and to a No. 8 cylinder hold down stud. Install a new gasket on the front main crankcase and fasten the front end of the pipe to the crankcase with the nuts.

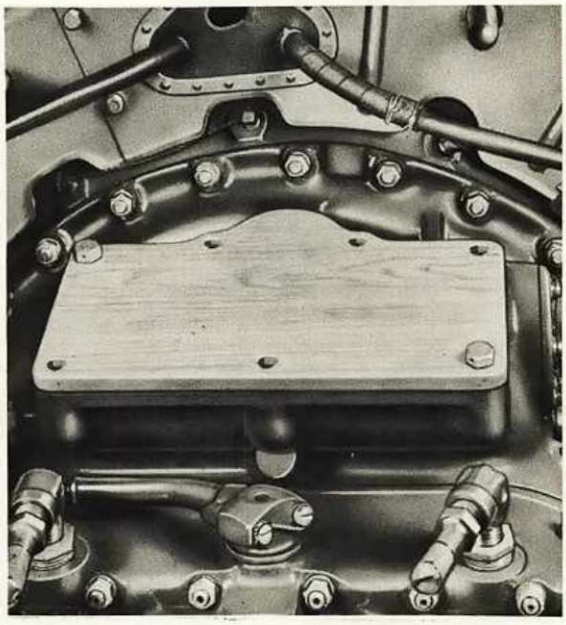
Carburetor

Removal. If it is necessary to replace the carburetor, close the fuel system shut-off

valve and drain the fuel from the engine at the strainer drain cock. Unscrew the nuts which attach the air scoop to the carburetor, unfasten the top section of the cowling, and lift off the cowling section and air scoop. Disconnect the throttle control rod from the throttle lever and the manual mixture control rod from the manual mixture control lever. Detach the fuel line, the fuel pressure gage line, the vapor vent connection return line, the line to the primer distributor, and the primer electrical connection. Unfasten the three screws which secure the fuel transfer pipe to the carburetor, unfasten the fuel transfer bolt which secures the pipe to the carburetor adapter, and remove the fuel transfer pipe and gaskets. Remove the carburetor attaching screws and lift off the carburetor and its adapter. If another carburetor is not to be mounted immediately, close the opening in the intermediate rear case with a suitable cover so that no foreign matter will enter the engine.

Installation. When installing a carburetor on the engine, be sure to use a gasket between the carburetor and the adapter. Do not use any grease or sealing compound on the gaskets. Tighten the attaching screws to a torque of 200 to 225 inch-pounds. Gaskets are also required between the carburetor and the air screen and between the air screen and the air scoop. Reinstall the air scoop with the top section of the cowling. Attach the fuel transfer pipe between the carburetor and the carburetor adapter. Connect all lines which were disconnected.

When a new carburetor is installed or when the carburetor has been empty for 48 hours or longer, fill it with gasoline and allow to stand for 8 hours before flight. This insures flexibility of the diaphragms and accurate fuel metering. If it is impossible to soak the diaphragms for 8 hours, soak them

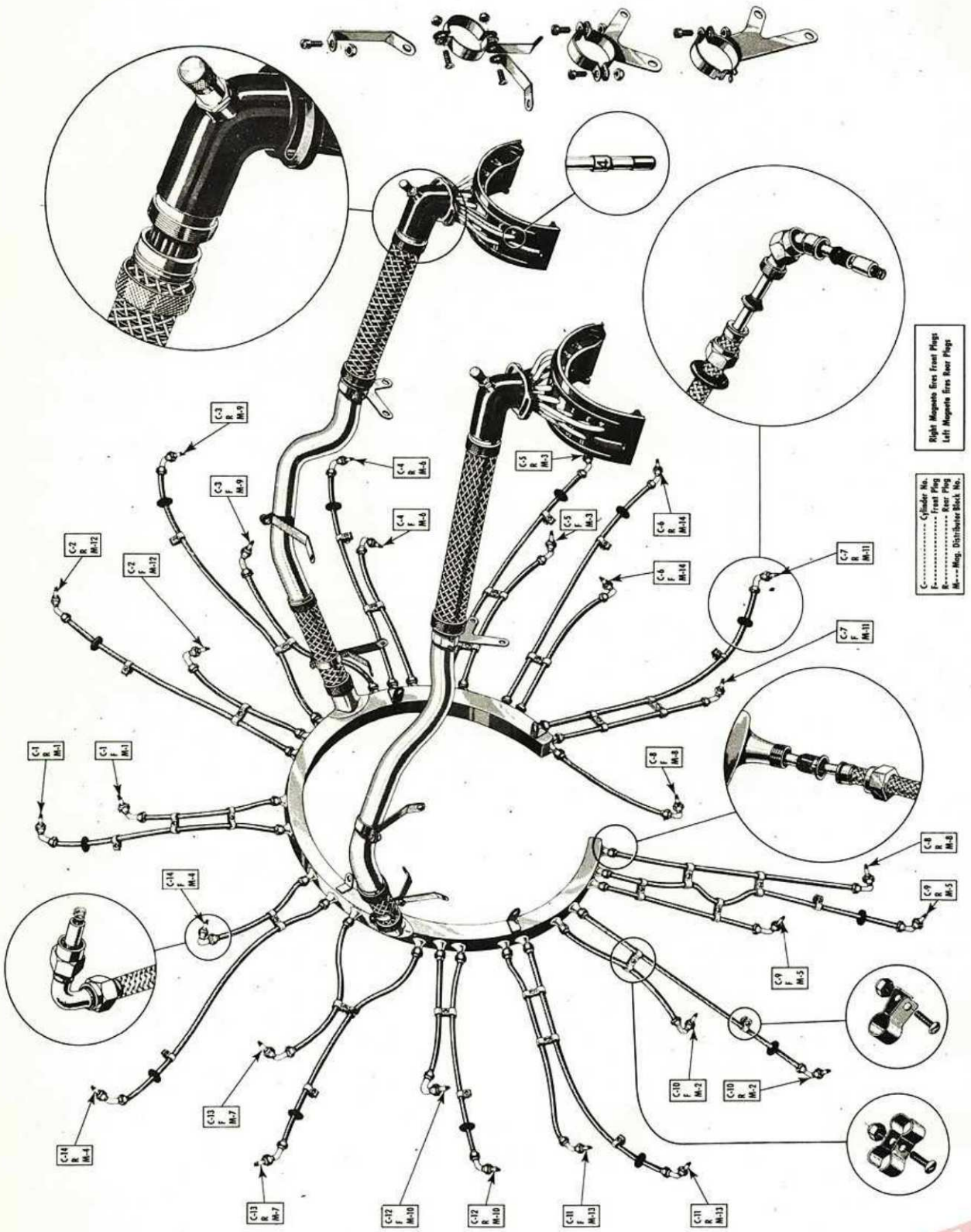


Carburetor Opening Covered

Air Duct, Screen, and Gaskets

for a minimum period of 2 hours. In this case, it will be necessary to make additional idling adjustments as the diaphragms become more flexible.

> **Note:** The soaking procedure may be completed prior to the installation of the carburetor on the engine. Do not fill the carburetor with gasoline more than 10 days in advance, as stale gasoline is somewhat harmful to neoprene diaphragms.



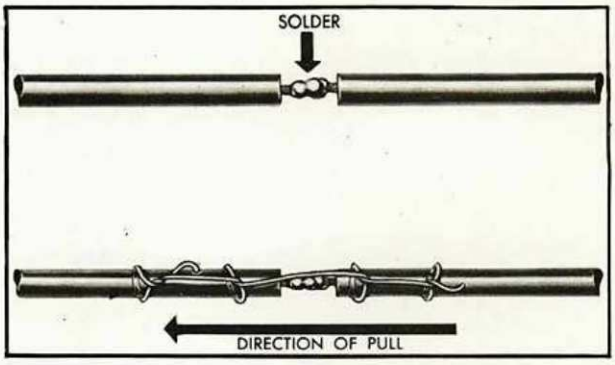
Ignition Manifold and Cable Assembly Showing Magneto Distributor Block and Spark Plug Lead Numbers

Replacing Ignition Wire

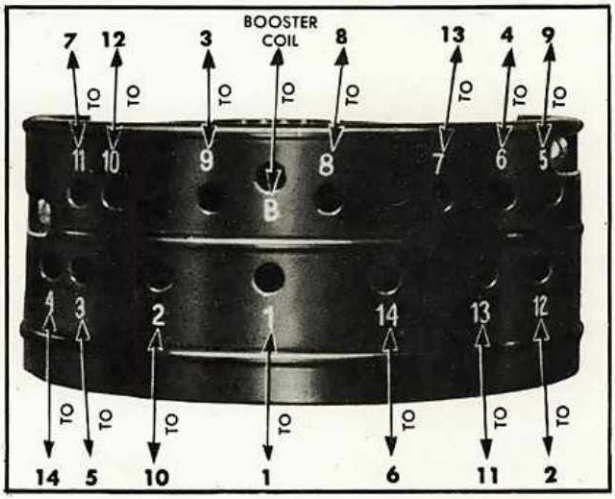
A wire in the ignition manifold can be replaced by a new wire without disturbing the other wires in the manifold. Remove the spark plug connector and detach the spark plug lead shielding from the manifold. Remove the wire from the distributor block. Loosen the large conduit nut at the manifold and slide the conduit toward the magneto. Determine in which direction the wire will pull the easiest and splice and solder the new wire to the opposite end of the old wire. Lightly coat the new wire with Dow Corning No. 4 compound; pull out the old wire, and, at the same time, carefully feed the new wire into the manifold. Take particular care to see that the insulation on the new cable is not damaged while it is being pulled into the manifold.

After the wire is in place, install the spark plug lead shielding and the spark plug connector. Be particularly careful when installing the spark plug connectors on the spark plug leads. Cut sufficient insulation from the wire to permit the central wire core to extend through the wire outlet approximately 1/8 inch. Be very careful not to cut into the central wire core when removing the insulation. Slide the connectors in position on the ignition wire, taking care not to twist or bend the wire. Bend the wire of the central core back over the wire opening in a radial pattern. Do not solder the wire in position.

The numbers on the distributor blocks show the serial firing order of the magneto, not the firing order of the engine. The diagram on page 60 shows the relation of the distributor block numbers to the cylinders which are fired. The lower row of cylinders represents the firing order of the engine. The right magneto fires the front spark plugs of all cylinders and the left magneto fires the rear spark plugs.



New Cable Soldered to Defective Cable



Block-to-Cylinder Wiring Arrangement

Stud Replacement

Loose or broken studs normally can be replaced without damage to the threads in the hole. Select the proper oversize stud. Broken studs can generally be removed by using the hole in the flange of the mating part as a guide for a drill which is used to spot a center in the broken stud after which a smaller drill is used to drill out the central portion of the stud. Drive some type of steel extractor, such as an Easy-Out or a home made extractor, into the drilled center and turn out the broken stud with a wrench on the extractor. To facilitate stud removal, heat may be applied to the particular locality. If a small amount of damage is noted in the threads of the hole where the stud

OVERSIZE	+.004 in.	+.008 in.	+.012 in.
P. & W. A. STANDARD	OR GREEN DYE	OR RED DYE	OR PURPLE DYE
STAMPED NO. WITH PREFIX +	+4	+8	+12
STAMPED NO. WITHOUT PREFIX	4	8	12
STAMPED OR SCRIBED LINE			
STAMPED OR SCRIBED LINE			

Oversize Stud Identification

was removed, clean the threads with an oversize tap.

The table above illustrates the various methods of marking oversize studs for identification. The identifying mark is on the anchor end of the stud. The conical projection or green dye for .004 inch oversize studs, the conical cup or red dye for .008 inch oversize studs, and the drilled hole or purple dye for .012 inch oversize studs are the Pratt & Whitney Aircraft standard identifying marks. The other marking methods are illustrated because they are used by various vendors and licensees and may be encountered in the field.

CAUTION

When installing an oversize stud in a stud hole which goes completely through a part, make sure that the anchor end of the stud does not project beyond the hole sufficiently to cause interference with other parts. If necessary, file off the anchor end enough to insure against such interference; then reidentify the stud with the proper oversize mark.

If a cylinder hold down stud requires replacement, all the other studs in the particular pad should be replaced. Proper fit of a stud is indicated by a driving torque of 250 to 450 inch-pounds. The driving torque must be within these limits, otherwise, cylinder hold down stud replacement is faulty.

Spark Plug Heli-coil Inserts

Removal. Insert PWA-4102 Extractor in the spark plug hole and apply a light blow to the end of it to imbed the knife edges in the insert. Turn the extractor in a counterclockwise direction to back the insert out of the head [1].

(1)

Note: For easier extraction insert extractor so that one of the knife edges is approximately ¼ of an inch from the end of the first coil of the insert.

Installation (Cylinder on Engine). Before installing a new Heli-coil insert make certain that:

1. The face of the spark plug hole is free from burrs.
2. The threads of the spark plug hole are completely clean and dry.
3. The new insert is perfectly clean and dry.

Note: Use no oil on the insert or the tapped threads when installing the insert.

Using PWA-3001 Driver, withdraw the mandrel beyond the recessed section of the sleeve; then slip the insert into the recess **[2]**, tang forward, and advance the mandrel until the slot engages the tang of the coil. Press forward slightly on the handle of the mandrel and turn it clockwise to engage the coil in the threaded end of the sleeve. While holding the sleeve, continue turning the handle of the mandrel until the serrated portion of the coil disappears into the first thread of the sleeve. The coil should be wound tightly around the mandrel, with each coil touching the adjacent one.

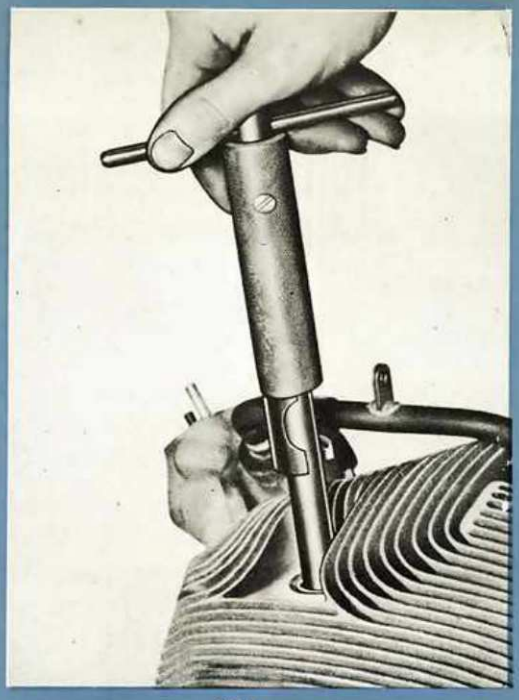
Start the insert into the spark plug hole by turning the entire inserting tool over the hole **[3]** until the first coil picks up the first thread. Turn the coil into the hole until the face of the sleeve is approximately 1/16 of an inch from the face of the hole **[4]**. Then, holding the sleeve stationary, continue turning the coil with the mandrel until the coil is free of the threaded portion of the sleeve **[5]**. Continue turning the coil in a clockwise direction until the serrated end of the coil has entered to from ½ to ¾ of a turn into the top thread of the hole **[6]**. Remove the inserting tool and check the coil position at the top. In order to effect satisfactory staking, the serrated end of the coil must be held closely to the above specified ½ to ¾ of a turn into the top thread of the hole. If, upon inspection, the end of the coil is not at least ½ of one turn into the top thread of the hole, the tool can be reinserted and the coil driven further.

(2)

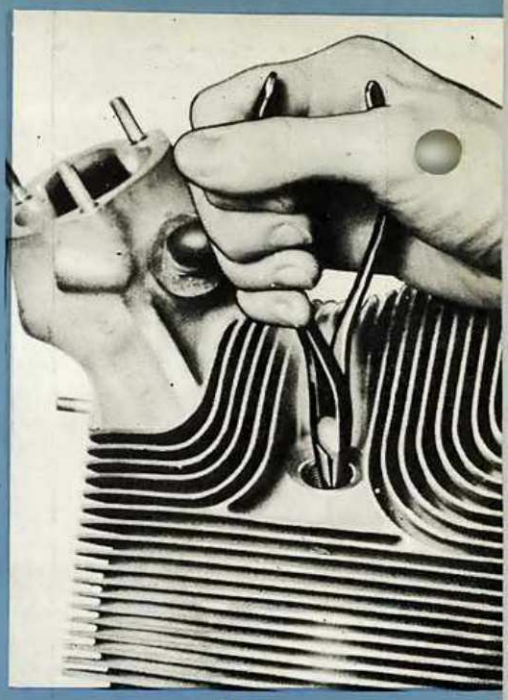
(3)

(4)

(5)



(6)



(7)

CAUTION

Do not put excessive pressure on the inserting tool during the inserting operation, as this may prematurely break off the tang of the coil. In reinserting the tool to drive the coil in farther, be careful when engaging the tang in the slot of the tool in order to avoid pushing the bottom coil of the insert out of its thread. Do not try to back a coil out by using the inserting tool; this will probably break off the tang.

Slip a noose of string over the tang and draw the noose taut. Using a pair of long-nose pliers, grasp the tang near the notch and break off the tang **[7]**, being careful to lift the coil from the thread.

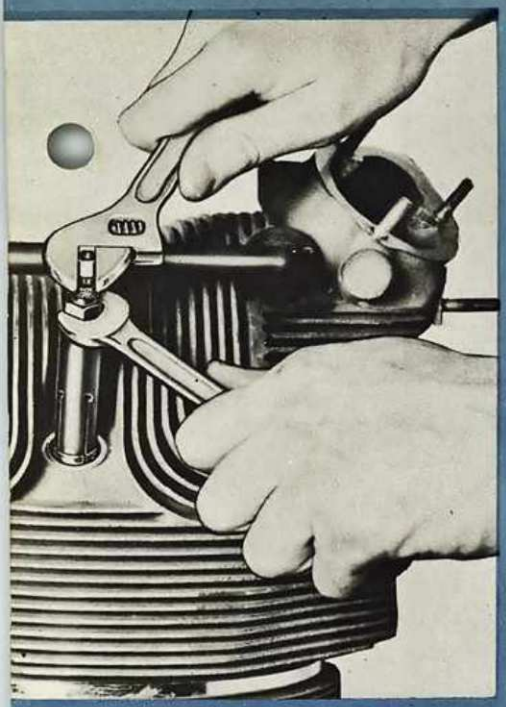
Note: When breaking off the tang twist it in a clockwise direction to prevent the coil from being pulled out of its seat.

Screw PWA-3367 Primary Expander into the insert as far as it will go **[8]**. Set the adjustable nut and tap the head of the plunger until the insert coil is firmly seated in the tapped threads of the spark plug hole. Draw out the plunger by turning down the adjustable nut; then back out the expanding tool.

Insert PWA-3944 Gage into the insert for a check of the inside diameter. If the inside diameter is too small, use PWA-3367 Primary Expander again. If necessary, the expander may be reset for additional expansion by moving the position of the fixed nut slightly towards the head of the plunger. If the inside diameter is too large (this is less likely to occur), the insert must be removed and a new insert installed.

PWA-3420 Expander is a combination of an offset expanding and a staking tool. The offset expanding part is used to offset and embed the points on the outside of the top coil of the insert into the side of the bushing. The staking part is used to stake each serration, and to stake the end of the top coil.

Remove the plunger from the offset ex-



(8)

(9)

(10)

pander and insert the offset expander into the coil insert. Engage the top coil of the insert in the short, threaded portion of the tool and turn clockwise until the end of the coil hits the stop on the tool. Make certain that the end of the coil is firm up against the stop on the tool. Insert the plunger and set the adjustable nut on the plunger's spindle. The slot in the adjustable nut should line up with the slot in the fixed nut. Tap the head of the plunger **[9]** until the adjustable nut contacts the top of the offset expander. This operation embeds the points of the last coil into the side of the hole. Leave the tool in this position until the next operation is completed.

Slide the staking sleeve over the offset expander **[10]** and tap it with a hammer sufficiently hard to bottom the sleeve on the edge of the spark plug hole. This operation stakes the serrations on the top coil, and stakes the end of the top coil. Make certain that the coil is fully staked, because once the offset expander is removed, it is not possible to index the staking sleeve for restaking. Remove the staking sleeve and draw out the plunger by turning down the adjustable nut; then remove the offset expander from the spark plug hole. Never try to remove the expander without first withdrawing the plunger. Insert PWA-3944 Gage into the insert for a check of the inside diameter.

PARTS INSPECTION

SPARK PLUGS AND SPARK PLUG LEAD CERAMIC CONNECTIONS.—Examine the ceramic insulation in the spark plugs for cracks or chips and replace any damaged plugs with new ones. Install new ceramic connectors on the spark plug leads if connectors are cracked or broken.

INTER-EAR DEFLECTORS.—Inspect for loose blast tubes and dents.

PRIMER LINES.—Look for breaks, dents, pinched tubing, and broken unions. If necessary, replace with new primer lines.

ROCKER BOX COVERS.—Inspect for cracks and warpage. Inspect the gaskets and replace with new ones if torn.

INTAKE PIPES.—Inspect for dents and cracks. Check condition of paint.

INTAKE PIPE NUTS AND PACKING.—Examine the nuts for breaks and condition of the threads. Replace packing if it is not in good condition.

PUSH RODS.—Inspect for cracks and check the oil holes in the ball ends for clogging Examine the rods for roundness and straightness by rolling them on a plane surface. Replace any ball ends which are loose or excessively worn.

PUSH ROD COVERS.—Look for cracks and dents. Check the nuts at each end for condition of threads.

INTERCYLINDER DEFLECTORS. — Examine the deflectors for dents, bonding, and the condition of the paint.

CYLINDER BARRELS.—Check the hold down flange for flatness. Examine the inside of the barrel for wear, which usually occurs at the rear. Check the bore of the barrel for out of roundness. Look for cracks, scoring, damaged fins, and other irregularities on the barrel.

CYLINDER HEADS.—Examine the fins around the head for cracks and breaks. Blend any sharp corners of broken fins before installing the cylinder. Inspect areas adjacent to the spark plug bushings for cracks and also around the exhaust ports. Inspect valve guides for wear.

CYLINDER FIN BREAKAGE.—If more than 12 inches in length of any one fin is completely broken off or if the total fin breakage on any one cylinder head exceeds 33 square inches, the cylinder must be replaced. Where adjacent fins are broken in the same area, the total permissible length of breakage is 6 inches on any two adjacent fins and 4 inches on any three or more adjacent fins.

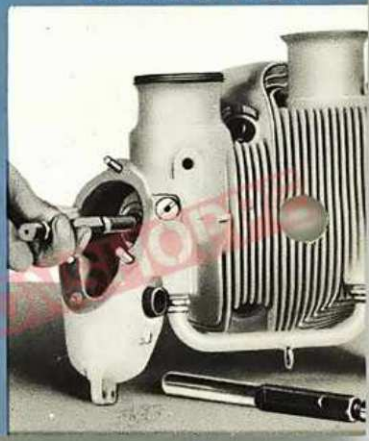
CYLINDER HOLD DOWN NUTS AND STUDS.—All cylinder studs and hold down nuts should be examined for cracks, dam-

Flatness Check

Straightness Check

Check of Bore

Diameter Check



aged threads and other visible defects. Clean the threads of the studs and nuts thoroughly, using a hand wire brush if necessary. Remove any roughness or burrs on the nuts, studs, or cylinder flanges. If one or more cylinder pad studs have failed or the cylinder has become loose on its pad, replace all of the studs in that particular pad.

> **Note:** When replacing present cylinders with lapped cylinders, a ½ hour ground run-up is required at 1200 to 1400 rpm.

PISTONS. — Inspect the pistons for cracked heads and skirts, broken or distorted ring lands, scored or worn piston pin holes, excessive carbon deposits, broken rings, or rings seized in their grooves. Replace piston and rings together with cylinder. (See Note above.)

PISTON PINS.—Inspect the piston pin for scoring, cracks, excessive wear, rust pitting, and out of roundness. Check the fit of each piston pin in its bushing in the corresponding articulated rod and in its bosses in the corresponding piston.

ROCKERS. — Examine the rockers for cracks and galling on the inside diameter. See that no oil passages are obstructed. Inspect the socket in the push rod end of each rocker for looseness and excessive wear. If the surface is rough or uneven, the socket should be replaced. Check the condition of the threads in the valve end of each rocker.

VALVE SPRINGS.—Inspect for cracks, broken ends, inadequate spring pressure, rust, and improper length.

VALVE LOCKS.—Examine for burrs and galling. Check the fit of each pair of locks with its valve. A lock should have no perceptible movement when it is in place on the valve, and the radii of the lock and valve should coincide.

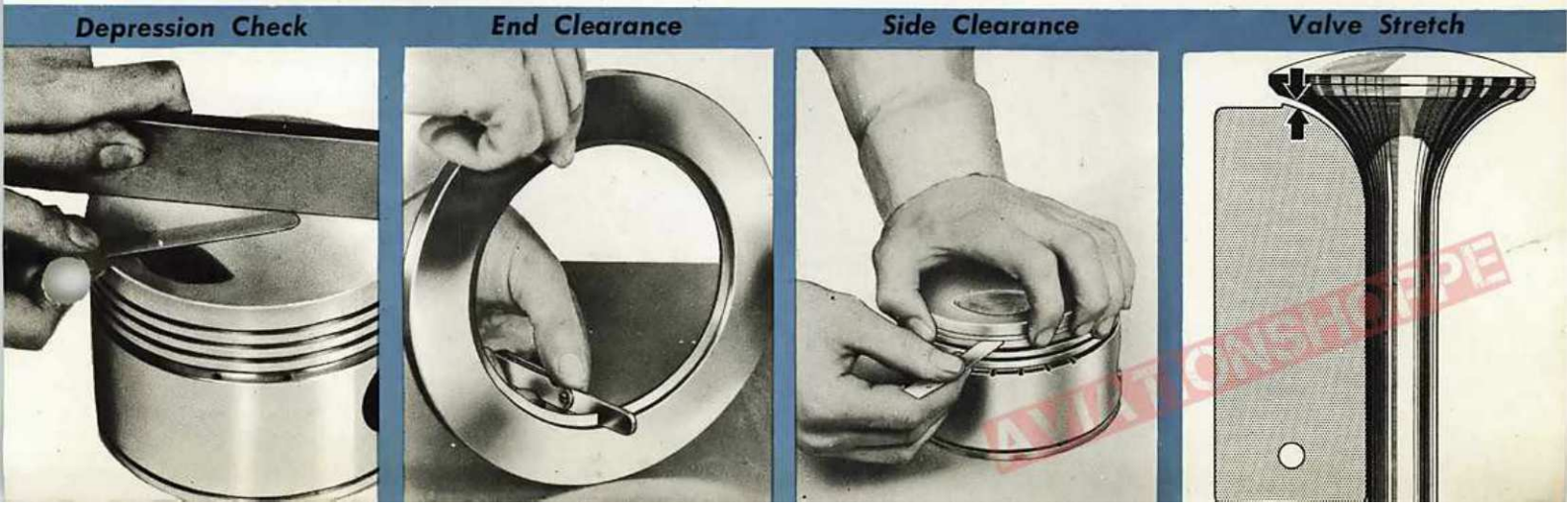
VALVE SPRING WASHERS.—Inspect for cracks, pitting, and galling.

VALVES. — Examine each valve for stretching and drawing of the valve stem, poor seating surface, and excessive carbon.

STUDS.—Check all studs for looseness, possible fractures at the base of the threads, and projection length. Examine for cracks, nicks, burrs, and bent studs. Replace all damaged studs.

FAILED CYLINDER ASSEMBLIES.—Experience has proven that an engine which has suffered a valve or cylinder head failure may be successfully returned to service if the cylinder assembly is replaced. In order to understand the success of this practice, it is necessary to review the circumstances which cause cylinder head and valve failures.

Cylinder heads usually fail when the tensile strength of their material has been lowered by excess heat and when the pressure inside the cylinder is extremely high. These two factors can cause rupture of the head. The same conditions may exist in other cylinders which do not fail, and they regain their tensile strength when they have cooled.



Because of this regeneration, it is clear that the cylinders are not permanently weakened by the excessive temperatures and pressures to which they are subjected.

Exhaust valve failures can usually be traced to an adverse condition in the particular cylinder in which they fail. For instance, there may have been insufficient valve clearance, valve sticking, high cylinder head temperature, or other factors which tend to weaken the valve.

Although experience has proven that engines with valve or cylinder head failures may be successfully returned to service, it is not recommended that all engines subjected to these failures be kept in service. Before replacing the cylinder be certain that no metal particles have entered the engine. Examine the link rod to ascertain whether or not it has been bent or damaged. Make a visual check of all combustion chambers to determine whether or not they have been damaged in any way. Examine the push rods for damage also.

After the installation of a new cylinder assembly, a complete compression check should be made. The engine should then be given a complete ground check. After this ground check, a second compresion check should be made. In addition, make a thorough visual check of the engine, paying particular attention to the condition of the cylinder hold down studs, cylinder heads, and combustion chambers.

After the replacement of a cylinder assembly, operate the engine in accordance with the recommended run-in schedule.

TOP OVERHAUL LIMITS

These tables should be used in conjunction with the Limits and Lubrication Charts, pages 72, 73, and 74. The letters "L" and "T" are used to represent loose and tight fits, respectively. The symbol "*" indicates that worn parts should be replaced if any looseness is found. The expression "Fit To" indicates that a fitting operation may be necessary at assembly to obtain the required fit. The expression "By Selection" indicates that it may be necessary to select other parts or relationships of parts to obtain the required fit. Unless otherwise specified, fits are diametrical. Reference numbers not listed in the following tables but appearing in the Limits and Lubrication Charts are required only in overhaul procedures, and are covered in the Overhaul Manual, Part No. 86405.

TABLE FOR PAGE 72

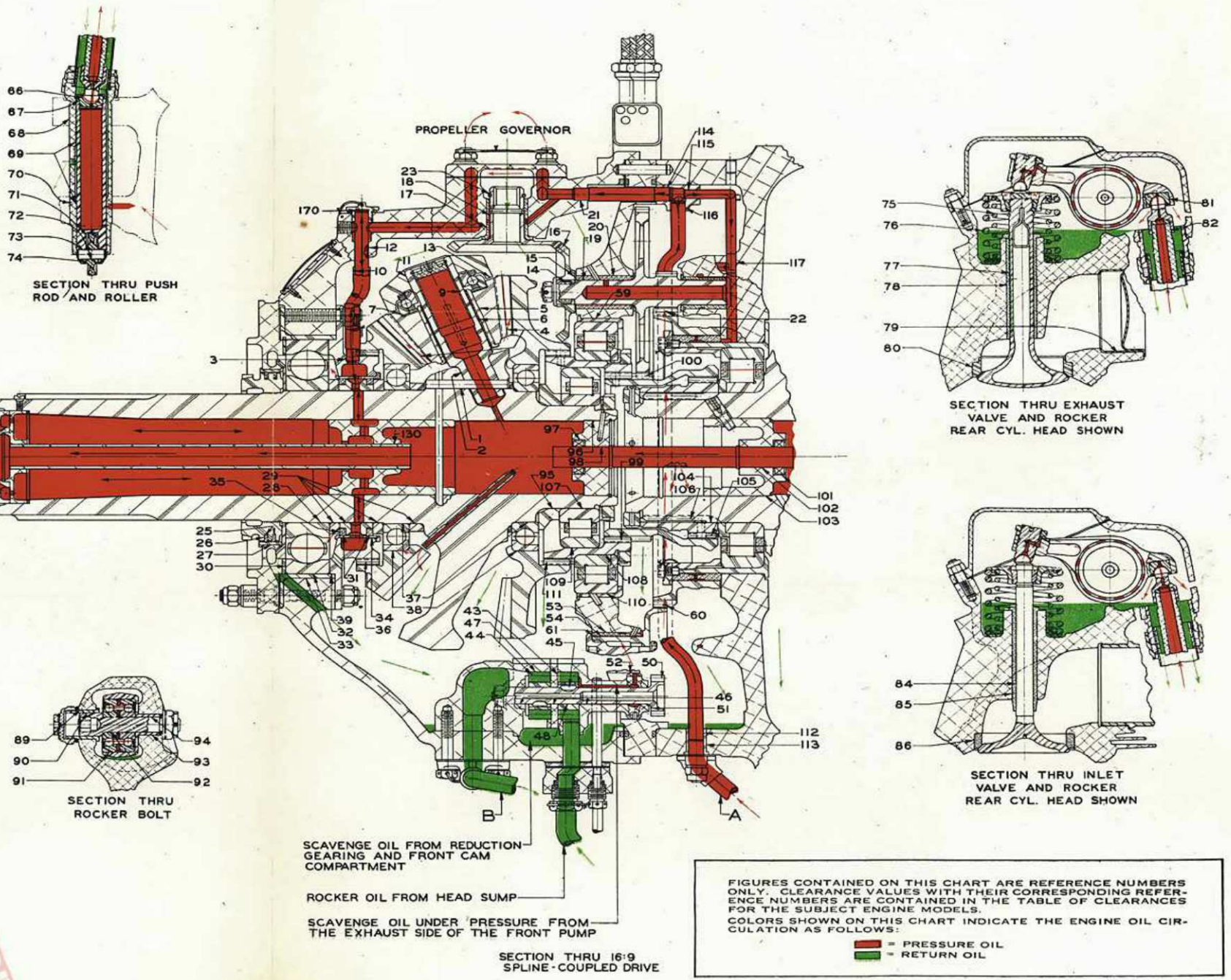
Ref. No.	Description	Min.	Max.	Replacement
25	Propeller Shaft Thrust Bearing Oil Seal Ring Gap (Fit To)	.008	.012	.016
26	Propeller Shaft Thrust Bearing Oil Seal Ring Side Clearance	.0004	.0046	.016
27	Propeller Shaft Thrust Bearing Cover Liner—Cover	.001T	.005T	*
30	Propeller Shaft Thrust Bearing Spacer Pinch—Thrust Bearing Cover (Fit To)	.004T	.008T	*
75	Inlet and Exhaust Valve Inner Spring Pressure at 1½ in.	88 lb.	92 lb.	83 lb.
76	Inlet and Exhaust Valve Outer Spring Pressure at 1½ in.	98 lb.	102 lb.	93 lb.
77	Exhaust Valve Guide—Valve	.003L	.0055L	.010
78	Exhaust Valve Guide—Cylinder Head	.0005T	.003T	*
79	Exhaust Port Liner—Cylinder Head	.006T	.013T	*
80	Exhaust Valve Seat—Cylinder Head	.006T	.010T	*
81	Rocker Ball Socket—Rocker	.000	.0025T	*
82	Push Rod Ball End—Push Rod	.001T	.0025T	*
84	Inlet Valve Guide—Valve	.0015L	.004L	.010
85	Inlet Valve Guide—Cylinder Head	.000	.001L	.002
86	Inlet Valve Seat—Cylinder Head	.0005T	.003T	*
89	Rocker Shaft Large Bushing—Cylinder Head	.006T	.010T	*
90	Rocker Shaft Large Bushing—Rocker Shaft	.001T	.004T	*
91	Rocker Bearing—Rocker	.000	.0013L	.002
92	Rocker Bearing—Rocker Shaft	.0005T	.0015T	*
93	Rocker Shaft Small Bushing—Cylinder Head	.000	.0008L	.0015
94	Rocker Shaft Small Bushing—Rocker Shaft	.001T	.004T	*

TABLE FOR PAGE 73

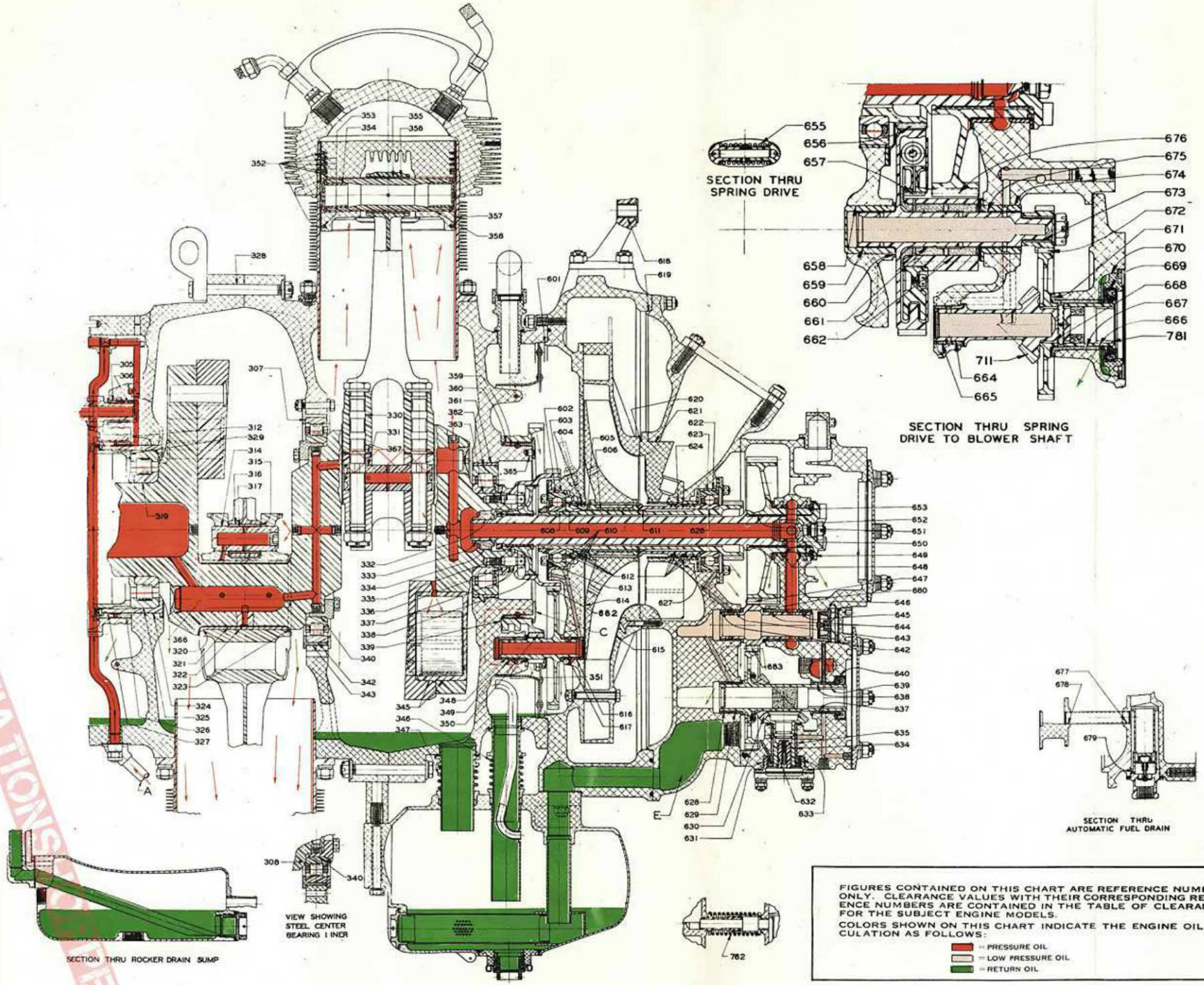
Ref. No.	Description	Min.	Max.	Replacement
352	Piston Ring Gaps			
	Wedge Type Compression—Top Groove	.060	.070	
	Wedge Type Compression—2nd Groove	.0595	.0665	
	Wedge Type Compression—3rd Groove	.0595	.0665	
	Rectangular Compression—Top Groove	.0565	.0635	
	Rectangular Compression—2nd Groove	.0565	.0635	
	Rectangular Compression—3rd Groove	.0565	.0635	
	Dual Oil Control—4th Groove	.0565	.0635	
	Scraper—5th Groove	.040	.050	
	Compression—5th Groove	.0565	.0635	
353	Piston Ring Side Clearance			
	Wedge Type Compression—Top Groove	.001	.005	
	Wedge Type Compression—2nd Groove	.001	.005	
	Wedge Type Compression—3rd Groove	.001	.005	
	Rectangular Compression—Top Groove	.007	.009	
	Rectangular Compression—2nd Groove	.0055	.0075	
	Rectangular Compression—3rd Groove	.0055	.0075	
	Dual Oil Control—4th Groove	.004	.007	
	Scraper—5th Groove	.003	.005	
	Compression—5th Groove	.003	.005	
354	Piston Pin Aluminum Plug—Pin	.000	.0015T	.001
355	Piston Pin Bushing—Pin	.0017L	.0033L	.005
356	Piston Pin Bushing—Master and Articulated Rods	.0045T	.006T	*
357	Piston—Cylinder Barrel	.021L	.025L	.031
358	Piston Pin—Piston (By Selection)	.0003L	.001L	.003
618	Engine Mounting Rigid Bracket Bushing—Bracket	.0005T	.0025T	*
631	Vacuum Pump Oil Seal Retainer—Rear Crankcase	.001L	.005L	
632	Vacuum Pump Drive Gear Splines—Coupling Splines	.002L	.005L	
633	Vacuum Pump Drive Gear Oil Seal—Retainer	.0015T	.0065T	*
640	Generator Drive Gear Oil Seal—Rear Crankcase	.002T	.007T	*
649	Accessory Drive Shaft End Clearance	.007	.025	.030
650	Accessory Drive Gear Bushings—Gear	.0025L	.0045L	.006
652	Accessory Drive Gear Splines—Starter Jaw Splines	.0003T	.0012L	
653	Accessory Drive Gear Oil Seal Ring Side Clearance	.002	.010	
669	Magneto Drive Gear Oil Seal—Retainer	.001T	.007T	*
670	Magneto Drive Gear Oil Seal Retainer—Magneto Adapter	.0005T	.0025T	*
679	Fuel Drain Valve Upper Housing—Lower Housing	.0005T	.0025T	*

TABLE FOR PAGE 74

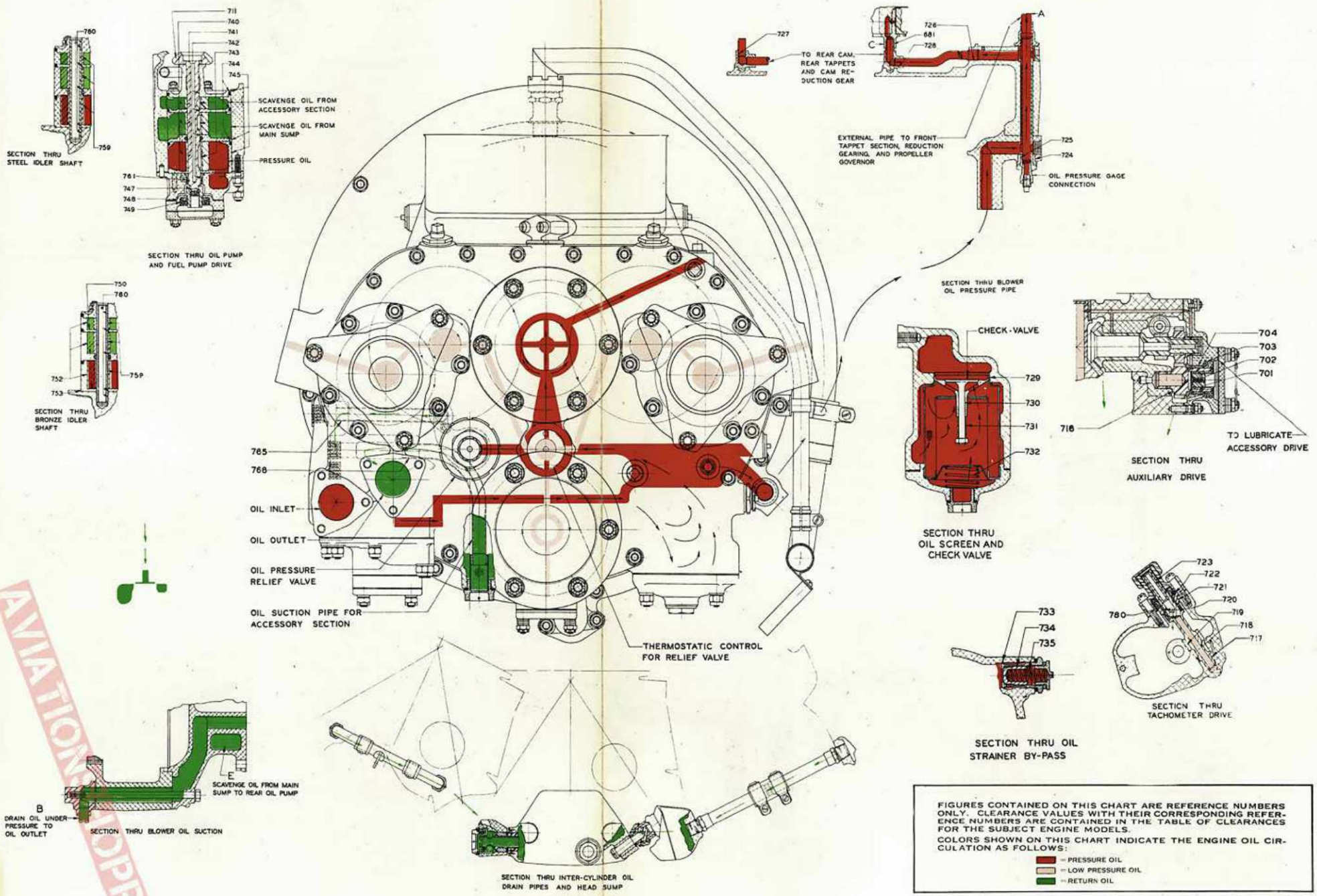
Ref. No.	Description	Min.	Max.	Replacement
702	Auxiliary Drive Coupling Splines—Gear Splines	.000	.002L	.006
703	Auxiliary Drive Gear Oil Seal—Auxiliary Drive Adapter	.0015T	.0065T	*
722	Tachometer Drive Gear Inner Adapter—Oil Seal	.0015T	.0065T	*
724	Pressure Oil Transfer Pipe Bushing—Intermediate Rear Crankcase	.001T	.003T	*
725	Pressure Oil Transfer Pipe Bushing—Pipe	.001L	.008L	
729	Main Oil Screen—Rear Crankcase	.003L	.015L	
730	Main Oil Screen Check Valve Stem—Valve Seat	.0005L	.0035L	
731	Main Oil Screen Check Valve Spring Pressure at 13/16 in.	2.25 lb.	2.75 lb	1.75 lb.
732	Main Oil Screen Retaining Spring Pressure at 13/16 in.	9 lb.	13 lb.	6 lb.
733	Main Oil Screen By-pass Valve Housing—Rear Crankcase	.000	.0035L	
734	Main Oil Screen By-pass Valve Housing—Valve	.002L	.006L	
735	Main Oil Screen By-pass Valve Spring Pressure at 1⅜ in.	2.5 lb.	3 lb.	1.5 lb.
749	Fuel Pump Adapter—Oil Seal	.0015T	.0065T	*
771	Dual Auxiliary Intermediate Drive Gear Oil Seal—Retainer	.001T	.007T	*
777	Dual Auxiliary Drive Gear Splines—Coupling Splines	.002L	.004L	
778	Dual Auxiliary Drive Gear Oil Seal Retainer—Adapter	.000	.004L	



Limits and Lubrication Chart for Front Section



Limits and Lubrication Chart for Crankcase Section



FIGURES CONTAINED ON THIS CHART ARE REFERENCE NUMBERS ONLY. CLEARANCE VALUES WITH THEIR CORRESPONDING REFERENCE NUMBERS ARE CONTAINED IN THE TABLE OF CLEARANCES FOR THE SUBJECT ENGINE MODELS.

COLORS SHOWN ON THIS CHART INDICATE THE ENGINE OIL CIRCULATION AS FOLLOWS:

- = PRESSURE OIL
- = LOW PRESSURE OIL
- = RETURN OIL

Limits and Lubrication Chart for Rear Section

PRESERVATION OF INACTIVE ENGINES

The corrosion preventive mixture used in the following instructions is composed of three parts engine lubrication oil, and one part corrosion preventive compound, Rust Ban 604 or equivalent.

ENGINES INACTIVE FROM ONE TO SEVEN DAYS

When it is definitely known that the airplane will be idle for more than one day but not more than seven days, the engine should be operated every second day at 1000 rpm for 15 minutes or until the oil temperature reaches 65°C (149°F.)

ENGINES INACTIVE OVER SEVEN DAYS

PARTS	PROCEDURE	INSTALLED		Not installed in aircraft
		7 to 30 days	30 days or more	
Engine Cleaning	Before washing the engine look for oil leaks which may indicate loose connections, packing, or nuts. Wash the engine externally with kerosene or cleaning solvent removing all oil, grease, and dirt.			✓
Preliminary Preservation	Drain the oil from the engine and from the oil tank through a clean cloth into clean containers. Examine the cloth for foreign matter. Store this oil for use in subsequent preparation of the engine for service. Reinstall the oil drain plugs, and fill the oil tank with enough corrosion preventive mixture to insure lubrication during the preservative running period. Blank off or by-pass the oil cooler so as to produce an inlet oil temperature of 95°C to 102°C (203°F to 215°F) for engines installed in aircraft, or an outlet oil temperature of 104.4°C to 121°C (220°F to 250°F) for engines not installed in aircraft. Run the engine on normal leaded gasoline for at least 15 minutes at idling speeds, using the corrosion preventive mixture as a lubricant. At the end of the run, open the throttle to attain a speed of 1500 to 1600 rpm just before shutting down the engine. Immediately prior to the cessation of the firing impulses, inject from 1¾ to 3½ pints of corrosion preventive mixture (under air pressure from an auxiliary tank) into a suitable opening between the carburetor and impeller such as the blower rim temperature connection or the manifold pressure gage connection in order to coat the		✓	✓

PARTS	PROCEDURE	INSTALLED		Not installed in aircraft
		7 to 30 days	30 days or more	
Preliminary Preservation (Con't.)	induction system and cylinder bores. If facilities are not available for the injection of corrosion preventive mixture through the induction system, spray the cylinder bores through the spark plug holes within 2 hours after engine shut-down. Spray sufficient mixture into each cylinder with the piston at the bottom of its stroke to insure adequate coverage of all internal surfaces.			
Mixture Drainage	While the mixture is still warm, drain the corrosion preventive mixture from the engine, the lines, and the oil tank. Remove, clean, and reinstall the main oil screen and scavenge oil strainer. Reinstall all oil drain plugs.		✓	✓
Spark Plugs	Disconnect the spark plug leads and remove the spark plugs. Install protector caps on the spark plug lead connectors. Clean the spark plugs in clean unleaded gasoline and dry them with compressed air. Coat the spark plug threads with a light oil or suitable rust inhibitor and store them in a dry place. Install protector caps on both ends of the plugs if special cylindrical protective cartons are not available. Place the plugs in a suitable container to be shipped with the engine.	✓	✓	✓
Exhaust Valves	Thoroughly spray each exhaust valve with corrosion preventive mixture through the spark plug holes or the exhaust ports. Be sure each exhaust valve is fully open when it is being sprayed. Use only dry air to operate the spray gun. Rotate the propeller shaft at least four revolutions in the normal direction of rotation to work the mixture into the exhaust valve guides. Install exhaust port covers.	✓	✓	✓

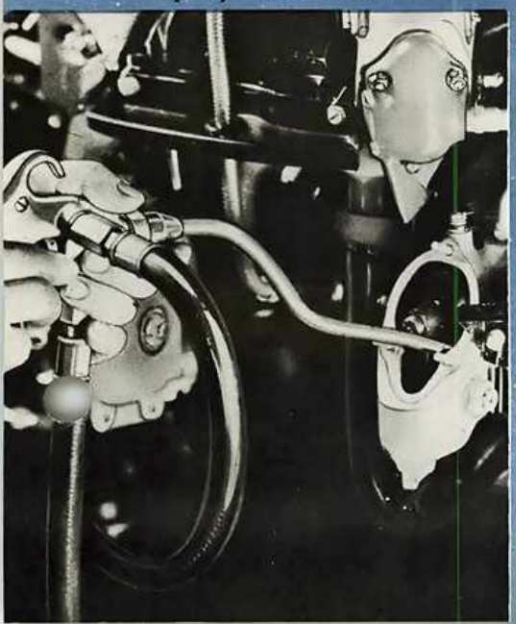
Remove Drain Plug

Install Protector Cap

Spray Exhaust Valves

PARTS	PROCEDURE	INSTALLED		Not installed in aircraft
		7 to 30 days	30 days or more	
Rocker Boxes	It will not be necessary to remove the rocker box covers and spray the rockers if the engine was preserved at the oil temperature given above in "Preliminary Preservation". If, in cold weather, the engine was preserved at low temperature, or if the alternate method of treating cylinder bores was used, the rocker box covers must be removed and the rockers, valve springs, washers, and valves sprayed with corrosion preventive mixture.	✓	✓	✓
Cylinder Treatment	With the inlet valve open and the piston at the bottom of its stroke, spray corrosion preventive mixture into the front spark plug hole of each cylinder. This spray should be deposited on the inlet valves and the cylinder walls. Rotate the propeller or propeller shaft at least six revolutions to insure piston ring coverage for each cylinder. Respray each cylinder without turning the propeller shaft to cover the cylinder walls. **Do Not Turn the Propeller Shaft After This Spraying of the Cylinders.** If the shaft is turned, the spraying procedure must be repeated.	✓	✓	✓
Dehydrator Plugs	Install dehydrator plugs in the spark plug holes of all cylinders and tighten them to a torque of 20 to 25 inch-pounds. Do not remove the moisture seals from the plugs until ready to install. Install a dehydrator plug in the top of the rear case.	✓	✓	✓
Thrust Bearing	Remove the thrust bearing cover and thoroughly coat the thrust bearing with corrosion preventive mixture, then reinstall the cover.		✓	✓

Spray Rocker Boxes



Spray Inlet Valves

Install Dehydrator Plugs

PARTS	PROCEDURE	INSTALLED		Not installed in aircraft
		7 to 30 days	30 days or more	
Carburetor Opening in the Intermediate Rear Case	When the carburetor is removed from the engine, secure a ½ pound bag of dehydrating agent to the inside of the carburetor mounting flange cover. Secure the cover to the flange using acid-free waxed paper as a gasket between the cover and the flange. Seal the parting line of the cover and flange with tape.			✓
Propeller Shaft	Coat the exposed surfaces of the propeller shaft with corrosion preventive mixture. Install a thread protector on the front of the propeller shaft and cover the splines with acid-free waxed paper.			✓
Accessories	All accessories not attached to the engine should be treated for proper storage preparation. Slush the fuel pump and propeller governor pump with the specified slushing oil. Drain the excess oil and wrap these accessories in acid-free waxed paper before placing them in a shipping carton.		✓	✓
Accessory Drives	Remove all accessory drive cover plates. Cover the drive ends with corrosion preventive mixture, then reinstall the cover plates.			✓
Openings	Seal all breathers, oil inlet and outlet connections or any other openings not otherwise covered by plates or covers with moisture-resisting sealing tape.		✓	✓
External Inspection	Inspect the engine carefully, checking all nuts and cap screws for tightness. Inspect for loose or broken safety wire, missing plugs, or damaged parts. Make certain that the intake pipes are tight at both ends.		✓	✓

Dehydrating Agent

Cover Shaft Splines

Coating Accessory Drive

Accelerating Pump

PARTS	PROCEDURE	INSTALLED		Not installed in aircraft
		7 to 30 days	30 days or more	
Accelerating Pump	Remove the pump assembly from the carburetor adapter by unscrewing the six long screws. Keeping the pump assembly together, fasten nuts to the six screws. Remove the ⅛ inch NPT plug in the boss on the pump body and attach an oil flushing line to the connection. Plug the blower throat vacuum passage on the pump adapter to prevent slushing oil from entering the air side of the diaphragm. Place the pump in an upright position with the discharge nozzle pointing upward and flow oil into the assembly until it discharges from the four ¼ inch holes in the pilot end of the pump adapter. Remove the oil flushing line from the pump and install the ⅛ inch plug in the boss. Drain the oil from the pump, wipe it clean, and remove the plug in the vacuum passage. Remove the nuts from the screws and install the gasket and the pump on the carburetor adapter, making sure the vacuum passage in the pump lines up with the passage in the adapter.			✓
Warning Tag	Place a warning tag on the propeller or the propeller shaft and a similar tag in the airplane cockpit stating that the propeller or the propeller shaft must not be turned until all dehydrating materials have been removed from the engine.	✓	✓	✓
Inspection	All dehydrator plugs must be inspected every 7 days and the color of the dehydrating agent compared with that on the humidity indicator. Any plugs indicating a relative humidity of more than 20 percent are unsafe and should be replaced. When it becomes necessary to replace a dehydrator plug, the dehydrating agent in the exhaust tail pipe and in the carburetor air scoop should also be replaced. If frequent replacement of a particular plug becomes necessary, the section of the engine in which that plug is located should be checked for inadequate sealing.	✓	✓	✓

Preserving Carburetor Installed on Engine

Disconnect the carburetor fuel transfer pipe from the carburetor and the fuel supply line from its mounting pad. Install a suitable nipple in the carburetor fuel inlet connection. Taking care to keep the slushing oil, Grade 1065, away from the automatic mixture control and the air chambers of the carburetor, completely fill the carburetor through the fuel inlet with slushing oil. Remove the drain plugs from the bottom of the carburetor and allow the slushing oil to drain. Actuate the throttle and mixture controls several times while flushing the carburetor. After allowing all oil to drain from the carburetor, reinstall the connections

and plugs but leave the fuel transfer pipe disconnected. Seal all of the openings in the carburetor and the ends of the fuel lines with suitable plugs.

Preserving Carburetor Not Installed on Engine

When an injection carburetor is to be out of service for a period exceeding 10 days, prepare it for storage in accordance with one of the methods outlined in the following instructions. Use only unleaded gasoline or naphtha for cleaning. Use only oil Grade 1065 for preservation purposes.

Regular Method

Remove the drain plugs from the metered and unmetered fuel chambers. Remove the fuel drain plug from the lower left side of the carburetor adjacent to the knurled idle mixture adjusting nut. The fuel will drain from the carburetor when these plugs are removed. Unscrew the air chamber drain plug and allow any moisture to drain out, replacing this plug immediately so that no slushing oil will get into the air chambers.

When the carburetor has drained thoroughly, replace the three plugs. Remove, inspect, and reinstall the fuel strainer. If there is a plug installed in the vapor vent outlet, remove it at this time.

Place the manual mixture control lever in the auto rich position and the throttle valves in the wide open position.

Connect the oil supply line to the carburetor fuel inlet and inject slushing oil at 10 to 15 pounds per square inch pressure until oil flows from the fuel outlet. Do not permit the overflow oil to run into the main or boost venturis and the impact tubes, or on the automatic mixture control unit, because the presence of oil on these parts will cause a collection of dust and grime which will tend to alter the contour of the main and boost venturis, clog the impact tubes, and cause a variation in the calibration of the automatic mixture control unit.

Remove the fuel drain plug and the plugs to the metered and unmetered fuel chambers and drain the excess oil.

> **Note:** Slushing oil used in carburetor preservation is continually picking up gasoline. Although the oil can be reused, it should be discarded when the gasoline content reaches 2 percent by volume.

Replace and safety all plugs. Plug the fuel inlet. If the fuel transfer pipe from the fuel control unit to the fuel discharge nozzle is not to be left on the carburetor, plug the outlet provided for this pipe. Plug the vapor vent line connection and all other openings in the carburetor. Lubricate all joints in the control linkages with slushing oil; then lockwire the throttle valve in the closed position.

If the carburetor is to be shipped over salt water or stored near salt water, spray the exterior surfaces with slushing oil, making sure no oil comes in contact with the main or boost venturis, the impact tubes, or the automatic mixture control unit. Set the carburetor aside and allow the excess oil to drain.

Air Pressure Method of Carburetor Preservation

The oil slushing operations may be expedited by applying a definitely controlled air pressure to the air chamber in the regulator front body. This air pressure will open the poppet valve and allow oil to flow freely into the carburetor. This operation should be performed with extreme caution according to the following instructions.

Flush and drain the carburetor as previously described in the regular method; then remove the "A" chamber plug in the top of the regulator front body and install

a fitting having a .3125-24 thread, a taper seat, and a No. 40 (.098 inch) drilled hole.

Attach an air pressure line to the fitting, with a pressure regulator and a pressure gage incorporated in the air line. Regulate the air pressure so it will not exceed 20 pounds per square inch.

CAUTION

It is extremely important that the air pressure applied to the regulator air chamber not exceed 20 pounds per square inch. Any increase in this pressure could cause damage to the large air diaphragm or reverse the small balance diaphragm, both of which are in this chamber of the regulator.

When the oil line and the air line are connected to the carburetor, turn on the oil pressure; then turn on the air pressure. Let the oil flow into the carburetor until it comes out the fuel outlet in the fuel control unit. Turn off the air pressure first; then turn off the oil pressure.

Replace and lockwire all plugs. Plug the fuel inlet. If the fuel transfer pipe from the fuel control unit to the fuel discharge nozzle is not to be left on the carburetor, plug the outlet provided for this pipe. Plug the vapor vent line connection and all other openings in the carburetor. Lubricate all joints in the control linkages with the flushing oil; then lockwire the throttle valves in the closed position.

If the carburetor is to be shipped over salt water or stored near salt water, spray the exterior surfaces with slushing oil, again making sure that no oil comes in contact with the main or boost venturi surfaces, the impact tubes, or the automatic mixture control unit. Set the carburetor aside and allow the excess oil to drain.

Represerving the Engine

At inspection, when the color of the crystals of the dehydrating agent contained in the humidity indicator indicates a humidity greater than 20 percent, use the following procedure to represerve the engine:

Cut off the engine envelope seal and carefully roll the envelope down to the top of the support cone.

Remove all of the bags of dehydrating agent and all dehydrator plugs indicating an unsafe color and any bags of dehydrating agent in the induction system or the exhaust manifolds of the cylinders affected. Remove the humidity indicator.

Attach fresh bags of dehydrating agent to the cylinders and install new dehydrator plugs in the open spark plug holes. Secure new bags of dehydrating agent in the induction system and exhaust manifold in place of those removed.

If the crepe paper around the cylinders was removed, replace it after attaching a new humidity indicator in place on No. 1 cylinder.

Roll up the envelope, clean the open edges, and seal them with a heat-sealing iron along the top. Gather the envelope and fasten it around the propeller shaft.

Cylinders whose dehydrator plugs indicate a greater humidity than 20 percent should be inspected through the spark plug holes. If a band of corrosion is observed at the top of the cylinder barrel, remove one cylinder from each row and inspect for further corrosion. Remove the rust and respray the cylinder. When significant corrosion is present other than in a band at the top of the cylinder above the limit of ring travel, or if there is corrosion in the power section, the engine should be turned in for overhaul.

PACKING THE ENGINE

Arrange Envelope

Fasten Dehydrating Agent

All Pratt & Whitney Twin Wasp Engines which have been prepared for storage should be packed in the engine packing case. The use of the protective envelope eliminates preserving the exterior of the engine. For ease of installation, handle the envelope at temperatures above 20°C (68°F).

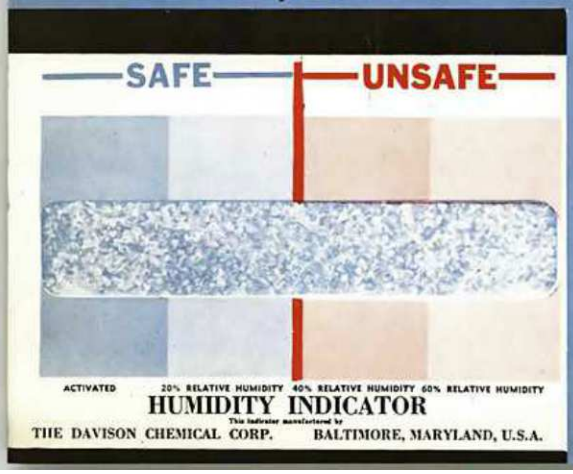
Unfasten and remove the engine from the stand using PWA-1333 Lifting Eye and a hoist with a minimum capacity of two tons. Remove the rigid mounting brackets and install the rigid bracket and bent bolt assemblies.

Place the support cone on the packing case base, fitting the holes in the cone over the studs in the base. Fasten the cone to the base with washers and nuts. Place the packing case mounting plate in position but do not secure it.

Place the engine case base with the support cone attached and the mounting plate in position, under the engine. Carefully spread the protective envelope inside the support cone, locating the large reinforcing washers over the holes in the mounting plate.

Carefully lower the engine onto the mounting plate, secure nuts to two opposite bent bolts, raise the engine and mounting plate, and fasten the remaining bolts to

Humidity Indicator



Cut Protective Paper

Seal Envelope

the mounting plate. Lower the engine onto the cone and fasten the mounting plate to the cone.

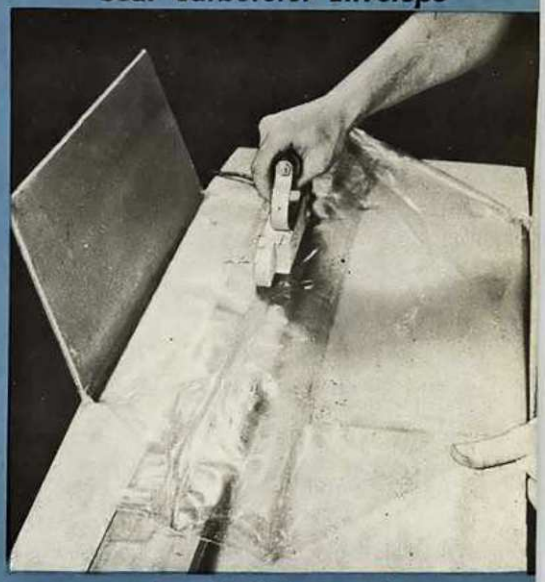
Cover with tape any protruding nuts, studs, or safety wire which might damage the protective envelope.

Fasten two 1 pound bags of dehydrating agent to each cylinder. Attach the humidity indicator to No. 1 cylinder, wrap crepe paper around the power section and bring the protective envelope up around the engine. Install the spacer on the propeller shaft, place the reinforced opening in the envelope over the shaft, and screw the spanner nut tight against the envelope. Install the protector cap. Seal the protective envelope, withdrawing as much air as possible without shrinking the envelope tight against the engine. A good seal is transparent. Fasten the excess envelope material around the propeller shaft.

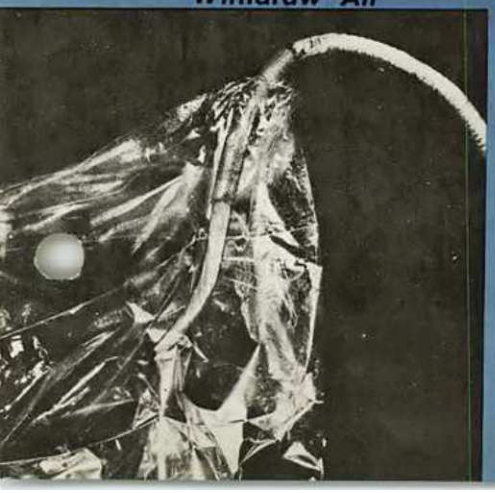
Install the four side panels in the base, attach the carburetor and accessories to the packing case cover, and lower it in position. Pass two steel straps over the top and under the bottom of the case and tighten the turnbuckles. Pass the third strap around the case horizontally and tighten it. Place the engine log data sheets behind the inspection port cover and wire the cover.

Lower Cover

Seal Carburetor Envelope



Withdraw Air



Gather Excess Material

Install Side Panels

SERVICE TOOLS

Tool No.	Tool Name	Application
PWA-144	Wrench	Removing and installing intake pipe upper nut
PWA-197	Bar	Turning the propeller shaft
PWA-455	Depressor	Depressing valve springs
PWA-459	Compressor	Compressing valve springs
PWA-489	Clamp	Compressing piston rings
PWA-672	Gage	Measuring valve clearances
PWA-917	Sling	Lifting engine in flight position
PWA-1333	Eye	Lifting engine in vertical position
PWA-1683	Wrench	Removing and installing spark plug lead nuts
PWA-1686	Puller	Loosening main oil sump
PWA-1886	Wrench	Loosening or tightening nut on radio shielding
PWA-2210	Wrench	Removing and installing rocker box sump supports
PWA-2302	Pusher	Removing piston pin
PWA-2417	Indicator	Timing and synchronizing magnetos
PWA-2420	Template	Timing magnetos
PWA-2446	Straightedge	Timing breaker points of magneto
PWA-2537	Indicator	Finding top center of piston stroke
PWA-3687	Tester	Testing ignition harness assembly
PWA-2724	Wrench	Removing and installing cylinder hold down nuts
PWA-2835	Wrench	Adjusting valve clearances
PWA-3001	Driver	Installing spark plug Heli-coil inserts
PWA-3013	Wrench	Removing and installing push rod packing nuts
PWA-3168	Wrench	Removing and installing spark plugs
PWA-3197	Nut	Installing cylinder
PWA-3252	Plug	Replacing spark plugs
PWA-3367	Expander	Spark plug Heli-coil insert
PWA-3420	Expander	Spark plug Heli-coil insert staking
PWA-3492	Tap	Spark plug Heli-coil insert
PWA-3944	Gage	Spark plug insert
PWA-4102	Extractor	Spark plug Heli-coil insert
PWA-4142	Indicator	Positioning No. 1 piston
PWA-5002	Wrench	Removing and installing palnuts
PWA-5072	Wrench	Removing and installing intake pipe lower nut
TAM-1161	Stand	Holding engine
TD-28797	Plate	Holding engine in stand

APPENDIX

The data included in this Appendix is intended as a handy reference for the users of this publication. The nature of the data should expedite the solution of the many mathematical problems which arise daily in the course of one's work.

Suggestions for the enlargement of this type data are invited so that this publication will serve the dual purpose of giving specific maintenance instruction and in addition, information of a general nature desired by the users of this book.

CONVERSIONS

INCH FRACTION CONVERSIONS

Inch Fraction	Decimal Equiv.	Area Sq. In.	mm Equiv.
1/64	.0156	.0002	.397
1/32	.0312	.0008	.794
3/64	.0469	.0017	1.191
1/16	.0625	.0031	1.587
5/64	.0781	.0048	1.984
3/32	.0937	.0069	2.381
7/64	.1094	.0094	2.778
1/8	.125	.0123	3.175
9/64	.1406	.0154	3.572
5/32	.1562	.0192	3.969
11/64	.1719	.0232	4.366
3/16	.1875	.0276	4.762
13/64	.2031	.0324	5.159
7/32	.2187	.0376	5.556
15/64	.2344	.0431	5.953
1/4	.25	.0491	6.350
17/64	.2656	.0553	6.747
9/32	.2812	.0621	7.144
19/64	.2969	.0692	7.540
5/16	.3125	.0767	7.937
21/64	.3281	.0845	8.334
11/32	.3437	.0928	8.731
23/64	3594	.1014	9.128
3/8	.375	.1105	9.525
25/64	.3906	.1198	9.922
13/32	.4062	.1296	10.319
27/64	.4219	.1398	10.716
7/16	.4375	.1503	11.112
29/64	.4531	.1612	11.509
15/32	.4687	.1726	11.906
31/64	.4844	.1842	12.303
1/2	.5	.1964	12.700
33/64	.5156	.2088	13.097
17/32	.5312	.2217	13.494
35/64	.5469	.2349	13.891
9/16	.5625	.2485	14.288
37/64	.5781	.2625	14.684
19/32	.5937	.2769	15.081
39/64	.6094	.2916	15.478
5/8	.625	.3068	15.875
41/64	.6406	.3223	16.272
21/32	.6562	.3382	16.669
43/64	.6719	.3545	17.065
11/16	.6875	.3712	17.462
45/64	.7031	.3883	17.859
23/32	.7187	.4057	18.256
47/64	.7344	.4235	18.653
3/4	.75	.4418	19.050
49/64	.7656	.4604	19.447
25/32	.7812	.4794	19.844
51/64	.7969	.4987	20.241
13/16	.8125	.5185	20.637
53/64	.8281	.5386	21.034
27/32	.8437	.5591	21.431
55/64	.8594	.5800	21.828
7/8	.875	.6013	22.225
57/64	.8906	.6229	22.622
29/32	.9062	.6450	23.019
59/64	.9219	.6675	23.416
15/16	.9375	.6903	23.812
61/64	.9531	.7134	24.209
31/32	.9687	.7371	24.606
63/64	.9844	.7610	25.003
1	1.	.7854	25.400

CENTIGRADE-FAHRENHEIT CONVERSIONS

$°F = 9/5°C + 32 = 1.8\ (°C + 17.8)$
$°C = 5/9\ (°F - 32)$

C. ←F.↓C.→ F.			C. ←F.↓C.→ F.		
—62.2	—80	—112.0	26.7	80	176.0
—56.7	—70	— 94.0	29.4	85	185.0
—51.1	—60	— 76.0	32.2	90	194.0
—45.6	—50	— 58.0	35.0	95	203.0
—40.0	—40	— 40.0	37.8	100	212.0
—34.4	—30	— 22.0	40.6	105	221.0
—31.7	—25	— 13.0	43.3	110	230.0
—28.9	—20	— 4.0	46.1	115	239.0
—26.1	—15	+ 5.0	48.9	120	248.0
—23.3	—10	14.0	51.7	125	257.0
—20.6	— 5	23.0	54.4	130	266.0
—17.8	0	32.0	57.2	135	275.0
—15.0	5	41.0	60.0	140	284.0
—12.2	10	50.0	62.8	145	293.0
— 9.4	15	59.0	65.6	150	302.0
— 6.7	20	68.0	68.3	155	311.0
— 3.9	25	77.0	71.1	160	320.0
— 1.1	30	86.0	73.9	165	329.0
1.7	35	95.0	76.7	170	338.0
4.4	40	104.0	79.4	175	347.0
7.2	45	113.0	82.2	180	356.0
10.0	50	122.0	85.0	185	365.0
12.8	55	131.0	87.8	190	374.0
15.6	60	140.0	90.6	195	383.0
18.3	65	149.0	93.3	200	392.0
21.1	70	158.0	96.1	205	401.0
23.9	75	167.0	98.9	210	410.0

C. ←F.↓C.→ F.			C. ←F.↓C.→ F.		
101.7	215	419.0	232.2	450	842.0
104.4	220	428.0	237.8	460	860.0
107.2	225	437.0	243.3	470	878.0
110.0	230	446.0	248.9	480	896.0
112.8	235	455.0	254.4	490	914.0
115.6	240	464.0	260.0	500	932.0
118.3	245	473.0	265.6	510	950.0
121.1	250	482.0	271.1	520	968.0
126.7	260	500.0	276.7	530	986.0
132.2	270	518.0	282.2	540	1004.0
137.8	280	536.0	287.8	550	1022.0
143.3	290	554.0	293.3	560	1040.0
148.9	300	572.0	298.9	570	1058.0
154.4	310	590.0	304.4	580	1076.0
160.0	320	608.0	310.0	590	1090.0
165.6	330	626.0	315.6	600	1112.0
171.1	340	644.0	326.7	620	1148.0
176.7	350	662.0	337.8	640	1184.0
182.2	360	680.0	348.9	660	1220.0
187.8	370	698.0	360.0	680	1256.0
193.3	380	716.0	371.1	700	1292.0
198.9	390	734.0	382.2	720	1328.0
204.4	400	752.0	393.3	740	1364.0
210.0	410	770.0	404.4	760	1400.0
215.6	420	788.0	415.6	780	1436.0
221.1	430	806.0	426.7	800	1472.0
226.7	440	824.0	437.8	820	1508.0

CONVERSION FACTORS

Weight

Multiply	By	To Obtain
Ounces (avdp)	.0625	Pounds (avdp)
	437.5	Grains
	28.35	Grams
	.9115	Ounces, (troy)
Pounds (avdp)	16	Ounces (advdp)
	7000	Grains
	.454	Kilograms
	1.21528	Pounds (troy)
Tons (short)	2000	Pounds (avdp)
	907.18	Kilograms
	.90718	Tons (metric)

Weight

Multiply	By	To Obtain
Tons (long)	2240	Pounds (avdp)
	1016	Kilograms
Tons (metric)	1000	Kilograms
	2205	Pounds (avdp)
	1.1025	Tons (short)
Kilograms	2.205	Pounds
Grams	980.7	Dynes
Dynes	2.248×10^{-6}	Pounds
Pounds/hp	.459	Kg/cv

CONVERSION FACTORS

Pressure

Multiply	By	To Obtain
Pounds/sq. in.	.06804	Atmospheres
	2.036	In. of mercury
	703.1	Kg/sq meter
	70.31	Grams/sq cm
Pounds/sq ft.	.19242	In. of water
	4.883	Kg/sq meter
Atmospheres	76.0	Cm of mercury
	29.92	In. of mercury
	1.033	Kg/sq cm
	14.7	Pounds/sq. in.
	2116	Pounds/sq ft
	1013.2	Millibars
Bars	1000	Millibars
	75.01	Cm of mercury
	14.5	Pounds/sq ft
	.98692	Atmospheres
	29.53	In. of mercury
Inches of water	.07349	In. of mercury
	25.38	Kg/sq meter
	5.198	Pounds/sq ft
Kg/sq meter	.2048	Pounds/sq ft
Kg/sq cm	1.0197	Piezes
	14.22	Pounds/sq in

Based on water at 15°C and mercury at 0°C.

Density

Multiply	By	To Obtain
Pounds/cu in.	27.68	Grams/cu cm
	27680	Kg/cu meter
	1728	Pounds/cu ft
Pounds/cu ft	.01602	Grams/cu cm
	16.02	Kg/cu meter
Grams/cu cm	62.46	Pounds/cu ft
	.03613	Pounds/cu in
	1000	Kg/cu meter
Kg/cu meter	.0624	Pounds/cu ft

Energy

Multiply	By	To Obtain
Hp-hr	2545	Btu
	641.7	Kg cal
Kg calories	3.968	Btu
	3086	Foot-lb
	426.9	Meter kg
Foot-pounds	.1383	Meter kg
Meter kg	7.233	Foot-lb
Btu	777.98	Foot-lb
Ergs	7.376×10^{-8}	Foot-pounds

Power

Multiply	By	To Obtain
Btu/min	12.96	Ft-lb/sec
	.02356	Horsepower
	17.57	Watts
	.2520	Kg cal/min
Ft-lb/sec	.07717	Btu/min
	.01945	Kg cal/min
	1.356	Watts
Horsepower	42.44	Btu/min
	550	Ft-lb/sec
	1.014	Metric hp (cv)*
	10.70	Kg cal/min
	.7457	Kilowatts

Power

Multiply	By	To Obtain
Kg cal/min	51.43	Ft-lb/sec
	.09351	Horsepower
Hp metric (cv)*	41.83	Btu/min
	542.5	Ft-lb/sec
	.9863	Horsepower
	10.54	Kg cal/min
	.7355	Kilowatts

*(Cheval-vapeur)

CONVERSION FACTORS

Length

Multiply	By	To Obtain
Inches	2.540	Centimeters
	1000	Mils
Feet	30.48	Centimeters
	12	Inches
	.3048	Meters
	0.333	Yards
Yards	3	Feet
	.9144	Meters
Miles	5280	Feet
	1.609	Kilometers
	1760	Yards
	.8684	Naut. miles
Centimeters	.3937	Inches
Meters	39.37	Inches
	3.281	Feet
	1.094	Yards
Kilometers	3281	Feet
	.6214	Miles
	1094	Yards
Degrees (Angle)	.01745	Radians

Area

Multiply	By	To Obtain
Square inches	6.452	Sq cm
Square feet	929	Sq cm
	144	Sq inches
	.09290	Sq meters
	.111	Sq yards
Square yards	9	Sq feet
	.8361	Sq meters
Square miles	640	Acres
	2.590	Sq km
Square cm	.1550	Sq inches
Square meters	10.76	Sq feet
	1.196	Sq yards
Square km	.3861	Sq miles
Hectares	2.471	Acres
Acres	43560	Sq feet
Circular mils	.785	Sq mil
	7.85×10^{-7}	Sq inches
	5.067×10^{-6}	Sq cm

Volume

Multiply	By	To Obtain
Cu inches	1639	Cu cm
	.01732	Quarts
Cu feet	1728	Cu inches
	.02832	Cu meters
	.03704	Cu yards
	7.48052	U.S. gal
	28.32	Liters
Cu yards	27	Cu feet
	.7646	Cu meters
	202	U.S. gal
U.S. gal, liquid	.1337	Cu feet
	231	Cu inches
	4	U.S. quarts

Volume

Multiply	By	To Obtain
Quarts	2	Pints
Barrels-oil	42	Gallons-oil
U.S. gal, dry	1.164	U.S. gal, liquid
	.83267	Imperial gal
	3.785	Liters
Imperial gal	1.201	U.S. gal
	4.546	Liters
	277.4	Cu inches
Liters	.03531	Cu feet
	61.02	Cu inches
	.2641	U.S. gal
Cu meters	35.31	Cu feet
	1.308	Cu yards
	264.2	U.S. gal

CONVERSION FACTORS

Velocity

Multiply	By	To Obtain
Feet/min	.01667	Feet/sec
	.01136	Miles/hr
Feet/sec	1.097	Km/hr
	.5921	Knots
	.6818	Miles/hr
Miles/hr	.447	Meters/sec
	1.467	Feet/sec
	1.609	Km/hr
	.8684	Knots
Rpm	.1047	Radians/sec

Velocity

Multiply	By	To Obtain
Knots	1.689	Feet/sec
	1.853	Km/hr
	1.152	Miles/hr
	.5148	Meters/sec
Km/hr	.9113	Feet/sec
	.5396	Knots
	.6214	Miles/hr
	.2778	Meters/sec
Meters/sec	3.281	Feet/sec
	2.237	Km/hr
	3.6	Miles/hr

WEIGHTS

MATERIALS

Material	Specific Gravity	Density lb/cu in.
Aluminum	2.70	.097
Al. Alloys, 2S	2.71	.098
3S	2.73	.099
4S	2.72	.098
24S	2.79	.101
52S	2.66	.096
195	2.77	.100
355	2.68	.097
Asbestos	2.46	.089
Bakelite	1.35	.049
Beryllium	1.8	.065
Brass	8.45 to 8.70	.305 to .313
Bronze, Al.	7.70	.278
Bronze, Phos.	8.88	.321
Copper	8.90	.322
Cork, compressed	.23	.008
Feet	.08	.003
Formica	1.35	.049
Glass, safety	2.53	.091
Gold	19.32	.697
Inconel	8.55	.309
Iron, cast	7.20	.260
Iron, wrought	7.90	.284
K-Monel	8.58	.310
Lead	11.40	.411
Leather	.95	.034

MATERIALS

Material	Specific Gravity	Density lb/cu. in.
Magnesium	1.74	.063
Mag. Alloys	1.80	.065
Micarta	1.35	.049
Monel	8.90	.323
Nickel	8.90	.324
Plastecele	1.35	.049
Plexiglas	1.18	.043
Pyralin	1.35	.049
Rubber		
(Eng. Mount.)		
45 Durometer Reading	1.06	.038
50 " "	1.11	.040
60 " "	1.17	.042
70 " "	1.24	.044
Silver	10.5	.380
Steel	7.84	.283
Steel, stainless	7.86	.284
Tin	7.29	.263
Woods, Ash	.66 to .85	.024 to .031
Cedar	.44 to .57	.018 to .021
Fir	.48 to .55	.017 to .020
Hickory	.74 to .80	.027 to .029
Mahogany	.56 to .85	.020 to .031
Pine	.38 to .60	.014 to .022
Spruce	.48 to .70	.017 to .025
Zinc	7.19	.259

LIQUIDS

Liquid	Specific Gravity	Density lb/U.S. gal
Alcohol (methyl)	.81	6.8
Benzine	.69	5.8
Gasoline	.72	6.0
Glycerine	1.26	10.5
Mercury	13.55	113.0
Oil	.89	7.4
Ethyline Glycol	1.12	9.3
Water	1.00	8.35

GASES

Gas	Density* lb/cu ft
Air	.07651 (at 59°F)
Air	.08071
Carbon Dioxide	.12341
Carbon Monoxide	.07807
Helium	.01114
Hydrogen	.005611
Nitrogen	.07807
Oxygen	.089212

*At atmospheric pressure and 0°C.

CODES AND EQUATIONS

COLOR CODE FOR AIRCRAFT PIPING

Line	Color Band
Anti-icing	White - red
Compressed Air —	
Low Pressure	Light blue - light green
High Pressure	Yellow - light green
Exhaust Analyzer	Light blue - brown
Fire Extinguisher	Brown
Fuel	Red
Hydraulic	Light blue - yellow - light blue
Manifold Pressure	White - light blue
Oil	Yellow
Oxygen	Light green
Pitot Pressure	Black
Prestone	White - black - white
Static Pressure	Black - light green
Steam	Light blue - black
Vacuum	White - light green
Vent	Red - black
Water	White

UNITED STATES CLASSIFICATIONS

NC	Commercial
NR	Restricted
NX	Experimental

AIRCRAFT INTERNATIONAL MARKINGS

CC	Chile	OB	Peru
CF	Canada	OH	Finland
CL	Cuba	OO	Belgium
CM	Cuba	OY	Denmark
CS	Portugal	PH	Holland
CX	Uruguary	PP	Brazil
D	Germany	SE	Sweden
EC	Spain	TC	Turkey
EI	Ireland	USSR	Russia
F	France	VH	Australia
G	Great Britain	VT	India
HA	Hungary	XA	Mexico
HB	Switzerland	XB	Mexico
HC	Ecuador	XH	Honduras
HH	Columbia	XT	China
I	Italy	YR	Rumania
J	Japan	YT	Yugoslavia
LG	Guatemala	YU	Yugoslavia
LN	Norway	YV	Venezuela
LV	Argentine	ZK	New Zealand
N	U.S.A.	ZS	Union of S. Africa

EQUATIONS RELATING TO ENGINE POWER

Standard Conditions for Power Measurement:

At Sea Level

Barometric pressure — 29.92 in. Hg.

Humidity (water vapor pressure) — 0.00 in. Hg.

Temperature = 59.6°F

At Altitude

Pressure and temperature of standard altitude

Humidity zero at all altitudes

Propeller Load Curve

$$hp_2 = hp_1 \left(\frac{rpm_2}{rpm_1}\right)^3 \qquad Torque_2 = T_1 \left(\frac{rpm_2}{rpm_1}\right)^2$$

Brake Mean Effective Pressure.

$$bmep = \frac{792{,}000 \times bhp}{Displacement \times rpm} \text{ lb/sq. in.}$$

$$Torque = \frac{63{,}025 \times hp}{rpm} \text{ lb-in.} = \frac{5250 \times hp}{rpm} \text{ lb-ft}$$

Indicated Horsepower. ihp = bhp + friction hp

$$\text{Mechanical Efficiency, per cent} = \frac{bhp}{ihp} \times 100$$

Thermal Efficiency,

$$\text{per cent} = \left(\frac{2545}{\text{Spec. fuel cons.} \times \text{Btu/lb fuel}}\right) 100$$

STANDARD ATMOSPHERE TABLE

Altitude Ft.	Temp. — t °F	Temp. — t °C	p in. Hg.	p	p/po
0	59.0	15.0	29.92	.002378	1.0000
1,000	55.4	13.0	28.86	.002309	.9710
2,000	51.9	11.0	27.82	.002242	.9428
3,000	48.3	9.1	26.81	.002176	.9151
4,000	44.7	7.1	25.84	.002112	.8881
5,000	41.2	5.1	24.89	.002049	.8616
6,000	37.6	3.1	23.98	.001988	.8358
7,000	34.0	1.1	23.09	.001928	.8106
8,000	30.5	— 0.8	22.22	.001869	.7859
9,000	26.9	— 2.8	21.38	.001812	.7619
10,000	23.3	— 4.8	20.58	.001756	.7384
11,000	19.8	— 6.8	19.79	.001702	.7154
12,000	16.2	— 8.8	19.03	.001648	.6931
13,000	12.6	—10.8	18.29	.001596	.6712
14,000	9.1	—12.7	17.57	.001545	.6499
15,000	5.5	—14.7	16.88	.001496	.6291
16,000	1.9	—16.7	16.21	.001448	.6088
17,000	— 1.6	—18.7	15.56	.001401	.5891
18,000	— 5.2	—20.7	14.94	.001355	.5698
19,000	— 8.8	—22.6	14.33	.001311	.5509
20,000	—12.3	—24.6	13.75	.001267	.5327
21,000	—15.9	—26.6	13.18	.001225	.5148
22,000	—19.5	—28.6	12.63	.001183	.4974
23,000	—23.0	—30.6	12.10	.001143	.4805
24,000	—26.6	—32.5	11.59	.001103	.4640
25,000	—30.2	—34.5	11.10	.001065	.4480
26,000	—33.7	—36.5	10.62	.001028	.4323
27,000	—37.3	—38.5	10.16	.000992	.4171
28,000	—40.9	—40.5	9.720	.000957	.4023
29,000	—44.4	—42.5	9.293	.000922	.3879
30,000	—48.0	—44.4	8.880	.000889	.3740
31,000	—51.6	—46.4	8.483	.000857	.3603
32,000	—55.1	—48.4	8.101	.000826	.3472
33,000	—58.7	—50.4	7.732	.000795	.3343
34,000	—62.2	—52.4	7.377	.000765	.3218
35,000	—65.8	—54.3	7.036	.000736	.3098
36,000	—67.0	—55.0	6.708	.000704	.2962
37,000	—67.0	—55.0	6.395	.000671	.2824
38,000	—67.0	—55.0	6.096	.000640	.2692
39,000	—67.0	—55.0	5.812	.000610	.2566
40,000	—67.0	—55.0	5.541	.000582	.2447
41,000	—67.0	—55.0	5.283	.000554	.2332
42,000	—67.0	—55.0	5.036	.000529	.2224
43,000	—67.0	—55.0	4.802	.000504	.2120
44,000	—67.0	—55.0	4.578	.000481	.2021
45,000	—67.0	—55.0	4.364	.000459	.1926
46,000	—67.0	—55.0	4.160	.000437	.1837
47,000	—67.0	—55.0	3.966	.000417	.1751
48,000	—67.0	—55.0	3.781	.000397	.1669
49,000	—67.0	—55.0	3.604	.000379	.1591
50,000	—67.0	—55.0	3.436	.000361	.1517

DRILL SIZE DECIMAL EQUIVALENTS

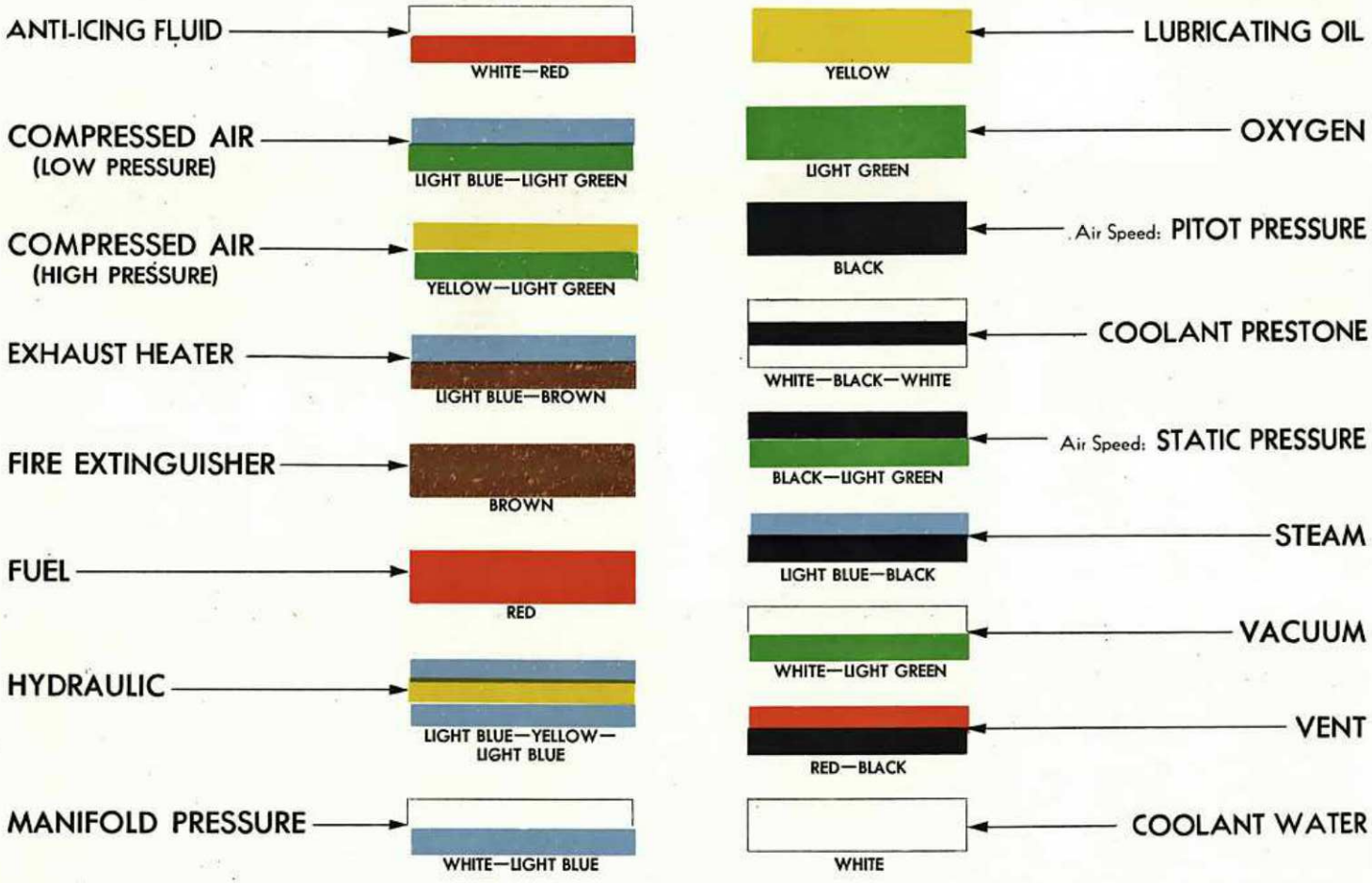
NUMBERED DRILLS

Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.
1	.2280	28	.1405	55	.0520
2	.2210	29	.1360	56	.0465
3	.2130	30	.1285	57	.0430
4	.2090	31	.1200	58	.0420
5	.2055	32	.1160	59	.0410
6	.2040	33	.1130	60	.0400
7	.2010	34	.1110	61	.0390
8	.1990	35	.1100	62	.0380
9	.1960	36	.1065	63	.0370
10	.1935	37	.1040	64	.0360
11	.1910	38	.1015	65	.0350
12	.1890	39	.0995	66	.0330
13	.1850	40	.0980	67	.0320
14	.1820	41	.0960	68	.0310
15	.1800	42	.0935	69	.0292
16	.1770	43	.0890	70	.0280
17	.1730	44	.0860	71	.0260
18	.1695	45	.0820	72	.0250
19	.1660	46	.0810	73	.0240
20	.1610	47	.0785	74	.0225
21	.1590	48	.0760	75	.0210
22	.1570	49	.0730	76	.0200
23	.1540	50	.0700	77	.0180
24	.1520	51	.0670	78	.0160
25	.1495	52	.0635	79	.0145
26	.1470	53	.0595	80	.0135
27	.1440	54	.0550		

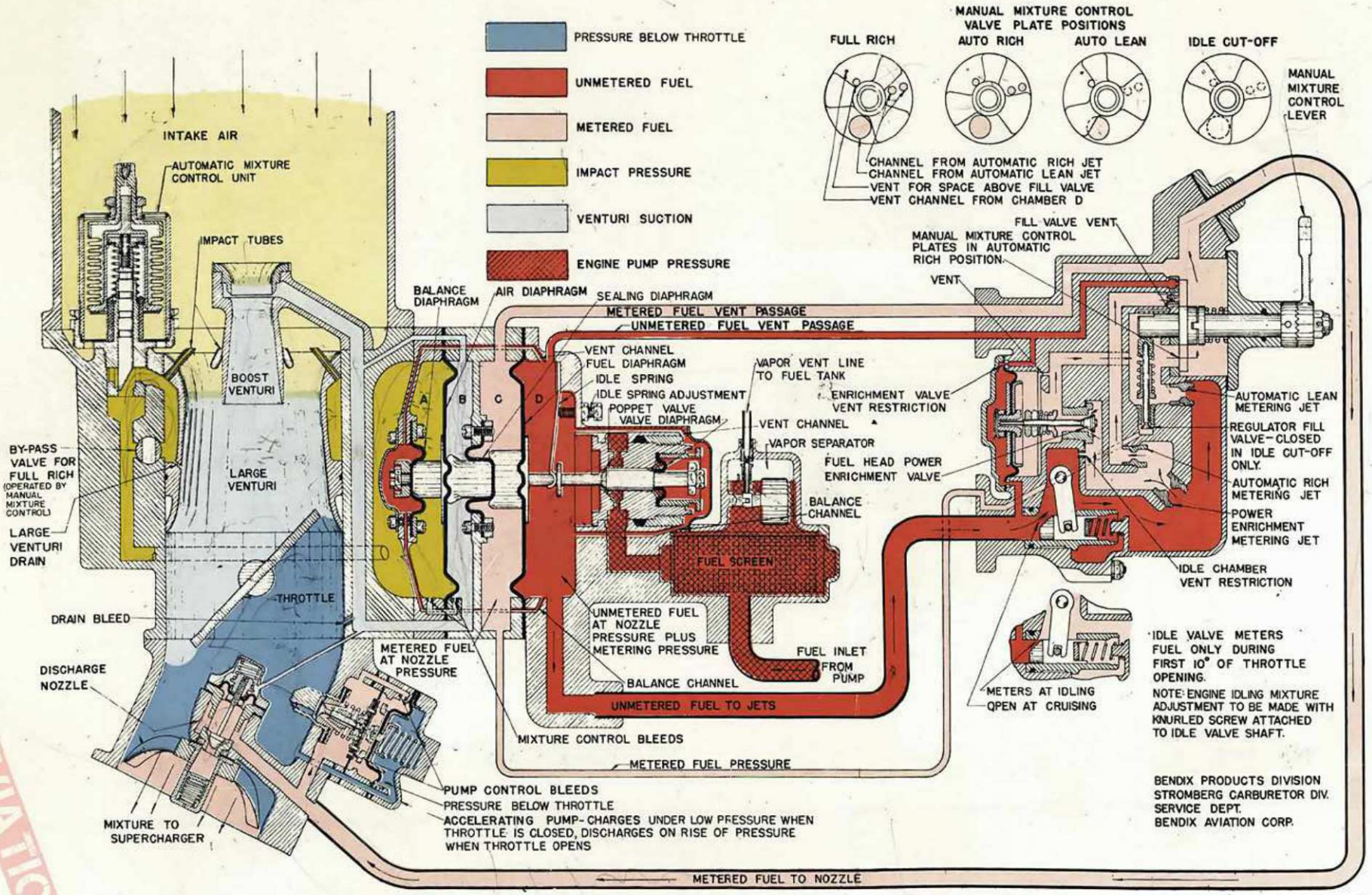
LETTERED DRILLS

Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.
A	.234	J	.277	S	.348
B	.238	K	.281	T	.358
C	.242	L	.290	U	.368
D	.246	M	.295	V	.377
E	.250	N	.302	W	.386
F	.257	O	.316	X	.397
G	.261	P	.323	Y	.404
H	.266	Q	.332	Z	.413
I	.272	R	.339		

COLOR CODE
FOR AIRCRAFT PIPING



Color Code for Aircraft Piping



Schematic Diagram of Stromberg Injection Carburetor

THIS PAGE INTENTIONALLY LEFT BLANK