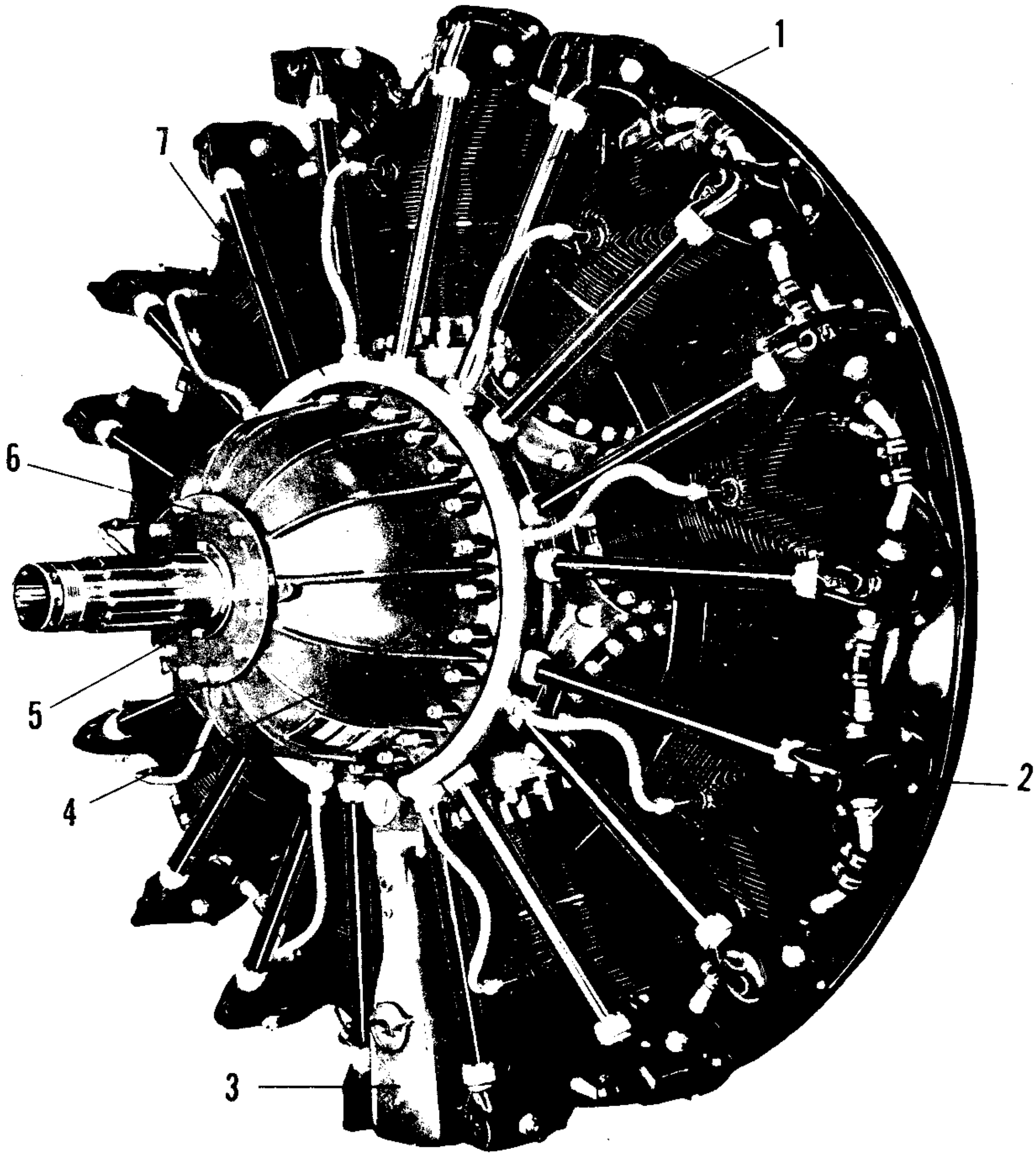


1. Pushrod Cover Tube
2. Sparkplug Lead
3. Oil Sump
4. Reduction Gear Housing
5. Thrust Cover Nut
6. Thrust Bearing Cover
7. Front Ignition Manifold

Left Front View of S3H1-G Engine

CHAPTER 1 . . . . DESCRIPTION

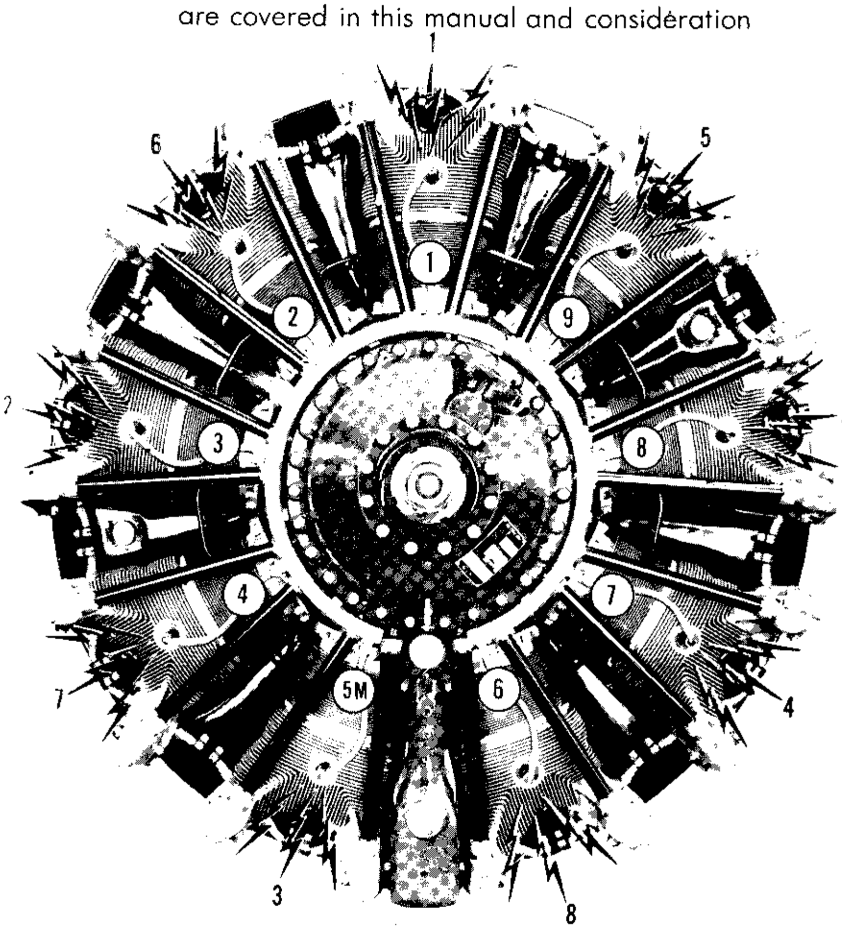
TABLE OF CONTENTS

DESCRIPTION

GENERAL

The Pratt & Whitney Wasp Jr. and Wasp series engines are single row, nine cylinder, supercharged, radial, air-cooled engines. The R-985-B5 and B4 of the Wasp Jr. series engines and the R-1340, S1H2, S3H1, S3H2 and S3H1-G of the Wasp series engines are covered in this manual and consideration is made for the differences among models. Throughout the remainder of this manual whenever these engines are discussed singularly, they may be referred to as the B5, the B4, the S1H2, the S3H1, the S3H2 or the S3H1-G engine. Whenever these engines are discussed in a series they may be referred to as Wasp Jr. or Wasp engines.

Differences Among Models — The B5 engine is designed for horizontal installation in a conventional-type aircraft; whereas the B4 engine is designed for vertical installation in a helicopter. To accommodate vertical installation, the B4 engine differs from the B5 engine in many ways; but the substitution of plain journal bearings at the im-



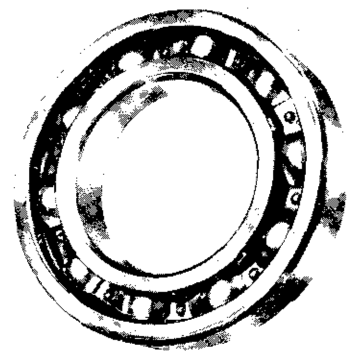
CYLNDER NUMBERING AND FIRING ORDER DIAGRAM
Firing Order
1-3-5-7-9-2-4-6-8
M = Master Cylinder

peller shaft in place of ball bearings as used on the B5 engine, the use of the rear case as a collector of engine oil in place of the conventional oil sump, and the location of a breather in the engine nose section in lieu of the conventional arrangement, constitute the main differences between these two models.

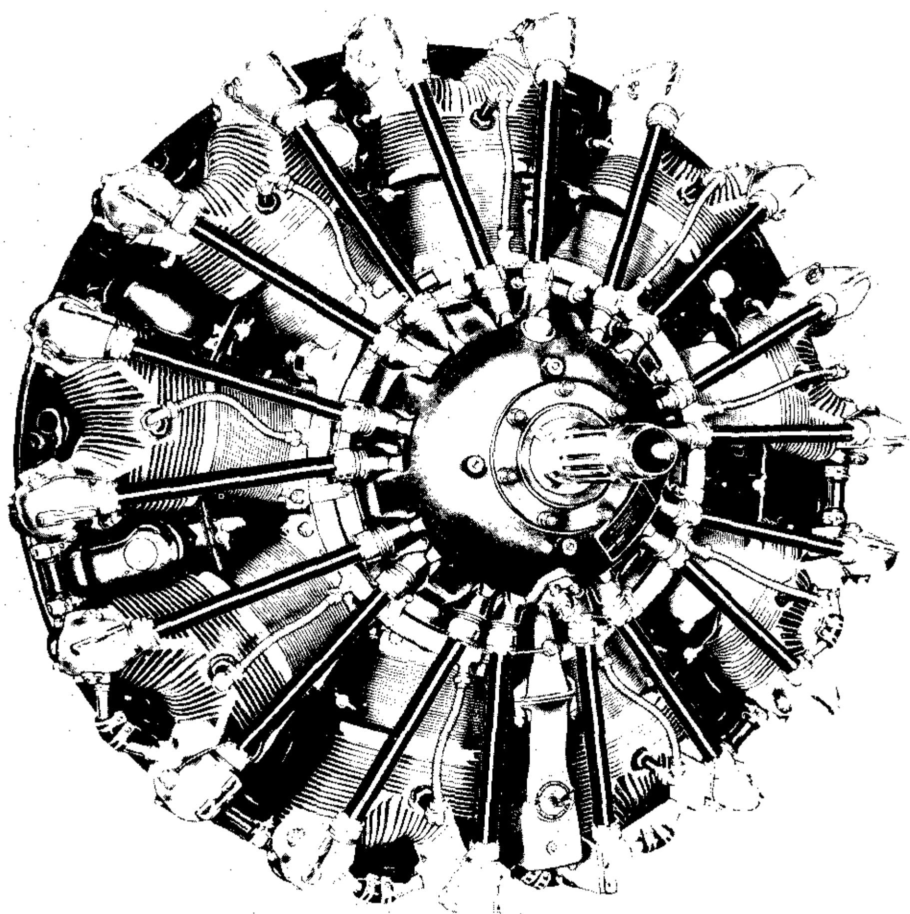
A Wasp Jr. engine is basically similar to a Wasp engine; however, the latter is larger and develops more horsepower than the former engine.

The Wasp engines covered in this Manual are designed for both horizontal and vertical installation. The S3H1 and S3H1-G engines incorporate ball bearings at the impeller shaft with a 10:1 blower ratio.

The S3H1 engine is a direct drive engine; whereas the S3H1-G engine incorporates a decoupled propeller shaft and has a 3:2 reduction gearing. The S1H2 and S3H2 engines are converted for installation in helicopters. The S1H2 incorporates a supercharger with a 12:1 ratio and mounts at a 39 degree angle.



Thrust Bearing

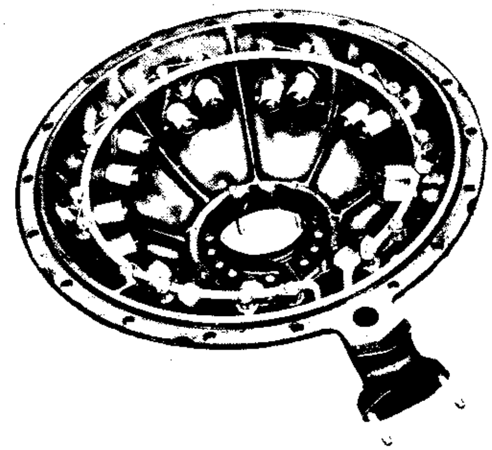


Wasp Jr. B5 Engine

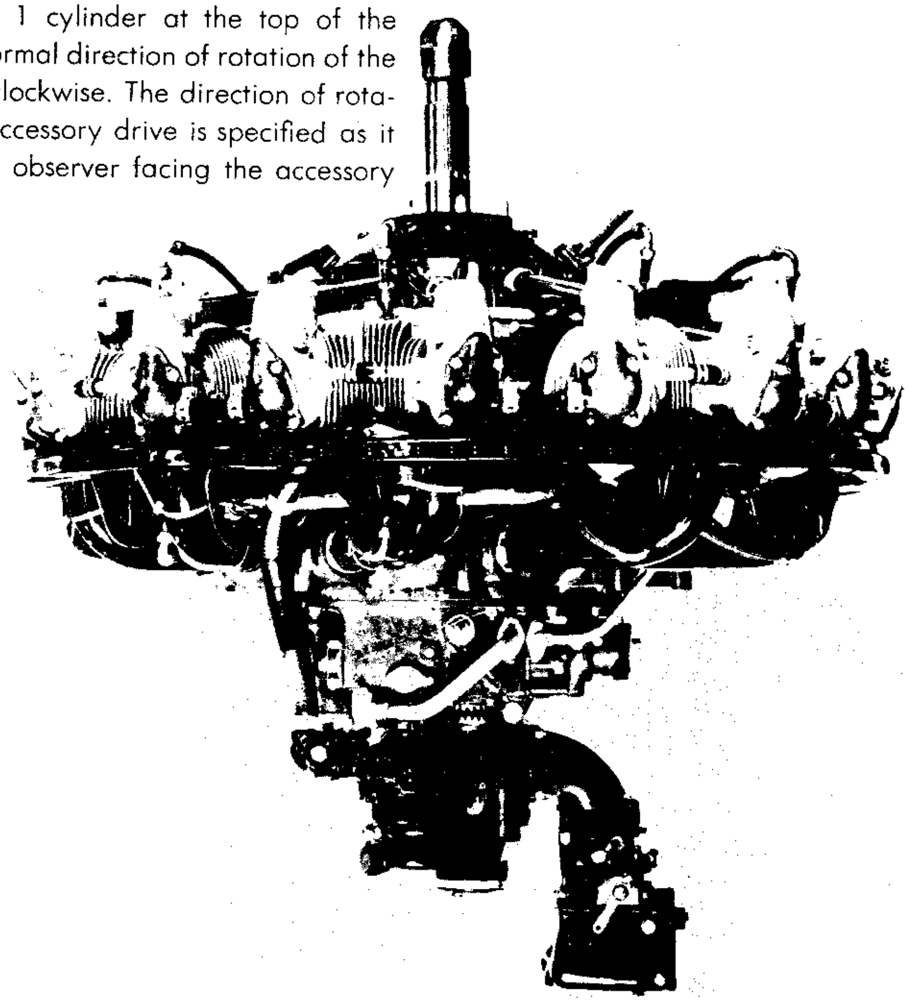
The S3H2 differs from the S1H2 in its supercharger ratio of 10:1.

Commercial vs Military Equipment — The S3H1 is equivalent to a R-1340-AN1 (with a 10:1 Blower). The S1H1 is equivalent to a S3H1 (with 12:1 Blower). The S1H2 is equivalent to a R-1340-48 and -57. The S3H1G is equivalent to a R-1340-AN2 and a R-1340-59 (with 10:1 Blower). The S1H1G is equivalent to a R-1340-61 (with a 12:1 Blower). The S3H2 is equivalent to a R-1340-40.

Directional References — Right and left, clockwise and counterclockwise, upper and lower, and similar directional references, 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 is clockwise. The direction of rotation of each accessory drive is specified as it appears to an observer facing the accessory mounting pad.



Front Case (B5)



Wasp Jr. B4 Engine

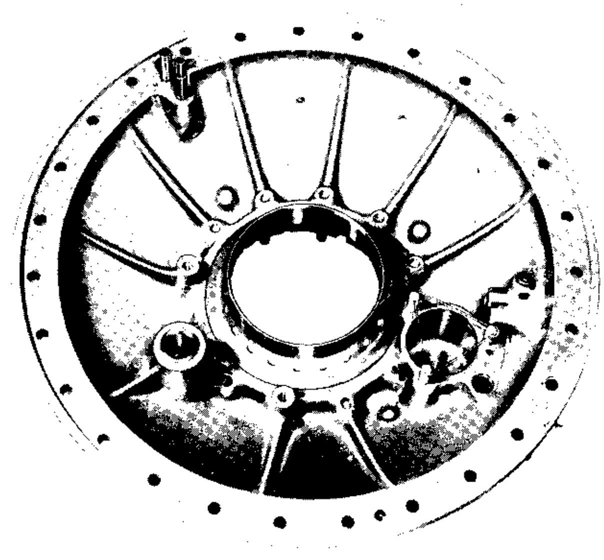
The lubrication system, the carburetor, and the ignition system are briefly explained on the following pages. Throughout this manual the seven engines under consideration will be discussed as one engine whenever their respective features are comparable.

FRONT SECTION

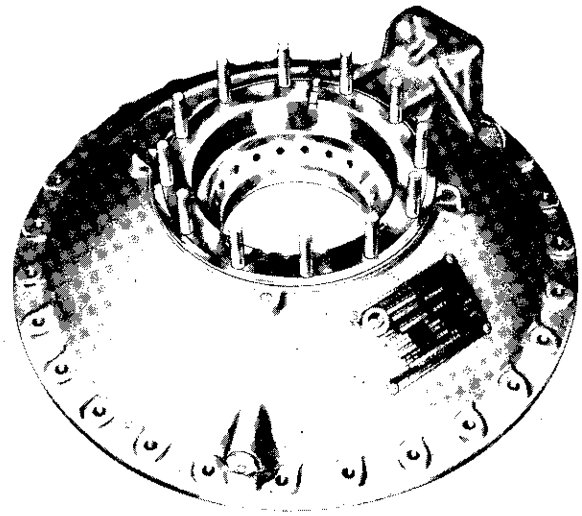
Front Case (Wasp Jr. B5 Engine) — The front case supports in its bore a ball bearing, which transmits part of the propeller thrust from the crankshaft to the engine mounting brackets, via the crankcase. The crankshaft is located in the thrust bearing by means of the thrust bearing spacer.

Bosses in the front case provide support for the valve tappet guides which accommodate the valve tappets, rollers and pins. A rocker oil manifold ring in the front case is part of the automatic rocker lubricating system.

The B5 engine incorporates tubing in the front case for operation of a hydro-controllable propeller and either a control valve (for the two position propeller) or a plug with an oil transfer hole for the constant speed or hydromatic propeller.



Front Case



Front Case

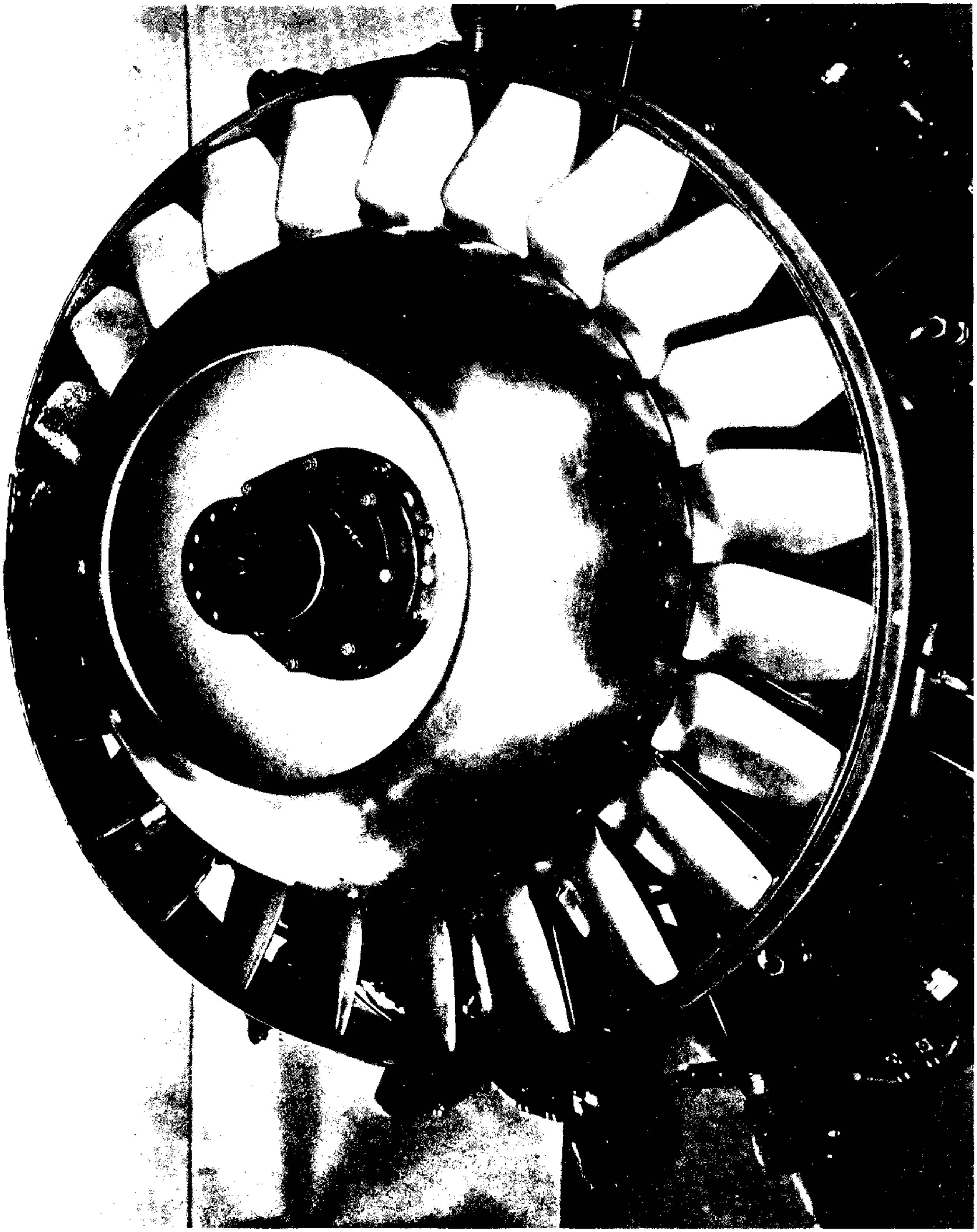
Front Case (Wasp Jr. B4 Engine) — The front case differs from the B5 engine front case in three ways.

(1) On the B4 engine, the propeller control valve is omitted and a gasket and cover are mounted on the valve boss.

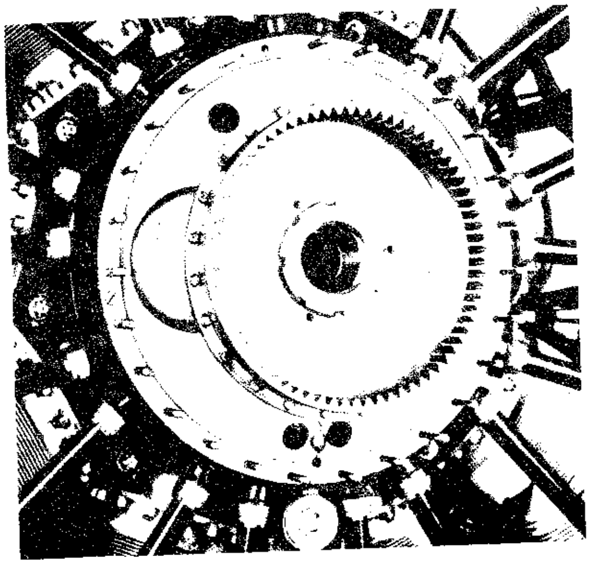
(2) The plug opposite the propeller control valve boss is replaced by a breather pipe assembly which is attached to the rear of the thrust bearing liner. This breather assembly vents the engine.

((3) The B4 engine does not incorporate an oil sump, so the drain hole in the sump mounting boss is blocked with a cover and a gasket. A drain hole is provided in the rear face of the boss and two studs are installed to provide for the attachment of the front section to the oil pump oil scavenge tube.

Front Case (Wasp S1H2, S3H1 and S3H2 Engines) — The front case supports in its bore a ball bearing, which transmits part of the propeller thrust from the crankshaft to the engine mounting brackets, via the crankcase. The crankshaft is located in the thrust bearing by means of the thrust bearing spacer.



Typical Helicopter Cooling System

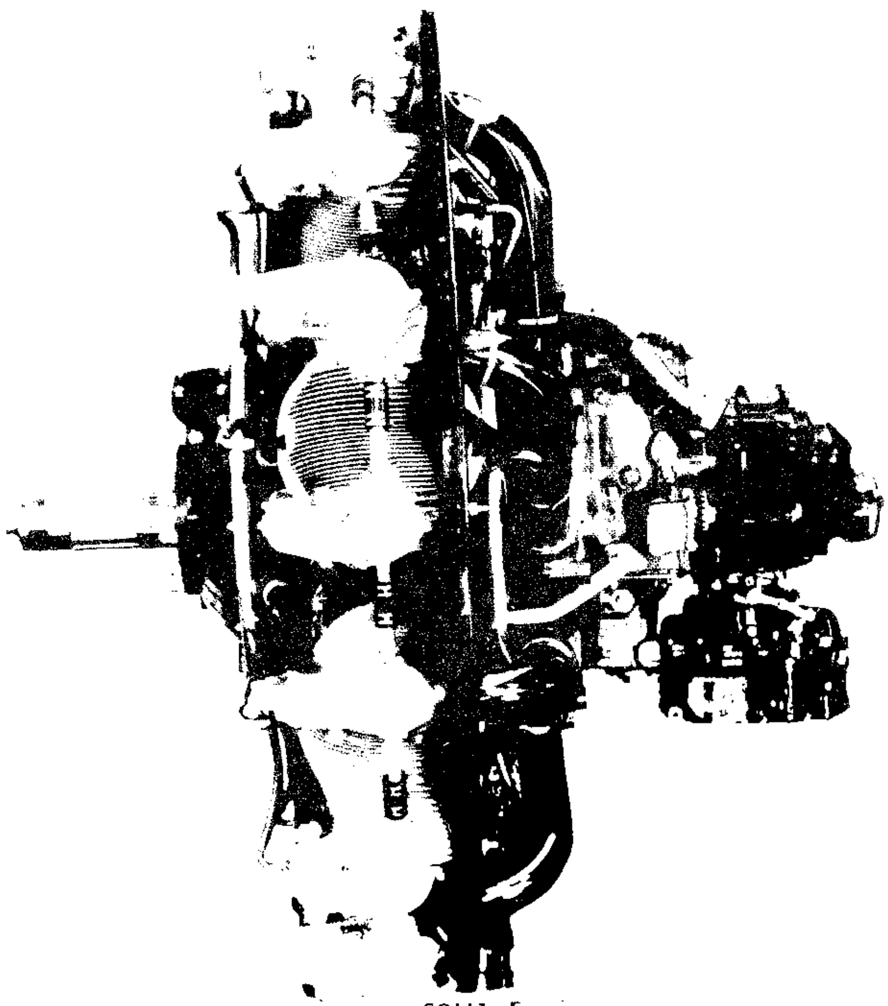


Reduction Drive Gear

The front case of the S3H1 engine incorporates provision for mounting and driving a propeller governor. The propeller governor drive is omitted on the S1H2 and S3H2 engines.

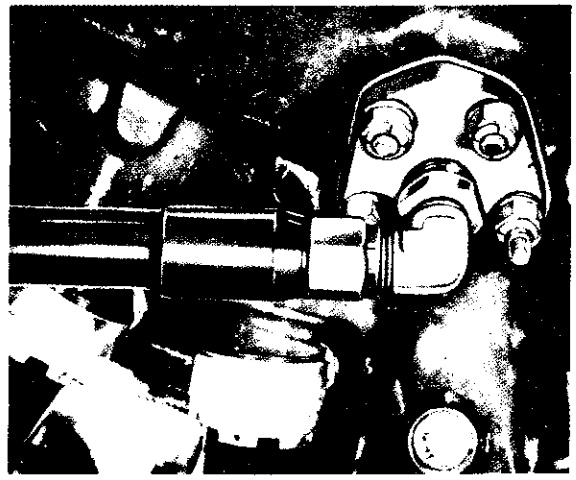
Front Case (Wasp S3H1-G Engine) — The front case differs from the other Wasp engine front cases in that it is constructed larger in depth in order that it may house the decoupled propeller shaft and the reduction gearing.

The front case does not incorporate provision for mounting and driving a propeller governor.

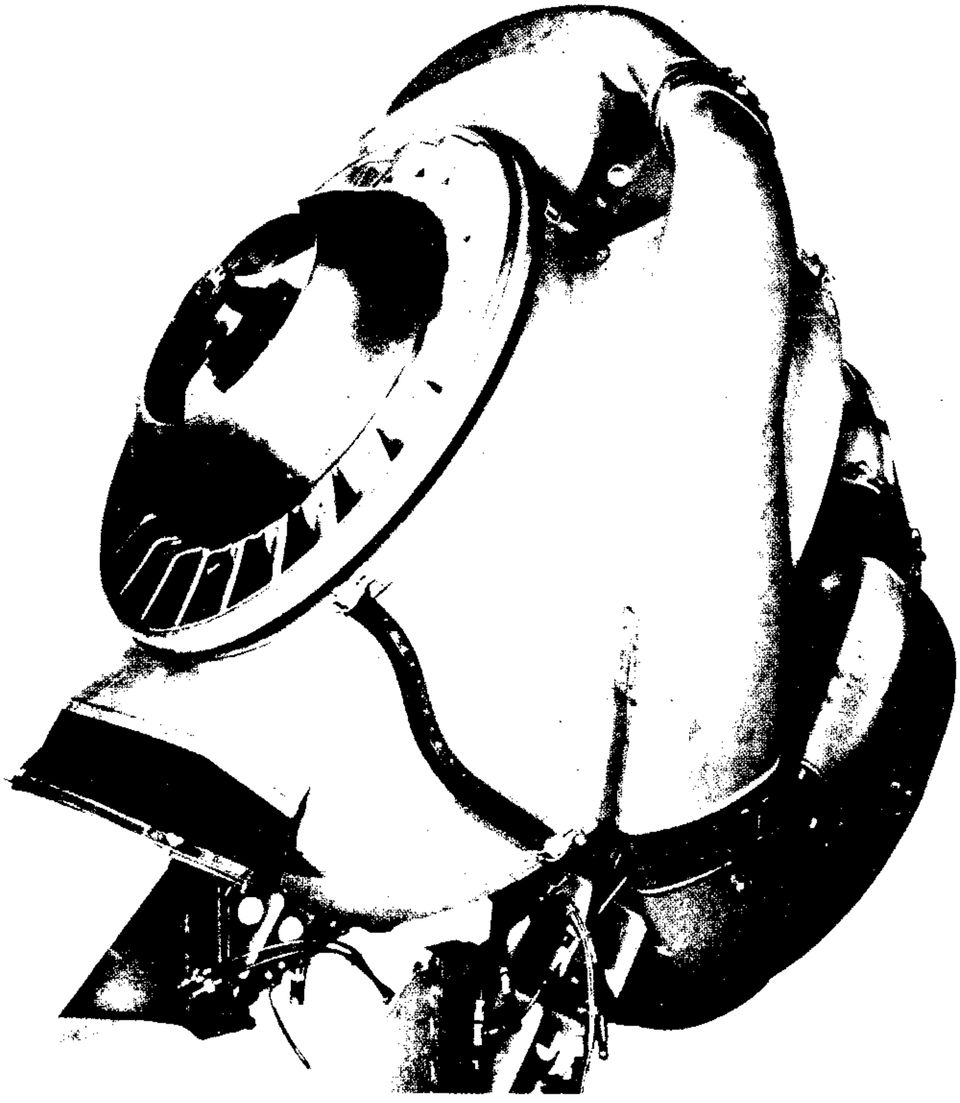


Wasp S3H1 Engine

Reduction Gearing (Wasp S3H1-G Engine) — The propeller shaft is supported at the rear end by a steel-backed lead bronze bearing located inside the front end of the crankshaft. The reduction gearing is of the spur planetary type. A reduction drive gear, with internal teeth, is splined to the front end of the crankshaft and receives additional support from a bearing in the bore of the support plate. A reduction drive fixed gear is bolted to the inner side of the forward end of the front case. Six pinions, which are mounted in a pinion cage splined to the propeller shaft, mesh with the reduction drive fixed gear and



Propeller Control Tubing (B5)

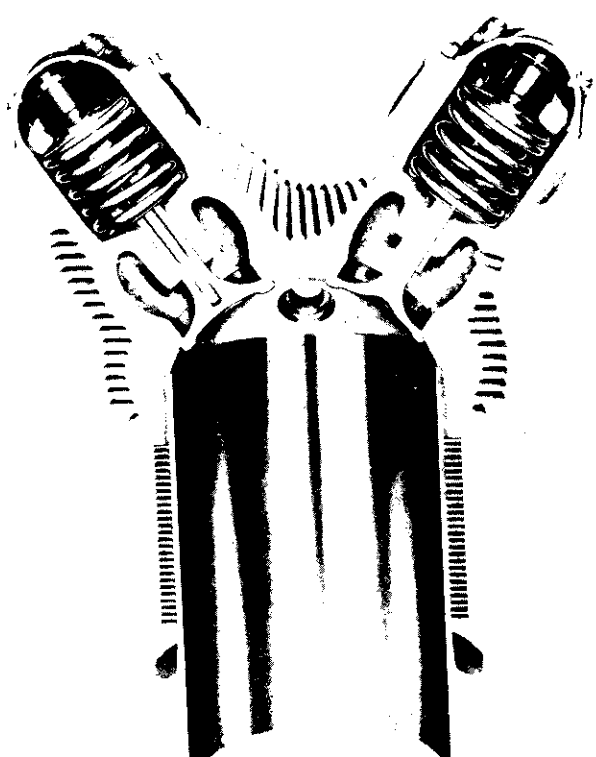


Power Package (S3H2)

with the drive gear. Engine speed, emanating from the crankshaft and the reduction drive gear rotation, is reduced as it is transmitted through the fixed gear and the pinions to the pinion cage splined to the propeller shaft, so that the propeller shaft makes but two revolutions for every three revolutions made by the crankshaft.

CYLINDERS

Cylinder Heads and Barrels — The cylinders are of steel and aluminum construction. The barrels are machined from steel forgings and have integral cooling fins. The heads are made from aluminum castings and have deep cooling fins and rockerboxes cast integrally. The head is screwed and shrunk onto the cylinder barrel, thus forming a semi-permanent assembly. Each cylinder has one inlet valve and one exhaust valve. The inlet valve seats on a bronze seat and the exhaust valve on a steel seat, both of which are shrunk into the cylinder head. The cylinder also incorporates



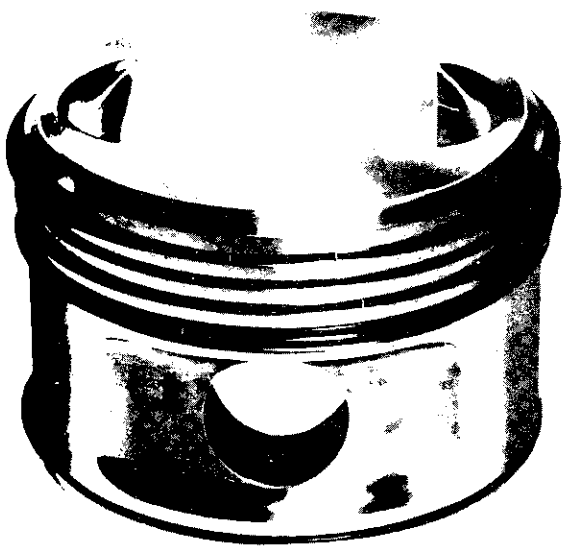
Cutaway of Cylinder

bronze inlet and exhaust valve guides, bronze bushings for two sparkplugs, 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. Oil drain tubes are installed in the exhaust and inlet rockerboxes and are connected by a rubber sleeve. Pressure type deflectors force a high velocity flow of cooling air between and over the cylinder fins.

Valve Mechanism — All valve operating parts are enclosed and are pressure lubricated. The rockers are housed in rockerboxes cast integrally with the cylinder head and are supported on double row ball bearings. Eighteen tappets, located in the front case on Wasp Jr. engines and in the front crankcase on Wasp engines, are actuated by the action of the rollers on the cam lobes and in turn actuate the rockers through tubular pushrods. The pushrods are protected by removable oil-tight covers. The valve clearance adjusting screw in the front end of each rocker has a screwball for self alignment with the valve stem. Rockerbox covers enclose the rockers in the rockerboxes.

Two concentric valve springs are secured to each valve stem by an upper and lower washer and a valvelock. A snapring is installed on each valve stem to prevent a valve from dropping into the cylinder while a valvelock is being removed or installed. The inlet valves are solid; whereas the exhaust valves are hollow and are sodium-filled for cooling. The sodium turns to liquid form under the heat of the exhaust and dissipates some of the heat assimilated by the exhaust valve in operation. A stellite face prolongs the life of the seating surface of the exhaust valve.

Pistons — The pistons are machined from aluminum alloy forgings and are of the flat-head, full-skirt type. Each piston has five ring grooves and is fitted with wedge-type com-



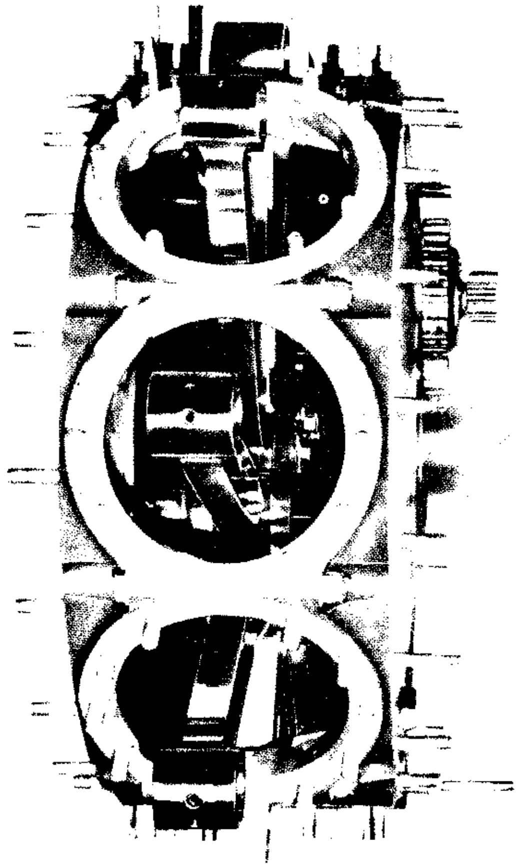
Piston

pression rings in the first three grooves, dual oil control rings in the fourth groove and an oil scraper ring in the bottom groove. The top compression ring is chromium plated on the face which bears against the cylinder wall. Pistons in cylinders five and six are undrilled in the bottom groove to prevent possible hydraulic lock. Steel pistonpins connect the pistons to the masterod and linkrods.

CRANKCASE SECTION

Crankcase — The crankcase section is comprised of the front and rear crankcases which are held together by nine crankcase bolts located between the cylinder mounting pads. The crankcases are machined together and are not interchangeable. The front and rear main bearings, located in the front and rear crankcases respectively, support the crankshaft assembly in the crankcase. A bronze bushing is pinned in the forward face of the front crankcase to support the rear end of the cam reduction drive gear.

On Wasp Jr. engines, the cam rotates on a sleeve supported on the crankshaft; whereas on the Wasp engines the cam rotates on a bronze bushing mounted on a shelf which is integral with the front crankcase.



Crankcase Section

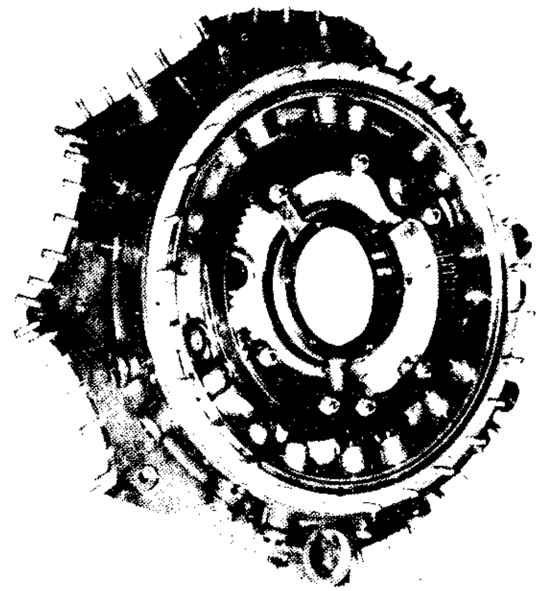
On Wasp engines, bosses in the front crankcase provide support for the valve tappet guides which contain the valve tappets, rollers and pins.

Valve Timing Gears — The cam drive gear is splined to the crankshaft and is driven at crankshaft speed. The larger gear of the cam reduction drive gear meshes with and is driven by the cam drive gear. The smaller gear of the cam reduction drive gear meshes with the internal teeth of the cam and drives the cam at ⅛ crankshaft speed and in the opposite direction from crankshaft rotation.

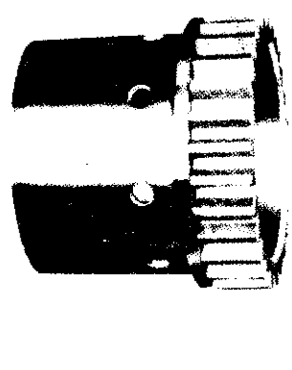
Two four-lobed tracks are machined on the outer circumference of the cam. As the cam rotates, the valve tappet rollers are actuated by the cam lobes, and the impulse is transmitted through the valve tappets to the pushrods to the rockers and finally to the exhaust and inlet valves in the respective cylinders.

Crankshaft — The crankshaft is a single throw, two piece, split-pin type supported

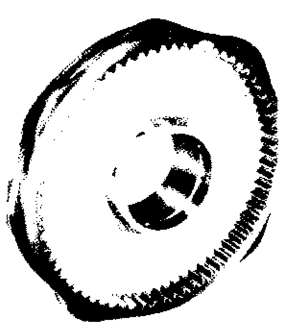
DESCRIPTION



Front Crankcase



Cam Drive Gear

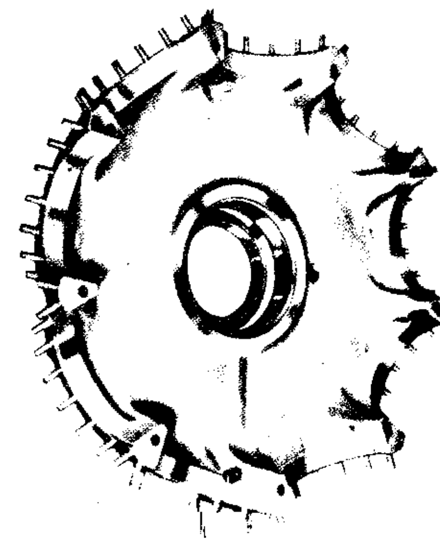


Cam

by three bearings. The two main bearings are located on either side of the crank throw in the front and rear crankcase. A ball bearing housed in the front case supports the front end of the shaft on direct drive engines; whereas on the S3H1-G engine, a ball bearing mounted in the support plate supports the reduction drive gear, which is splined to and supports the front end of the crankshaft.

The front section of the crankshaft is splined to the rear section of the shaft and is held rigid by a through-bolt.

The reciprocating and rotating parts of the crankshaft are counterbalanced by weights which are riveted to the cheeks of the crank



Front Crankcase

shaft. Two flyweights in the rear counterweight ensure vibrationless performance at all speeds.

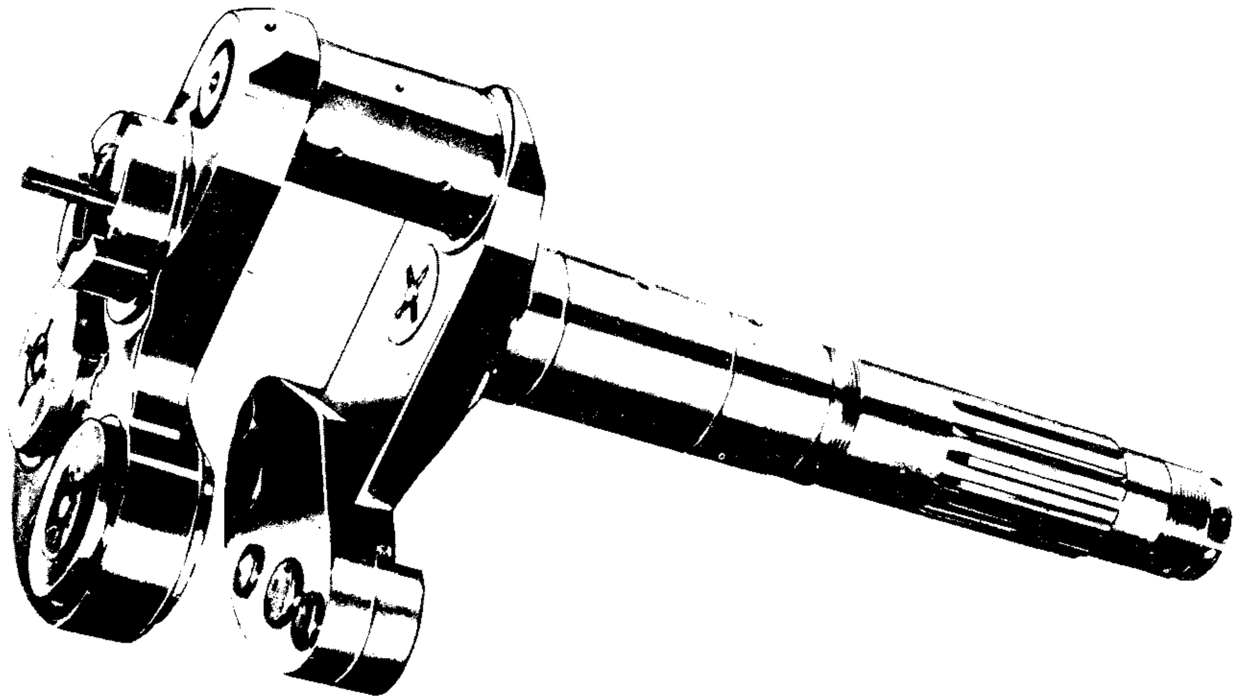
An oil nozzle in the crankshaft front half rear plug and another on the top of the rear cheek furnish spray lubrication to the pistons, pistonpins and cylinder walls.

Masterod and Linkrods — The masterod is of one-piece construction, incorporating a pressed-in, steel-backed, leaded silver bearing. Eight "I" section linkrods, having bronze linkpin and pistonpin bushings, are connected to the masterod by linkpins and to the pistons by full-floating pistonpins.

SUPERCHARGER SECTION

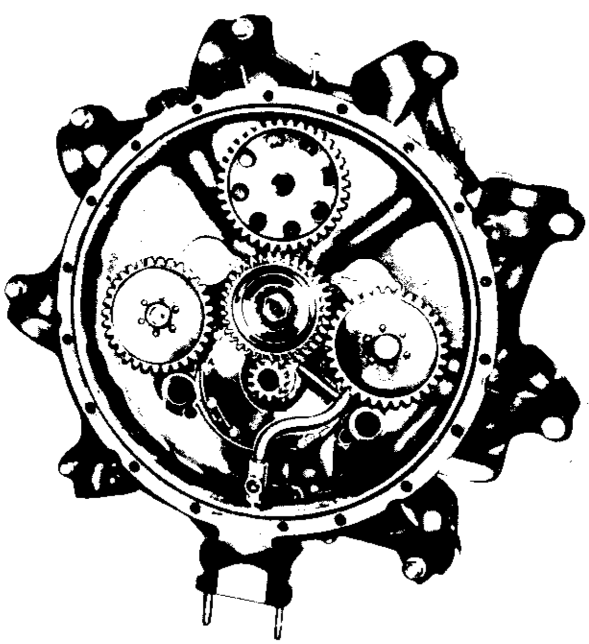
Supercharger Case — The supercharger case is attached to the rear of the crankcase and is provided with nine bolt bosses for securing the engine in the aircraft. The front end of each magneto drive gear shaft is supported by a bronze bushing set into the front end of the case, and the front end of the starter gear is supported by a ball bearing mounted in the front of the case.

On the B5, S3H1 and S3H1-G engines, a breather assembly is located between the No. 2 and 3 intake pipe bosses on the supercharger case. The B4, S1H2, and S3H2 engines are vented through the front case, so the breather assembly on the supercharger case is replaced by a recessed head plug.

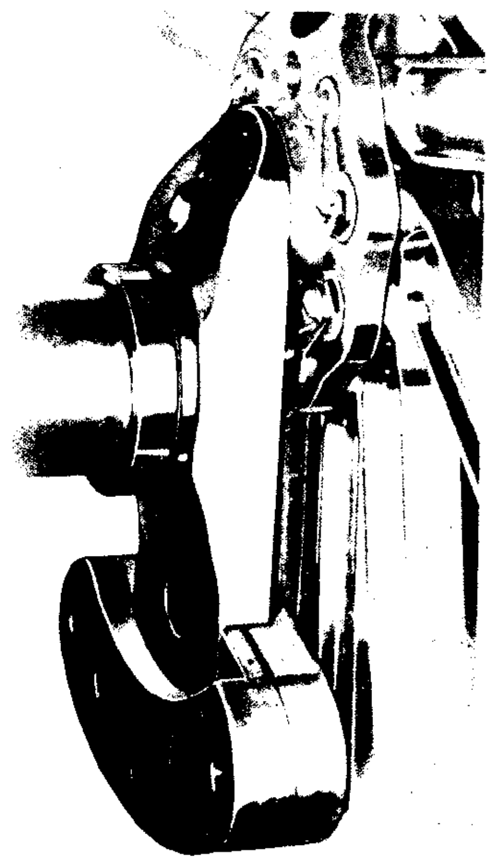


Crankshaft

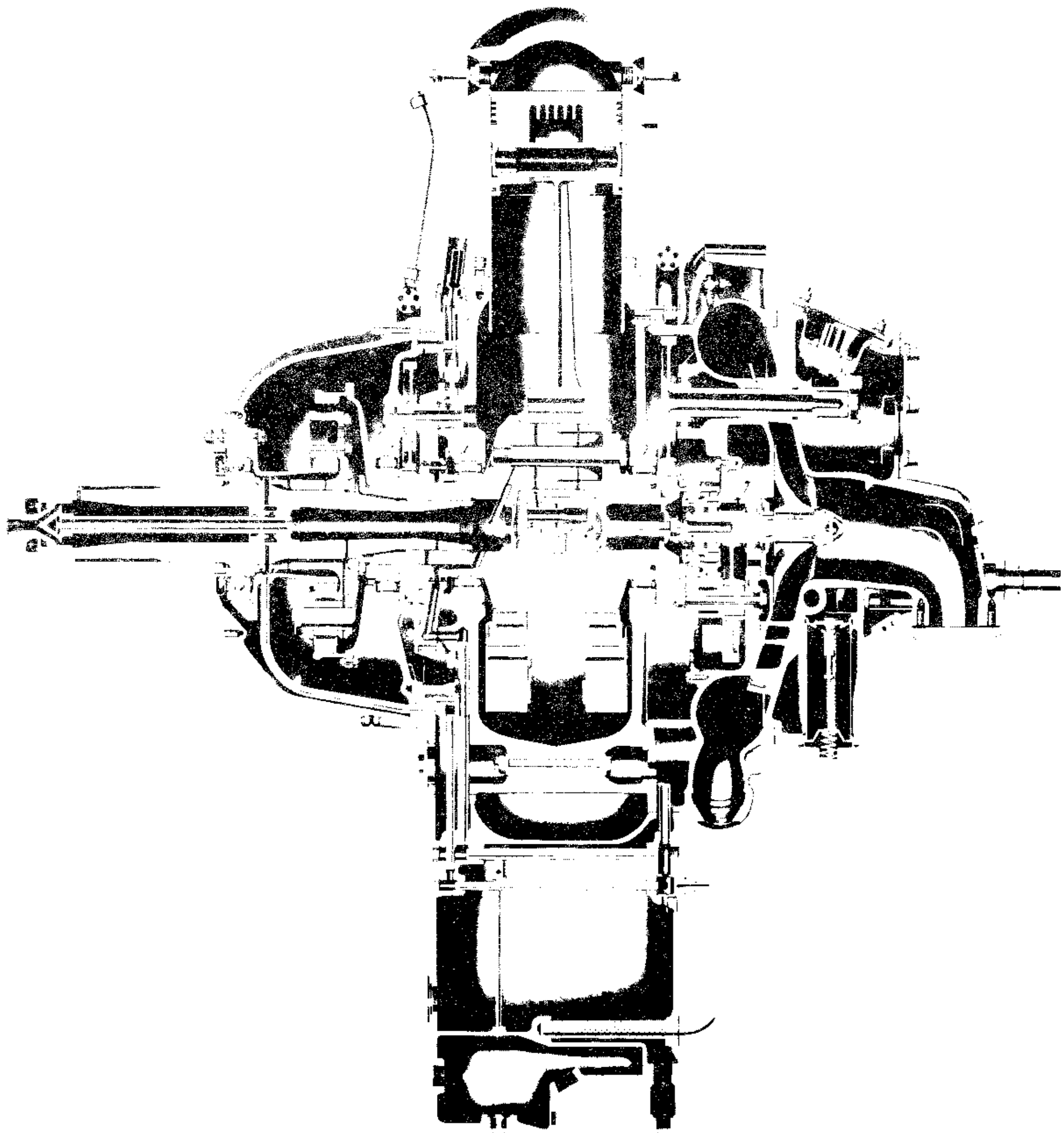
On the B4 engine three duraluminum oil scavenge sleeves are provided in the supercharger case to carry oil from the supercharger case to the rear case which acts as a sump. The sleeves are a tight fit in the supercharger case.



Front View of Supercharger Case



Counterweight

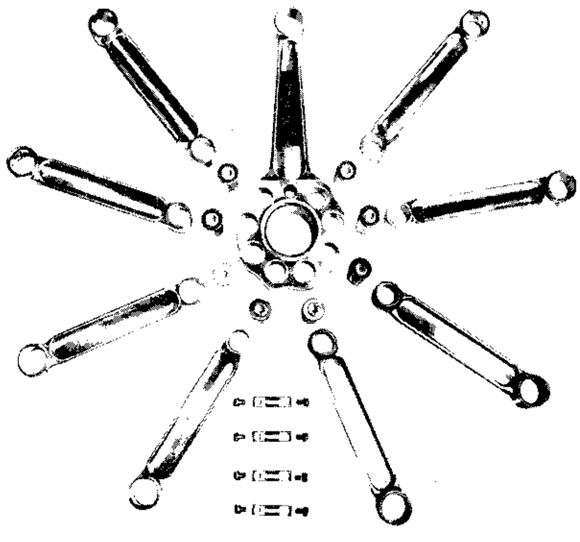


Cutaway of S3H1-G

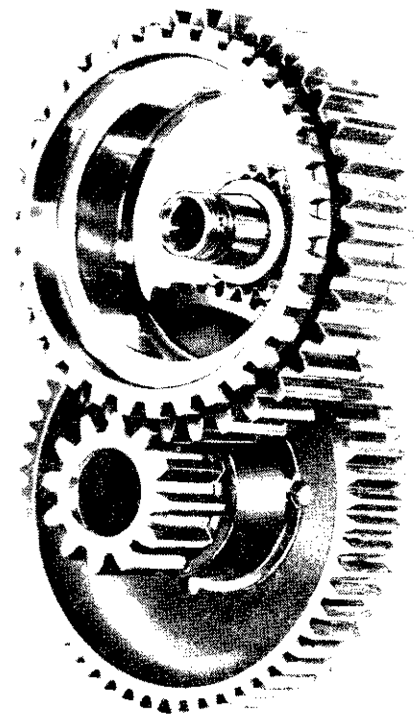
Impeller and Gears — The impeller is splined to the rear of the impeller shaft with the flat face adjacent to the rear face of the supercharger case. The impeller is driven through the impeller spring-drive coupling, a floating gear, and the impeller intermediate drive gear, at 10 times crankshaft speed or 12 times crankshaft speed, on engines having journal bearings at the impeller shaft.

On B5, S3H1 and S3H1-G engines the impeller shaft is supported in the case by three ball bearings; whereas on B4, S3H2 and S1H2 engines the impeller shaft is supported by two steel-backed bronze bushings.

In addition, on B4 engines, a steel journal is splined on the impeller shaft at the rear of the impeller shaftgear to provide a smooth

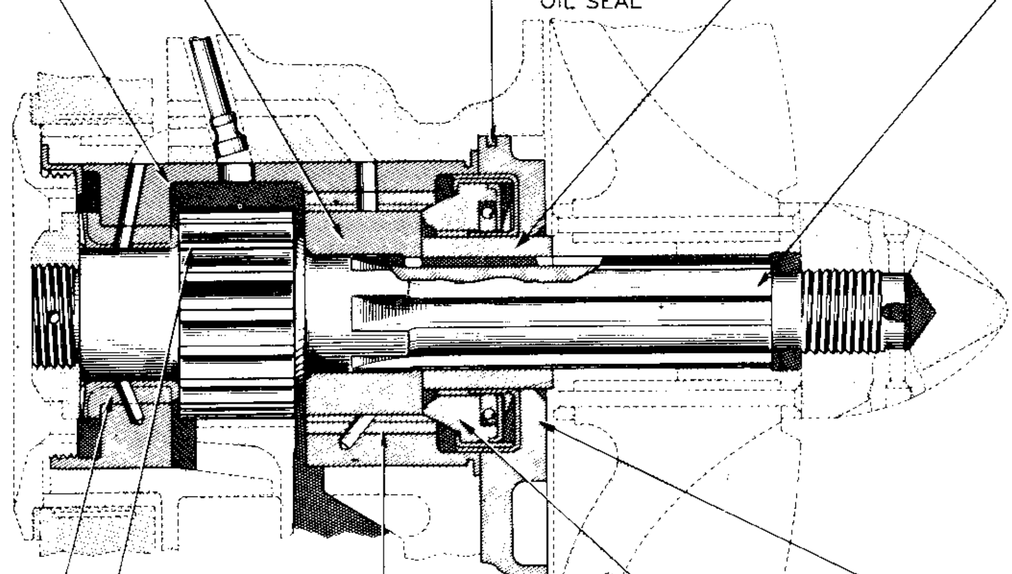


Masterod and Linkrod Assembly



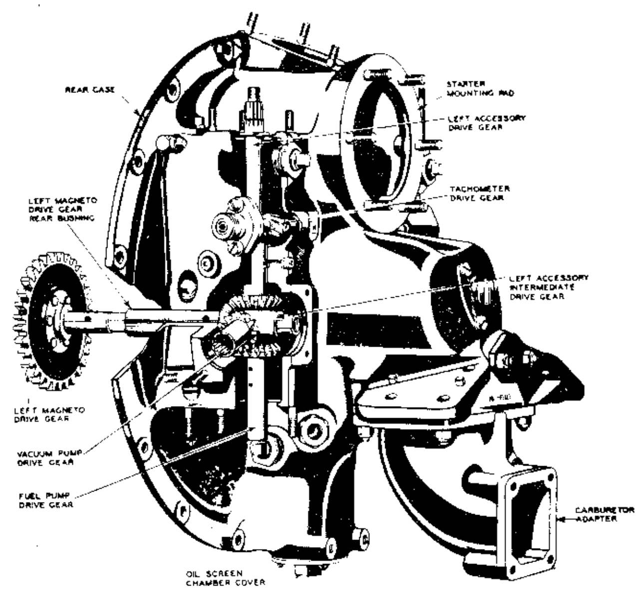
Impeller Gear Train (B5)

contact with the rear impeller bearing. These engines incorporate a groove in the OD of the rear supercharger bearing cover for the installation of a neoprene oil seal. This seal replaces the gasket used on engines designed for horizontal installation. A spring-loaded oil seal is inserted in the bore of the rear supercharger bearing cover.



Cutaway View of Blower Case at Impeller Shaft (B4)

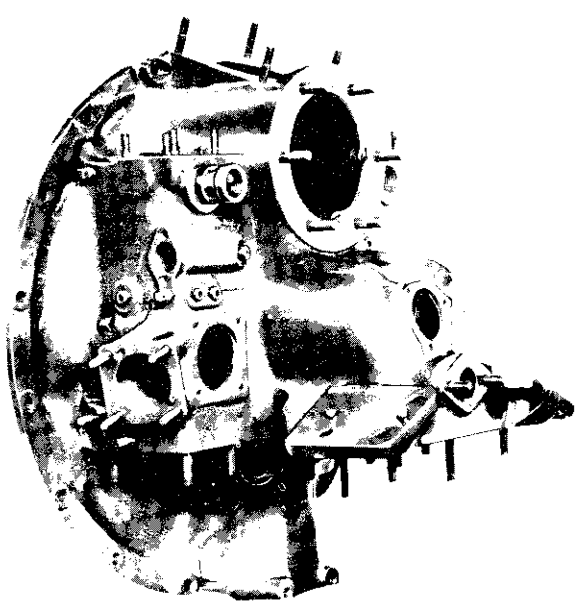
Oil Sump — An oil sump containing two chambers is located between cylinders No. 5 and 6, on the B5, S1H2, S3H1, S3H2 and S3H1-G engines. On the B5 engine, the sump is attached to the front and supercharger sections respectively; on Wasp engines the sump is attached to the front crankcase section and the supercharger section. The B4 engine does not incorporate a conventional sump, but uses the rear case as a sump.



Rear Case Showing Accessory Drives

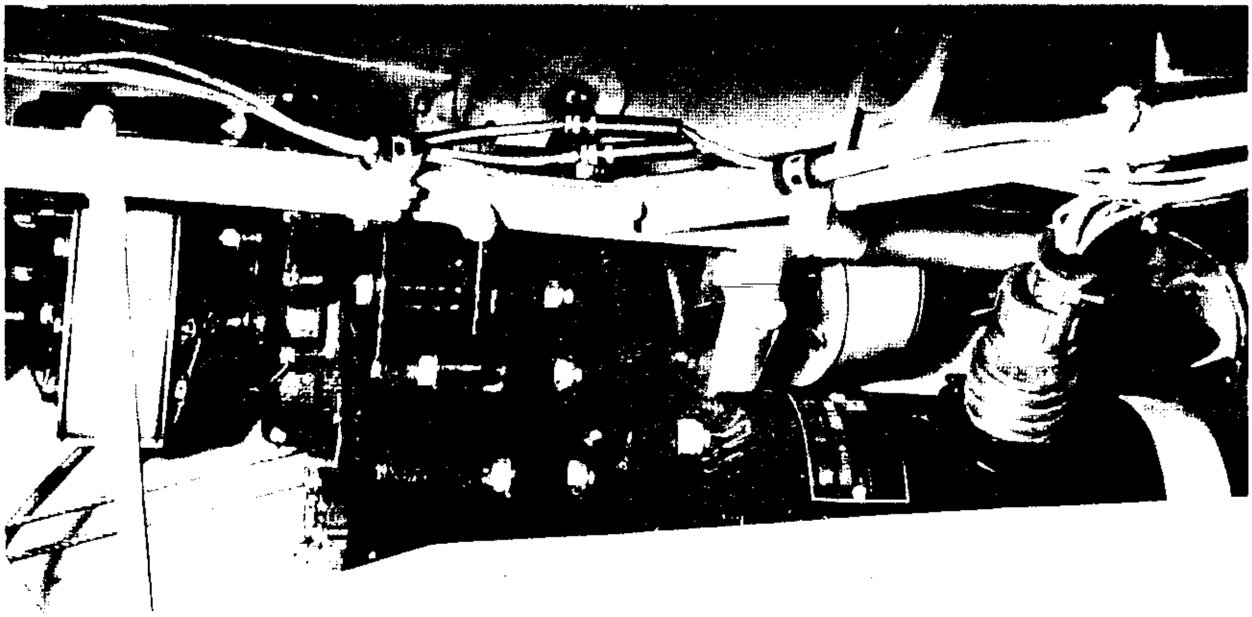
REAR SECTION

Rear Case — The rear case attaches to the rear of the supercharger case and supports the accessories and accessory drives. The front face incorporates a vaned diffuser and the rear face an intake duct containing three vanes in its elbow. The case also incorporates an oil pressure chamber containing an oil strainer and check valve, a three section oil pump and an oil pressure relief valve. Mounting pads are provided for the carburetor adapter, two magnetos, a fuel pump, starter, vacuum pump adapter, and tachometer. The B5, S3H1, and S3H1-G engines provide drives for a generator; whereas the B4, S1H2 and S3H2 engines do not. The generator may be driven by the helicopter's tail rotor shaft.



Rear Case

Accessory Drives — The accessories are driven by three shafts which extend entirely through the supercharger and rear sections. Each shaft carries a spur gear at its forward end which meshes with a gear coupled to the rear of the crankshaft. The upper shaft provides a drive for the starter and for the generator on the B5, S1H2, S3H1, S3H2 and S3H1-G engines. Each of the two lower shafts drive a magneto through an adjustable flexible coupling. Four vertical drives are provided for by a bevel gear keyed to each magneto drive shaft. Two vertical drive shafts for operating accessories and two tachometers are driven from the upper side of the bevel gears. The under sides of the bevel gears drive an oil pump on the right side and a fuel pump on the left. An additional drive for a vacuum pump is located at the lower left of the left magneto drive.



Helicopter Generator Location

LUBRICATION SYSTEM

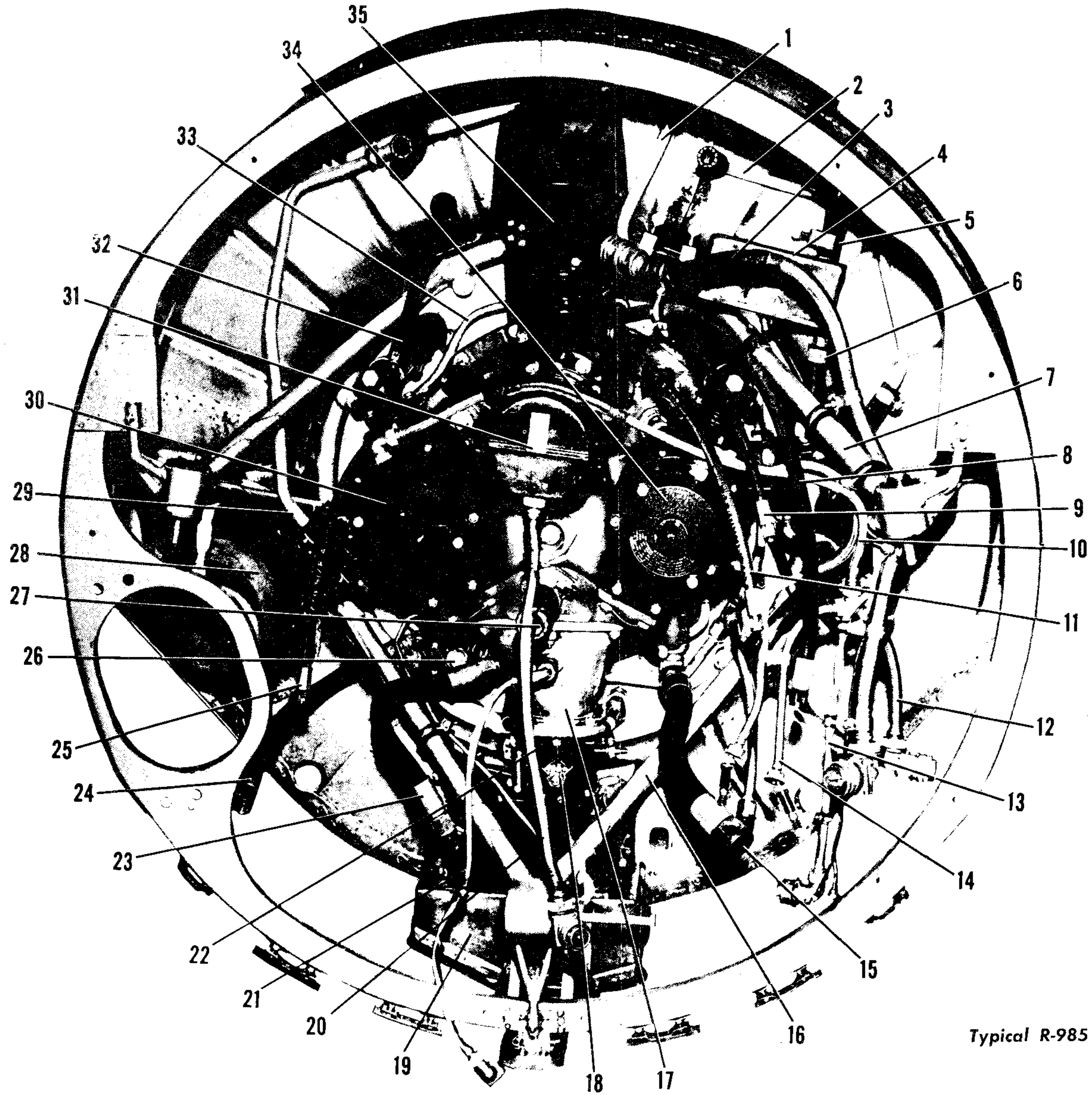
Oil is circulated through the engine by a three section gear pump mounted in the lower right hand side of the rear case. Oil from the tank enters the oil inlet at the bottom of the pump and is directed to the pressure (lower) section of the pump, where it is forced to the oil strainer chamber through a cored passage in the rear case. The oil passes through the strainer assembly and the pressure of the oil opens the spring-loaded check valve. When the engine is not operating, the check valve prevents oil from seeping into the engine.

When the oil emerges from the check valve, it is diverted into two main branches.

In the first branch, the oil is directed through a passage to an annulus around the right magneto drive gear shaft rear bushing. Part of the oil from this annulus is carried by drilled passages to the right accessory drive gear bushing. Here the oil enters the hollow accessory drive gear shaft and flows upward to the starter shaft bushing. Part of the oil from this annulus flows upward through a drilled passage to lubricate the accessory and another part enters the magneto drive gear shaft and flows forward to lubricate the front bushing.

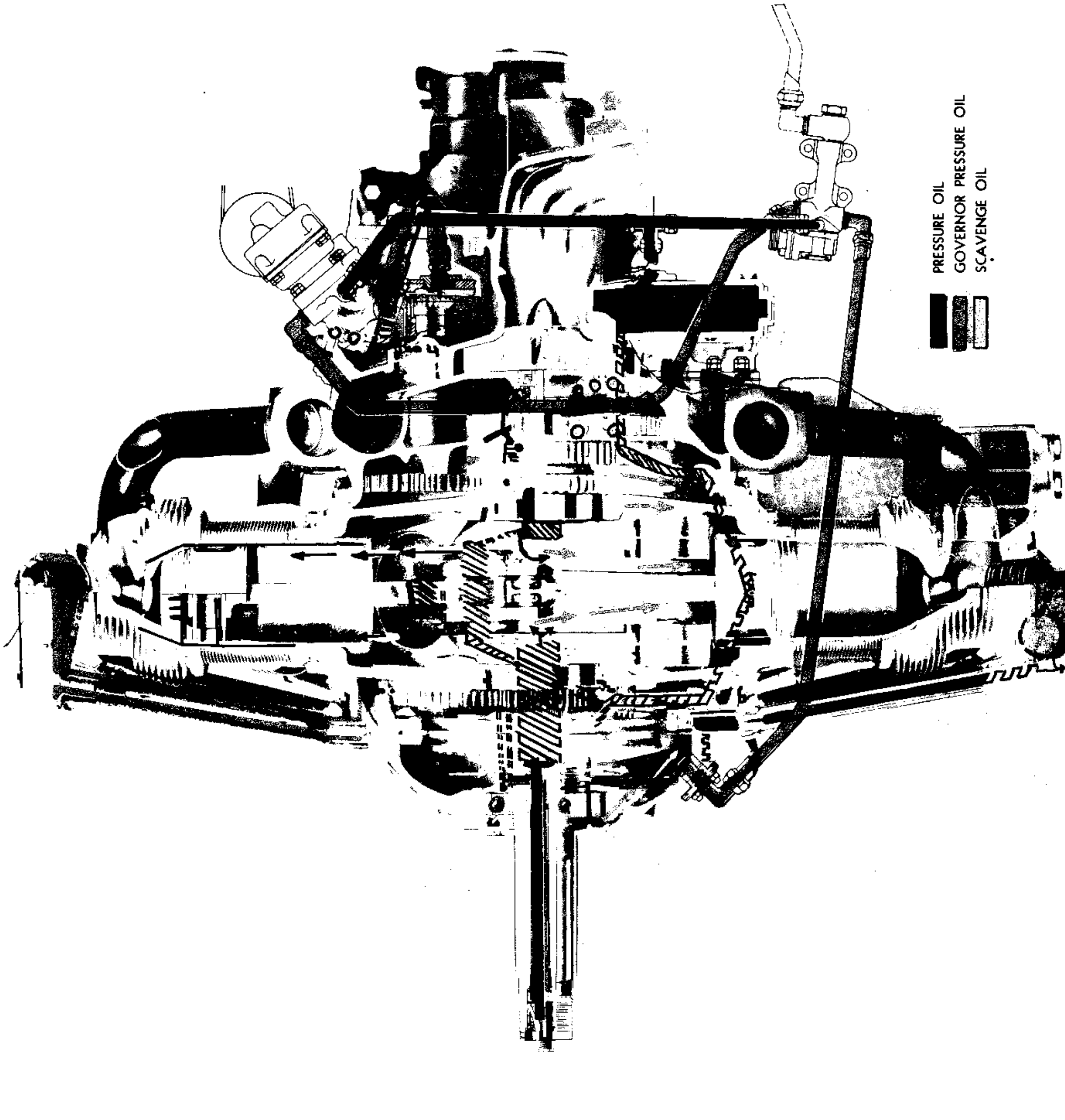
Another passage carries the oil from the annulus encircling the right magneto drive gear shaft rear bushing to the oil pressure relief valve, which regulates the engine oil pressure. By-passed oil is returned to the inlet side of the oil pump pressure section.

In the second branch, oil is directed to the left side of the rear case where the oil flow divides. Part of the oil enters the annulus which encircles the left magneto drive gear shaft rear bushing. Drilled passages from this annulus carry oil to the left accessory drive gear bushing. Here the oil enters the hollow accessory drive gear shaft and flows upward to the starter shaft bushing. Other drilled passages and tubes carry the oil to the vacuum pump, tachometer and starter gears. Oil from the annulus around the left magneto drive gear shaft rear bushing flows upward through a drilled passage to lubricate the accessory section; oil also



1. Line from Oil Separator to Vacuum Pump
2. Vent Line to Oil Tank
3. Generator Line to Firewall Cannon Plug
4. Oil Separator
5. Vent Line from Oil Separator Overboard
6. Drain Line from Oil Separator to Engine
7. Engine Mount
8. Line for Governor
9. Manifold
10. Magneto Lines
11. Primer Lines
12. Magneto Ground Conduit to Firewall Cannon Plug
13. Conduit to Propeller Feathering Switch
14. Conduits from Booster to Magneto
15. Oil Inlet
16. Engine Mount
17. Carburetor Adapter
18. Carburetor Idle Mixture
19. Carburetor Air Box Heat Deflector
20. Starter Cable
21. Carburetor Adapter Temperature
22. Fire Extinguisher Line Around Top of Carburetor
23. Fuel Line from Fuel Pump to Carburetor
24. Fuel Supply Line to Fuel Pump
25. Oil Pressure Line
26. Fuel Pump
27. Oil Outlet
28. Diaphragm Extension for Attachment of Exhaust Tail Pipe Muffler
29. Vacuum Pump Line
30. Left Magneto
31. Starter
32. Propeller Anti-Icer Line
33. Fire Extinguisher Line Attached to Engine Seal
34. Right Magneto
35. Generator

Typical R-985 Engine Installation



Lubrication Chart for Wasp Jr. B5 Engine enters the shaft and flows forward to an annulus around the front bushing where it is directed by a drilled passage to the front of the supercharger case. Here the oil provides lubrication for the impeller shaft bearings.

Oil from the crankcase and front sections is carried from the left side of the rear case through the rear and supercharger case by a tube. The supercharger case oil pressure tube bracket supports a tube assembly which transfers the oil to the crankcase and also provides spray lubrication for the floating gear and impeller intermediate drive gear. On the Wasp Jr. engine the oil passes from the pressure tube bracket through a series of tubes and drilled passages in the crankcase to the cam oil-feed bracket on the front face of the crankcase; whereas on the Wasp engine the oil is directed to a tube in the top of the sump and then to the cam oil-feed bracket.

At this point the oil is introduced into the crankshaft by means of the cam oil-feed bracket, where a drilled passage in the crankshaft directs it to the crankpin for lubrication of the masterod bearing, linkpins, pistonpins, and cylinder walls. The cylinder walls and pistonpins are lubricated by spray from the oil nozzles — one in the rear of the front crankshaft and the other at the top of the rear cheek — and also from oil which passes the masterod bearing and linkpin bushings.

On the S3H1-G engine, a portion of the oil which enters the crankshaft travels forward through a hollow chamber in the propeller shaft, where it is dispersed through drilled passages for the lubrication of the propeller shaft reduction gearing.

Part of the oil at the cam oil-feed bracket is routed to the cam bearing and cam reduction gear bushing to provide lubrication at these points.

On the S3H1-G engine, an additional tube from the sump connects with a tube in the nose section and conducts oil to the nose, then into the propeller shaft through an oil transfer bracket, for the operation of a hydro-controllable propeller. Oil entering this passage is controlled by a two-position valve at the rear of the sump, if a two-position propeller is used. An oil transfer plug is installed at this location if the engine is equipped with a constant speed propeller.

On the B5 engine, oil from the cam oil feed bracket flows through a tube to a two-position valve in the nose section, whence it is introduced into the propeller shaft through an oil-transfer bracket for the operation of a hydro-controllable propeller. In the event that a constant-speed governor is mounted on the rear section of the B5 engine, a plug is installed in the nose section in place of the two-position valve, and an external oil line from the governor is connected to this plug to furnish oil for the operation of the constant-speed propeller, in which case oil from the feed bracket is not utilized.

On the B4 engine, oil from the cam oil-feed bracket is piped to a bushing in the front case, where the propeller control-valve is ordinarily located on the Wasp Jr. engines. The oil flows around the bushing and is directed through a tube to the thrust-bearing spacer to provide a constant flow of oil to the thrust-bearing.

On the Wasp Jr. engines, an oil manifold ring, fastened to the tappet bosses in the front section, conducts oil to the tappet guides. On the Wasp engine, oil is distributed from the cam oil-feed bracket to the tappets through a groove around the front crankcase section to internal passages drilled in the case. Oil from the tappets feeds through the pushrods to the rockers, rocker bearings, and valve clearance adjusting screws.

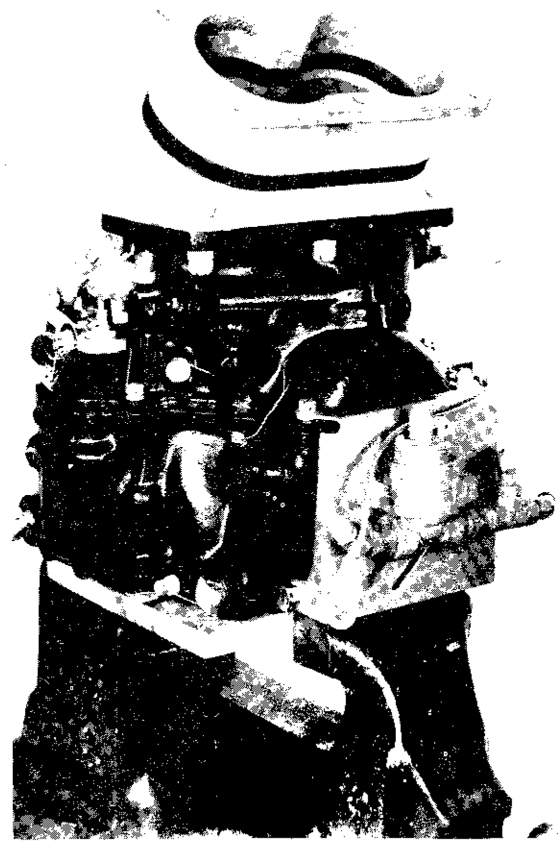
On the B5, S1H2, S3H1, S3H2 and S3H1-G engines, the surplus oil in the engine proper drains into the sump, from where it is pumped back through the scavenge pump. Oil from the rockerboxes drains through the pushrod covers to the front case, or through a system of intercylinder drains to an additional compartment in the sump where it is returned to the oil tank. The rear case oil drains through a tube into the supercharger case, then into the sump.

On the B4 engine, the rear case acts as a sump. Drain oil from the rockerboxes is carried by inter-rockerbox and inter-cylinder drain tubes to the rockerbox oil scavenge tube. This tube carries the oil to the rear case. Oil from the crankcase drains into the rear case through three sleeves extending through the supercharger case. A tube attached to the lower side of the front case section carries drain oil to the rear case, where it enters the small scavenge section of the oil pump. The large scavenge section of the oil pump scavenges the rear case through an external tube extending from the bottom to the right side of the rear case. The scavenge sections of the pump force the oil through the oil outlet port located in the center of the carburetor mounting flange.

CARBURETOR

These engines are equipped with float-type carburetors. The carburetor meters fuel in proportion to the mass air flow to the engine. The mass air flow to the engine is determined by the throttle opening. After being metered by the carburetor, the fuel is discharged into the air stream to the impeller where it is thoroughly mixed with the air, vaporized, and then delivered to the cylinders through the intake pipes and inlet valves. On the B4, S3H2, S1H2 and S3H2 engines a right angle adapter elbow is provided for the carburetor mounting to bring the carburetor into its normal operating position.

1. **Manufacturer's prefix:** All Stromberg Aircraft float-type carburetors have the manufacturer's prefix "NA."
2. **Type:** The next letter indicates the type as follows: "R" single barrel; "Y" double barrel; double float chambers fore and aft of the barrels; "C" two barrels down draft.
3. **Size:** The first numeral indicates the nominal rated size of the carburetor throat. The size starts with a one-inch diameter, which is number 1, and increases in one-quarter inch steps. For example: a two-inch carburetor is number 5. The actual diameter of the carburetor barrel opening is three-sixteenths of an inch greater than the nominal rated size, in accordance with the standards of the Society of Automotive Engineers.

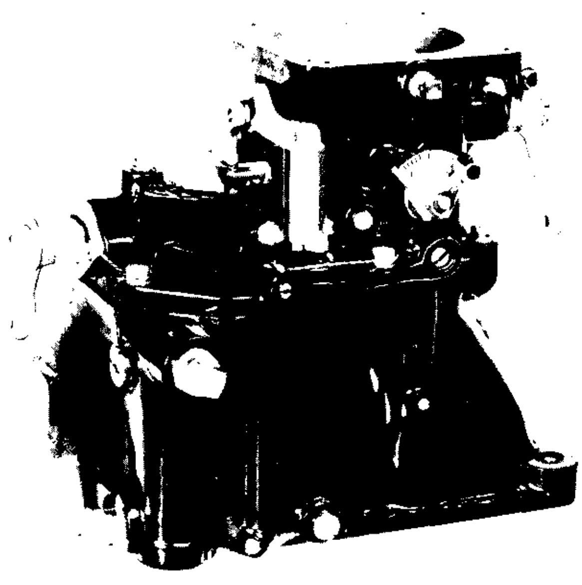


NA-Y9E1 Carburetor and Elbow

4. **Model:** A letter which follows the numeral indicating the nominal rated size of a carburetor is used to designate the various models of a given type.

5. **Model modification:** On some carburetor models, a number will follow the model letter, which indicates that the original has been modified.

6. **Setting number:** A manufacturer's carburetor setting number is an arbitrary number assigned to a particular combination of venturi, jets, bleeds and adjustments which give the desired operational characteristics in the particular model carburetor to which it is assigned.



NA-R9B Carburetor

General Description

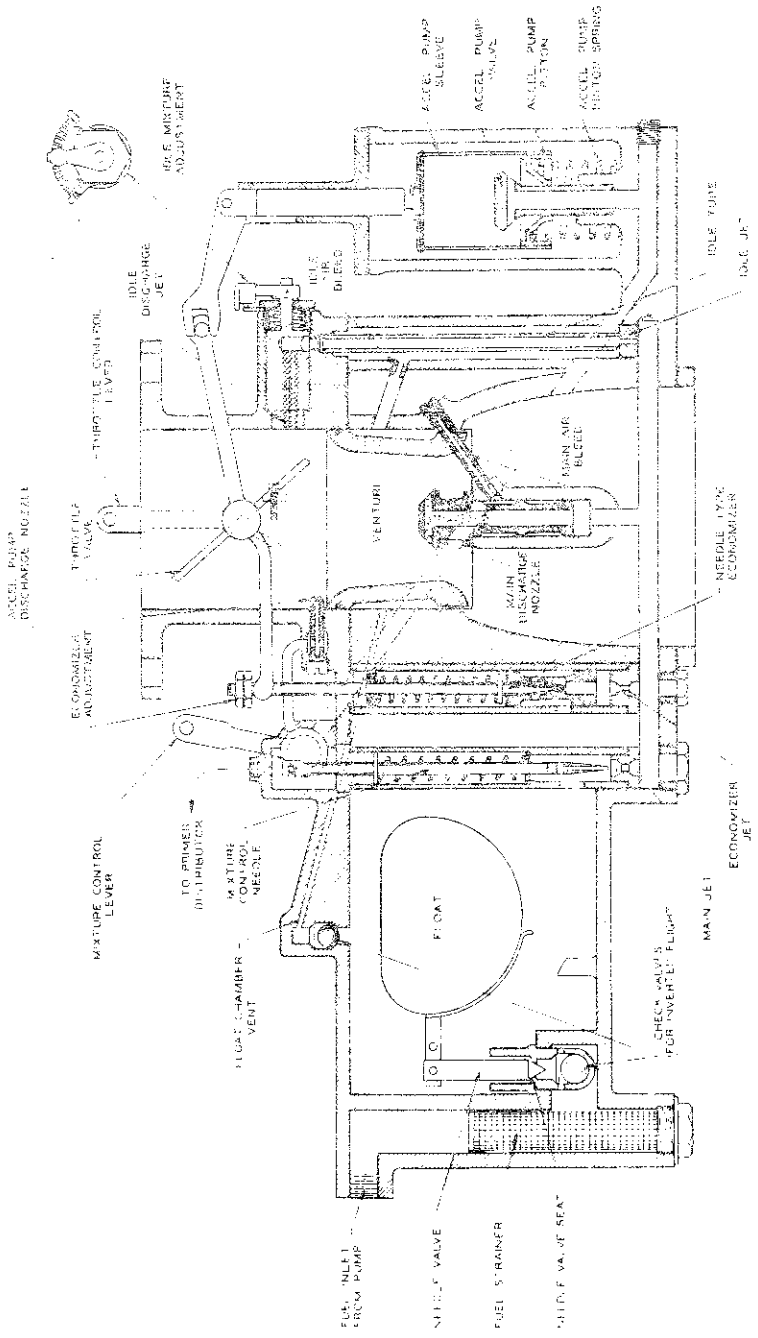
The NA-R9B carburetor, which is standard on the Wasp Jr., R-985 engine, is a single barrel, up draft carburetor. This relatively simple, venturi type carburetor has a single float, and is equipped with an economizer, manually operated needle valve type mixture control, accelerating pump, and self-primer. The NA-Y9H carburetor used on the Wasp R-1340 engine is basically the same as the NA-R9B carburetor except that it has two barrels, two floats, uses the back suction type mixture control and has idle cut-off. The NA-Y9E1 carburetor is essentially the same as the NA-Y9H with the exception of the fact that it does not have a self-primer.

Main Metering System

The main metering system consists of a venturi, main jet, main air bleed, and a discharge nozzle. It is fortunate that the pressure differential in a venturi varies as the square of the air velocity through it, while the fluid flow through a fixed orifice varies as the square root of the pressure drops across it. Thus, theoretically, the fuel flow through a simple carburetor will vary directly as the velocity of the air through the venturi, and if the density of the air is maintained constant in the venturi, the fuel flow will theoretically vary directly as the mass air flow. Actually, this theoretical condition does not strictly hold true, but the fuel flow increases at a more rapid rate than the increase in mass air flow. To correct this condition and assist in the vaporization of the fuel as it leaves the carburetor, Stromberg uses the principle of bleeding air into the fuel as it enters the discharge nozzle. This air bleed is known as the main air bleed and is a jet, bleeding air into the main discharge nozzle passage. Such a jet provides a constant F/A ratio throughout the useful range of airflows required by the engine. The fuel-air ratio can be modified as desired by the proper selection of the dimensions of the air bleed, main jet, and discharge nozzle.

Idle System

It is necessary to have an idling system to take care of the engine at lower speeds. During idling, the air velocity through the main venturi is very low and there is not sufficient venturi suction to draw fuel from the discharge nozzle. At the same time, however, there is



Schematic Diagram of NA-R9H Carburetor a very high suction on the intake manifold side of the throttle and, therefore, the fuel feed is arranged to deliver into this region of high suction. To utilize this suction, a complete discharge jet system in miniature is used with the fuel metering jet, air bleed, and discharge jet, opening into the small air passage around the throttle, formed by the slot in the idling discharge jet. Idling adjustment is accomplished by adjusting the idle discharge nozzle in connection with the throttle valve opening.

Economizer

It is desirable to have a lean mixture for maximum economy at part throttle or cruising speeds, and a much richer mixture for climb and take-off, for the cooling effect at high power. In order to obtain this change in mixture ratio, as the throttle is opened, various forms of economizer systems are used. These, in their present form, are in reality enrichening devices. The NA-R9B, NA-Y9E1, and NA-Y9H carburetor economizers consist of a needle valve, which is opened by the throttle at a predetermined throttle position, and permits a quantity of fuel flow through the economizer jet in addition to that furnished by the main metering jet, to mix with the air in the carburetor.

Mixture Control

As the airplane ascends to altitude, the atmosphere decreases in pressure and temperature resulting in a decrease in density. The weight of the air charge taken into the engine decreases with the decrease in air density, cutting down the power in about the same percentage. In addition, the mixture proportion delivered by the carburetor is affected, the mixture becoming richer at a rate inversely proportional to the square root of change in air density. In order to compensate for this change in mixture, a mixture control is provided on all Stromberg Aircraft Carburetors. The NA-R9B carburetor uses the needle valve type of mixture control. The needle restricts the flow of fuel to the jets. The NA-Y9E1 and NA-Y9H carburetors, used on the Wasp engine, employ the back suction type mixture control with idle cut-off which reduces the fuel flow by lowering the pressure in the float chamber in order to reduce the flow of fuel through the jets. A small nozzle in the venturi which has a restricted passage leading to the float chamber produces the suction in the float chamber. When the mixture control is in full rich position, the float chamber is vented to the air scoop. As the mixture control is gradually leaned off, the valve closes off the float vent which in turn lowers the float chamber pressure.

Inverted Flight

Float type carburetors are designed to operate satisfactorily during all airplane maneuvers. During upside down flying, the float action reverses. Fuel is pumped to the jets at fuel pump pressure which would cause the carburetors to run very rich. Check valves are used to restrict the flow of fuel to the needle valve and to shut off the float chamber vent. Special fuel and oil systems are required if the airplane is to be operated upside down for a long period of time.

Accelerator

For quick acceleration of the engine, a quantity of fuel in addition to that supplied by the main metering system is required. A fuel pump, operated by the throttle has, therefore, been incorporated in the design. This pump gives a positive accelerating charge, regardless of the suction existing in the carburetor. It delivers this charge as a momentary spurt of fuel followed by a sustained discharge for a few seconds.

Self Primer

The accelerator pump on all the recent float type carburetors, except the NA-Y9E1, is also used for a primer. When the mixture control is placed in the full lean position, a valve on the mixture control shaft opens allowing the discharge from the accelerating pump to flow into the engine primer lines.

Idle Cut-Off

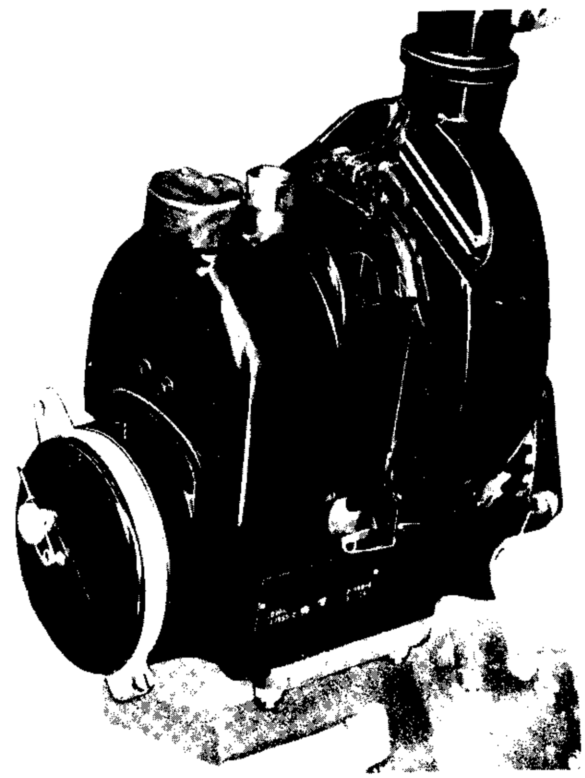
The idle cut-off is a part of the mixture control assembly. It consists of a valve and the necessary channels drilled in the bodies. The valve is opened during the last few degrees of mixture control lever movement toward the full lean position. With valve open and the throttle closed, the manifold suction existing above the throttle valve is transposed directly on top of the fuel chamber by means of a drilled passage in the body, and the fuel flow through the idle system is stopped, thereby causing the engine to cease firing immediately.

Summary

The specifications or settings in these carburetors are the result of a great deal of test work conducted by the engine and carburetor manufacturers in the laboratory and in flight, and should not be changed unless specific instructions are issued by the manufacturer. In a case where unusual operating conditions necessitate a change, the carburetor manufacturer will issue any necessary instructions upon application.

IGNITION

Ignition is furnished by a synchronized dual, high tension, magneto ignition system. An installation includes two magnetos, two distributor assemblies, a manifold assembly, and two sparkplugs in each cylinder. The magnetos are mounted at the rear of the engine. The right magneto fires the front

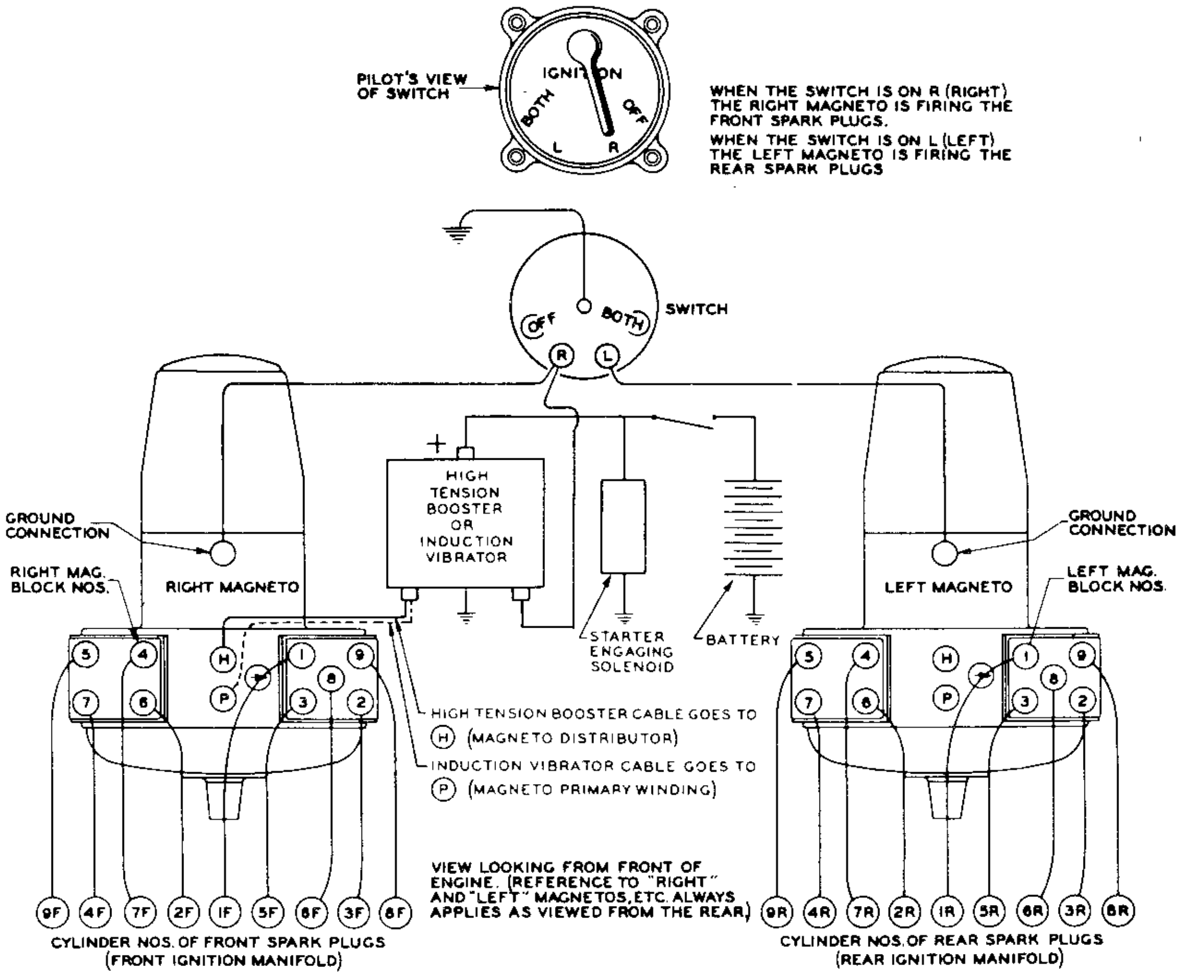


Magneto

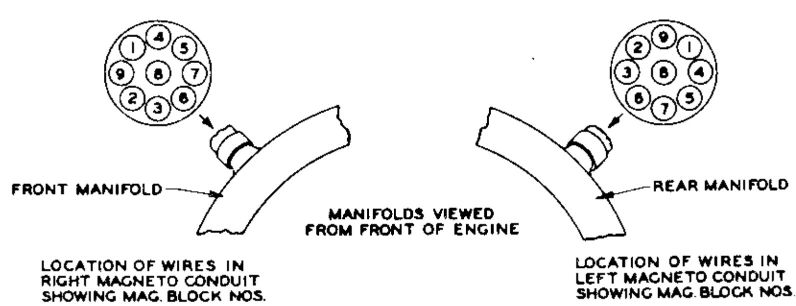
sparkplug in each cylinder; the left magneto fires the rear sparkplug, and both plugs are fired simultaneously. However, since the two ignition systems are electrically independent, satisfactory operation will still be obtainable with reduced power should one system fail.

Dual ignition permits greater horsepower output with less tendency of the fuel to detonate. High tension current is generated and timed by the magneto which is independent of any other accessory, thereby assuring uninterrupted performance of one of the most vital parts of the aircraft engine. Radiation of uncontrolled high frequency current emanating from the ignition system is minimized by encasing the entire ignition system with a metallic covering known as radio shielding.

The magneto employs four magnetic poles. The poles of the rotating magneto are arranged in alternate polarity so that a change in the flux direction occurs with rotation. The number of flux reversals during one complete



MAG. BLOCK NO.	1	2	3	4	5	6	7	8	9
CYLINDER NO.	1	3	5	7	9	2	4	6	8

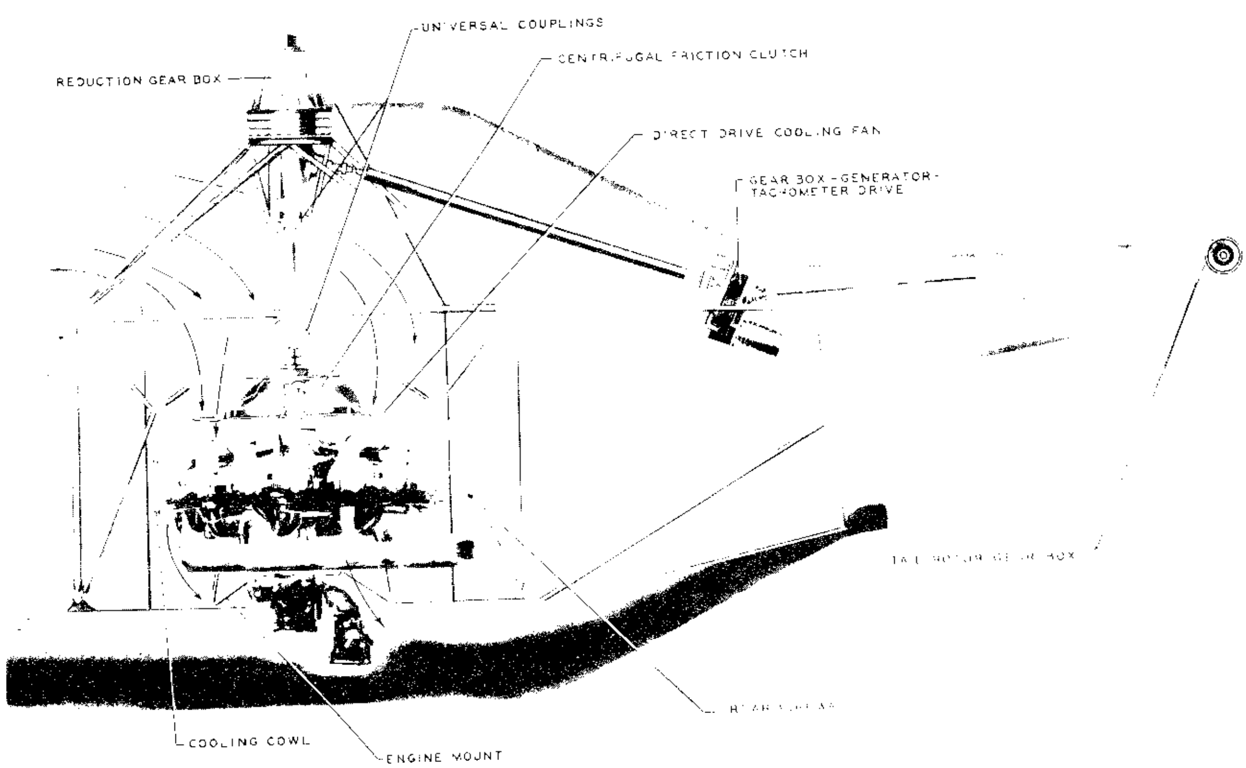


Ignition Wiring Diagram

revolution of the assembly is equal to the number of poles on the magnet. In this arrangement, the coil assembly remains stationary. The flux density depends on the area of the magnetic pole engaged by the pole shoe. The electromotive force induced across the windings is proportional to the rate of change of the flux. The voltage that the magneto is allowed to develop is determined by the sparkplug gap dimension and the density of the charge in the cylinder at the time of discharge.

A TYPICAL HELICOPTER INSTALLATION

A clutch housing, which carries the fan and the clutch driving member, is attached to the propeller shaft. Actuated by centrifugal force, the driving member engages the driven member, which rotates on ball bearings about the crankshaft. Through a universal joint, the clutch-driven member is connected to the vertical drive shaft, which in turn transmits power through a second universal joint to the reduction gear and free wheeling units from which the main rotor is driven. Tail rotor drive is accomplished by shafting from the tail rotor which joins a "take-off" shaft from the main rotor drive at a gearbox from which the generator is driven. The take-off is "ahead" of the free wheeling unit so that the tail rotor will be operative during auto-rotation. A separate lubrication system is provided for the gear boxes. The fan and clutch housing afford a sufficient amount of "flywheel effect" to protect the crankshaft and supercharger drive from undesirable vibrations. The engine is mounted on a conventional-type tubular mount structure. Rubber bushings are used for vibration isolation. Number 1 cylinder projects forward. Retention of the standard engine nomenclature results in the right side of the engine being on the left side of the ship. As with other submerged engine installations, auxiliary cooling means are required and are provided for in the form of a fan and suitable



Typical Wasp Jr. B4 Installation

cowling. Cooling air is taken in through louvers at the forward side of the rotor pylon, and is exhausted at the sides of the ship. Recirculation of heated air back into the fan is prevented by means of a cloth diaphragm or seal near the cowl entrance which extends from the cowl to the sides of the engine compartment, thus isolating the cooling air exit from the fan entrance. A diaphragm or shroud separates the accessory compartment from the power section, making the installation a two-zone arrangement as in most aircraft. Blast tubes for magneto cooling receive air from between the baffles. The throttle mixture control is conventional, with full-rich and full-lean positions. With this control in the full-lean position, the engine is primed by movement of the throttle control. The control is connected mechanically with the pitch control in such mannner that, as the main rotor blade pitch is increased, the throttle is opened to provide the necessary increase in power. An override for throttle adjustment is incorporated in the rotatable hand grip on the pitch control stick. Actuation of the throttle for priming as described above is accomplished by raising and lowering the pitch control lever. The magneto switch, fuel selector valve, carburetor air control, starter switch, and other controls are standard.

CHAPTER 2 . . . . TOOLS

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TOOLS

Standard Tools — No attempt has been made to list all the standard tools which might be used for maintenance operations. If no tool is specified for an operation which obviously requires one, it is assumed that a suitable standard tool will be used. Inquiries pertaining to standard tools should be directed to the respective manufacturer.

Illustrations — Because of progressive changes in design, certain tools used at a maintenance activity may differ somewhat in appearance from those which were used to illustrate this manual.

NUMERICAL TOOL LIST

Tool No.	Tool Name	Description or Use
PWA-10	Holder	Inlet valve lapping
PWA-11	Holder	Exhaust valve lapping
PWA-13	Clamp	Compressing piston rings (Wasp)
PWA-37	Sling	Engine lifting
PWA-85	Pointer	Engine timing (Wasp Jr.)
PWA-112	Bar	Crankshaft turning (Wasp Jr.)
PWA-155	Bar	Propeller shaft turning (Wasp S3H1-G) Crankshaft turning (Wasp except S3H1-G)
PWA-186	Wrench	Cylinder hold-down installation and removal
PWA-228	Wrench	Oil screen cover nut assembly and disassembly
PWA-237	Wrench	Intake Pipe gland nut assembly and disassembly (Wasp Jr.)
PWA-249	Clamp	Compression piston rings (Wasp Jr.)
PWA-455	Depressor	Rocker arm
PWA-459	Depressor	Valve spring

TOOLS

Tool No.	Tool Name	Description or Use
PWA-491	Driver	Installation of pushrod cover connector in cylinder head
PWA-520	Eye	Engine lifting (Wasp Jr.)
PWA-535	Pointer	Engine timing (Wasp S3H1-G)
PWA-614	Drift & Base	Rocker arm ball bearing assembly and disassembly
PWA-662	Eye	Crankshaft lifting (Wasp S3H1-G)
PWA-671	Wrench	Oil pressure relief body installation and removal
PWA-849	Driver	Pushrod cover connector removal from cylinder head
PWA-1084	Wrench	Thrust bearing nut installation and removal (Wasp S3H1-G)
PWA-1092	Wrench	Thrust bearing nut installation and removal (Wasp except S3H1-G)
PWA-1093	Wrench	Thrust bearing nut installation and removal (Wasp Jr.)
PWA-1327	Puller	Oil pump
PWA-1332	Eye	Propeller shaft lifting (Wasp S3H1-G) Crankshaft lifting (Wasp except S3H1-G)
PWA-1526	Tap	Sparkplug bushing
PWA-1683	Wrench	Sparkplug lead elbow nut installation and removal (on center)
PWA-1791	Pliers	Piston rings installation and removal
PWA-1886	Wrench	Strap
PWA-2006	Wrench	Cylinder hold-down nut installation and removal (Use with PWA-2398)
PWA-2238	Wrench	Torque indicating 0-2200 inch lbs.
PWA-2239	Wrench	Torque indicating 0-600 inch lbs. (Use with PWA-2240)
PWA-2240	Adapter	Torque indicating wrench (Use with PWA-2239)
PWA-2373	Wrench	Breather plug installation and removal (Wasp Jr.)
PWA-2388	Hook	Engine lifting
PWA-2397	Wrench	Cylinder hold-down nut installation and removal (Use with PWA-2411)
PWA-2398	Handle	Cylinder hold-down nut wrench (Use with PWA-2006 and 2399)
PWA-2399	Wrench	Cylinder hold-down nut installation and removal (Use with PWA-2398)
PWA-2411	Handle	Cylinder hold-down nut wrench (Use with PWA-2397)
PWA-2417	Indicator	Magneto synchronizer (battery type)

TOOLS

Tool No.	Tool Name	Description or Use
PWA 2474	Pointer	Engine timing (Wasp except S3H1-G)
PWA 2488	Holder	Holding masterod or linkrods
PWA 2537	Indicator	Top center — battery-type
PWA 2630-20	Plate	Checking cylinder barrel flange (Wasp Jr.)
PWA 2630-22	Plate	Checking cylinder barrel flange (Wasp)
PWA 2645	Bar	Crankshaft turning (Wasp S3H1-G)
PWA 2713	Wrench	Crankshaft front plug, PN 40355 or PN 39375 (SB 1761)
PWA 2898	Lap	Lapping cylinder barrel flange (Wasp Jr.)
PWA 3410	Gage	Checking piston dishing
PWA 3145	Puller	Intake pipe removal
PWA 3168	Wrench	Sparkplug installation and removal
PWA 3252	Plug	Venting cylinders
PWA 3315	Wrench	Sparkplug lead elbow nut installation and removal (off center)
PWA 1762	Puller	Magneto drive oil seal
PWA 3800	Protector	Intake port (Wasp Jr.)
PWA 3926	Remover	Exhaust port cover
PWA 4142	Indicator	Piston top center locator and 25° ignition timing — Time Rite, Gabb. Spec. Products Div., Conn., Inter. Corp., Windsor Locks, Conn., 06095.
PWA 4152	Driver	Valve adjustment screw
PWA 4153	Drift & Base	Magneto drive oil seal
PWA 4675	Gage	Checking valve clearance

TOOLS

Tool No.	Tool Name	Description or Use
PWA-4766-101	Remover	Studs — ¼ inch
PWA-4766-102	Remover	Studs — 5/16 inch
PWA-4766-103	Remover	Studs — ⅜ inch
PWA-4877	Puller	Pushrod ballend assembly and disassembly
PWA-4911	Pusher	Piston pin disassembly
PWA-5008	Protector	Intake port (Wasp)
PWA-5072	Wrench	Intake pipe gland nut assembly & disassembly (Wasp)
PWA-5124	Valve	Depreservation
PWA-5187-30	Wrench	Thrust bearing nut, installation and removal, hydromatic installation (Wasp Jr.)
PWA-5187-40	Wrench	Thrust bearing nut, installation and removal, hydromatic installations (Wasp except S3H1-G)
PWA-5187-40A	Wrench	Thrust bearing nut, installation and removal, hydromatic installation (Wasp S3H1-G)
PWA-5630	Wrench	Pushrod gland nut assembly and disassembly (use with PWA-2239)
PWA-5689	Cutter	Pushrod cover packing
1313-T-5	Gage	Checking cylinder bore (Wasp — use with PWA-312-11)
3472-T-3	Gage	Checking cylinder bore (Wasp Jr. — use with PWA-312-11)
TAM-1161	Stand	Engine mounting (use with TC 51259)
TC-51259	Plate	Engine mounting (use with TAM-1161)

CHAPTER 3 . . . . . PREPARATION FOR SERVICE

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PREPARATION FOR SERVICE

UNPACKING THE ENGINE

All Pratt & Whitney Wasp and Wasp Jr. 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.

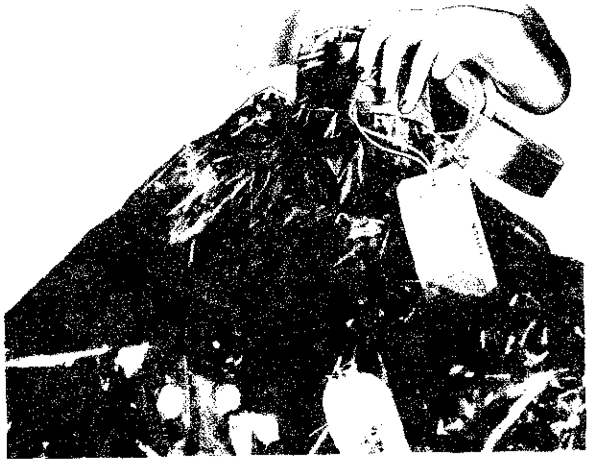
When raising or lowering the packing case, use a chain hoist with a minimum capacity of 2 tons. Support the bottom of the case by passing a double sling underneath. Use the lifting rings on the cover only for lifting the cover from the case.

Remove the metal straps from the case.

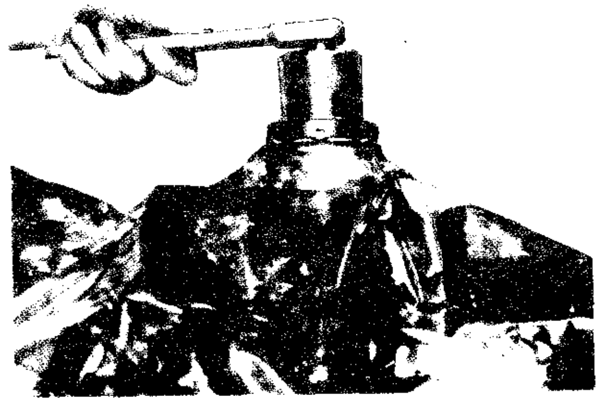
Attach a sling to the two rings on each side of the cover, and lift the cover from the case [**Figure 3—1**] carefully to prevent damage to the carburetor, which is in a carton fastened inside the packing case cover. Lift the four sides out of the base [**Figure 3—2**].

[3—1] Lift Cover from Case

[3—2] Lift Sides from Base



[3—3] Remove Tape

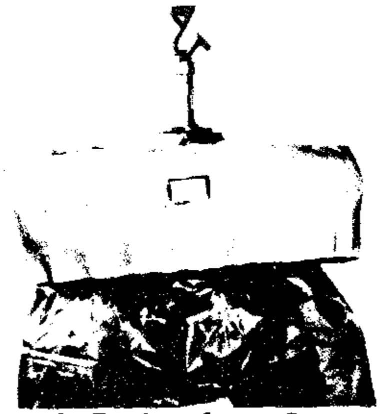


[3—4] Unscrew Protector Cap

Remove the tape **[Figure 3—3]** which gathers the top of the engine protective envelope around the propeller shaft and open the envelope by cutting off the sealed portion. Cut off as little envelope material as possible so that the envelope can be reused. Unscrew the protector cap and spanner nut **[Figure 3—4]**; then remove the protective envelope and spacer from the propeller shaft **[Figure 3—5]**.

Remove the nuts and lockwashers which secure the engine mounting plate to the support cone. Install PWA-520 (Wasp Jr.) or PWA-1332 (Wasp) Lifting Eye on the crankshaft, and lift the engine from the cone by means of a chain hoist **[Figure 3—6]**. Unfasten the mounting plate and remove it from the engine. Roll the protective envelope down from the engine, wipe it clean; and store it for further use. Remove the paper from around the power section, the humidity indicator, and the bags of dehydrating agent.

[3—5] Remove Protective Envelope



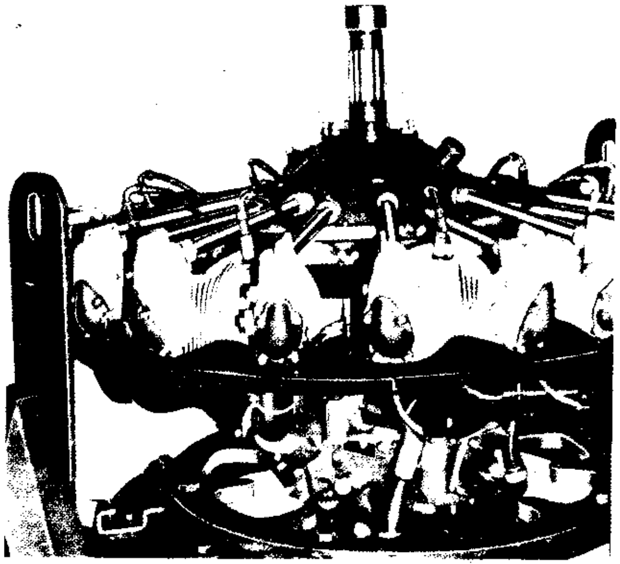
[3—6] Lift Engine from Cone

Lower the engine into TAM-1161 Engine Stand equipped with TC-51259 Mounting Plate and secure it with the bolts, lockwashers, and nuts **[Figure 3—7]**. Cut the straps and remove the carburetor and accessory packing cartons from the packing case cover.

ENGINE BUILD-UP

General

The instructions for engine build-up treat only major components. In case any part of the [illegible] instructions are in conflict with, or superseded by, the airframe manufacturer's [illegible] the instructions contained in the [illegible] applicable. For additional details on specific requirements refer to the installation drawings for the particular aircraft



[3–7] **Lower Engine into Stand**

involved; these drawings are provided by the aircraft manufacturer.

The vertical auxiliary accessory drive pads have drilled .188 in. diameter holes for pressure oil if the pads are of the low type. High pads have no provisions for pressure oil. An oil supply is available through the center of the propeller shaft by removing a plug in the end of the shaft. The vacuum pump pad is provided with a .1405 in. drilled hole for pressure oil.

When a propeller governor is used on the Wasp Jr. engine, oil under pressure should be piped from the main oil screen chamber to the governor. The governor return oil should be drained to the rear section by an external pipe connected to the point shown on the Installation Drawing.

The propeller governor pad on the direct-drive Wasp engine is provided with a .313 in. diameter hole for oil supply to the constant speed governor and a .313 in. diameter hole to supply high pressure oil to the propeller.

When a propeller governor is used on the geared Wasp engine, the governor is driven by means of the vertical accessory drive. Oil under pressure should be piped from the main oil screen chamber to the governor. The return oil should be drained to the rear section by an external pipe connected to the point shown on the Installation Drawing.

For lubrication requirements of various accessories, refer to the applicable accessory manufacturer's instructions.

For torque recommendations refer to Specific Torque Recommendations, Limits Chapter.

DEPRESERVATION

General

Remove the moisture-resisting coverings, tape, dehydrating agent, and dehydrator plugs from the engine and the accessories.

> ***Do not remove the cover from the carburetor mounting pad until the carburetor is to be installed.***

Mixture Drainage

Remove the sump drain plugs and allow the excess corrosion preventive mixture to drain.

> ***The oil sump on Wasp Jr. B5 and Wasp engines contains an upper and lower chamber. The upper chamber collects drain oil from the crankcase section. The lower chamber collects drain oil from the rockerbox drain system. On Wasp Jr. B5 engines, the front plug drains the lower chamber. On Wasp engines, the front plug drains the lower chamber while the rear plug drains the upper chamber.***

Remove the sparkplug leads from the dehydrator plugs; then remove the dehydrator plugs from the cylinders. Using a small inspection light inspect the cylinders through the sparkplug holes to ensure that oil or mixture has not accumulated in them. If an appreciable quantity is present, remove it with a hand pump.

Remove the two bottom most intake pipes and drain all corrosion preventive mixture from them. If excess mixture is found in the intake pipes, remove and examine the adjacent intake pipes on each side of the engine, continuing toward the top cylinder until no excess mixture is found. Refer to Intake Pipes, Replacement of Parts chapter, for complete removal and installation instructions.

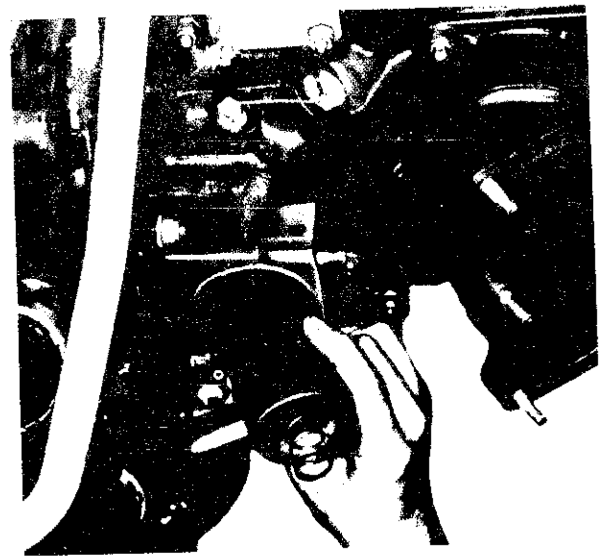
Prior to operation of the engine it must be ascertained that the lower cylinders and intake pipes are completly free of corrosion preventive mixture.

Installed Engines — Motor the engine through a minimum of six revolutions with the sump drain plugs and the lower-most intake pipes removed to facilitate engine draining.

Un-installed Engines — Remove the starter and the oil inlet and outlet shipping covers. With the sump drain plugs and the lower-most intake pipes removed, crank the bed of the engine stand until the crankshaft is in a vertical position. Allow the corrosion preventive mixture to drain. Turn the engine through by hand, using PWA-112 Turning Bar for Wasp Jr. engines, PWA-155 Turning Bar for Wasp engines or PWA-2645 Turning Bar for S3H1-G engines, at least six complete revolutions in the normal direction of rotation to facilitate draining. Crank the bed of the engine stand until the crankshaft is in a horizontal position and then repeat the preceding instructions. Thoroughly clean the sump drain plug and the intake pipes removed and reinstall in the engine.

Pressure Oil Screen

Remove the pressure oil screen from the rear case **[Figure 3—8]**. Allow any corrosion preventive mixture to drain from the oil screen chamber. Clean the screen thoroughly; then reinstall it making certain that the cover gasket is in good condition.



[3—8] Remove Pressure Oil Screen

Washing the engine

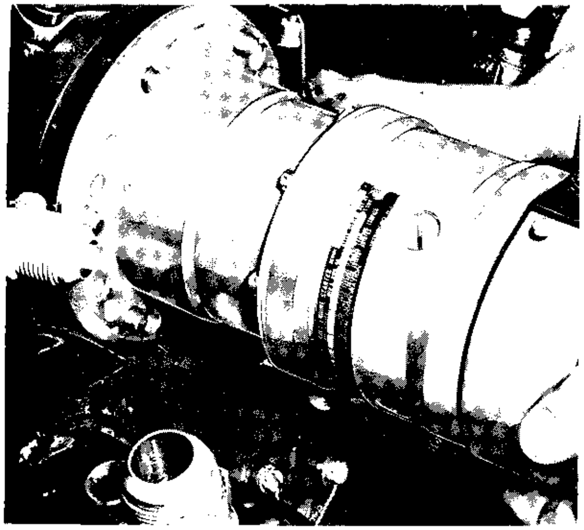
If necessary, wash the exterior of the engine thoroughly with cleaning solvent, being careful to keep the cleaning fluid away from the ignition cable assembly. Dry the engine with compressed air.

Starter

Check the jaw of a new starter with the engine meshing jaw for size, number and slant of teeth. If the sizes differ, the starter is the wrong model for the engine. Check the starter to make sure it rotates in the proper direction.

Wipe the mounting pad and the starter mounting flange clean, and place a clean, dry gasket on the studs; then mount the starter **[Figure 3—9]** secure it with washers and nuts; and tighten to the recommended torque.

Remove paint, dirt, and grease from the starter flange to provide electrical bonding contact for the starter mounting nuts.



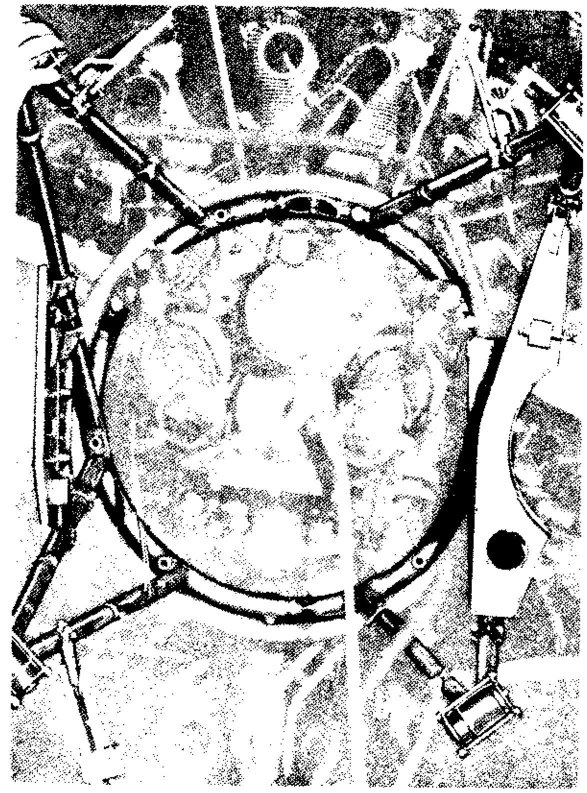
[3—9] Mount the Starter

Engine Mount

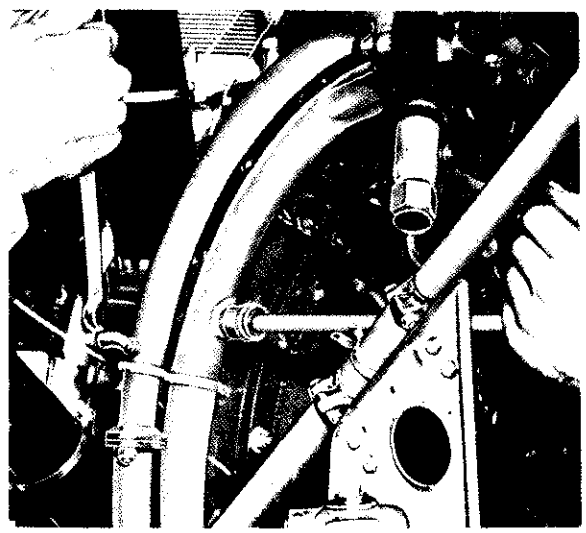
Two types of engine mounting may be used. In one case, through-bolts are used to attach the mount lugs to the engine at the nine points of attachment on the ring.

The second type of mounting uses vibration isolators. The vibration isolators are not engine parts and therefore are not covered in these instructions.

Remove the engine from the engine stand by means of a suitable hoist and sling. For build-up, the engine may be supported by the hoist and sling or installed in a transportation stand if one is available. Align the mounting ring bolt holes with the mating holes in the mounting bosses [**Figure 3—10**]. Install the bolts and nuts; then tighten [**Figure 3—11**] to the recommended torque.



[3—10] Align Bolt Holes



[3—11] Tighten to Torque

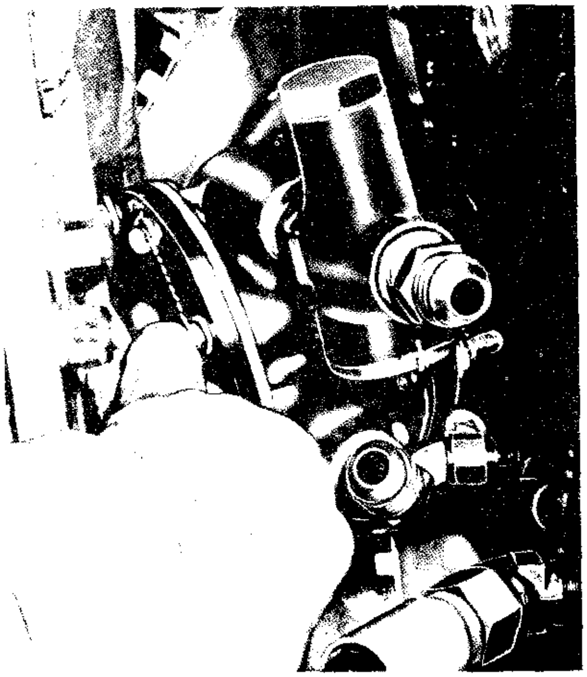
Vacuum Pump

Remove the cover plate and the gasket from the engine pump pad, and wipe the pad clean. Check the oil holes in the pad to ensure free oil passage.

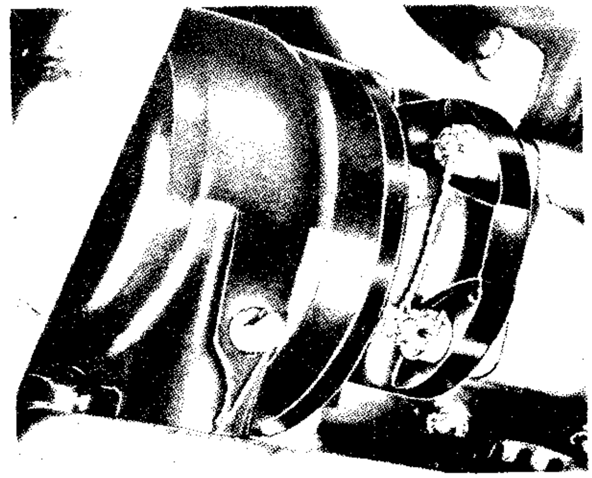
Remove the shipping plugs from the two ports, and test the pump manually for freedom of operation.

Pour a small quantity of engine lubricating oil into the pump ports and rotate the drive coupling assembly several times by hand to ensure a good distribution of lubricating oil on the walls, vanes, and bearings. The pump rotor should turn freely. If there is any evidence of binding, the pump should be forwarded to overhaul.

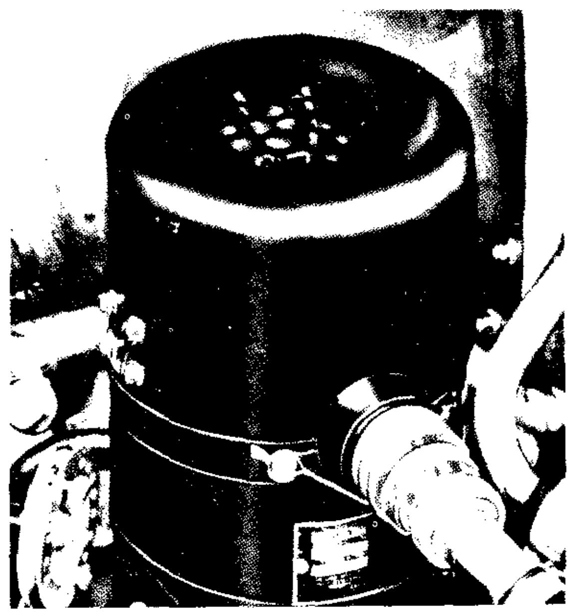
PREPARATION FOR SERVICE



[3—12] Engage Pump Drive



[3—13] Secure and Lockwire



[3—14] Generator

Coat the drive spline of the pump with a suitable spline lubricant (Plastilube No. 3). Exercise extreme care to apply the lubricant in a thin even coat and to remove completely any excess lubricant from the part or adjacent parts.

Place the mounting gasket that is supplied with the pump on the engine mounting pad studs making sure that the oil holes in the gasket line up with the oil holes in the engine mounting pad.

Carefully mate and engage the pump drive with the engine drive member [**Figure 3—12**] then secure and lockwire [**Figure 3—13**].

The pump may be rotated to the desired position to facilitate completion of the air tubing connections to the pump ports.

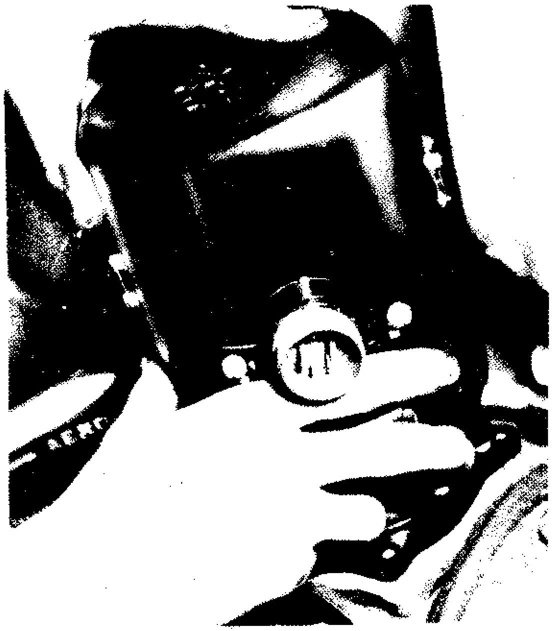
Generator [Figure 3—14]

Remove the cover plate and gasket from the engine mounting pad; wipe the mounting pad clean and reassemble the gasket on the pad.

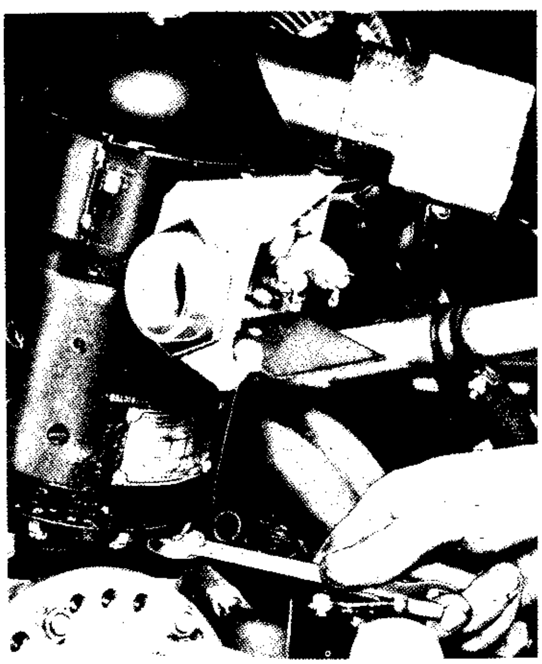
Remove paint, grease, and dirt from the generator flange to provide electrical bonding contact for the generator mounting nuts.

Coat the drive spline of the generator with a suitable spline lubricant (Plastilube No. 3). Exercise extreme care to apply the lubricant in a thin even coat and to remove completely any excess lubricant from the part or adjacent parts.

Determine the best mounting position for alignment and attachment of the electrical leads. Place the generator on the mounting studs [**Figure 3—15**] and screw on the mounting stud nuts. Tighten the nuts securely [**Figure 3—16**].



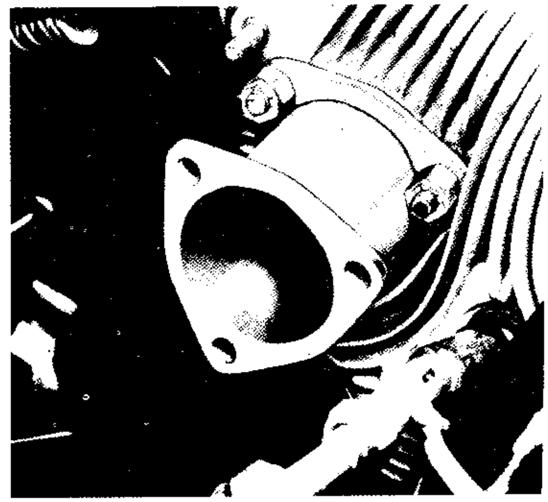
[3—15] Generator on Studs



[3—16] Tighten Nuts

Loosen the screws holding the blast tube adapter, swing the adapter to the required angle.

For additional details, refer to the installation drawings provided by the aircraft manufacturer.



[3—17] Secure Exhaust Stack

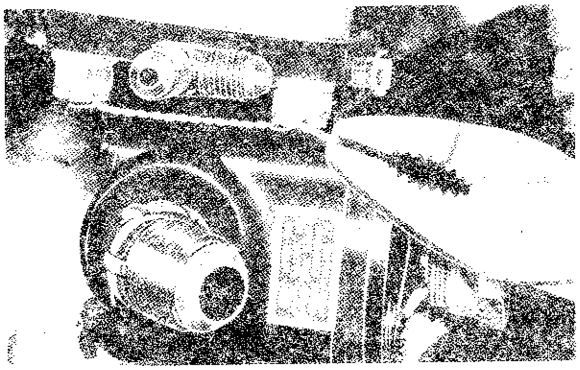
Exhaust Stacks

Place the exhaust stack and gasket on the mounting studs; then secure with nuts and palnuts [**Figure 3—17**].

Fuel Pump

Check the part and type numbers stamped on the pump against the specific requirements. Prepare the pump for installation by removing the shipping block from the flange, the Protek plug from the inlet port and the plain plug from the outlet port. Oil flushed pumps should be cleaned by flushing with naphtha. Turn the drive shaft with the fingers to check freedom of pump operation.

Make certain the mounting surfaces of the pump and engine are clean. Place a new gasket on the studs and mount the pump. Secure with washers and nuts; then lockwire [**Figure 3—18**]. Connect the proper fuel lines [**Figure 3—19**], using an approved antiseize thread compound, to the inlet and outlet ports. Remove the vent plug from the valve housing cover and install the balance line which vents this outlet with the carburetor top deck. Connect the drive shaft seal drain line to the drain fitting in the pump mounting pad [**Figure 3—20**].

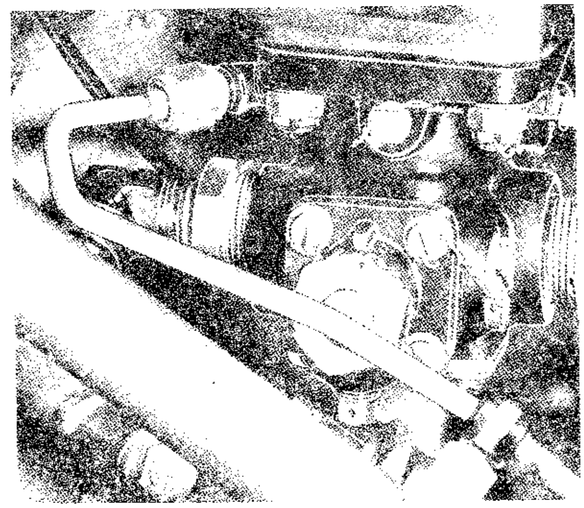


[3—18] Lockwire

[3—19] Connect Fuel Lines

Carburetor

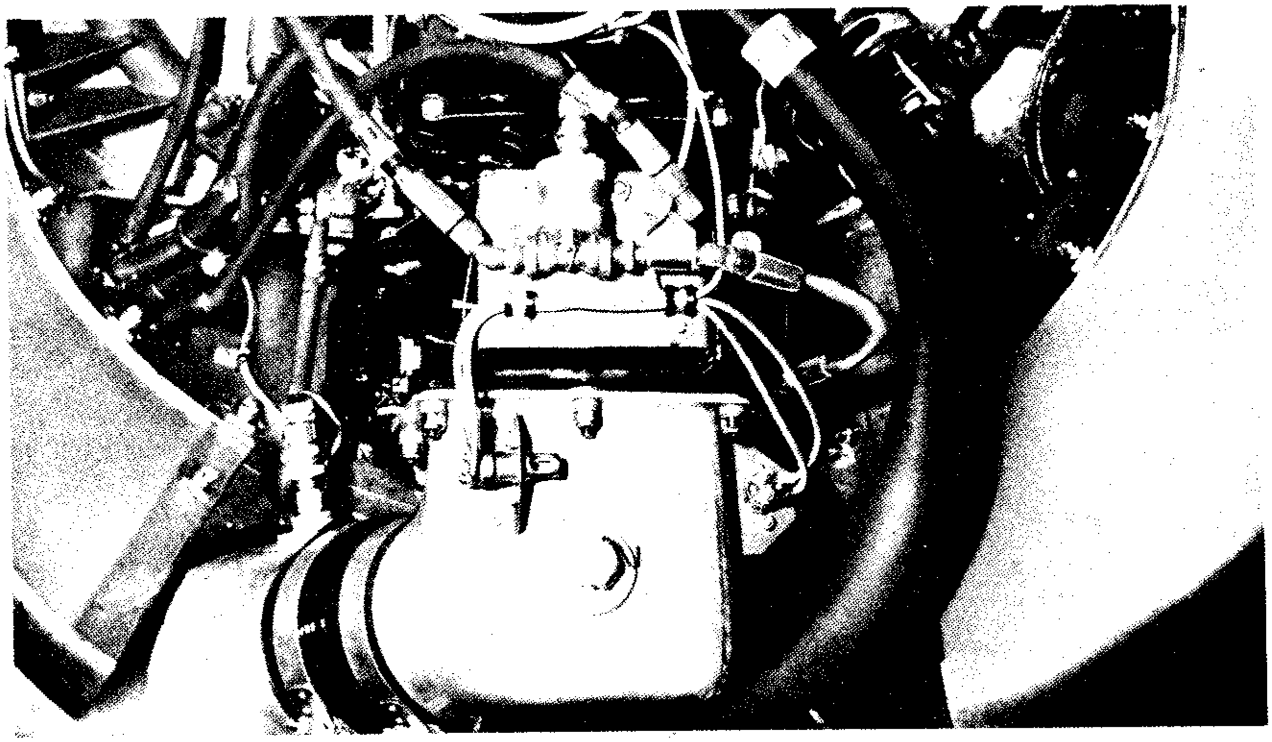
Remove the drain plugs from the carburetor float chamber and drain off the excess preservative oil. Flush the carburetor through the fuel inlet opening with naphtha and allow the cleaning fluid to drain. Repeat this operation until all the storage oil has [illegible] completely washed out. Discontinue the flushing operation, and reinstall all plugs and other components.



[3—20] Connect Drain Line

The NA-R9B carburetor is mounted on the engine with the float chamber at the side and with the fuel inlet to the rear. The fuel inlet is a ⅜ inch pipe tap connection located at the top of the strainer boss. A ⅛ inch pipe tap primer connection is located on top of the mixture control boss. The mixture control and throttle levers may be adjusted radially to any position. The 70 degree throttle lever travel, requires a control rod movement of 2-9/32 inches.

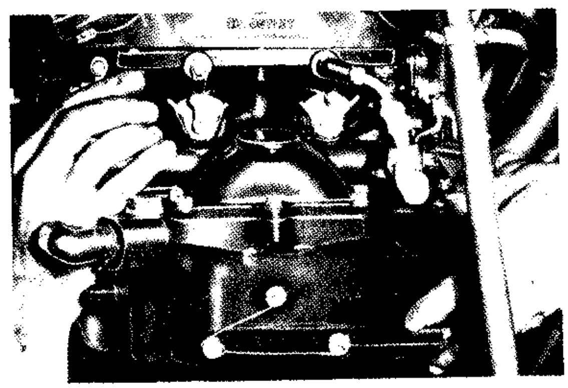
The NA-Y9E1 carbu[illegible] [Figure 3—21] is mounted on the engine [illegible] the float chambers are located [illegible] with the fuel inlet to the [illegible] inch pipe tap, is located [illegible] the fuel strainer boss. The fuel [illegible] connection, a ⅛ inch pipe [illegible] side of the [illegible] 70 degree [illegible] control rod [illegible]. The mixture [illegible] movement of [illegible] control lever has a [illegible]



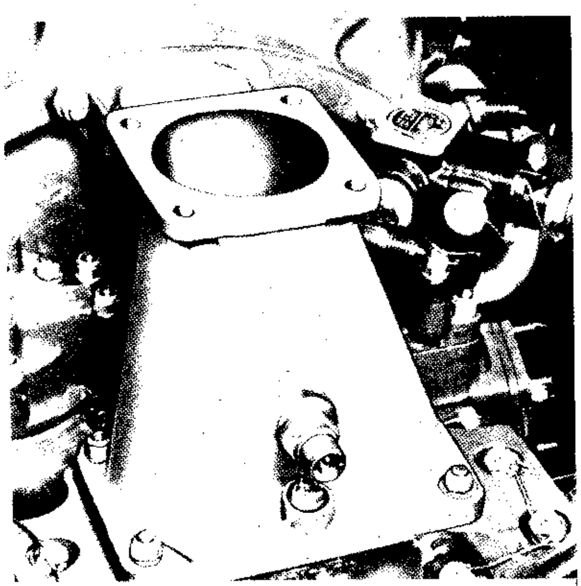
[3–21] NA-Y9E1 Carburetor Installed

Detach the carburetor mounting pad cover from the engine. On Wasp Jr. B5 engines install the carburetor adapter [**Figure 3–22**] on the carburetor mounting pad, no gasket is required, and tighten the six nuts.

Install the carburetor [**Figure 3–23**] (no gasket) and tighten the attaching nuts [**Figure 3–24**].

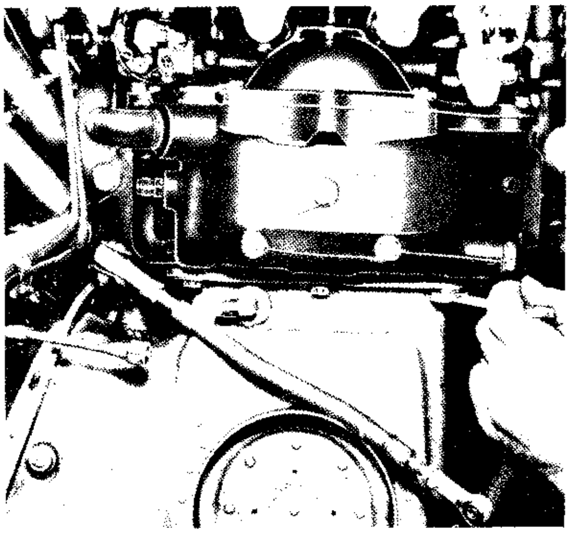


[3–23] Install Carburetor

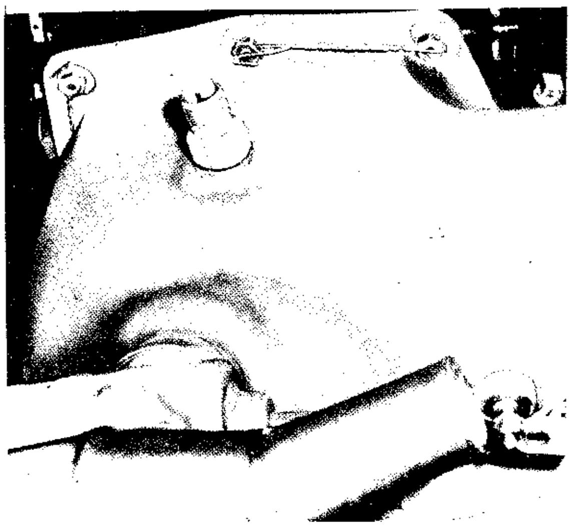


[3–22] Carburetor Adapter

[3–24] Tighten Nuts



[3—25] Airscoop Adapter



[3—26] Lockwire Adapter

Airscoop Adapter

Install the carburetor air intake screen assembly using a gasket on either side of screen mounting flange. Place the airscoop adapter over the screen and secure with washers and screws [**Figure 3—25**]; then lockwire [**Figure 3—26**].

Magneto Vibrator and Ground Leads

Lightly coat the magneto ground spring connectors with appropriate Dow Corning Compound if desired. Insert a connector into the ground terminal of each magneto. Screw the connector cap onto the ground terminal threads and secure with the clip.

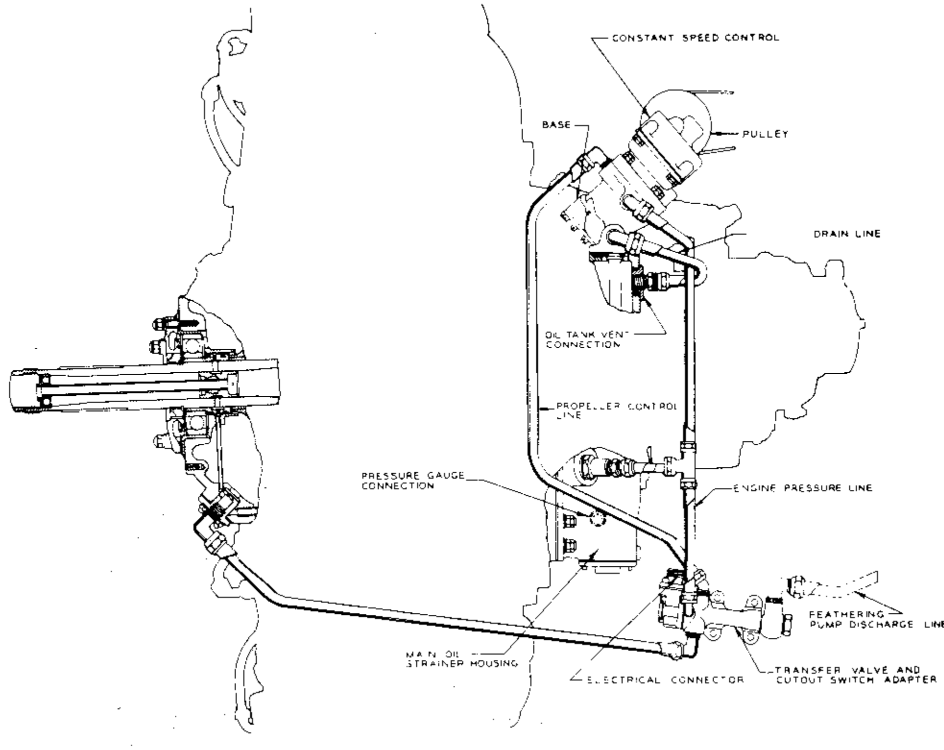
Propeller Governor (B5 and S3H1-G) [Figure 3—27 and Figure 3—28]

When a propeller governor is required, either the left or right vertical auxiliary drive may be used to mount a 35 degree angularly mounted constant speed control. Oil under pressure is piped from the main oil screen chamber to the governor. Return oil from the governor is drained into the engine rear section through the oil tank vent connection. Propeller control oil is piped from the governor to the engine front case through an external tube. Installations calling for the use of a "Hydromatic" propeller will use a feathering pump and a transfer valve and cutout switch. Complete instructions for the installation of a propeller governor are given in the service manual issued by the manufacturer of the governor. (Reference Hamilton Standard Service Manual #121B.). Make certain that engine drive bevel gear (PWA P/N 2628) to governor drive gear has at least .002 inch minimum backlash with governor bevel gear.

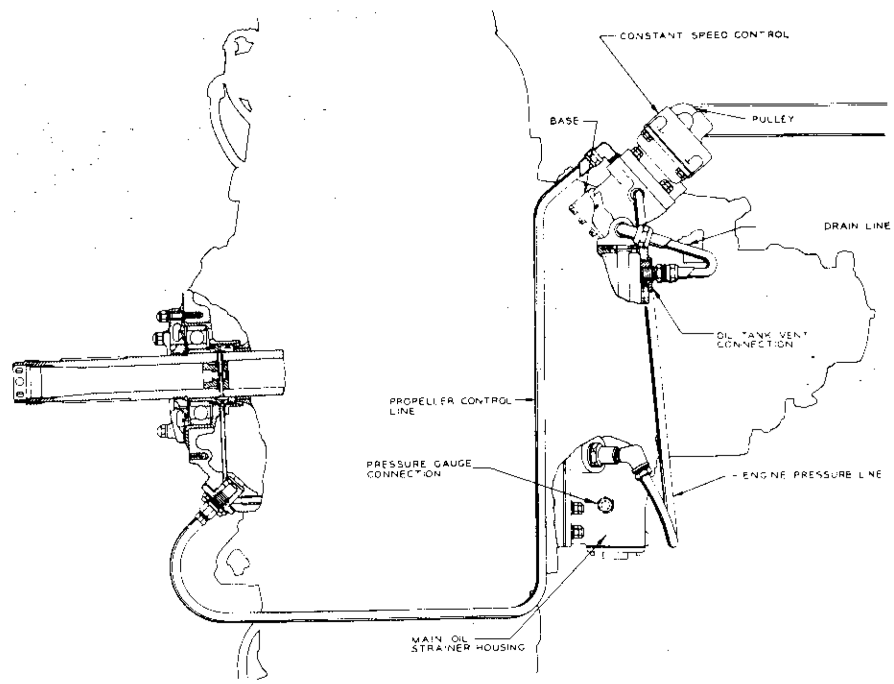
Propeller Governor (S3H1)

Make certain that screw plugs in the governor base are installed in the holes marked "B-B."

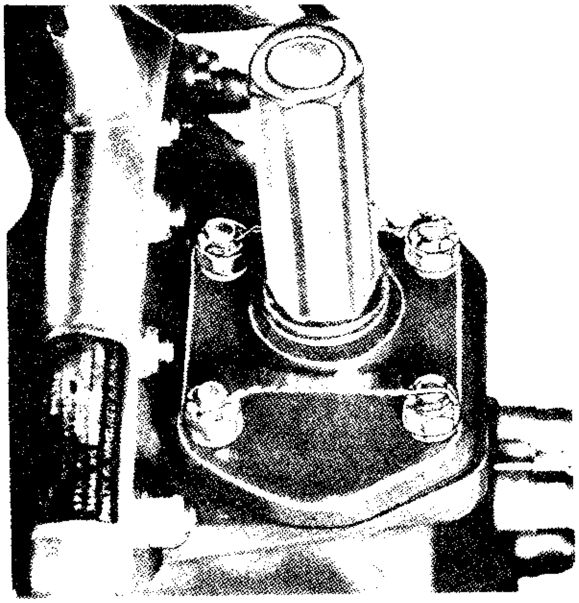
Engines are now shipped with a flight gasket installed on the governor mounting pad in place of the shipping gasket previously used. A new governor pad shipping cover plate, with its dehydrator plug **[Figure 3—29]**, are installed in place of the shipping adapter and dehydrator plug previously used. An additional flight gasket will be found in the manilla envelope attached to the propeller shaft on new engines. Clean the surfaces of both the mounting pad and the governor base, and be sure no foreign particles remain which



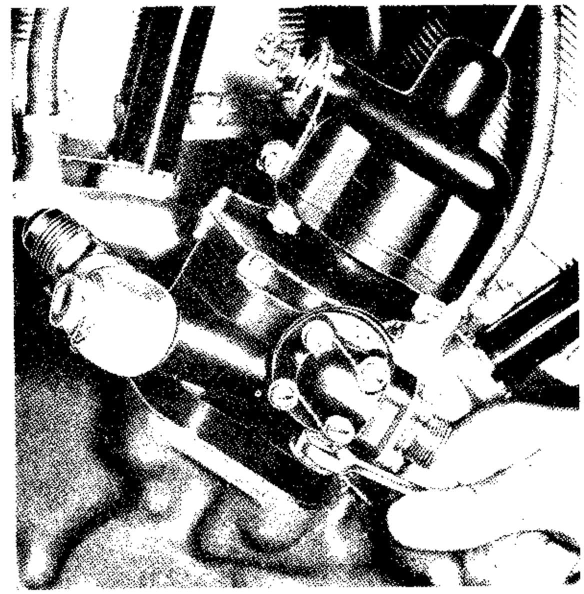
[3—27] Schematic Diagram of Governor for Hydromatic Propeller Installation
See Figure Page 1—19.



[3—28] Schematic Diagram of Governor for Constant Speed Propeller Installation



[3—29] Dehydrator Plug



[3—30] Securing Governor

might cause oil leakage or get into the governor and foul the operating mechanism.

Install the governor mounting pad gasket and the governor in accordance with the applicable manufacturers' recommendations.

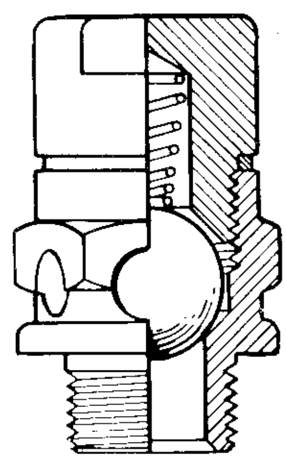
*It is essential on all governor installations that the governor mounting pad nuts be drawn down evenly [**Figure 3—30**], then tightened to the recommended torque. Excessive tightening may cause displacement of the gasket material in the vicinity of the mounting studs, resulting in warpage of the governor base, subsequent oil leakage, or possible mounting stud failure.*

Depreservation Valves

Install a PWA-5124 Depreservation Valve [**Figure 3—31**] in the lower-most sparkplug hole of the following cylinders; 4-5-6 and 7. Refer to Initial Ground Run, this chapter, for engine operating instructions using depreservation valves. PWA-5124 Depreservation Valves are useful in removing fluid from the combustion chamber and intake pipe of the cylinder in which they are installed. The valve is a check valve so constructed to allow complete suction through the intake pipe on the intake stroke and to allow expulsion of any excess fluid within the combustion chamber on the compression stroke. Sparkplugs are to be installed in the balance of the sparkplug holes.

Sparkplugs and Sparkplug Lead Connectors

Refer to Preparation for Installation of Sparkplugs, Repair and Replacement chapter.



[3—31] Depreservation Valve

Propeller

The propeller shaft front plug and gasket must be removed if a hydromatically operated propeller is to be installed. 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.

Installation of Engine

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

> Prior to installing an engine on an aircraft, which had the previous engine removed because of internal failure, ascertain by sufficient disassembly of oil lines and oil cooler tubes, that the system is completely free of foreign material.

Pre-oiling the Engine

Preoiling is required prior to the initial start of a new, newly overhauled, or installed engine depreserved from storage, to ensure proper lubrication for all bearing surfaces and other moving parts.

To ensure a clean flow of oil into the engine, install a 50 mesh screen in the preoiling system. Connect the preoiling pump to the oil pressure gage take-off on the upper left side of the rear case. Remove the main sump drain plug. Pump oil into the engine at 45 to 65 pounds per square inch pressure at a temperature of 60° to 70°C (140° to 160°F) until approximately one gallon of oil flows from the main sump drain plug hole.

While the preoiling is in progress, turn the propeller shaft in the normal direction of rotation to prevent the accumulation of oil in the lower cylinders and to aid in the distribution of the oil to the bearings. At completion, install the drain plug and washer in the sump, and lockwire the plug in position.

Pre-oiling the Engine (Optional Method)

Remove front row sparkplugs, one top cylinder rockerbox cover, and main oil sump plug. Service oil tank with an approved oil of appropriate weight (SB 1183L or later).

Turn engine with starter until flowing oil appears at top rocker assembly and a minimum of one (1) gallon of oil drains from the sump. Do not use starter for more than three (3) minutes at a time without allowing sufficient cooling period to prevent overheating of starter.

Replace sump plug, rockerbox gasket and cover, front row sparkplugs, and reservice oil tank.

Upon initial start, do not exceed 1,000 rpm until the engine oil temperature reaches 40°C (104°F), and do not exceed 1,800 rpm until oil temperature reaches 60°C (140°F), and the oil pressure is within the normal operating range.

Fuel and Oil Tank Servicing

Service the aircraft fuel and oil tanks with the proper grade of fuel and oil as specified in Specifications under lubrication and Fuel systems. After the oil tank has been serviced, turn the propeller over several times in order to prime the oil lines and the oil pump.

> When gasoline has been stored in the aircraft's tanks for a period of time it may, by evaporation or contamination with fuel cell plasticizeds, be altered in percentages of constituents and hence should be drained and replaced.

Pre-starting Inspection

Before starting an engine for the first time after installation, the following procedure shall be observed: Check the magneto ground wires for proper connections. Determine that the terminal marked GRD on the ignition switch is connected to the airplane structure. Inspect all mounting bolts and nuts on both the engine and mount to determine that they are tight and properly locked. Inspect the propeller hub for tightness and proper locking. Inspect the pressure gages, tachometer, thermometer and thermocouple for proper connection. Inspect all fuel, oil and primer lines and connections in accordance with the fuel and oil system diagram and the marking on the fuel valves. Inspect throttle and mixture controls for proper connections and operate them to redetermine that they function smoothly over the entire operating range. Open fuel valves and operate auxiliary pump and check for fuel leaks. During this latter check, the mixture control must be in the "IDLE CUT-OFF" position.

Initial Ground Run

If protector caps have not already been installed, cap (or ground) the leads to the depreservation valve cylinders with sparkplug terminal protectors before rotating the engine. Motor the engine through a minimum of six revolutions. Start the engine in accordance with Starting Instructions, Ground Checks chapter, and operate the engine at 800 rpm to 1000 rpm for approximately 30 seconds. Replace the depreservation valves with sparkplugs and connect the leads. Restart the engine.

If the engine oil pressure does not begin to rise immediately after engine starting, stop the engine and determine the cause.

After starting, run the engine slowly (600-800 rpm) for one minute and then at 1000 rpm in order to accomplish a gradual warm-up. After the engine has been warmed up and is functioning normally, run it approximately 1000 rpm for one hour. Then increase the speed to 1200 to 1400 rpm for 15 minutes.

During this run it may be necessary to adjust the carburetor idling speed and mixture.

The initial run-in should preferably be made with no cowling over the engine accessory compartment. When practicable, keep the aircraft headed into the wind during all ground running.

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

Ground tests should be conducted in accordance with the instructions under Ground Checks.

After the preceding operation, stop the engine and inspect the entire installation. Remove the pressure and scavenge oil strainer; inspect and clean.

Refer to Foreign Material in the Oil System, Periodic Inspection chapter, if necessary.

Take-off power and speed used for new and newly overhauled engines should be limited to the minimum practicable consistent with safety during the first ten hours of operation. Likewise, high power climbs, high BMEP lean mixture cruising (high manifold pressure) and overspeeding should be avoided during this period, except in cases of emergency. Higher than normal cylinder temperatures may be evident for the first several hours of operation until rings are properly seated, and particular care should be taken to ensure that specified temperature and manifold pressure limits are not exceeded.

CHAPTER 4 . . . . GROUND CHECKS

TABLE OF CONTENTS

GROUND CHECKS

PRESTARTING INSTRUCTIONS

General

Before an engine is started, the operator should consult the aircraft manufacturer's handbook for the applicable control position checks and specific ground operating procedures.

Pinion Bearings

Reduction gear pinion bearings distress usually results from insufficient lubrication during the starting period. Rotate the engine prior to start to assist in preoiling these bearings. This is particularly essential during starts following an oil dilution shut down as the viscosity of the oil is lower, and excessive drain off of lubricating oil from the bearing areas occurs.

Hydraulicking

During the periods of idleness, residual oil from the power section will flow toward the lower cylinders, seep past the piston and pistonrings, then accumulate in the lower combustion chambers. Likewise, if the engine is overprimed, excess fuel will flow into the combustion chambers of the lower cylinders, through the inlet valves and intake pipes. With liquid in the combustion chamber, the original compression ratio will be raised causing extremely high pressures to be produced when the piston of a cylinder so affected is moved toward top center of the compression stroke. These pressures may be great enough to damage the cylinder head, piston, or link-rod. In extreme instances the piston may actually "bottom" against the liquid. This condition is known as "hydraulicking" the engine.

DIRECT CRANKING STARTERS — On installations incorporating direct cranking starters equipped with a slippage clutch, motor the engine through a minimum of ten blades for a two bladed propeller (fifteen blades for a three bladed propeller) before starting. It has been determined that the collection of dormant fuel in the intake pipes will be substantially reduced by this procedure which renders hydraulicking of the engine highly improbable. If sufficient liquid to cause a hydraulic lock is trapped within a cylinder, the starter clutch will slip as the piston locks against the liquid on the compression stroke. In this event, the engine will slow down or stop abruptly without damage. Disengage the starter and inspect the cylinders for the presence of liquid.

ELECTRICALLY DRIVEN INERTIA STARTERS — On installations incorporating inertia type starters not equipped with a clutch, it is especially important to pull the propeller through four or five engine revolutions by hand before starting the engine. In the case of a submerged installation or if the propeller cannot be reached to be pulled through by hand, this function must be performed by "inching" the engine over with the starter. While pulling the engine through or "inching" with the starter, the operator must be alert for any sign of the piston being forced against unusually high compression. This will be evidenced by a sudden resistance when being pulled through by hand, or by a sudden slowing down when the starter is engaged. If this condition exists, any further attempt to rotate the crankshaft will result in damage to the engine. Disengage the starter and inspect the cylinders for the presence of liquid.

INSPECTION OF CYLINDERS FOR HYDRAULIC LOCK — Remove the front sparkplugs; in the case of vertical installations, remove the lower sparkplugs. Inspect for the presence of fuel or oil which could have caused the lock. Remove any liquid found in the cylinders or the exhaust pipes. Leave the sparkplugs out, and, with the ignition "OFF," motor the engine through, checking to see if additional liquid is spewed out from the sparkplug holes. When it is ascertained that the cylinders are purged of all excessive liquid, reinstall the sparkplugs, motor the engine with the starter and if no stoppage occurs proceed with normal start procedures.

Locating the cylinder containing liquid may be desirable in certain instances. This may be quickly and accurately done by performing the following check: Do not move the propeller from the point at which the lock was encountered. Remove the breaker cover from one magneto and locate No. 1 lobe on the cam. (The No. 1 lobe is identified by a machined dot adjacent to the lobe on the edge of the cam.) Starting with No. 1 lobe, count in the direction opposite cam rotation, to and including the lobe that the contact follower is resting on. (The direction of the cam is indicated by an arrow on the cam). Apply this count to the firing order of the engine; for example, suppose the follower rests on the fifth lobe of the cam. The firing order is 1-3-5-7-9-2-4-6-8. The lobe firing order is 1-2-3-4-5-6-7-8-9. Therefore, cylinder No. 9, the fifth cylinder in the engine firing order, contains liquid.

If no evidence of liquid lock can be detected, the lock of the engine must be attributed to other causes. The cylinder responsible for the lock should be examined thoroughly for the presence of mechanical interference, such as a dropped valve. In the event that localized mechanical damage in the cylinder is non-existent, further investigation of the engine should be accomplished to determine the cause of the lock.

If hydraulic lock occurs after the engine has fired once or twice, or severe hydraulicking is evident during motoring of installations incorporating electrically driven inertia type starters, remove all cylinder suspected of liquid lock and inspect the linkrods for distortion. Place a straight edge along the sides of the linkrod in two planes giving particular attention to the area in the vicinity of the linkpin hole. Any distortion of the linkrod, however slight, is cause for removal of the engine. If the linkrods are found to be free from damage, inspect the pistons, pistonpins, cylinders, and cylinder hold-down studs thoroughly for evidence of injury. Stud damage is to be suspected if, when a cylinder is being removed, the hold-down nuts are found to be loose. Refer to Cylinders, Pistons and Pistonpins, Repair and Replacement Chapter, for inspection procedures. If inspection reveals no abnormal conditions, the engine may be reassembled and considered satisfactory for further service.

Personnel

Personnel servicing the aircraft should be cautioned to stand clear when a start is anticipated.

Ignition Switch

The switch must be in the "OFF" position at all times, except for actual starting.

Propeller Control

The propeller control for Hamilton Standard counterweight propellers will be found in the low rpm (high pitch) position from the previous shut-down. This is to protect the blade operating cylinder from dust and also to empty the oil within the cylinder which otherwise might congeal in cold weather. After the engine is running and obtaining oil pressure, the propeller control should be shifted to high rpm (low pitch). Start the engine with the control in low pitch if a hydromatic propeller is installed.

Carburetor Heat

Carburetor heat should be in the cold position (OFF).

Carburetor Air Filter

Carburetor air filter (where applicable) should be in the unfiltered (OFF) position to prevent damage to these installations in case of backfire.

Cowl Flaps

It is essential that the cowl flaps be fully open during all ground operation.

Temperature in excess of 204°C (400°F) may develop in the push-rod cover gland nut, with subsequent deterioration of the sealing element and severe oil leakage when ground run-up is accomplished without utilizing all cooling airflow means.

Oil Cooler

Close oil cooler shutters to assist in heating the oil during the warm-up period.

Mixture Control

The mixture control should be in the full lean or idle cut-off position until such time as required by the following starting procedure.

Fuel Supply

The fuel supply valve should not be opened until preparation for starting is made.

Throttle

Consistent starting is dependent to a great extent on the correct positioning of the throttle. With the float type carburetor such as used on the Wasp Jr. and Wasp series engines, the carburetor furnishes fuel to the engine only when a definite pressure differential exists between the idle discharge and the fuel in the float chamber. With too great a throttle opening this differential becomes insufficient to produce the necessary flow for complete combustion, resulting, in all probability, in [illegible] firing. A throttle opening [illegible] mended under "Starting [illegible] provide the proper [illegible] good starting [illegible]

Priming

For the initial firing charge needed to start an engine, fuel must be supplied by the priming system. The carburetor will not supply fuel without airflow. The priming system introduces atomized fuel into the air contained in No. 1, 2, 3, 8, and 9 cylinders. As the starter turns the engine through, more air is introduced into the primed cylinders causing the mixture to be leaned out, but before the F/A ratio reaches the lower limit of combustion, a spark will ignite the mixture and a start is accomplished. The actual amount of priming desirable must be learned by experience, however, the operator may estimate the required amount by observing the following gages: Free Air Temperature (temperature of the air drawn into the engine during starting), Carburetor Air Temperature (temperature of the air in the duct), Oil Temperature (stiffness and temperature of the engine), Cylinder Head Temperature (the amount of heat available in the intake ports to vaporize the prime). Excessive priming will load the cylinders of a cold engine with raw fuel, making the engine difficult to start. Excessive priming also has a tendency to wash the oil off the cylinder walls and may result in barrel scoring or piston seizure. If the engine has been overprimed it is essential that fresh oil be sprayed on the cylinder walls, through sparkplug holes, before starting. Care should be taken to ensure complete circumferential coverage of the cylinder walls of No. 1, 2, 3, 8, and 9 cylinders. Dry cylinders may be indicated by a squeaking heard while the engine is being pulled through by hand. Rusting of the piston rings and cylinder walls will occur if the engine is allowed to stand for a day or more after unsuccessful attempts to start. Underpriming is usually indicated by backfiring of the engine through the intake system with attendant hazards. When underpriming is suspected, additional priming should be done cautiously.

STARTING INSTRUCTIONS

Ground operation of an engine should not be attempted until the aircraft has first been removed from the hangar. Preparing the engine for flight will include starting, warm-up, ground checks and, in the case of newly installed engines, complete inspection of the installation after the first run-up.

For engines installed in helicopters, various characteristics peculiar to these installations may change some of the conditions of operation as contained in these instructions.

Control Position Check

Ignition	Off
Mixture	Full Rich or Automatic Rich
Propeller	Counterweight Type — low rpm (high pitch) Other Controllable Types — high rpm (low pitch)
Carburetor	Cold (Off)
Filtered Air	Unfiltered (Off)
Cowl Flaps	Full Open
Throttle	Horizontal Installations 1/10 to 1/4 Open — Set for 600 Rpm
Throttle	Vertical Installations Closed
Oil Cooler Shutters	Closed

1. Note the manifold pressure gage reading before starting the engine as a reference for the power and magneto checks.

2. Motor the engine through a minimum of 4 to 5 engine revolutions. Do not back up the propeller as this may force fluid through the intake valves and allow for the possibility of fluid lock when engine is started. Refer to Hydraulicking, this chapter.

3. Fuel Supply — On.

Do not operate the throttle before the engine starts to fire. The fuel thus discharged from the accelerating pump may settle in the air intake, with the possibility of catching fire should the engine backfire as it starts.

4. Auxiliary fuel pump — build up fuel pressure. Not to exceed 3 psi.

Pressure in excess of 3 psi may flood the carburetor.

5. Energize starter (if inertia type).

6. Prime.

(a) Wasp Jr. engines

Move mixture control to Full Lean or Idle Cut-off.

Move throttle back and forth through its full travel, 0-2 strokes for a warm engine, 3-4 strokes for a cold engine. Return mixture control to Full Rich or Automatic Rich.

Raise fuel pressure to 3 psi momentarily.

(b) Wasp engines

The self-priming feature which utilizes the accelerating pump for priming is not incorporated in the NA-Y9E1 carburetor. With this carburetor, depending on the aircraft manufacturer, a hand-operated plunger type primer pump or an electric solenoid valve priming system may be used.

HAND OPERATED PRIMER — While maintaining fuel pressure, turn the plunger of hand priming pump to the "ON" position. Draw the plunger out slowly to ensure that the pump cylinder fills completely. Force plunger in rapidly in order to atomize the fuel effectively at the discharge nozzles. Prime the required number of strokes. Return the primer plunger to the "OFF" position and lock.

ELECTRIC PRIMER — Keep mixture control in full rich. Prime as required, intermittently if engine is warm or continuously if the engine is cold.

7. Ignition — If using inertia starter, ignition on **Both**; if using direct cranking starter, ignition **Off**, then switch to **Both** after one revolution of the crankshaft.

8. Engage starter (If manually controlled, close booster switch simultaneously).

9. After engine fires, adjust engine speed to 500-600 rpm watching for oil pressure rise.

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

10. Move propeller control to high rpm (low pitch) for 2-position and constant speed propellers (counterweight type).

11. Adjust the carburetor heat control to maintain 32°C (90°F) carburetor air temperature.

12. Adjust throttle to 1000 rpm for horizontal installations or 200 to 300 rpm above the rotor engagement rpm (approximately 1500 rpm) for vertical installations.

13. If a start is not effected almost immediately, reprime and repeat starting procedure.

If the engine does not start after two or three attempts, an investigation should be made to ascertain the cause.

WARM-UP

Control Position	Check
Mixture	Full Rich
Carburetor heat	To maintain 32°C (90°F) carburetor air temperature
Filtered air	As needed
Cowl flaps	Full open
Oil cooler shutters	Closed
Propeller	High rpm (low pitch)
Throttle (Horizontal installations)	1000 rpm
Throttle (Vertical installations)	20C to 300 rpm above rotor engagement rpm (Approximately 1500 rpm.)

Ignition Safety Check

Perform this check during warm-up. Switch ignition from **Both** to **Right** and back to **Both**. Switch ignition from **Both** to **Left** and back to **Both**. Switch ignition to **Off** momentarily and back to **Both**.

A slight drop in rpm when operating on each separate magneto, and complete cutting out at **Off** position indicates proper connection of the ignition leads so that higher powers may be safely imposed.

The following tests must be made with a minimum oil-inlet temperature of at least 40°C (104°F) and with the carburetor heat control in the cold position.

Propeller Governor Check

Check propeller governor according to the propeller manufacturer's recommendations.

Testing of the feathering action of the propeller is not recommended by the propeller manufacturer when the engine is inoperative; but in some installations this test is possible. If the feathering switch is held on after the propeller is completely unfeathered, high pressure oil will be discharged into the engine oil system through the propeller dome pressure relief valve. Since there is no engine oil pressure in the pressure oil screen chamber when the engine is inoperative, pressure from the feathering pump against the top of pressure oil screen assembly, may cause the screen to collapse. Therefore, if feathering action of a hydromatic propeller is tested, remove the pressure oil screen from the engine before the test is made. When the test is completed, remove the sump drain plug (front sump plug on Wasp Jr. B5 — rear sump plug on Wasp engines) to drain off oil discharged into the engine from the propeller.

Power Check (Horizontal Installations)

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 should be approximately 2000 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 the rpm that will result when opening the throttle to the manifold pressure equal to the field barometric pressure.

If the approximate check rpm can not be obtained when opening the throttle to the proper manifold pressure, the engine is not delivering the correct power, and an investigation should be made to determine the cause for this improper engine functioning or proper pitch setting.

Magneto Checks (Horizontal Installations)

Make magneto checks at manifold pressure equal to field barometric pressure. Switch ignition from **Both** to **Right** and back to **Both**. Switch ignition from **Both** to **Left** and back to **Both**. Normal drop-off in either position is 50 to 75 rpm. Maximum drop-off in either position should not exceed 100 rpm. Maximum difference in drop-off between positions should not exceed 40 rpm.

When Wasp magnetos are checked at the power recommended above, the drop off on the right magneto may be as high as 150 rpm. If this *is the case, recheck the magnetos at 2200 rpm. At this higher power, if the drop-off on the right magneto, as well as on the left magneto, is less than 100 rpm and the difference in drop between right and left is not more than 40 rpm, the check may be accepted as satisfactory. Advancing the spark (changing the magneto timing) to correct a high drop-off is definitely not recommended.*

Magneto Check (Vertical Installations)

With rotor engaged, set the main-rotor pitch and throttle control to obtain approximately 2000 rpm and 20 in. manifold pressure.

Switch ignition from **Both** to **Right** and back to **Both**. Switch ignition from **Both** to **Left** and back to **Both**. Normal drop-off in either position is 75 to 100 rpm. Maximum drop-off in either position should not exceed 120 rpm. Maximum difference in drop-off between positions should not exceed 40 rpm.

Instrument Readings

Check oil pressure, oil temperature, fuel pressure and other items at manifold pressure equal to field barometric pressure, propeller in low pitch (high rpm).

Cylinder Head Temperature

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

Oil Pressure Limits

	Psi Min.	Psi Max.
At idle rpm	10	
1400 to 1900 rpm	50	
1900 to 2000 rpm	55	
2000 rpm	60	90
At rated take-off rpm	70	90

Desired oil temperature at all configurations is (60 to 70°C) 140 to 158°F.

Desired oil pressure at Field Barometric 60°C (140°F) oil temperature, is 75 to 85 psi.

Oil Temperature Limits

	Oil Inlet	
Minimum for Ground Test and Flight	(40°C)	104°F
Maximum for Ground Test and Flight	(93°C)	199°F

Fuel Pressure Limits

	Psi Min.	Psi Max.
Idling	2	
Above 1200 rpm	4	6

Carburetor Idling Mixture Strength Check (450 to 500 rpm)

While observing the tachometer, slowly move the mixture control toward idle cut-off or full lean while noting rpm change. Return the mixture control to full 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.

For engines installed in helicopters, the throttle stop will be set to allow the engine to idle at approximately 850 rpm. At this rpm, a pickup of not more than 100 rpm when the mixture control is placed in full lean indicates the proper mixture strength.

This check should be made in relatively still air and with cylinder head temperatures at stabilized idling temperature. A strong wind or abnormal cylinder head temperatures affect the rpm change. Refer to Carburetor Idling Adjustment, Adjustments chapter for specific adjustment instructions.

Engine Equipment or Accessories Check

Consult the Airplane Manufacturer's Handbook for instructions.

Stopping

If a cold weather start is anticipated, refer to Oil Dilution, Extreme Weather Maintenance chapter for the specific dilution procedure to be used.

1. Idle until cylinder head temperature is less than 204 C (400°F). Idle B4 engines 200 to 300 rpm above rotor engagement rpm.
2. If Hamilton Standard counterweight propeller is used, shift propeller control to LOW rpm.
3. Move mixture control to Idle Cut-Off or Full Lean.
4. When engine stops, turn ignition off.
5. Turn fuel selector off.

After stopping, leave cowl flaps wide open for 15 minutes.

If Idle cut-off or full-lean does not stop engine:

1. Close throttle.
2. Turn ignition off.
3. Slowly open throttle.

After stop, leave cowl flaps wide open for at least 15 minutes.

CHAPTER 5 .............TROUBLESHOOTING

CONTENTS

TROUBLESHOOTING

The tabulation below enumerates the general conditions which may be encountered such as; "Improper Idling," and is further divided into the probable causes contributing to such conditions. Corrective action to be taken is indicated in italics beneath the probable cause except in cases where the action to be taken is obvious as; adjust, dry, clean, lubricate, replace, etc.

The items listed in the chart are presented with consideration given to frequency of occurrence, ease of accessibility and complexity of the corrective action indicated.

FAILURE TO START

Ignition

Master switch OFF.

Spark plug inoperative and to moisture.

Faulty ignition switch.

Moisture or oil in the magneto and/or distributor.

Water in the ignition harness.

Defective ignition booster.

Connection to cockpit grounded.

Apply continuity test.

Fuel and Induction System

Fuel supply OFF.

Incorrect mixture control setting (mixture too lean).

Underprime condition (Probable backfiring).

Overprime condition.

Primer inoperative.

Fuel lines obstructed.

Carburetor control linkage out of adjustment.

Insufficient fuel pressure.

To increase pressure, turn adjustment screw on fuel pump to right.

Internal trouble in carburetor.

Replace carburetor.

Defective priming solenoid valve.

Check for sticking. Replace if necessary.

Vapor in fuel system.

Remove carburetor vent plug, energize boost pump until fuel spurts from vent. Replace plug.

Lack of fuel or wrong grade of fuel.

Lubrication System

Oil too cold resulting in insufficient cranking speed.

Use engine preheat.

TROUBLE SHOOTING

ROUGH RUNNING

Ignition

Defective sparkplugs.

Dirty or glazed breaker points.

Breaker out of adjustment.

Fouled sparkplugs due to prolonged idling.

Moisture or oil in the magneto and/or distributor.

Water in the ignition harness.

Improper magneto timing.

Faulty magneto internally.

Defective ignition manifold.

Defective sparkplug lead connectors.

Magneto ground to cockpit switch connection partially grounded.

Apply continuity test.

Fuel and Induction System

Wrong grade of fuel or contaminated fuel.

Partial obstructions of the fuel lines or screens.

Improper mixture settings.

Carburetor or connections leaking.

Air leaks in induction system.

Internal trouble in carburetor.

Replace carburetor.

Vapor in fuel system.

Remove carburetor vent plug and vent system.

Fuel feed valve leaking or not operating properly.

Inspect and replace as necessary.

Insufficient or fluctuating fuel pressure.

Check fuel boost pumps. Replace as necessary.

Engine

Sticking or burned valves.

Broken valve springs.

Improper valve clearances.

Loose intake manifolds.

Defective pushrods.

Defective rocker or rocker bearing.

Worn or broken pistonrings, cracked piston or cylinder, burned piston.

Replace cylinder assembly.

Broken or worn cam lobe(s).

Replace engine.

Broken tappet roller(s).

Replace engine.

Defective valve guides.

Replace cylinder assembly.

Loose or broken engine mount fixtures.

Repair or replace as necessary.

Loose or broken cylinder hold-down nuts.

Repair or replace.

Uneven compression.

Perform compression check on warm engine.

Critical speed.

Use different RPM setting.

Propeller

Faulty operation of propeller governor.

Propeller blade out of track.

Propeller out of balance.

Propeller shaft run-out excessive.

Propeller damaged.

Cross wind on propeller-ground operation.

Loose propeller shaft nut.

Remove propeller and check engine thrust bearing nut for correct torque.

LOW POWER

Ignition

Defective sparkplugs.

Defective or dirty sparkplug lead connectors.

Dirty, burned or pitted breaker points.

Magnetos not synchronized or incorrectly timed to engine.

Defective magneto or components.

Moisture or oil in the magneto and/or distributor.

Water in the ignition harness.

Fuel and Induction

Ice or other foreign matter in induction system.

Wrong grade of fuel.

Internal carburetor troubles.

Replace carburetor.

Incorrectly adjusted carburetor control linkage.

Air leaks or restrictions.

Insufficient of fluctuating fuel pressure.

Fuel feed valve leaking or not operating properly.

Carburetor air temperature too high.

Check carburetor heat control.

Engine

Low compression.

Perform compression check.

Warped or burned valves, pitted seats.

Improper valve clearances.

Sticking valves.

Broken valve springs.

Worn or sticking pistonrings, cracked pistons or cylinders.

Replace cylinder assembly.

Scored pistons and cylinder barrels.

Replace cylinder assembly.

Propeller

Incorrect blade angle.

Malfunctioning of propeller governor.

Propeller governor adjustment required.

(Refer to aircraft manufacturer's instructions)

IMPROPER ACCELERATION

Ignition

See Rough Running.

Fuel and Induction

Incorrect idle adjustment.

Internal carburetor trouble.

Replace carburetor.

Faulty accelerating pump.

Airleaks or restrictions in induction system.

Insufficient or fluctuating fuel pressure.

Fuel feed valve leaking or not operating properly.

Incorrectly adjusted carburetor linkage.

Engine

See Rough Running

ENGINE STOPS

Ignition

Master switch or magneto switch inadvertently cut-off.

Short in system.

Check all wiring for security, breaks or chafing.

Check all systems components.

Fuel and Induction

Fuel lines obstructed.

Mixture control moved to IDLE CUT-OFF.

Vapor lock in fuel lines.

Defective carburetor.

Replace carburetor.

Foreign object in induction system.

Fuel pump failure.

Broken fuel lines.

Engine

Internal failure.

Among those causes of internal engine failure are attempts to operate the engine with no oil in the oil system.

Sudden stoppage due to propeller contacting a solid object.

Replace engine.

EXCESSIVE CYLINDER HEAD TEMPERATURE

Ignition

Magneto incorrectly timed to engine.

Fuel and Induction

Mixture too lean.

Wrong grade of fuel.

Air leaks in induction system.

High carburetor inlet air temperature.

Engine

Restrictions in cooling air flow.

Damaged baffles.

Damaged cooling fins.

Incorrect valve operation or clearance.

High power operation.

Restrictions in exhaust system.

Thermocouple system or indicator defective.

Exceeding operating limits.

Improper use of cowl flaps.

EXAMPLES OF INFREQUENT PROBLEMS IN TROUBLESHOOTING

The following instrument misreadings may be encountered:

a. High cylinder head temperature readings could be caused by the instrument being mismatched to the thermocouple material or to the resistance bulb, or the thermocouple circuit wires are too close to the exhaust piping and are burned, or the thermocouple material is not continuous through the fittings.

b. A defective oil pressure gage transmitter or indicator would give incorrect, high or low pressure readings. Low oil inlet temperature caused by failure of the oil cooler, or malfunction of the relief valve, will cause high pressure readings. Low oil pressure readings may be caused by use of incorrect grade of oil, excessively diluted oil, oil too hot, oil leaks or insufficient quantity of oil.

c. Engines that have been run-up prior to take-off and have checked out normally, may become rough during take-off run or just after becoming airborne. A check for the following conditions should be made:

1. Fouled sparkplugs.
2. Broken valve springs.
3. Sticking valves.
4. Fuel feed valve malfunction.
5. Carburetor malfunction.

d. Oil foaming and spewing from the breathers is usually attributed to an over-full oil tank;

excessive oil dilution which has not been allowed to boil-off; excessive fuel in oil system due to leaking oil dilution solenoid valve. Mixing oils of different brands will sometimes cause excessive foaming.

e. Any sudden stoppage of the engine due to the propeller striking an object, should be sufficient reason for an engine change to preclude any possibility of subsequent engine failure.

CHAPTER 6 . . . . ADJUSTMENTS

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ADJUSTMENTS

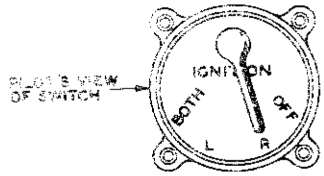
IGNITION SYSTEM [Figure 6—1]

The magnetos seldom need attention between overhauls. Under normal conditions, the wear or burning of the breaker points offsets the wear of the cam follower. However, a faulty condenser or the presence of oil or grease on the points may cause excessive burning of the points. 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 will result. If ignition trouble occurs, examine the sparkplugs, leads, and connectors. If a magneto is found to be malfunctioning, replace it with a new or reconditioned magneto.

Breaker Point Inspection [Figure 6—2]

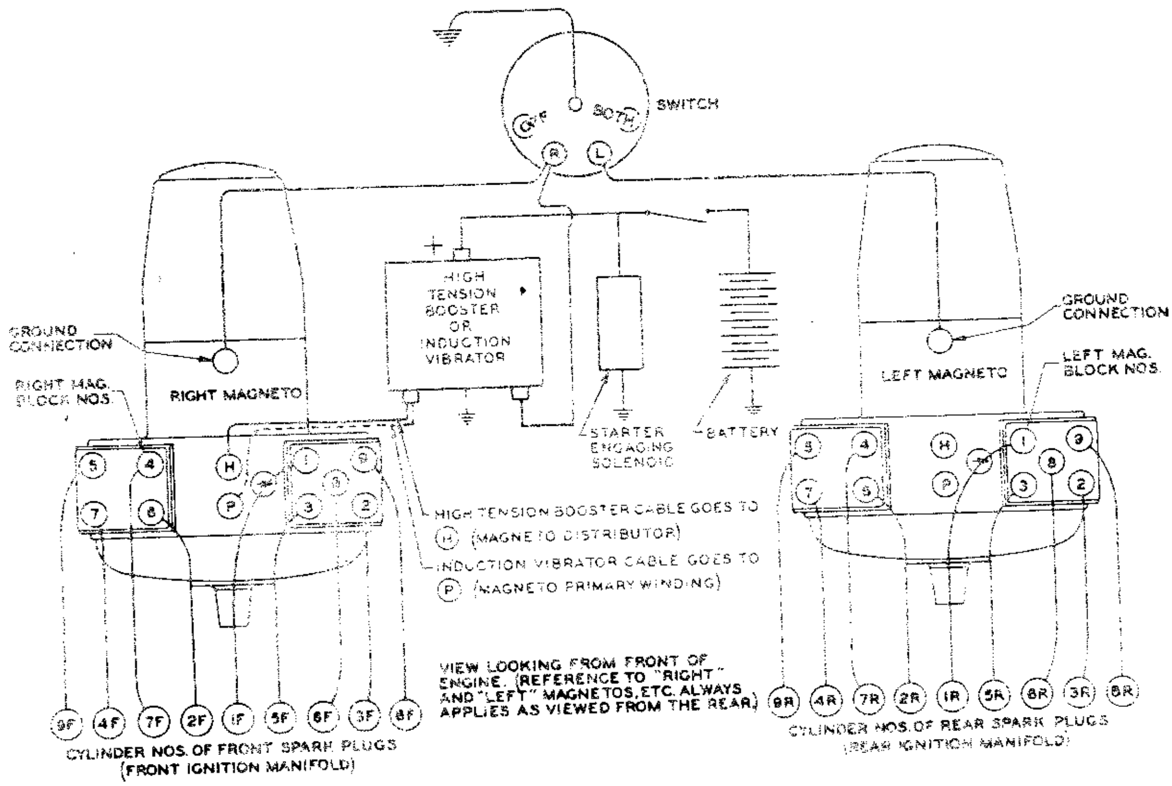
If the breaker point surfaces are fouled with oil or dirt, or are burned excessively, replacement of the complete breaker assembly is recommended. In an emergency, when no replacement parts are available, a fouled assembly can be made serviceable for temporary use by removing it from the magneto and washing the point surfaces carefully using acetone, or equivalent as a cleaning agent. When this is done, the cleaning agent must be allowed to completely evaporate before placing the assembly back in service. After the assembly has thoroughly dried, check the cam follower felt for the proper amount of oil by squeezing the felt tightly between the thumb and forefinger. If the fingers are moistened with oil when this is done, the felt is adequately lubricated and NO more oil should be applied. If no oil is left on the fingers, the follower felt is too dry and should be oiled as follows: Apply one drop of SAE No. 60 Aircraft engine oil to the bottom felt pad, and one drop to the upper felt pad. Allow at least 15 minutes for the felt to absorb the oil; then blot off any access oil with a clean cloth. Reinstall the assembly in the magneto and secure it with the two locking screws. The breaker points must now be checked for proper adjustment (timing and synchronizing).

When inspecting the breaker points, do not raise the breaker main spring beyond a point giving 1/16 inch clearance between the points. Any further tension on the spring will weaken it and adversely affect the performance of the magneto.

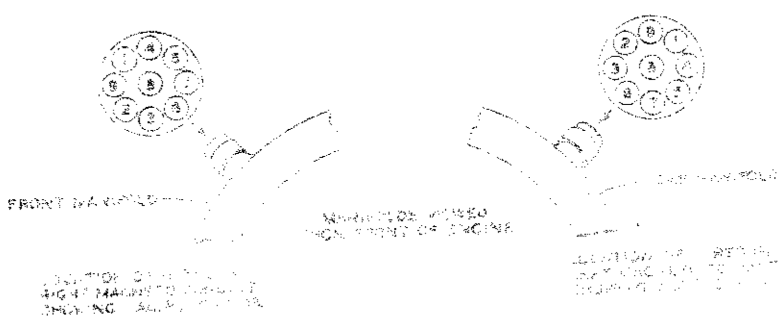


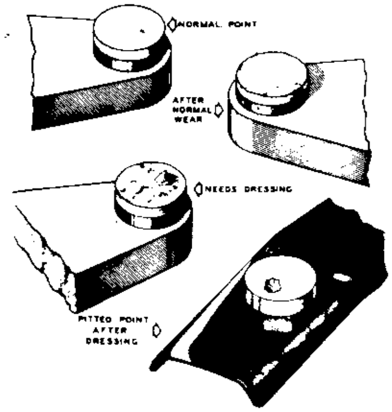
WHEN THE SWITCH IS ON R (RIGHT) THE RIGHT MAGNETO IS FIRING THE FRONT SPARK PLUGS.

WHEN THE SWITCH IS ON L (LEFT) THE LEFT MAGNETO IS FIRING THE REAR SPARK PLUGS



MAG. BLOCK NO.	1	2	3	4	5	6	7	8	9
CYLINDER NO.	1	3	5	7	9	2	4	6	8





[6—2] Breaker Point Conditions

Breaker Point Adjustment

Do not change the adjustment of the breaker points unless the following check indicates the necessity.

Remove one sparkplug from each cylinder and install PWA-3252 Vent Plugs in the sparkplug holes. Turn the crankshaft, by means of the cooling fan or propeller, until the piston of No. 1 cylinder is at the top center of its compression stroke. Remove the breaker compartment covers of the magneto.

Attach the red wires of PWA-2417 Timing indicator to the breaker points of the magneto and ground the black wire to the engine. Turn the ignition switch in the cockpit to the "Both" position.

Turn the propeller in horizontal installations or the cooling fan in vertical installations opposite the normal direction of rotation approximately 90 degrees; then turn it in the normal direction until the lights of the indicator just flash on. As the lights flash on, the cam of each magneto should be just beginning to open the breaker points, and a straight edge should align within 1/32 inch of the timing marks on the magneto housing. If the straight edge is not within the 1/32 inch alignment, adjust the breaker points as follows:

With the magneto cam in its proper position to open the breaker points — that is, with the straight edge aligned with the timing mark on the magneto housing, loosen the contact bracket screws. Turn the eccentric adjusting screw until the indicator light just flashes on, indicating that the points are opening. Tighten the screws.

Check the setting of the points by turning the crankshaft approximately 90 degrees opposite the normal direction of rotation, by turning the propeller in horizontal installations or the cooling fan in vertical installations back, until the indicator light just flashes on. At this point the straight edge should line up within 1/32 inch of the timing marks on the magneto housing. If the points cannot be adjusted so that the straight edge will align 1/32 inch of the timing marks, replace the breaker assembly. Turn the ignition switch in the cockpit to the "Off" position. Remove the timing indicator and straight edge from the magneto. Install the breaker compartment cover.

Timing and Synchronizing Magnetos

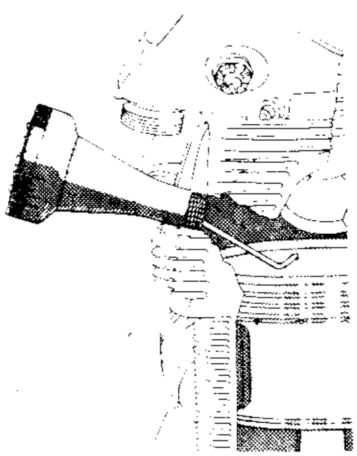
To determine whether the magnetos are properly timed to the engine and synchronized with each other, the following check should be made.

Remove one spark plug from each cylinder and install PWA-3252 Vent Plugs. Rotate the crankshaft by means of the cooling fan or propeller until No. 1 piston is on the beginning of the compression stroke; then install PWA-4142 Indicator (Time Rite) in the top or front sparkplug hole of No. 1 cylinder **[Figure 6—3]**.

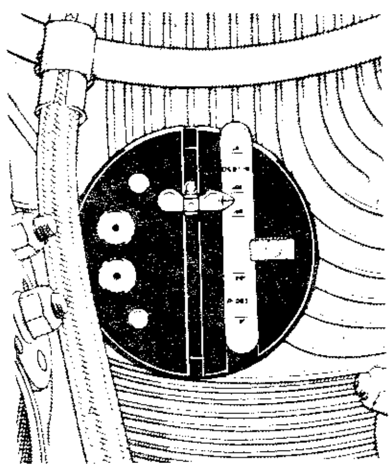
> ***Use pivot arm "A" with hook end up for Wasp Jr. engines. Use pivot arm "A" with hook end down for Wasp engines.***

Attach the red wires of PWA-2417 Indicator to the breaker points of the magnetos and ground the black wire to the engine. Align the cap of PWA-4142 Indicator so the slide slot lines up with the vertical axis of the cylinder and the scale is at the right of the slot. Each the slide pointer up close to the pivot arm [**Figure 6—4**]. Turn the crankshaft in the normal direction of rotation until the pivot arm pushes the slide pointer to its farthest point [**Figure 6—5**]. Turn the crankshaft 90 degrees opposite rotation to return the pivot arm to the top of the slot. Adjust the proper engine scale (R-985 or R-1340) so that the zero degree mark on the scale aligns with the reference mark on the slide pointer [**Figure 6—6**]. Move the slide pointer up to align with the 25 degree mark on the scale [**Figure 6—7**]. Turn the crankshaft until the pivot arm just contacts the slide [**Figure 6—8**], at which time the lower light in PWA-4142 Indicator flashes on. The No. 1 piston is now 25 degrees before top center.

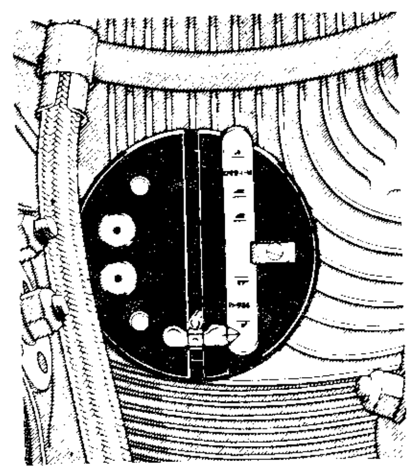
In timing engines that are not installed, the spark advance mark under the thrust bearing cover plate, rather than PWA-4142 Indicator, may be used. This requires removing the thrust bearing cover plate and the use of PWA-85 Timing Pointer for Wasp Jr. engines, PWA-2474 Timing Pointer for S1H2, S3H1 and S3H2 Wasp engines, PWA-535 Timing Pointer for S3H1G Wasp engines, together with PWA-112 Turning Bar for Wasp Jr. engines or PWA-155 Turning Bar for Wasp engines, or PWA-2645 Turning Bar for S3H1G Wasp engines.



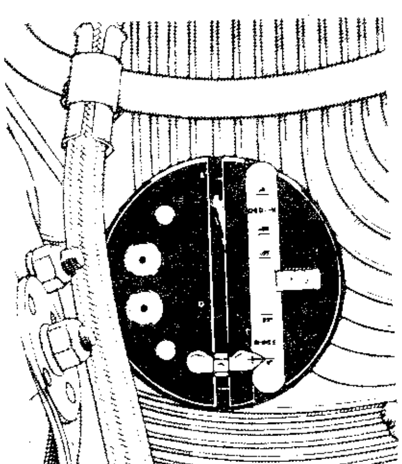
[6—3] Indicator in Sparkplug Hole



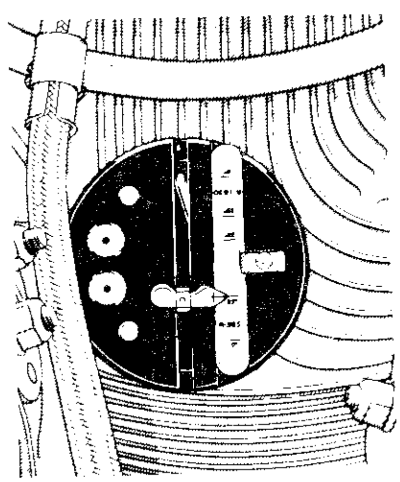
[6—4] Slide Close to Pivot Arm



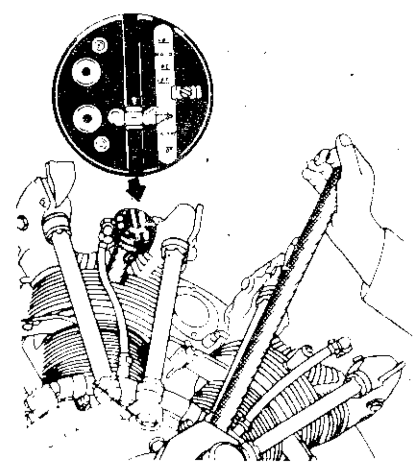
[6—5] Slide at Farthest Point



[6—6] 0° Aligned with Slide



[6—7] Slide at 25° Mark



[6—8] Pivot Arm Contacts Slide

At this point the lights of PWA-2417 Indicator should flash on simultaneously, indicating that the points are just opening. Check the alignment of the timing marks with a straightedge. This will give the correct "E" gap. Permissible limits are 1/32 inch on either side of the timing marks. An adjustment, described in the following paragraph, will be necessary if the magnetos are not synchronized. When the piston is 25 degrees before top center, the breaker points should break simultaneously if the straightedge is in correct relationship to the timing marks . If the magnetos are found to be properly synchronized after the above check is made, restore the engine to its condition prior to this check.

If the timing of one or both magnetos to the engine is incorrect, it will be necessary to remove the bolts which attach the incorrectly timed magneto to its mounting pad and move the magneto away sufficiently to turn the rubber drive coupling. Make sure the piston of No. 1 cylinder is 25 degrees before top center. If it is desired to advance the timing, the rubber coupling should be turned one or two notches in a counterclockwise direction, the magnetos reinstalled in place, and the timing rechecked as described above. To retard the timing, the rubber coupling must be turned in a clockwise direction. Because of the fact that the coupling has 19 notches on one side and 20 notches on the other side, a very fine adjustment can be made by rotating it one notch. It is important that the two magnetos be synchronized to break simultaneously and with the straightedge or timing indicator in correct relationship to the marks on the breaker housing. Slide the magneto back into position and install the bolts. Recheck the magneto timing and synchronization. Lockwire the bolts.

VALVE CLEARANCE ADJUSTMENT

GENERAL — Remove the rockerbox covers, rockerbox cover gaskets, and the front spark-plug from all of the cylinders. The valve clearances are adjusted in the engine firing order (1-3-5-7-9-2-4-6-8).

ADJUSTMENT
Wasp Jr.

a. Install PWA-2537 Indicator (top dead center) in the No. 1 cylinder. Rotate the crankshaft in the normal direction of rotation until the No. 1 piston is at top dead center of its compression stroke (both valves closed).

b. Insert the .010 inch feeler of PWA-4675 Gage between the valve stem and the adjusting screw of the inlet and exhaust valve of No. 1 cylinder. If adjustment is required, loosen the adjusting screw locknut three or four turns; then using PWA-4152 Driver, set the adjusting screw so that there is a slight drag on the feeler. Lock the adjusting screw in this position by tightening the locknut to the recommended torque.

c. Adjust the clearances of the valves in the remaining cylinders in the same manner and in the engine firing order sequence.

Wasp — The Wasp series engine incorporates a floating cam arrangement necessitating the use of a "positive method" of valve adjustment to eliminate cam float during adjusting operations. To ensure that all of the valves have uniform clearances, the valves of each individual cylinder must be adjusted while the cam rests as nearly as possible against the cam bearing at that cylinder. To position the cam in its desired position the following procedure is recommended.

a. Install PWA-2537 Indicator (top dead center) in the No. 1 cylinder. Rotate the crankshaft in the normal direction of rotation until the No. 1 piston is at top dead center of its exhaust stroke

b. Using PWA-455 Depressors, depress the No. 8 inlet valve and No. 3 exhaust valve rocker arms as indicated in the Valve Adjusting Chart [**Figure 6—9**]. Slowly release the depressed rocker arms simultaneously.

Follow the sequence outlined in the Valve Adjusting Chart with extreme care to ensure that the proper valves are depressed. The valves listed under the Depress Rockerarm column will be open due to normal cam action, and may be fully depressed without the pushrods falling free from their rockerarm sockets. A pushrod may fall free of its rockerarm socket if a valve in its closed position is fully depressed.

c. Insert the .040 inch feeler of PWA-4675 Gage between the No. 5 inlet valve stem and the adjusting screw on engines using aluminum pushrod assemblies.

The valve adjustment clearance for Wasp engines using steel pushrod assemblies is .035 inch. This difference in valve setting is to compensate for the difference in thermal expansion of the different materials in the pushrods.

If adjustment is required, loosen the adjusting screw locknut three or four turns then using PWA-4152 Driver, set the adjusting screw so that there is a slight drag on the feeler. Lock the adjusting screw in this position by tightening the locknut to the recommended torque. Check and set the clearance of the No. 6 exhaust valve in the same manner.

d. Check and/or adjust the clearances of the valves in the remaining cylinders in the same manner as described and in the sequence as indicated in the Valve Clearance Chart [Figure 6—9].

Set Piston at Top Center of its Exhaust Stroke	Depress Rockerarms		Adjust Valve Clearances	
	Inlet	Exhaust	Inlet	Exhaust
1	8	3	5	6
3	1	5	7	8
5	3	7	9	1
7	5	9	2	3
9	7	2	4	5
2	9	4	6	7
4	2	6	8	9
6	4	8	1	2
8	6	1	3	4

Figure 6—9. Valve Adjusting Chart

INSPECTION

a. The valve adjusting screw should protrude above the locknut after valve clearance has been adjusted within the following limits:

Locknut	Min.	Max.
Part No. 9294-C	1/8 inch	1/4 inch
Part No. 9294-D	3/32 inch	7/32 inch

b. There should be a clearance of not less than .031 inch between the outer valve spring washer and the rockerarm with the valve closed. If this clearance is less than .031 inch or if the valve adjusting screw protrudes more than the maximum allowable limit above the locknut, the flat face of one or both of the pushrod ballend spacers may be ground; the spacer may be replaced with a thinner one; or the spacer may be eliminated entirely to obtain the desired clearance. Neither spacer should be less than .055 inch thick after grinding. If the valve adjusting screw protrusion above the locknut is less than the allowable limit, a thicker spacer should be used at one or both ends of the pushrod. Refer to Repair and Replacement chapter for procedures on ballend replacement.

CLEARANCE CHECK — After setting all valve clearances, rotate the crankshaft two revolutions in the normal direction of rotation, and recheck the clearance of each valve in the engine firing order.

Wasp Jr. — Reset any valve clearance found below .010 inch. It is not necessary to reset clearances greater than .010 inch unless the clearance is in excess of .025 inch.

Wasp — Reset any valve clearance found to vary more than .005 inch from the specified clearance.

INSTALLATION

a. Using new rockerbox cover gaskets, install the rockerbox covers; then tighten the nuts to the recommended torque.

b. Using serviceable sparkplug gaskets, reinstall the sparkplugs and tighten to the recommended torque.

FUEL PRESSURE ADJUSTMENT

Loosen the adjusting screw locknut on the fuel pump; then turn the adjusting screw clockwise to increase or counterclockwise to decrease the fuel pressure. As the locknut is being tightened it may change the adjustment so it is advisable to take this into account when making the adjustment. After the desired adjustment has been obtained, tighten and lockwire the adjusting screw locknut.

CARBURETOR IDLING ADJUSTMENT

When a carburetor is once set for proper idling, it does not ordinarily require readjustment except to correct for wide variations in atmospheric conditions. An idling adjustment which has been satisfactory should not be changed until all other possible causes of unsatisfactory idling have been investigated. If it is necessary to reset the idle adjustment, or when a new or replacement carburetor is installed, proceed in the following manner:

Start the engine and run it 200 to 300 rpm above the rotor engagement rpm (approximately 1500 rpm) for helicopter installations or at approximately 1000 rpm for conventional installations until the oil temperature reaches 60° to 70°C (140° to 158°F) and the cylinder head temperatures are normal.

Run the engine up to 2000 rpm and check the sparkplugs by operating each magneto separately. Refer to magneto checks (Horizontal or Vertical installations), Ground Checks chapter, for complete magneto check instructions. If the drop-off in rpm is normal, proceed with the idling adjustment.

Slow down to closed throttle, approximately 850 rpm for helicopter installations, or 450 to 500 rpm for conventional installations. Adjust the throttle stop of the engine to idle at approximately this rpm.

Move the mixture control slowly toward "Full Lean" or "Idle Cut-Off," and observe the rise or fall in rpm. This should occur at a point approximately 2/3 to 3/4 of the quadrant travel from the "Full Rich" position. Read instruments. If the idling adjustment is properly set at approximately 850 rpm for helicopter installations or at 450 to 500 rpm for conventional installations, there will be a rise not in excess of 100 rpm in the former case and not in excess of 20 rpm in the latter as the control is moved toward "Full Lean" or "Idle Cut-Off," and a corresponding drop as the control is moved back to "Full Rich."

If the engine rpm decreased when the mixture control was moved toward "Full Lean" or "Idle Cut-Off," turn the idle mixture adjustment lever one or two notches to the left (counterclockwise) to richen the mixture and again check the rpm when the control is moved toward the "Full Lean" or "Idle Cut-Off" position. In the case of twin barrel carburetors, turn the lever toward the center to richen. Repeat until the correct rpm rise is obtained.

If the increase in engine rpm was excessive, turn the idle mixture adjustment lever one or two notches to the right (clockwise) to lean the mixture; then again move the mixture control toward "Full Lean" or "Idle Cut-Off" and check the rpm. In the case of twin barrel carburetors, turn the levers away from the center to lean.

It is desirable to maintain cylinder head temperatures which will approximate the coolest stable temperatures encountered at idling rpm under the atmospheric conditions prevailing at the time the adjustment is being made.

An enrichment not in excess of 20 rpm for conventional installations or not in excess of 100 rpm for helicopter installations is needed to aid in cold starting when the engine has a tendency to backfire and not to be rich as to foul sparkplugs under warm operation. Tendencies of the engine to foul plugs or to torch are indications of idle adjustment being too rich. Tendencies to backfire under very cold starting can be alleviated by richening the idle two or more notches before starting and resetting after the engine is up to idling temperatures.

OIL PRESSURE ADJUSTMENT

Remove the cap from the main oil pressure relief valve. Loosen the adjusting screw locknut; then turn the adjusting screw clockwise to increase or counterclockwise to decrease the oil pressure. As the locknut is being tightened it may change the adjustment so it is advisable to take this into account when making the adjustment. After the desired adjustment has been obtained, tighten the locknut, reinstall the relief valve cap, and lockwire.

CHAPTER 7.......... PERIODIC INSPECTION

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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 aircraft. In the following periodic inspection schedule, it is suggested that "A" represents a 50 hour inspection period, "B," 100 hour, "C," 200 hour, and "D," the midpoint period between overhauls. Experience and the type and conditions 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. The term "Inspect" denotes visual inspection unless otherwise noted.

Nature of Inspection	Preflight	A	B	C	D	Remarks
GENERAL						
Inspect engine and accessory section for failures, and fuel or oil leaks.	✓					On some installations it may be desirable to remove sections of cowling.
Inspect engine cowling for security of fasteners.	✓					
Inspect propeller governor for oil leaks.		✓				Evidence of oil leakage at the governor mounting pad may indicate warpage of the governor base, or governor mounting pad stud failure. If any stud is found to be broken, replace all four studs. It is essential that the governor mounting pad nuts be drawn down evenly and tightened to the recommended torque.
Inspect the propeller shaft thrust bearing cover for oil leakage.		✓				Leakage at the thrust bearing cover necessitates further investigation to determine source of leakage (Improper pinch fit of thrust cover to case, cracked oil slinger, cracked crankshaft). Check thrust bearing nut for tightness.
Remove, clean, and inspect engine and accessory cowling.		✓				
Inspect for loose nuts and broken lockwire.		✓				Frequently indicated by signs of oil or fuel leakage.
Inspect drain plugs and covers for proper lockwiring.		✓				

Nature of Inspection	***Preflight***	***A***	***B***	***C***	***D***	***Remarks***
Check cowl flap operation and general condition.	✓					
Inspect deflectors for security and fin clearance.		✓				
Inspect general condition of cylinder assemblies, and for evidence of loose or broken flange nuts or studs.		✓				Refer to **Cylinders, Pistons, and Pistonpins** in the **REPAIR AND REPLACEMENT** Chapter.
Inspect pushrod housing gland nuts for security, evidence of oil leakage, and lockwiring.		✓				Never overtighten pushrod housing gland nuts to stop oil leakage as damage to the pushrod housing may result. Replace the seal, tighten the gland nut to the recommended torque, and lockwire as required.
Inspect rocker covers for security, chafing, and evidence of oil leakage.		✓				Never overtighten rocker cover attaching nuts to cease oil leakage as warpage of the cover may result. Replace the gasket and tighten the nuts to the recommended torque.
Retighten exhaust port stud nuts.			✓			Retighten at "B" check, and again at approximately 500 and 1000 hours. This prevents excessive exhaust blowby, and on installations utilizing exhaust port gaskets, prevents exhaust port gasket blowout.
Inspect exhaust system for cracks and signs of burning.		✓				Slipjoints should be free, and all connections tight.
Examine all engine controls for excessive play, restriction of movement, and security of attachment.			✓			Lubricate all joints as required.

Nature of Inspection	Preflight	A	B	C	D	Remarks
Inspect all accessories for leaks, security, and condition.		✓				
Inspect clamps, bonding, rods, and lines for security and condition.		✓				
Inspect engine mount, mount bolts, and mount shock units for cracks, corrosion, security, and lockwiring.		✓				
Perform engine compression check.			✓			
Check cold valve clearance.			✓		✓	Perform cold valve clearance check during "B" check, and again at approximately mid-overhaul.
Clean oil separator.			✓			Check for clogged ports.
Clean vacuum relief valve.			✓			

LUBRICATION SYSTEM

Nature of Inspection	Preflight	A	B	C	D	Remarks
Remove, disassemble, inspect and then clean main pressure oil screen.		✓	✓			Examine screens, sump plugs, and drained oil for presence of metal or foreign matter. If metal chips are found, they may be an indication of trouble within engine. Further investigation should be made to discover source of material. Refer to "Foreign metal in oil system" (page 7-11). Occasionally a P/N 39749 Linkpin Plug is found loose in sump. Loss of one or more of this aluminum part is not detrimental to engine operation. Clean main oil screens at 25 to 50 hours (mineral oil) or 60 to 120 hours (dispersant oils).
Remove, inspect and then clean all sump plugs.		✓				
Remove, inspect and then clean scavenge oil screen (sump)		✓	✓			

Nature of Inspection	Preflight	A	B	C	D	Remarks
Inspect all oil lines and connections for leaks, dents, cracks, chafing, and security.		✓				
Inspect connections and clamps for general condition, positioning, and tightness.		✓				
Change oil.	The time between oil changes should be determined by the type, and condition, of engine operation.					Drained oil should be collected, strained, and examined for presence of metal particles. After servicing oil tank, rotate propeller several times to prime the oil pump.
ELECTRICAL SYSTEM						
Remove sparkplugs, and install new or reconditioned sparkplugs.			✓			Operating conditions may establish a longer period before replacement.
Clean sparkplug lead insulators with naptha, acetone, alcohol, or clear unleaded gasoline.			✓			Inspect lead insulators for chipping or cracks. Replace if necessary.
Check sparkplug lead elbow nuts for security and condition.		✓				Tighten lead elbow nuts to the recommended torque as overtightening may damage the sparkplug insulator.
Inspect the ignition harness for signs of overheating, security and condition.			✓			Examine harness and lead shieldings for presence of moisture.
Inspect ignition cables for evidence of chafing and deterioration of insulation.			✓			Check ignition system with a high voltage leakage tester if leakage is suspected.

Nature of Inspection	Preflight	A	B	C	D	Remarks
Inspect the magneto ground wires for security and condition.			✓	✓		At "C" check remove the ground wires from the magnetos, clean, inspect, and carefully reinstall.
Inspect the magnetos for security and condition.			✓			Inspect vent screens for clogging.
Inspect breaker points, and cam follower for excessive wear.			✓			Refer to Breaker Point Inspection, ADJUSTMENTS Chapter, for procedures of inspection of breaker assembly and lubrication of cam follower felt.
Check magneto timing and synchronization.			✓			Refer to Timing and Synchronizing, ADJUSTMENTS Chapter.
Clean breaker compartments, distributor rotors, and distributor blocks.			✓			Wipe with a clean dry cloth.
Inspect all electrical conduits and connectors for security and condition.		✓				Assure that areas of conduits under hold-down clamps are not chafed through.
Inspect the induction vibrator cables and connections for security and condition.		✓				
Inspect thermocouple leads for security and condition.		✓				Ascertain that there is no sparkplug gasket used with the thermocouple.
Inspect the starter for security and condition.			✓			Inspect condition of starter brushes and commutator.

Nature of Inspection	Preflight	A	B	C	D	Remarks
Inspect the generator for security and condition.			✓			Inspect condition of generator brushes and commutator.
FUEL AND INDUCTION SYSTEM						
Drain fuel screens and tank drains.	✓					Examine for presence of metal particles, water, and/or foreign matter. The presence of metal particles demands investigation of source.
Remove, inspect, and clean all main fuel screens.		✓				Examine for presence of metal particles, water, and/or foreign matter. The presence of metal particles demands investigation of source.
Remove and inspect the carburetor fuel screen.		✓				Examine screen for damage and presence of foreign matter. Clean, install, and lockwire as required.
Inspect air intake ducts for security, condition, and for obstructions.		✓				
Inspect the entire fuel system from the tank to the carburetor for leaks, under pressure.		✓				Fuel booster pump on.
Inspect the priming system for evidence of leakage, security, and condition.		✓				
Inspect all fuel line supports and clamps for security and condition.		✓				Inspect for bends, cracks, leaks, and signs of abrasion or interference with other parts.

Nature of Inspection	Preflight	A	B	C	D	Remarks
Inspect the carburetor for leaks at the parting surfaces, and hold-down nuts for tightness.		✓				
Inspect intake pipes for leaks, security, and condition.		✓				Refer to Intake Pipe Inspection, Repair and Replacement chapter.
Inspect the fuel pump for signs of leakage, security, and condition.		✓				

FOREIGN MATERIAL IN THE OIL SYSTEM

General

Rubber-like particles found in the oil screen are an indication of disintegrating oil seals or a faulty oil line. On all reciprocating engines, the oil system has an oil screen by-pass valve. This valve opens at any time the oil screen is clogged enough to restrict the oil flow, thereby allowing unscreened oil to flow through all oil passages on the engine.

Frequently, carbon tends to break loose from the interior of the engine in large pieces which have the outward appearance of metal. However, carbon can be distinguished from metal by placing the foreign material on a flat metal object and hitting it with a hammer. If the material is carbon, it will disintegrate when struck with a hammer, whereas metal will either remain intact or change shape, depending on the malleability of the metal.

Metal Particles

Metal particles on the engine oil screens or on the magnetic sump plugs are generally an indication of partial internal failure of the engine. However, due to the construction of aircraft oil systems, it is possible that metal particles may have collected in sludge in the oil system at the time of a previous engine failure; consequently, this must be taken into account when metal particles are found in the engine oil screens or on the magnetic sump plugs.

Before removing an engine for suspected internal failure as indicated by foreign material on the oil screens or oil sump plugs, collect all obtainable metal particles for analysis. In order to collect fine metal particles, it may be necessary to strain the oil through a cloth.

> ***An oil soaked rag can very easily cause spontaneous combustion unless placed in a tightly closed container, such as a quart or pint can with a press-fit lid.***

The serviceability of the engine will depend upon the quantity and the form of the metal. Granular metal particles, in any amount greater than a trace, require a very careful inspection of the engine, as the presence of these particles is usually an indication of an impending part failure.

Identification of Metal Particles

Metal particles found in an engine may be any of five kinds; steel, tin, aluminum, silver, and copper (or bronze). A visual inspection as to color and hardness will occasionally be sufficient to determine the kind of metal present.

When visual inspection does not positively identify the metal, the kind of metal present may be determined by a few simple tests performed with a permanent magnet, electric soldering iron, and approximately two ounces each of concentrated hydrochloric (muriatic) acid and concentrated nitric acid, as follows:

Exercise care in handling the acids.

STEEL PARTICLES — can be isolated by means of a permanent magnet. The presence of any amount of steel particles requires engine removal.

TIN PARTICLES — can be identified by their low melting point. The soldering iron should be cleaned, heated to about 26°C (500 F), and tinned with 50-50 solder (50% lead — 50% tin). Wipe off the excess solder. A tin particle dropped on the heated iron will melt and fuse with the solder. Exercise care to avoid excess overheating of the iron during this test. The presence of tin requires no action since tin is used only in plating engine parts, and in thickness not greater than .0005 inch.

ALUMINUM PARTICLES — may be identified by their reaction with hydrochloric acid. When a particle of aluminum is emersed into hydro- chloric (muriatic) acid, it will "fizz" [illegible] rapid emission of bubbles. The [illegible] gradually disintegrate and [illegible] due (aluminum chloride [illegible] aluminum flakes smaller than 1/16 inch x 3/16 inch does not demand engine removal, however, they may indicate a piston failure. Visually inspect the cylinder bores through the sparkplug holes and compression check the engine in effort to locate a faulty piston. If a faulty piston is found, remove the cylinder assembly, carefully inspect the piston assembly, linkrod, and the cylinder bore for damage. If the damage is of an insignificant amount that the engine is not contaminated with aluminum particles, replace the cylinder assembly, ground check the engine, and then reinspect the main pressure oil screen and the sumps for additional presence of metal particles. If no metal particles are found return the engine to service. Additional checks of the screen and sumps should be accomplished for a short period following a failure to assure that the failure is not recurring.

If at any time aluminum particles greater than 1/16 inch x 3/16 inch are found in the screen or sumps, a failure is indicated to the extent that significant damage and subsequent contamination of the engine has occured requiring removal of the engine as a precautionary measure.

SILVER PARTICLES — may be identified by their reaction with nitric acid. When a silver particle is emersed into nitric acid, it will react rather slowly, producing a "whitish" fog in the acid. Silver is used in plating form on numerous parts. Since silver is quite soft, some small flakes will occasionally be released due to the normal working of these parts. If the size of the silver particles does not exceed 1/16 inch x 3/16 inch, and the quantity of particles does not exceed ten in number, no action is required. However, a small quantity of silver from the masterod bearings will make a large number of tiny flakes as it passes through roller bearings or gears within the engine. Therefore, large quantities of silver flakes indicate an excessive loss of plating material, or a masterod bearing failure, requiring removal of the engine as a precautionary measure.

COPPER OR BRONZE PARTICLES — may be identified by their reaction with nitric acid. When a copper or bronze particle is emersed into nitric acid it will react rapidly, producing a bright green cloud. There is no need in this instance to separate the copper from the bronze. If the size of the copper or bronze particles does not exceed 1/16 inch x 3/16 inch, and the quantity of particles does not exceed ten in number, no action is required. However, copper or bronze particles of larger size, or in quantity, indicate disintegration of a bushing or valve guide, requiring removal of the engine as a precautionary measure.

INSPECTION OF CONTAMINATED AIRCRAFT OIL SYSTEMS AND OIL COOLERS

In case of an internal engine failure, metal chips and foreign material will be deposited throughout the aircraft oil system. If these contaminating materials are not removed before the replacement engine is installed, the latter will probably be damaged and an internal failure result. Experience has shown that the only satisfactory method of cleaning the oil system is to disassemble it sufficiently so that all surfaces where chips may be lodged can be cleaned and visually inspected to make sure that the foreign material has been eliminated. In particular, it is recommended that the oil cooler be removed to positively ensure that all tubes are free of metal particles, as it has been found that methods of cleaning which involve reverse or alternate flushing accompanied by shaking the oil cooler are not sufficiently effective. In propeller systems using engine oil, the propeller, the engine oil tank, and all components should be thoroughly cleaned or replaced.

SPARKPLUGS AND LEADS

General

A [illegible] fundamentally only an in- [illegible] is to sufficiently insulate [illegible] generated by the magneto, and to assure delivery of enough electric energy to overcome the resistance at the sparkplug gap. All other conditions being ideal, an engine will perform only as satisfactorily as do the sparkplugs which are in it. The proper handling and installation of sparkplugs has proven to be one of the most important factors contributing to smooth engine performance both on the ground and in flight.

Experience has shown that proper recognition and identification of sparkplug discrepancies are of the utmost importance, since some apparently faulty sparkplugs require cylinder assembly replacement while others require substitution by a satisfactory sparkplug.

As a result of inaccurate descriptive terminology and misinterpretation, considerable confusion at both overhaul and maintenance activities has resulted in removal from service of numerous satisfactory sparkplugs. Also, in some cases, cylinder assemblies which have suffered distress from overheating and/or detonation have been mistakenly continued in service, leading to more serious failure.

It is the purpose of this section to define several basic conditions which may be found and to make appropriate recommendations for the action to be taken for each. It is not intended to discuss all possible discrepancies which may be encountered such as cracked nose ceramic, shielding barrel insulation failures, etc., as they do not impose a recognition problem and the action to be taken is clear.

SILVER RUN-OUT OF FINE WIRE ELECTRODE-TYPE SPARKPLUGS — When a fine wire electrode type sparkplug is subjected to pre-ignition and detonation, the excessive combustion temperature may cause the silver spindle of the center electrode to flow toward the firing end of the electrode. Small globules of silver are usually formed at or near the junction of the nose ceramic and the center electrode. Silver run-out is attended by [illegible] tion chamber distress and, the[illegible] recommended that the affected cylinders be replaced.

COPPER RUN-OUT OF MASSIVE ELECTRODE TYPE SPARKPLUGS — This difficulty is usually the result of pre-ignition and detonation whereby abnormally high combustion chamber temperatures causes the copper core of the center electrode assembly to melt and flow. In most cases the copper will bridge the electrode gap, rendering the plug inoperative.

Visual inspection of the plug will disclose copper loss and concavity of the center electrode if the plug is so designed that the copper core is normally exposed. In sparkplugs which incorporate a nickel-steel capped center electrode, this type of failure is characterized by a minute perforation of the cap and the presence of copper outside of the steel cap.

When the foregoing is encountered, other attendant combustion chamber difficulties have been regularly noted. Hence, replacement of the affected cylinder assemblies is recommended.

CENTER ELECTRODE CORE EROSION — Sparkplugs in which the copper core of the center electrode is exposed to combustion will exhibit erosion of the soft copper. The concavity seldom progresses to a depth which seriously affects the sparkplug rating. Erosion to a depth of 3/32 inch is acceptable, provided that the sparkplug is satisfactory in other respects. Should the erosion exceed the foregoing limit, replace the sparkplug.

INTERGRANULAR CORROSION — In the initial stages, intergranular corrosion of the center electrode nickel alloy sheath is detectable by linear cracks of the sheath and dia[illegible] metric expansion of the center electrode. As the condition progresses, the sheath may crumble, leaving some of the copper [illegible] protruding beyond the sheath. The deterioration will be more pronounced in cylinders which operate at higher temperatures. This is considered to be a sparkplug fault and substitution of a satisfactory plug is required.

CENTER ELECTRODE TIP SCALE — The formation of scale on the end of the center electrode assembly has been confused at times, with copper run-out. The carbon-lead scale appears as a bulbous formation attached to the end of the center electrode, seldom protruding beyond its normal diameter.

In the usual quantities, such hemispherical scale is of no consequence to normal sparkplug operation. Usual abrasive cleaning of the plug will detach the formation. As a precaution, such plugs may be cleaned prior to reinstallation, or they may be replaced. No other corrective or precautionary measures need be undertaken.

CHAPTER 8 . . . . . REPAIR AND REPLACEMENT

TABLE OF CONTENTS

REPAIR AND REPLACEMENT

PRELIMINARY INFORMATION

These instructions are written with the understanding that all lockwire, cotterpins, cylinder flange locknuts, nuts, washers, bolts, and screws will be removed where necessary in disassembly procedures and that new gaskets, rubber oil seal rings, packings, lockwire, and cotter pins will be used at assembly. Fibre insert nuts may be continued in service as long as they are free from mutilation and provide an effective lock.

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 openings in the engine.

When installing accessories that are secured by bolts, it is of the utmost importance that the insert holes in the accessory mounting pad be thoroughly cleaned. Bolts that are installed in recesses that are contaminated with oil, grease, preservative compounds, or other liquids can produce a hydraulic force which may cause the insert hole to be hydraulicked.

Torque recommendations appear in the LIMITS chapter.

When other engine parts interfere with the removal of a single part, the procedure for removing them can be found under their individual headings in the following text. For information about other interfering parts peculiar to the particular installation, the applicable aircraft manufacturer's handbook should be consulted.

LOCKWIRING

General [Figure 8—1]

Lockwiring is the most positive method of securing in place the various bolts, nuts, cap screws, and studs which hold together the parts of an engine. Generally speaking, lockwiring is the tying together of two or more parts in such a manner that the tendency of any one part to loosen will automatically be encountered by the tightening of the wire. Cotterpins are usually associated with castle nuts; however, if a castle nut is used on a stud, a cotterpin would secure the nut to the stud, but would not prevent the stud from backing out of the housing. In a case such as this, the lockwire will act as a cotterpin, and if the wire is then attached to an adjacent part, the stud also will be held securely in place.

LOCKWIRE MUST ALWAYS TEND TO TIGHTEN — The wire must be installed in such a way that it will always counteract any tendency of the part to loosen.

LOCKWIRE MUST NEVER BE OVERSTRESSED — Extreme care must be exercised when twisting the wires together to ensure that wires are securely tightened but not stressed to the point where they will break under a slight load.

LOCKWIRE MUST BE TIGHT WHEN INSTALLED — This is most important to prevent vibration with resultant fatigue and failure, and also to prevent the wire from rubbing against some adjacent part, causing wear.

LOCKWIRE ENDS MUST ALWAYS BE BENT TOWARD THE ENGINE — This is primarily a safety precaution to guard against possible injury to the hands of the mechanics working on the engine. It is also imperative that the part or parts to be lockwired are torqued to specifications and the holes properly aligned before any attempt is made to proceed with the lockwiring.

Lockwiring Procedures [Figure 8—2]

Hex head bolts will be used for the purpose of describing the following general lockwiring procedure:

STEP 1 — Check the units to be saftied to make sure that they have been correctly torqued and that the wiring holes are properly positioned in relation to each other. When there are two units, the hole in the first unit should be between the three and the six o'clock position, and the hole in the second unit between the nine and twelve o'clock positions. Positioning the holes in this manner ensures that the wiring will have a positive locking effect on the two units, since the braid will always exert a tightening pull on both units.

Never over torque or loosen units to obtain proper alignment of the holes.

It should be possible to align the wiring holes when the units are torqued within the specified limits. However, if it is impossible to obtain a proper alignment of the holes without either over or under torquing, another unit should be selected which will permit proper alignment within the specified torque limits.

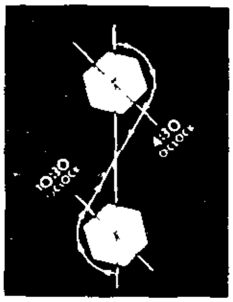
STEP 2 — Insert wire of the proper gage through the hole which lies between the three and the six o'clock position on the bolt head.

Use stainless steel wire rather than plated steel or brass wire. If stainless steel wire is not available, zinc coated or brass wire may be used externally but never internally.

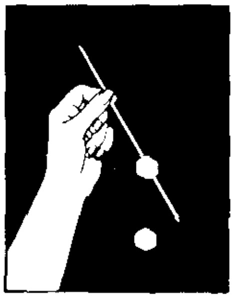
STEP 3 — Grasp the left end of the wire with the fingers and bend it clockwise around the head of the bolt under the other end of the wire. Pull the loop very tight around the head of the bolt with the pliers. Grasp the wire only at the end in order not to mutilate any portion which is to be twisted.

STEP 4 — Holding the wire ends apart and keeping the loop tight around the head of the first bolt, twist the wires in a clockwise direction to form a braid. Continue twisting the wires by hand toward the second bolt until the end of the braid is just short of the hole which lies between the nine and the twelve o'clock position.

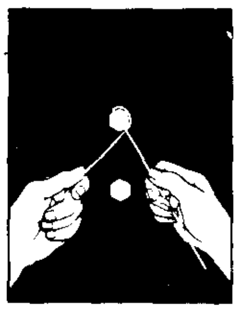
STEP 5 — Make sure that the loop around the head of the first bolt is still tight and in place; then grasp the wires in the jaws of the pliers just beyond the end of the braid, and, with the braid held taut, twist in a clockwise direction until the braid is stiff.



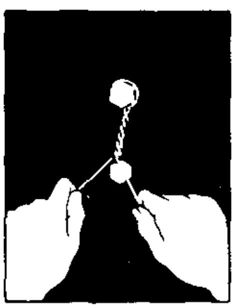
Position the holes



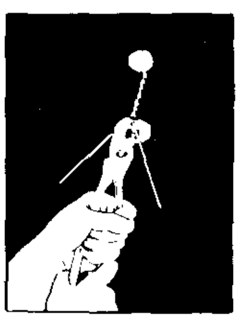
Insert proper gage wire. To determine the proper wire to be used in conjunction with a particular tightening operation refer to the correspondingly designated engine parts catalog or illustrated parts breakdown. Lockwire which is specially treated for 982°C (1800°F) applications has a dark gray to black color.



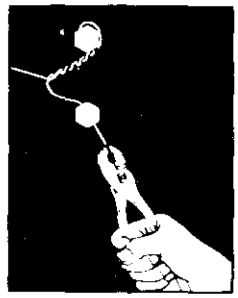
Grasp upper end of the wire and bend it around the head of the bolt; then under the other end of the wire. Be sure wire is tight around head.



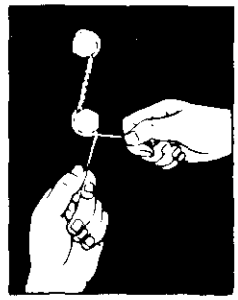
Twist wire until wire is just short of hole in the second bolt.



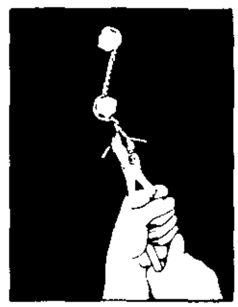
Keeping wire under tension twist in a clockwise direction until the wire is tight. When tightened the wire shall have approximately 8-10 turns per inch.



Insert the uppermost wire, which points towards the second bolt, through the hole which lies between the nine and twelve o'clock position. Grasp the end of the wire with a pair of pliers and pull the wire tight.

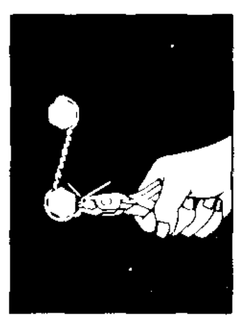


Bring the free end of the wire around the bolt head in a counterclockwise direction and under the end protruding from the bolt hole. Twist the wire in a counterclockwise direction.



Grasp the wire beyond the twisted portion and twist the wire ends counterclockwise until tight.

During the final twisting motion of the pliers, bend the wire down and under the head of the bolt.



Cut off excess wire with diagonal cutters.

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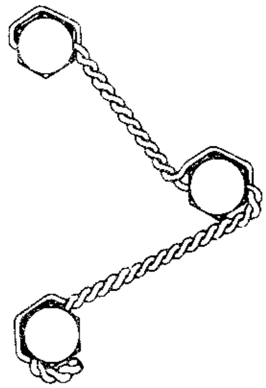
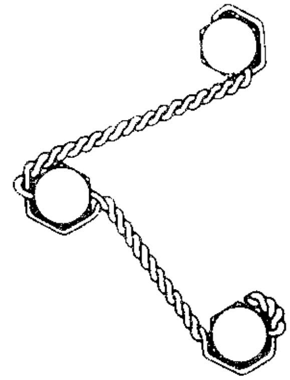
[8—1] Lockwiring Procedures

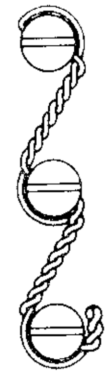
EXAMPLE 1



EXAMPLE 2



EXAMPLE 3

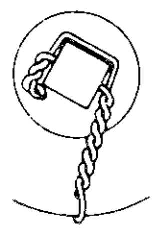


EXAMPLE 4

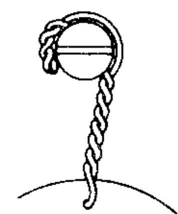
Examples 1, 2, 3, and 4 apply to all types of bolts, fillister head screws, square head plugs, and other similar parts which are wired so that the loosening tendency of either part is counteracted by tightening of the other part. The direction of twist – from the second to the third unit is counterclockwise to keep the loop in position against the head of the bolt. The wire entering the hole in the third unit will be the lower wire and by making a counterclockwise twist after it leaves the hole, the loop will be secured in place around the head of that bolt.

EXAMPLE 5

EXAMPLE 6

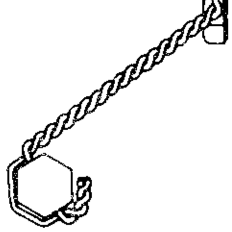


EXAMPLE 7



EXAMPLE 8

Examples 5, 6, 7 & 8 show methods for wiring various standard items. Note: Wire may be wrapped over the unit rather than around it when wiring castellated nuts or on other items when there is a clearance problem.

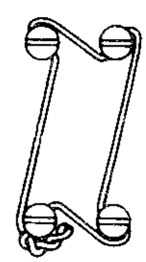


EXAMPLE 9

Example 9 shows the method for wiring bolts in different planes. Note that wire should always be applied so that tension is in the tightening direction.

EXAMPLE 10

Hollow head plugs shall be wired as shown with the tab bent inside the hole to avoid snags and possible injury to personnel working on the engine.



EXAMPLE 11

Correct application of single wire to closely spaced multiple group.

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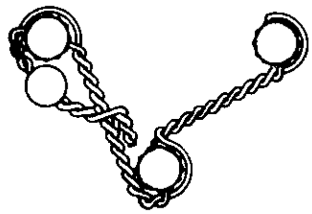
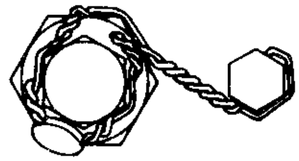
[8–2] Basic Lockwiring Examples (Sheet 1 of 3)



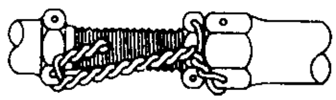
EXAMPLE 12



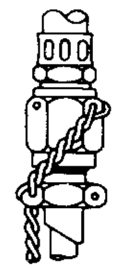
EXAMPLE 13

Examples 12 & 13 show methods for attaching lead seal to protect critical adjustments.

EXAMPLE 14



EXAMPLE 15

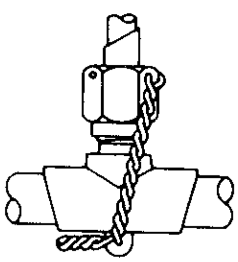


EXAMPLE 16

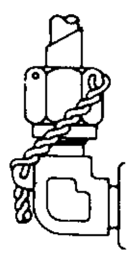
Example 14 shows bolt wired to a right angle bracket with the wire wrapped around the bracket.

Example 15 shows correct method for wiring adjustable connecting rod.

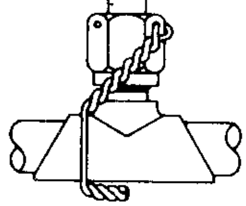
Example 16 shows correct method for wiring the coupling nut on flexible line to the straight connector brazed on rigid tube.



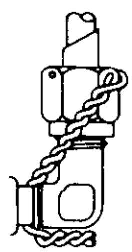
EXAMPLE 17



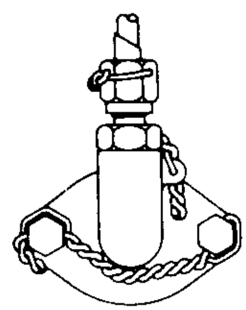
EXAMPLE 18



EXAMPLE 19



EXAMPLE 20



EXAMPLE 21

Fittings incorporating wire lugs shall be wired as shown in Examples 17 & 18. Where no lockwire lug is provided, wire should be applied as shown in Examples 19 & 20 with caution being exerted to ensure that wire is wrapped tightly around the fitting.

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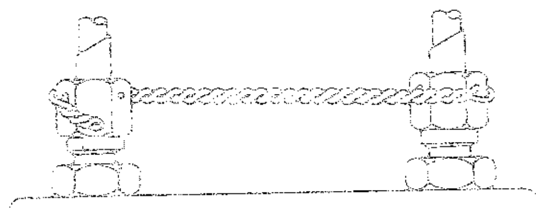
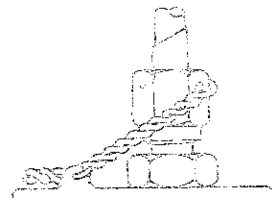
Small size coupling nuts shall be wired by wrapping the wire around the nut and inserting it through the holes as shown.

[8—2] Basic Lockwiring Examples (Sheet 2 of 3)

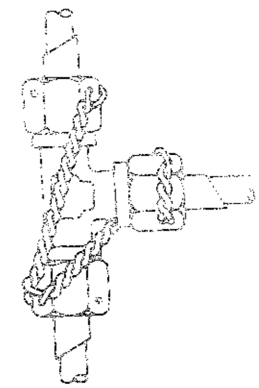


EXAMPLE 22



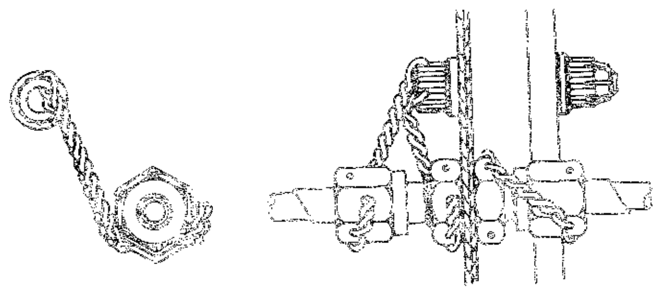
EXAMPLE 23

Coupling nuts attached to straight connectors shall be wired as shown when hex is an integral part of the connector.



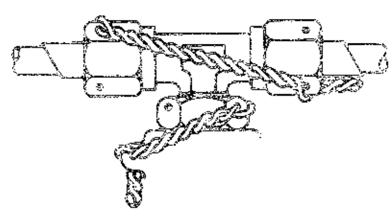
EXAMPLE 24

Coupling nuts on a tee shall be wired as shown above so that tension is always in the tightening direction.

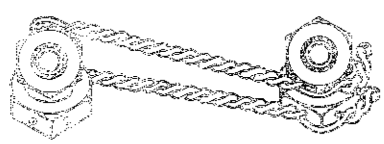


EXAMPLE 25

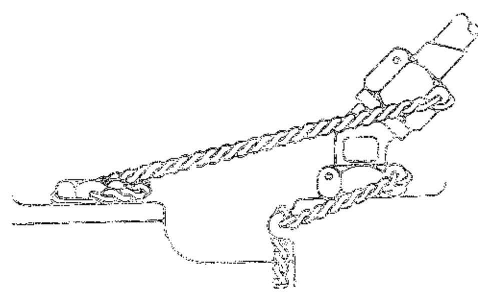
Straight Connector
(Bulkhead Type)



EXAMPLE 26



EXAMPLE 27



EXAMPLE 28

Examples 26, 27 & 28 show the proper method for wiring various standard fittings with check nut wired independently so that it need not be disturbed when removing the coupling nut.

[8–2] Basic Lockwiring [illegible]

Twisting the braid in a clockwise direction has the effect of securing the loop down around the head of the first bolt. The rigidity of the stiff braid reduces vibration and resultant wear. Do not overstress the wires by attempting to twist the braid too tightly.

STEP 6 — After making sure that the braid is not so long that it cannot be pulled taut between the bolts, insert the end of the wire which is on top through the hole between the nine and the twelve o'clock positions on the second bolt head. Grasp the end of this wire with the pliers and pull the braid taut.

STEP 7 — Bring the free end of the wire counterclockwise around the head of the second bolt and under the wire which protrudes from the bolt hole. Pull the resulting loop tight with the pliers; then to keep the wire in place down around the head of the second bolt, twist the wire ends together in a counterclockwise direction.

STEP 8 — Grasping the ends of the wire beyond the twist with the pliers, and, keeping the wires under tension, twist them in a counterclockwise direction until tight.

STEP 9 — With the final twisting motion of the pliers, bend the twisted wire ends counterclockwise around the head of the second bolt.

STEP 10 — Cut off the excess wire at the ends with diagonal cutters, leaving at least three full twists and avoiding sharp or projecting ends.

Do not twist off the ends of the wires with pliers.

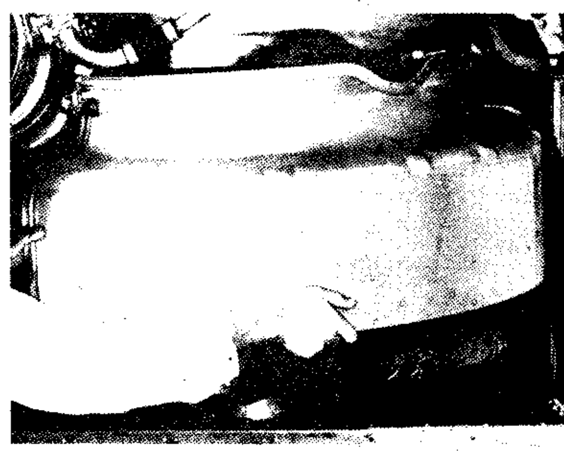
REPAIR AND REPLACEMENT

Cowling

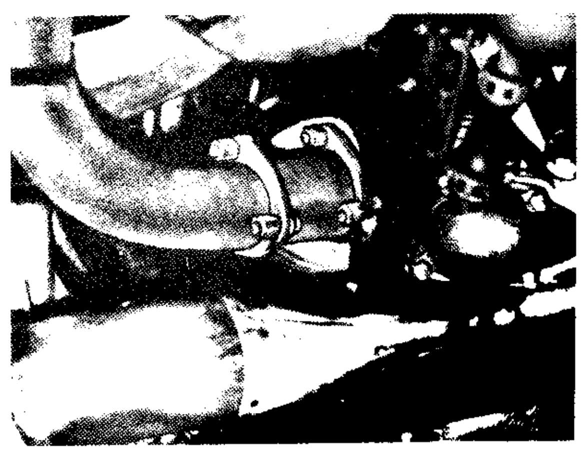
REMOVAL — Remove sufficient cowling **[Figure 8—3]** to have easy accessibility during the removal of any parts.
INSTALLATION — Install the cowling sections that were removed.

Exhaust Piping

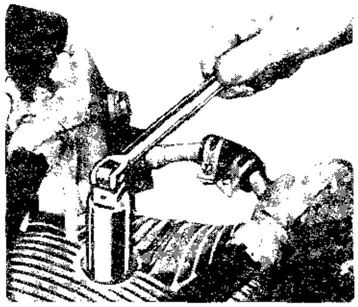
REMOVAL — Unfasten the nuts and bolts which fasten the exhaust piping to the engine **[Figure 8—4]**. Loosen the exhaust manifold and lower it as far as possible so that the cylinders and related parts will be more accessible.



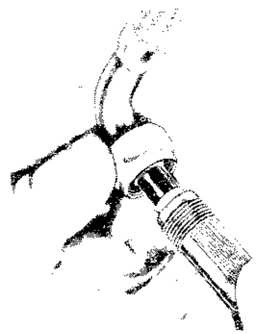
[8—3] Remove Cowling



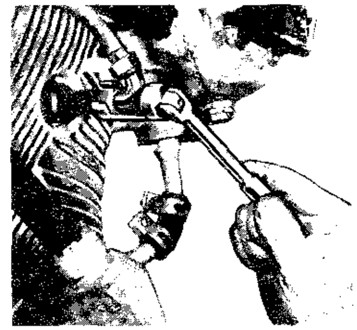
[8—4] Exhaust Piping



[8—5] Unfasten Sparkplug Lead



[8—6] Protector Cap



[8—7] Remove Sparkplug

INSTALLATION — Move the exhaust manifold upward and fasten the exhaust collector to the engine with nuts and bolts.

Sparkplug Lead Connectors and Sparkplugs

REMOVAL — Loosen the sparkplug lead shielding to elbow coupling nut. Using PWA-1683 or PWA-3315 Wrench, remove the sparkplug lead coupling nut from the sparkplug **[Figure 8—5]** being careful not to allow the elbow to turn or the wrench to slip. Withdraw the ceramic connector from the sparkplug, pulling the lead straight out and in line with the center line of the sparkplug barrel; then install a suitable protector cap over it **[Figure 8—6]**. Remove the sparkplug using PWA-3168 Wrench **[Figure 8—7]**. Do not "cock" the wrench on the sparkplug; make certain that the "hex" of the wrench is in full engagement with the "hex " on the plug. If the plug is difficult to remove, removal may be facilitated in some cases by turning the plug first in a tightening direction and then in a loosening direction. Install a PWA-3252 Plug in the sparkplug hole.

Inspect the firing end of the plug that was removed. If there are any signs of cracked or broken insulators, or bent or melted electrodes, it is recommended that an inspection of the cylinder be made for signs of operational damage to the piston and combustion chamber by removing the rear sparkplug, inspecting the piston and the cylinder barrel through the sparkplug holes, and by means of a compression check determine the condition of the valves.

PREPARATION FOR INSTALLATION OF SPARKPLUGS — Remove sparkplugs from boxes and place in a rack for vapor degreasing.

Vapor degrease (trichlorethylene, or equivalent) for 1 to 3 minutes. (A longer period will do no harm.) Vapor degreasing serves two functions: (1) It removes preservative and cleans plugs; (2) It removes any accumulated moisture.

Remove plugs from degreaser and inspect visually. Use a strong light to inspect the firing end of the insulator and barrel insulation for cracks, dirt, or lead compound accumulation. Observe the condition of the electrodes and inspect for mutilation of threads at the shell and barrel ends of the plug.

Check the gap clearance of each electrode with .015 inch "go" and .018 inch "no go" stainless steel piano wire. (Use Starrett pin vise as holder for wire and "roll" wire between the electrodes.) Do not attempt to push it through as an inaccurate gage will result. The wire will easily "roll" through electrodes of some plugs; whereas the same wire cannot be pushed through. The desired gap is .016 inch; however, if a .015 inch gage will pass through the electrodes but a .018 inch gage will not, the gap clearance is satisfactory.

Where a plug is found to be closed below the lower limits, no attempt should be made to disassemble the plug or to open the gaps to the specified clearances. Instead, return such plugs to the sparkplug overhaul shop.

Bomb check on a BG M519 tester, or the equivalent. Abrasive blasting time should be held to the absolute minimum, since excessive abrasive blasting will cause wear of electrodes and insulators. The color of the ceramic after abrasive blasting is unimportant, provided the ceramic is clean and free from carbon, and provided the plug passes the bomb test. Observe the spark at 200 psi to make certain that it occurs at the electrode and is steady. The plug should be rejected if there is failure to fire steady at 200 psi or if there is any indication of firing below the electrodes.

It is immaterial to the performance of the plug if the spark "hunts" or if it fires at one point only. Do not attempt to make adjustments to correct such a condition.

Visually inspect the condition of the sparkplug insert or bushing and make certain that the top of the sparkplug hole is clean and smooth.

Stainless steel sparkplug inserts or bushings may be cleaned with a stiff fiber or wire brush moistened with a cleaning solvent. The brush should be 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 cylinder head surrounding the insert. Special care should be taken on the sparkplug 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.

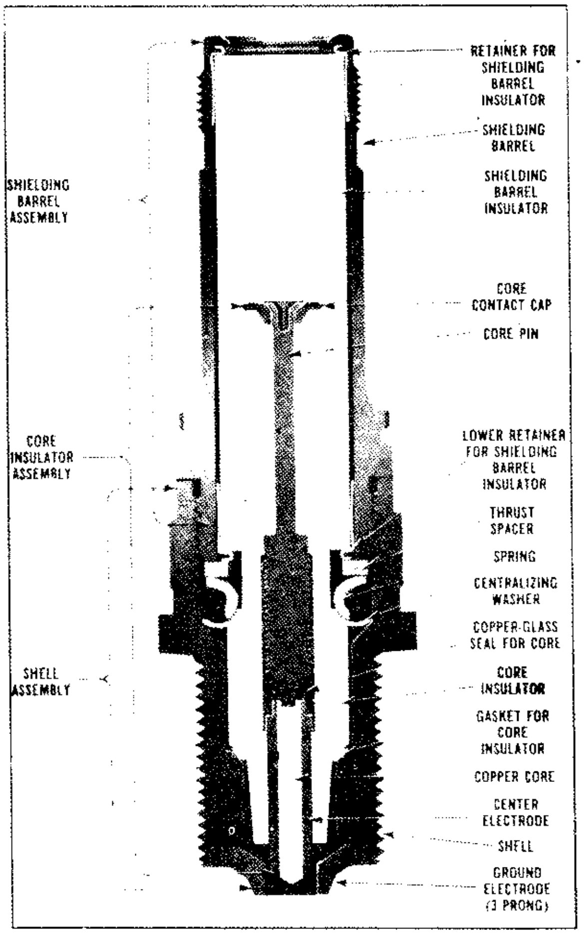
Do not use a tap if the cylinder is equipped with stainless steel sparkplug inserts or bushings.

Bronze bushings may be cleaned by running a 18 by 1.5 millimeter tap through the bushing. Care should be exercised to steady the tap holding wrench to prevent the tap from wobbling, which would cause bell-mouthing of the bushing. The tap should be worked alternately in and out, a fraction of a turn at a time. Coating the flutes of the tap with grease will help prevent foreign matter or chips from entering the cylinder.

INSTALLATION — In the case of ceramic sparkplugs, shocks such as occur from dropping or striking them against hard objects, or from slipping of a sparkplug wrench can cause an invisible fracture of the ceramic insulation. Therefore, plugs which have been abused in any way should be rejected. Such plugs might pass bomb and leakage tests only to fail after limited service in the engine. Never install a sparkplug that has been dropped. Refer to **Figure 8—8** for a cutaway view of a typical sparkplug.

Apply a light coating of Champion No. 119, graphite base, anti-seize compound sparingly as a thin film on the shell threads, taking special care not to coat the first two threads as the compound may run down onto the electrodes when hot. Make sure that the compound is throughly mixed, because after settling, the finely powdered mica or graphite separates from the compound and collects at the bottom of the container. A small brush should be used to apply the compound [**Figure 8—9**]. Do not apply with fingers.

REPAIR AND REPLACEMENT



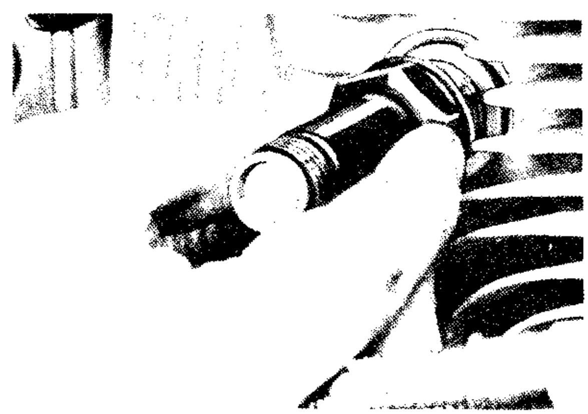
[8–8] Typical Sparkplug

Never allow anti-seize compound to get on the electrodes since this compound is conductive and will short out the sparkplug. Do not apply anti-seize compound to the barrel end threads.

Remove the PWA-3252 plug from the sparkplug hole just prior to installing the sparkplug. Making certain that there is a serviceable copper gasket (only one) on the sparkplug, screw the sparkplug into the cylinder with the fingers until the plug bottoms on the gasket **[Figure 8–10]**. If it does not screw in easily, remove and inspect the sparkplug and sparkplug bushing threads.

Minor imperfections of sparkplug threads should be corrected, where possible, by using

[8–9] Apply Compound



[8–10] Screw Plug Into Cylinder

a small three-cornered file. Avoid use of a die since the threads may be cut too deeply to permit a tight fit of the plug in the bushings. If a die must be used, it should be used by hand without a die holding handle. The die should be checked periodically to be certain it cuts a pitch diameter within the limits 0.6683 to 0.6693 inch.

Using PWA-3168 Wrench, tighten the sparkplug to the recommended torque. Avoid side loading or "cocking" of the wrench. The importance of using a torque wrench when tightening a sparkplug cannot be too highly emphasized. Some serious troubles resulting from subjecting the plug to excessive installation torques are:

a. Stretching the shell threads away from the shell flange which is seated on the cylinder gasket and bushing.

b. Loosening of the core insulator and loss of pressure seal.

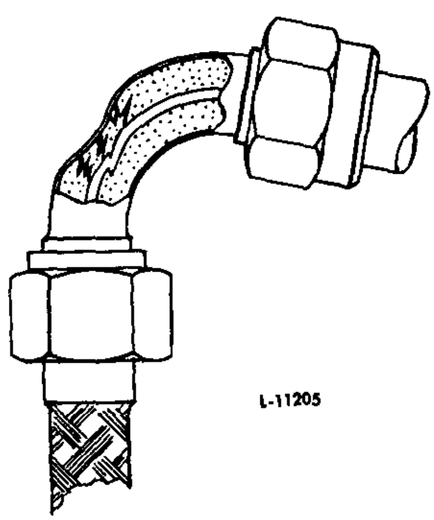
c. Compression of the gasket to a point where the unthreaded portion of the shell fouls against the sparkplug bushing threads.

d. Breakage upon removal.

e. Stretched core threads.

Except in an extreme emergency, never install a sparkplug in a hot engine as this may result in thread seizure with possible subsequent damage to the sparkplug bushing and the plug shell when removal is attempted.

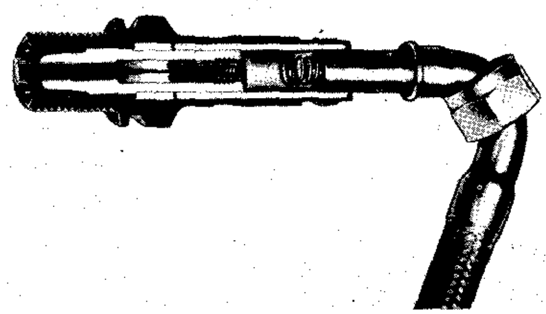
Remove the plastic protector from the sparkplug lead connector. Visually inspect the sparkplug lead elbow for dents or cracks **[Figure 8—11]**, and the lead ceramic connector for cracks or chipping. Replace if necessary. Wipe hands dry; then using a clean cloth moistened with acetone, alcohol, cleaning naptha, or clear unleaded gasoline, wipe



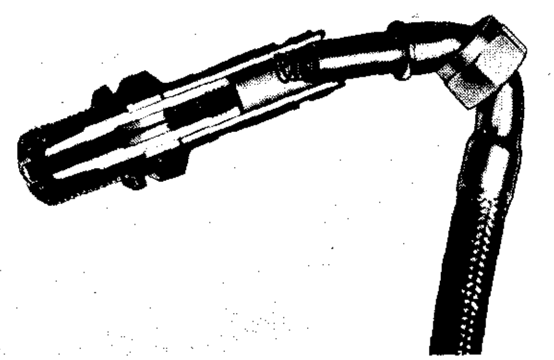
[8—11] Lead Elbow Damage

the ceramic connector clean. Without touching the connector or spring with the fingers, install the connector in the sparkplug barrel. Be very careful that the connector is inserted straight into the barrel **[Figure 8—12]** and not "cocked" **[Figure 8—13]** since this can result in a cracked lead ceramic connector or sparkplug ceramic barrel insulator. Wipe the sparkplug barrel end threads using a clean dry cloth, **[Figure 8—14]** to ensure an electrical bond between the sparkplug and its lead to prevent radio interference from this source.

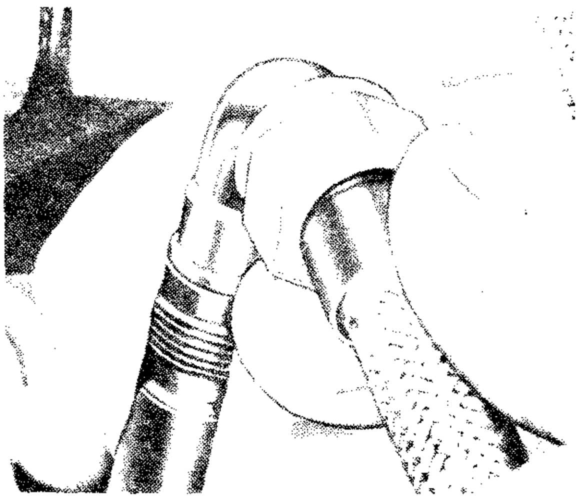
If the sparkplug lead ferrules at the elbow end of the conduits for the Nos. 5 and 6 cylinders are drilled, ensure that the hole is facing downwards upon installation.



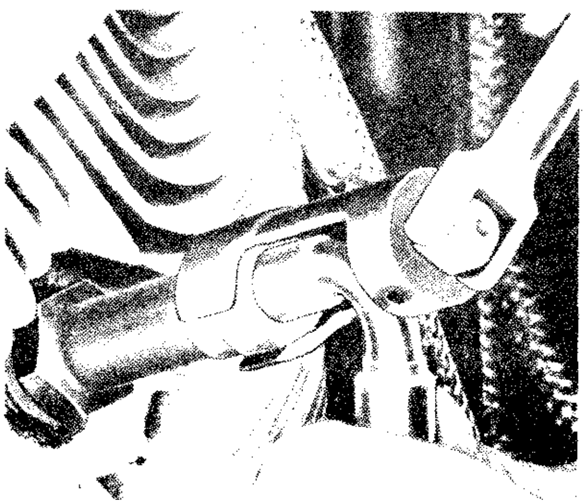
[8—12] Proper Installation of Connector



[8—13] Improper Installation of Connector



(8-14) Wipe Sparkplug Barrel End-threads



(8-15) Tighten Coupling Nut

Run the sparkplug lead coupling nut down on the sparkplug finger tight. Holding the elbow in its desired position, tighten the elbow coupling nut to the recommended torque using PWA-1683 or PWA-3315 (Figure 8-15) wrench; then tighten the sparkplug lead shielding to elbow coupling nut.

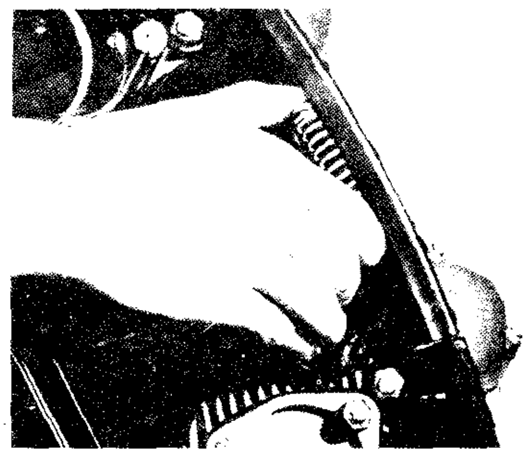
> Do not overtighten the elbow coupling nut nor use an open end wrench as damage to the ceramic barrel insulator may result.

Check the sparkplug leads to be sure they are not twisted.

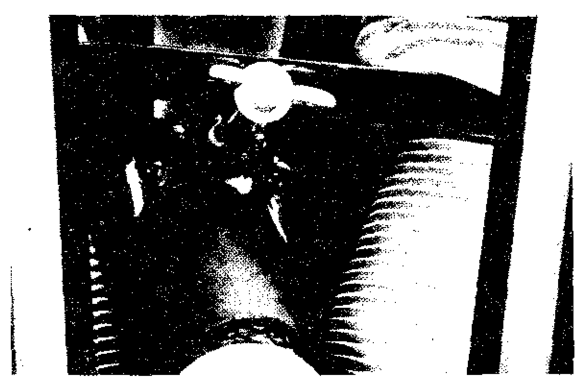
Cylinder Deflectors

REMOVAL -- Remove the nuts that secure the cylinder head deflectors to the cylinders. Release the spring loaded clamp (Figure 8-16) on the rear side of the intercylinder deflectors and remove the cylinder head deflectors. Remove the wing nuts (Figure 8-17) which secure the intercylinder deflectors to the retaining clamps; then remove the clamps and deflectors. The deflector between No. 7 and No. 8 cylinder cannot be removed until the clamp underneath the deflector has been loosened and the tee hose connection has been withdrawn from the deflector. Tag each deflector as it is removed so that it will be reinstalled in its proper location.

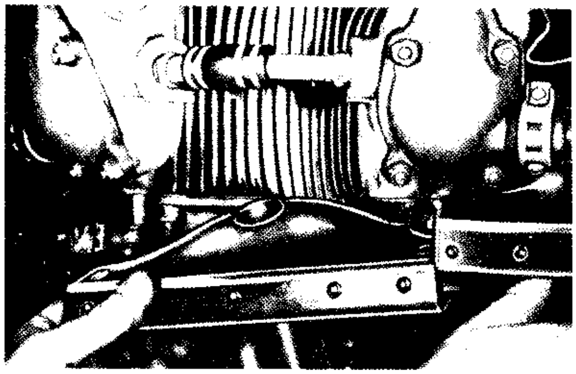
INSPECTION -- Examine the deflectors for dents, cracks, and the condition of the paint.



(8-16) Spring-loaded Clamp



(8-17) Wing Nuts



[8—18] **Install Head Deflectors**

INSTALLATION — Install the head deflectors [**Figure 8—18**] and secure them with the necessary nuts.

Assemble the intercylinder deflectors and secure them with the clamps and wing nuts.

Replacement of Cylinder Deflector Chafing Strip with Anti-Chafing Compound

REMOVAL OF OLD SHEET-TYPE CHAFING STRIPS — After removing the worn chafing strip, thoroughly clean and degrease the deflector. If the painted areas of the deflector are in good condition, mask them off. However, if the deflector is to be repainted, omit masking. Using Gerlack No. 70 Stripper or equivalent, and a stiff brush, thoroughly clean the surface, which is to be coated or painted with anti-chafing compound. Degrease the deflector to remove all stains.

APPLYING ANTI-CHAFING COMPOUND — If the deflector is to be repainted, mask the chafing strip area, apply the new paint, remove the mask from the chafing strip area, and bake in accordance with the Overhaul Instructions. Dilute one part of E. C. 1186 Compound with one to two parts Ethylene Dichloride (Commercial Grade) and 8% E. C. 1063 Accelerator (by weight, based on the weight of the undiluted E. C. 1186 Compound). Mix thoroughly to obtain a uniform mixture of a consistency for spraying. Using a spray gun, apply heavy coats of the mixture to the chafing strip area until a thickness of .018 to .028 inch is obtained.

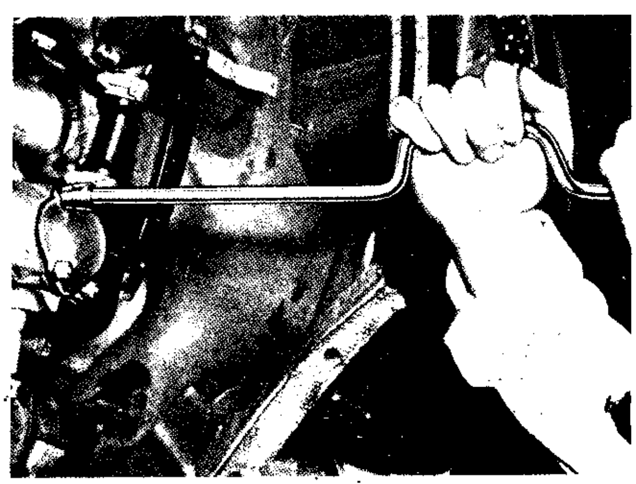
> ***Between coats, it is important that volatile solvents be evaporated by baking for 15 minutes 71° to 82°C (160° to 180°F) or by air-drying at room temperature for 30 minutes.***

After the final coat has been applied, remove the mask from the painted areas and bake the deflector for 1 hour at 126° to 154°C (260° 310°F).

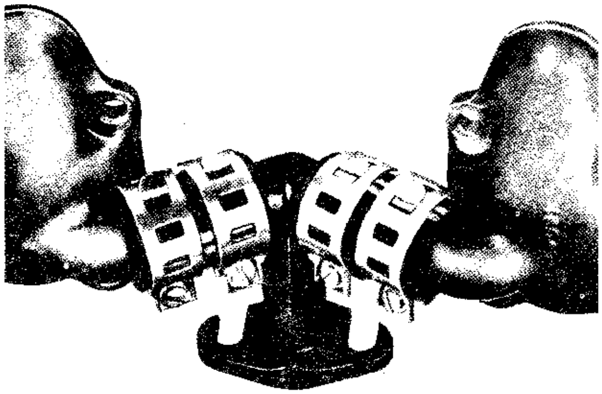
STRIPPING ANTI-CHAFING COMPOUND — Thoroughly clean and degrease the deflector. If the painted areas are in good condition, mask them off. Immerse the area of the deflector from which the old chafing compound is to be stripped in a tank containing a 10 percent solution of nitric acid for ten minutes. After rinsing the part twice throughly in airagitated cold running water, dry the part and inspect. Apply anti-chafing compound as described above.

Rockerbox Covers

REMOVAL — Unscrew the elastic stop nuts [**Figure 8—19**] which secure the rockerbox covers to the cylinder heads and remove the



[8—19] **Unscrew Stopnuts**



[8—20] Rockerbox Covers

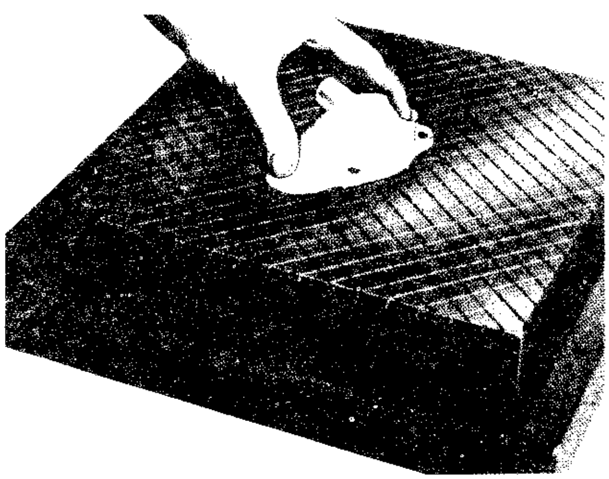
covers and gaskets. Rockerbox covers which are connected by intercylinder drain tubes should be removed in pairs **[Figure 8—20]**.

INSPECTION — Inspect for cracks and warpage. Check the rockerbox covers for flatness, using a .002 inch feeler gage and a surface plate. If necessary, face off the covers on a lapping plate **[Figure 8—21]**, using a small amount of lapping compound. This will ensure that the covers bear evenly on their gaskets.

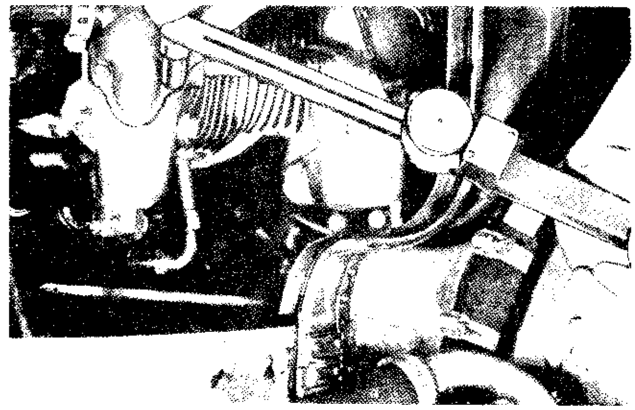
INSTALLATION — Place a new gasket on the rockerbox, then install the covers and tighten the nuts to the recommended torque **[Figure 8—22]**.

Primer Lines

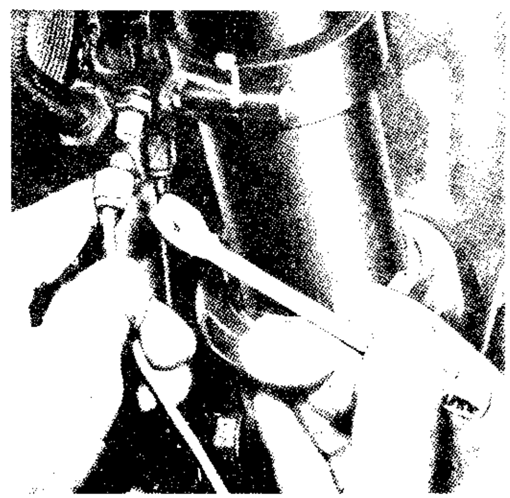
REMOVAL — Disconnect all primer lines at the primer distributor **[Figure 8—23]**, and at the Nos. 1, 2, 3, 8, and 9 cylinders to which



[8—21] Lap Covers



[8—22] Torque Covers



[8—23] Primer Lines

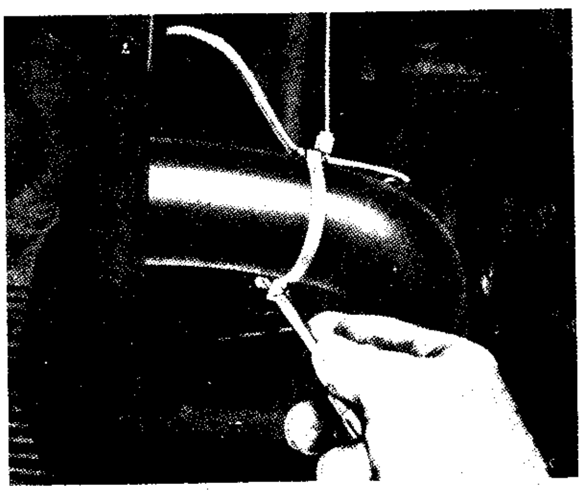
they are attached **[Figure 8—24]**. Unfasten the clamps holding them to the intake pipes **[Figure 8—25]**, and withdraw each line from the cylinder deflector through which it extends.

INSPECTION—Look for cracks, dents, pinched tubing, and broken unions. If necessary, replace with new primer lines.

INSTALLATION — Connect all primer lines at the primer distributor and insert the lines through the deflectors. Attach them to the cylinders to which they are attached. Fasten the clamps holding them to the intake pipes and supercharger section.

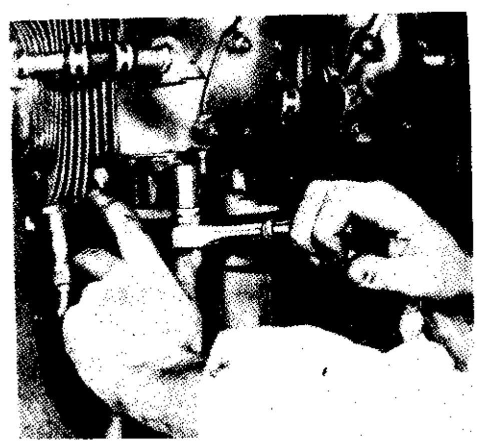
[8—24] Disconnect at Cylinders

[8—26] Intake Pipes



[8—25] Unfasten Clamp

[8—27] Loosen Nut



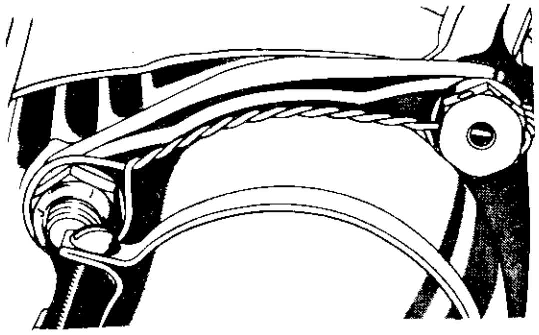
[8—28] Remove Nuts

Intake Pipes [Figure 8—26]

REMOVAL — Remove the lockwire and loosen the nut at the supercharger section using PWA-237 Wrench for Wasp Jr. engines **[Figure 8—27]** or PWA-5072 Wrench for Wasp engines. Remove the nuts and bolts at the cylinder end **[Figure 8—28]**; then remove the pipe. Install PWA-3800 Protector in the intake port opening for Wasp Jr. engines or PWA-5008 Protector for Wasp engines.

INSPECTION — Inspect for dents and cracks. Check condition of paint. Examine the nuts for thread and wrench slot condition. Replace packing if it is not in good condition.

INSTALLATION — Install a flat rubber seal at the supercharger end of each intake pipe after first coating the seal with a thin even coat of appropriate Dow Corning insulating compound. Remove the supercharger case opening protector and place the pipe in position on the engine. Install the blower end of



[8—29] **Secure Pipe To Cylinder**

each pipe first and tighten the packing nut finger tight. Coat a copper gasket with insulating compound; then install, split-side forward, at the cylinder intake port. Secure the pipe to the cylinder with the nut and bolts and lockwire [**Figure 8—29**]. Tighten the packing nut, using PWA-237 Wrench for Wasp Jr. engines or PWA-5072 Wrench for Wasp engines.

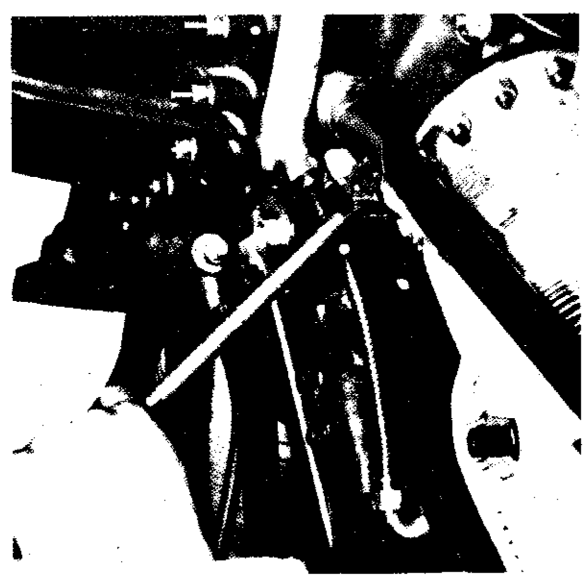
Dow Corning No. 4 Compound has been found to have remarkable properties as a non-hardening, non-softening preservative, lubricant and sealant at temperatures of −40°F to +500°F. As such, it tends to prevent the rapid oxidation and consequent hardening of intake pipe and pushrod tube packings. It reduces friction so as to minimize the possibility of false torquing, acts as an excellent sealant, and prevents stickage at disassembly. The compound contains minutely ground silica and mica which may act as irritants to the eyes and skin. When the compound is handled frequently, it is suggested that gloves be worn.

Pushrods and Covers

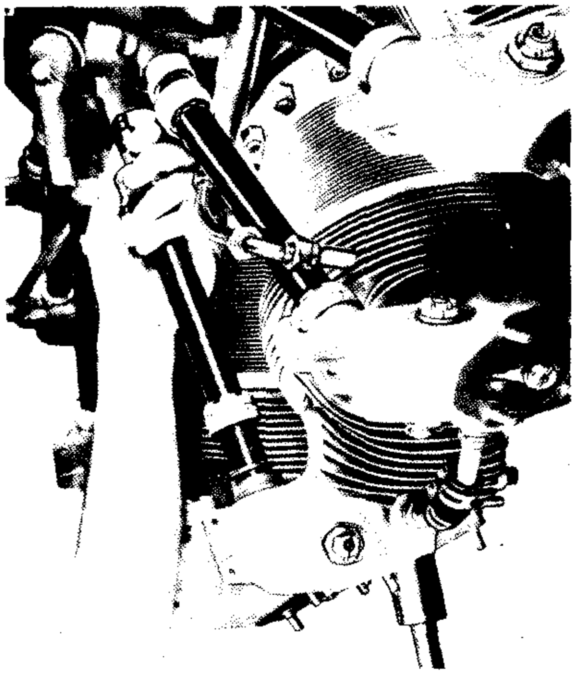
REMOVAL — Remove the rockerbox covers and gaskets. Refer to REMOVAL under Rockerbox Covers, in this chapter. Rotate the propeller until the piston in the cylinder is near the top of its compression stroke (both valves closed, and rocker arms free). Loosen the pushrod cover gland nut at the cylinder end first; then at the crankcase end [**Figure 8—30**], using PWA-5630 Wrench. Depress the rocker arm using PWA-455 Depressor [**Figure 8—31**], and remove the pushrod and cover assembly.

INSPECTION — Inspect the pushrods for cracks and make sure that the oil holes in the ballends are free from obstruction. Examine the rods for roundness and straightness by rolling them on a plane surface [**Figure 8—32**]. Steel pushrods should be straight within .010 inch full indication. It is permissible to straighten such rods as long as the bend is not more than ½ inch full indication or ¼ inch measured in the center of the rod in relation to a straight reference. There should be no sharp corners or dents to act as stress raisers and promote fatigue.

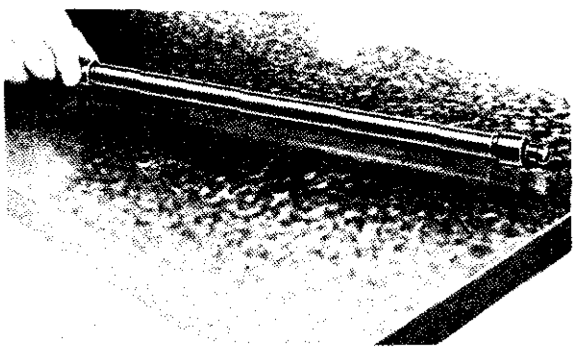
Replace any ballends which are loose or excessively worn using PWA-4877 Puller or PWA-2152-1 Drift. Scoring of the rods when installing the ballends could create an undesirable shoulder. To preclude this, chill the rods in dry ice for five to fifteen minutes and heat the ballends in oil heated to 177°C (350°F) for fifteen minutes. Using PWA-4877



[8—30] **Crankcase End**



[8—31] Depress Rockers



[8—32] Examine Rods

Puller assemble the ballends on the pushrods using the required quantity of spacers.

Care must be taken to maintain the proper alignment between the ball-end and the rod when assembling the parts.

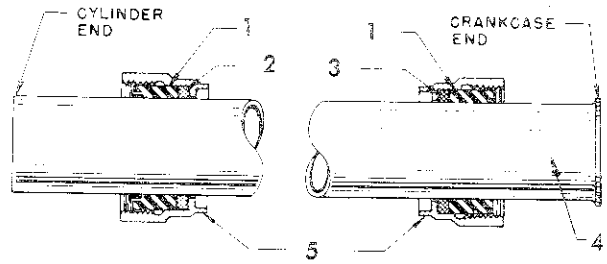
Inspect the pushrod covers for cracks and dents; and the gland nuts for thread and wrench slot condition. Replace if necessary. INSTALLATION — The pushrod ballend that contacts the tappet bears the number of the cylinder into which it fits. The exhaust rods are marked with an "Ex" after the cylinder number and the intake rods are marked "In". Apply a thin even coat of Dow Corning No. 4 insulating compound to the oil seal packing rings, if a black seal is being used.

Do not apply Dow Corning No. 4 when red seals are used. Red seals are used during the manufacture of new engines and are incorporated in the spare pushrod cover assemblies.

Install the packing rings in place in each gland nut **[Figure 8—33]**. Coat the ballends of each rod with oil. Assemble the pushrod and cover assembly with the marked end of the pushrod and the flared end of the cover tube toward the crankcase. Depress each rocker with PWA-455 Depressor and fit the corresponding pushrod and cover into position. If the valve tappet protrudes too far to allow installation of its pushrod, turn the crankshaft until the tappet has receded sufficiently to permit installation of the pushrod. After the pushrod 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, and tighten to the recommended torque using PWA-5630 Wrench. Next tighten the gland nut on the cylinder head end of the cover tube to the same torque, and lockwire both nuts **[Figure 8—34]**.

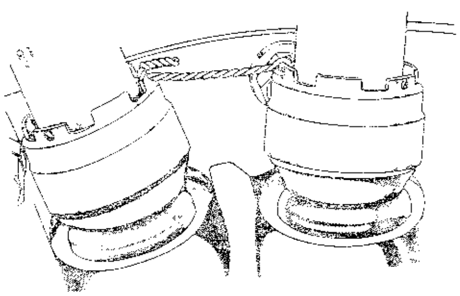
Never reverse the above sequence of operation as it might cause the packing on the tappet guide end to be pushed into the tappet compartment. Eventual mutilation of the packing during the engine operation would result.

PUSHROD COVER PACKING REPLACEMENT — Using wrench, unfasten pushrod cover nuts. Cut and remove packings. Using cutter, cut new packing and install around cover. Using wrench, tighten nut at tappet guide end to recommended torque, then torque nut at cylinder end. Always tighten nut at tappet guide end first. Lockwire nuts using procedure previously described.



	Wasp Jr.	Wasp
1. Seal	121839, 161701 or 559886	121839, 161701 or 559886
2. Fiber Packing (cylinder end)	14096	14096
3. Fiber Packing (crankcase end)	14096	52777
4. Pushrod Cover	282992	52775
5. Nut	9265	9265

[8—33] Pushrod Cover Packing Arrangement



[8—34] Lockwire Gland Nut

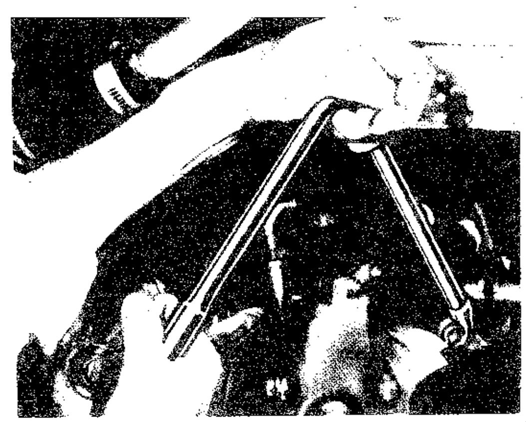
Cylinders, Pistons, and Pistonpins

PRELIMINARY INSTRUCTIONS — Observe the following instructions before removing cylinders:

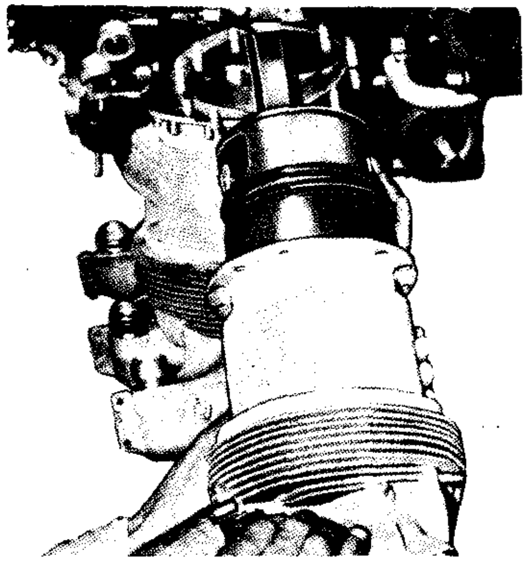
Remove the masterod cylinder (No. 5) last when its removal with one or more cylinders becomes necessary. If all cylinders are to be removed the following sequence should be observed: No. 6, 7, 8, 9, 1, 2, 3, 4, and 5.

Remove sections of the distributor air intake tubes, oil scavenge tube, or any tubes and controls which interfere with cylinder removal. Disconnect the rockerbox covers, pushrod covers, and remove the interfering intake pipes and exhaust stack extensions.

REMOVAL — Make certain that the piston in the cylinder to be removed is at the top of its compression stroke. Remove the palnuts and remove the cylinder hold down nuts with PWA-2397, PWA-2006 or PWA-2399 Wrench in conjunction with PWA-2398 or PWA-2411 Handle. Do not remove the top hold-down nut until just prior to the cylinder removal [**Figure 8—35**]. Support the cylinder with both hands while the top hold-down nut is being removed; then withdraw the cylinder straight out from the engine [**Figure 8—36**].



[8—35] Top Hold-Down Nut



[8—36] Remove Cylinder

Do not allow the linkrod (or masterrod) to strike the crankcase or the cylinder barrel as damage may result.

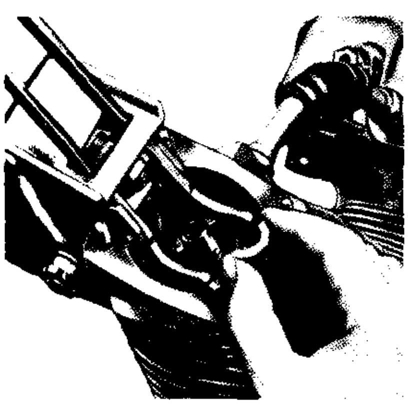
Place the cylinder in an appropriate carrier to prevent damage to the fin or flange areas. Using PWA-4911 Pusher, remove the pistonpin; then withdraw the piston straight out from the engine ensuring that the linkrod (or masterod) does not strike the crankcase. Place the piston and pistonpin in an appropriate carrier to prevent damage to the parts. Install PWA-2488 Holder on the linkrod (or masterod).

If a nut is found to be loose or there has been failure of a stud, replace that stud and the two adjacent studs in accordance with paragraph entitled ***Studs*** *in this chapter.*

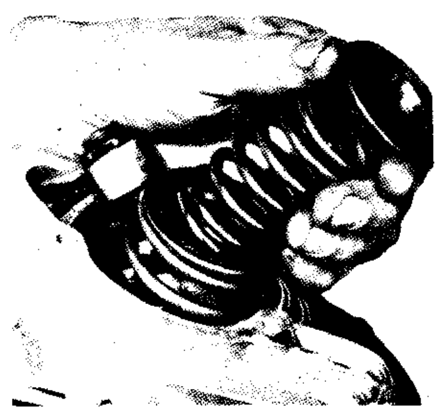
If only two adjacent studs have failed or two adjacent nuts have been found loose, the cylinder may be reused provided the nuts adjacent to the failed studs or adjacent to the loose nuts are found to be at least to the minimum torque.

If more than two adjacent studs have failed or if more than two adjacent nuts are known to have been loose during engine operation, the cylinder should be returned to overhaul, and all the studs on the cylinder mounting pad replaced.

DISASSEMBLY — VALVES AND SPRINGS — Place the cylinder over a wood or fiber block shaped to fit the contour of the cylinder head. Compress the valve springs, using PWA-459 Compressor, and remove the split locks **[Figure 8—37]**. Withdraw the upper washers and springs from the rockerbox **[Figure 8—38]**, and remove the snapring from the valve stems. Lift out the lower washers using long nosed pliers **[Figure 8—39]**. Raise the cylinder from

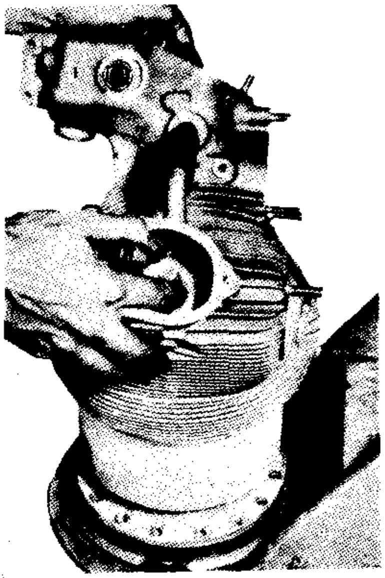


[8—37] Remove Split Locks

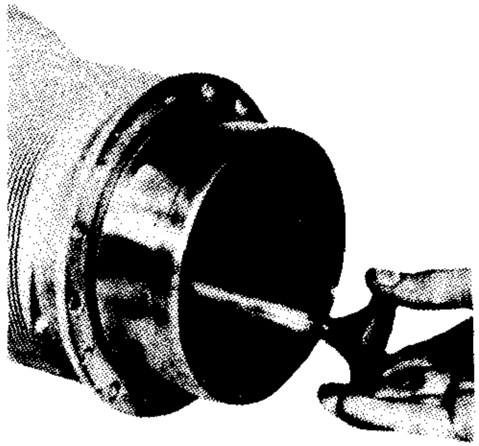


[8—38] Withdraw Washers

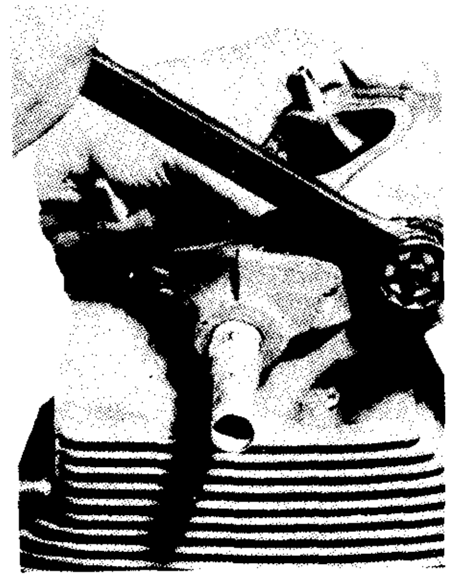
[8—39] Lower Washers



[8—40] Raise Cylinder



[8—41] Lift Out Valves

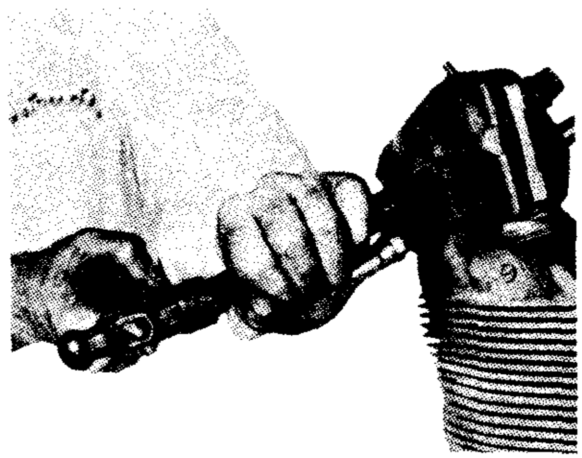


[8—42] Remove Nut

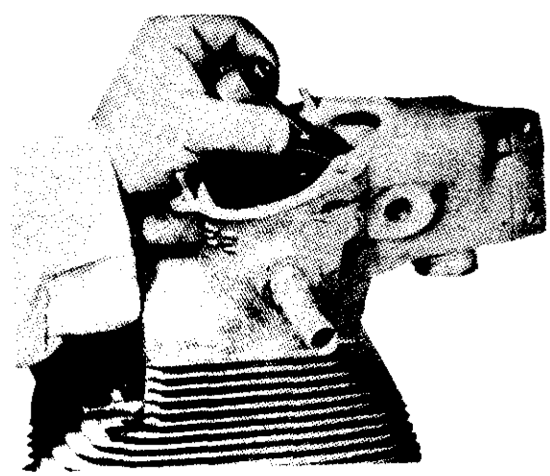
the block **[Figure 8—40]** and lift out the valves **[Figure 8—41]**. Do not let the valves fall out and strike the cylinder walls. Place the valves in a rack so that they will not be damaged.

If the valve springs and rockers are to be removed from a cylinder on the engine, the propeller should be rotated until the piston of the cylinder from which the springs and rockers are to be removed is at the top of its compression stroke. 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, in addition to facilitating removal.

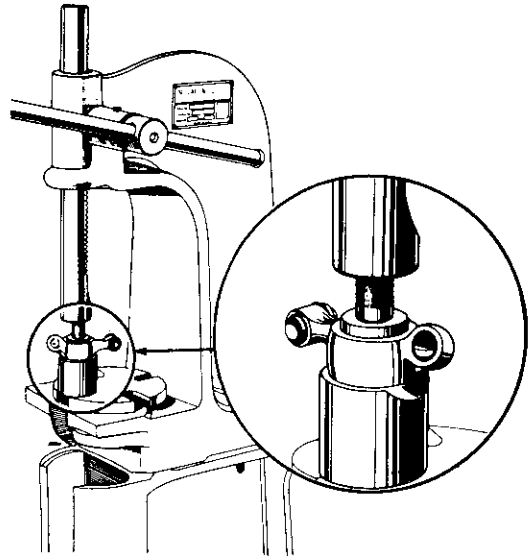
ROCKERS AND ROCKER BEARINGS — Remove the nut from the inner (large) end of the rockershaft **[Figure 8—42]**. Hold the inner end; remove the outer nut and washer. Drift out the shaft **[Figure 8—43]**, by driving on the small end with a fiber drift; then lift out the rocker **[Figure 8—44]**. If the bearing is to be removed, place the rocker on an arbor press and press out the rocker bearing, using PWA-614 Drift and Base **[Figure 8—45]**.



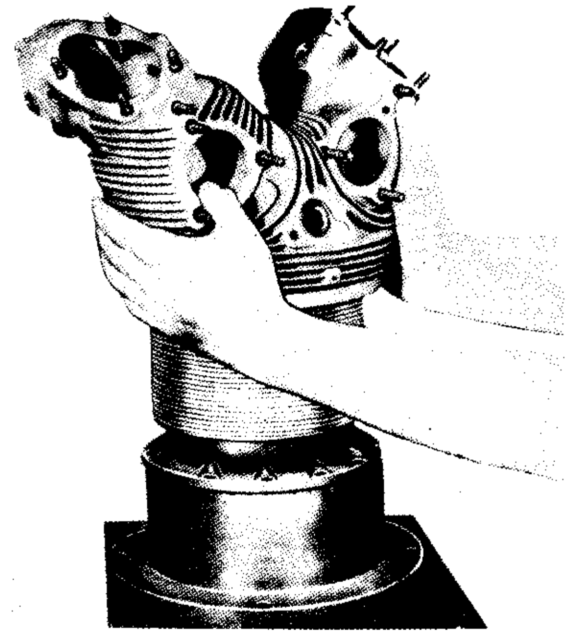
[8—43] Drive Out Shaft



[8—44] Lift Out Rocker



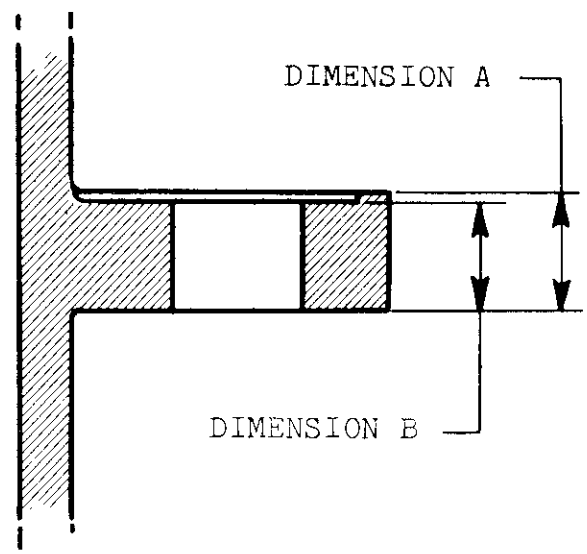
[8—45] **Rocker Bearing**



[8—46] **Lap Flange**

INSPECTION — If facilities are inadequate for the repair or replacement of defective parts, replace the cylinder with a complete new assembly, including new piston and rings which have been run-in lapped.

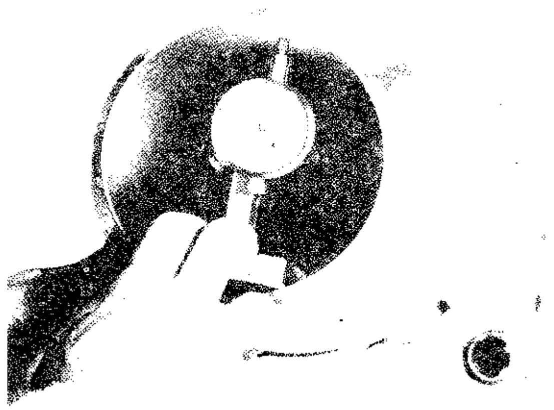
CYLINDER BARRELS — Using PWA-2630-20 Gage for Wasp Jr. engines, PWA-2630-22 Gage for Wasp engines, and pencil carbon paper, check the cylinder hold-down flange for flatness and squareness. If the flange is uneven or distorted and the distortion does not exceed .003 inch, lap the flange, using PWA-2898 Lap for Wasp Jr. engines **[Figure 8—46]** or PWA-2199 Lap for Wasp engines. If the distortion exceeds .003 inch, replace the cylinder assembly. If a cylinder has never been subjected to stud failure, the flange may be lapped flat to the minimum dimensions shown **[Figure 8—47]**. If a cylinder has been subjected to stud failure and the flange warpage has not exceeded .003 inch, the flange may be lapped flat to a maximum of 0.003 inch, but in no case below the minimum dimensions shown [Figure 8—47]. If, however, a cylinder which has been subjected to stud failure and which has once been lapped, is again subjected to stud failure, it must be scrapped or rebarreled.



Dimension A	.247
Dimension B	.237

[8—47] **Flange Minimum Dimension**

The greatest wear in a cylinder barrel



[8—48] Measure Barrel

usually occurs at the rear, slightly toward the thrust side, where the upper piston ring reaches the top of its travel. This wear extends only a short way down the barrel, and the main part of the barrel's choke is not appreciably affected unless the condition is extreme. As wear increases at the top of the barrel, a step is formed. If this step exceeds .006 inch at any part of the circumference, replace the cylinder assembly.

Check the bore of the barrel for out-of-roundness. The bore should not be more than .006 inch out-of-round. It is permissible to let the diameter of the barrel at the step location reach .006 inch over the diameter of a standard bore, providing .006 inch out-of-roundness is not exceeded. If the diameter of the barrel at the step location or the out-of-roundness of the barrel is found to be excessive before 1500 hours of service, and providing the cylinder head is still in good condition, return the cylinder to stock and hold for return to the manufacturer for rebarreling. Replace the cylinder assembly. (The cylinder assembly will include piston and rings.)

Use 3472-T-3 Gage for Wasp Jr. engines or 1313-T-5 Gage for Wasp engines and PWA-312-11 Indicator to measure the wear and out-of-roundness of the barrel **[Figure 8—48]**. Set the needle of the indicator at the zero mark in the gage, which represents the basic diameter of the cylinder barrel. The presence or extent of wear and distortion may be determined by moving the indicator along the length of the barrel while looking for any fluctuations in positive or negative directions on the indicator in various radial positions. A positive reading at the top of the barrel indicates the amount of choke left in the tapered (pre-ground) type of barrel. By observing any difference in the diameters of the cylinders at a given distance from the end of the barrel, out-of-roundness of the cylinder at that location may be determined. A step at the top may be calculated by subtracting the indicator reading obtained above the top of the upper ring travel from that obtained at the exact top of the upper ring travel.

Examine the cylinder barrel for cracks, scoring, damaged fins, and other irregularities. Check the condition of metallized surfaces.

CYLINDER HEADS — Examine the fins around the heads for cracks and breaks. Blend any sharp corners to broken fins before installing the cylinder.

Use spherical tungsten carbide rotary files of various diameters from 3/16 inch to 5/8 inch in an air drill. Finish blend the reoperated area with Metalite, or equivalent, No. 50 Grit cloth pencil 5/8 ID, and 2-3/4 inches long. Following reoperation, carefully etch the area from which the crack was removed. If no further indications are found, thoroughly remove any remaining etching or neutralizing solution by flushing with water, using particular care to see that none remains on any portion of the cylinder.

Inspect areas adjacent to the sparkplug bushings for cracks and also around the exhaust ports. Cowl mounting lugs may be repaired as follows: Thoroughly clean the surface of the break and the area immediately surrounding the lug. Using a welding torch adjusted to give a soft neutral flame and an

Oxweld Linite welding rod (5 percent silicon) with No. 4 flux, build up the lug with the aid of a sheet iron template approximating finished dimensions. Use of a template will help to avoid considerable hand filing. Finish the lug by hand filing or with a hand burring tool. Locating on a normal cylinder from the rocker shaft bushing holes, the valve guide bushing holes or both, make a simple drill jig. Using a hand drill and this jig, drill the holes in the rebuilt lug. It is unnecessary to bake or reheat the head after the repair has been made.

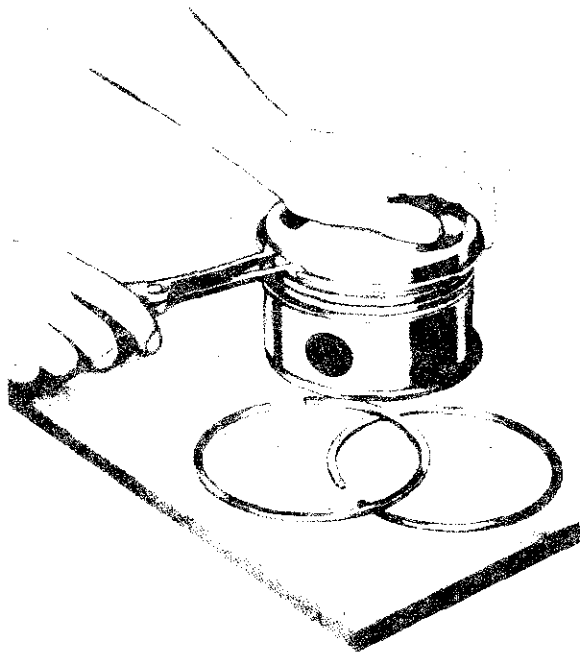
CYLINDER FIN BREAKAGE -- If more than 8 inches in length of any one fin is completely broken off or if the total fin breakage on any one cylinder head exceeds 20 square inches, the cylinder must be replaced. Where adjacent fins are broken in the same area, the total permissible length of breakage is 6 inches on any two adjacent fins and 4 inches on any three or more adjacent fins.

The length limits given are measured at the base of the fin. "Fin area" is defined merely as the total area exposed (both sides of fins) to cooling air.

Figure (8-49) and (8-50) deleted.

CYLINDER HOLD-DOWN NUTS AND STUDS -- Clean the threads of the nuts and studs thoroughly, using a hand wire brush if necessary. Inspect all studs for looseness, fractures at the base of the threads, straightness, nicks, burrs, and projection length. Inspect all hold-down nuts for thread condition. Replace all damaged studs or nuts as necessary. For replacement of studs refer to Studs, this chapter.

PISTONS -- Inspect the pistons for cracked heads and skirts, broken or distorted ring lands, scored or worn pistonpin holes, excessive carbon deposits, broken rings, or rings seized in their grooves. Rings may be removed with PWA-1791 Pliers (Figure 8-51). Clean the ring lands (Figure 8-52). Inspect the piston head for dishing, using PWA-3140 Gage. Replace the piston and rings together with the cylinder if necessary.



(8-51) Remove Rings

(8-52) Ring Lands

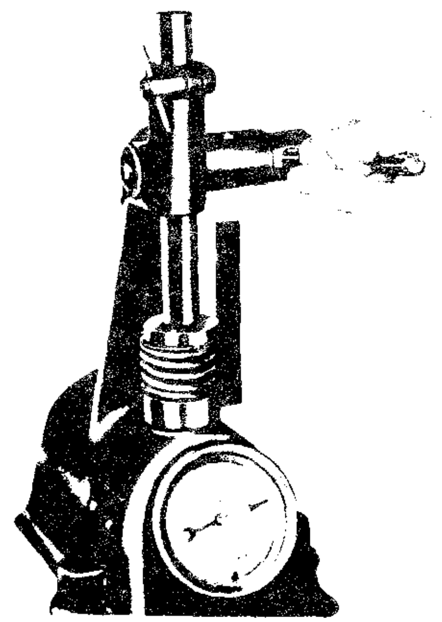
PISTONPINS -- Inspect the pistonpin for scoring, cracks, excessive wear, rust pitting, and out-of-roundness. Check the fit of each pistonpin in its bushing in the corresponding linkrod and in its bosses in the corresponding piston.

ROCKERS -- Examine the rockers for cracks and galling. See that no oil passages are obstructed. Inspect the socket in the pushrod 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.

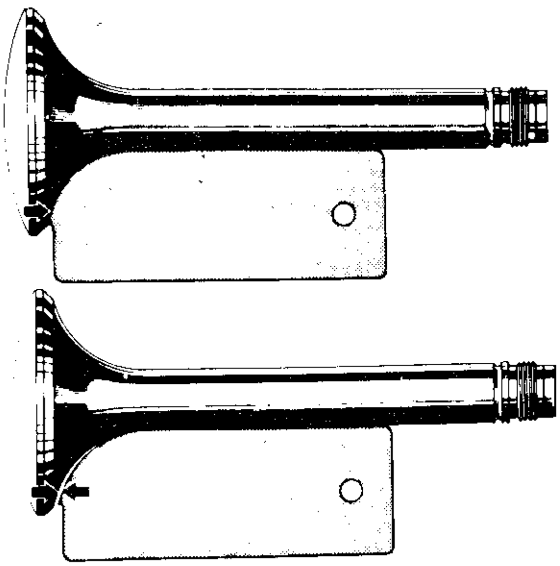
VALVE SPRINGS -- Inspect for cracks, broken ends, inadequate spring pressure (Figure 8-53), rust, and improper length.

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.



(8-53) Valve Springs



[8—54] **Exhaust Valve**

EXHAUST VALVES — Examine the exhaust valve for stretching and drawing of the valve stem, using PWA-737 Gage for Wasp Jr. engines **[Figure 8—54]** or PWA-450 Gage for Wasp engines. Inspect for poor seating surface, and remove excessive carbon.

To avoid possible injury to personnel, operators should dump discarded sodium filled valves in deep water where they cannot be recovered.

VALVE LAPPING — Lapping valves to the seat is not required if the seating surfaces show a ⅛ inch contact pattern around the full 360 degrees of the seating surface. Any valve that does not show the full contact pattern or that presents evidence of leakage should be lapped as follows:

Place a small amount of lapping compound on the seating surface of the valve; insert the valve stem into its guide.

Ensure that no lapping compound gets on the valve stem as undesired lapping of the valve guide will result.

Using PWA-10 Inlet Valve Holder or PWA-11 Exhaust Valve Holder, lap the valve to the seat with an oscillating motion, lifting the valve every few turns to a new location. Remove the valve at frequent intervals, wipe off the compound, and examine the seating surface. A properly lapped valve will show a ⅛ inch contact pattern around the entire seating surface, and will have a dull satin finish appearance.

The sealing efficiency of the valve assembly may be checked by partially filling the rocker box area over the valve with gasoline while the valve is in place and noting if the leakage occurs. Wash the valve and the valve seat thoroughly to remove all traces of the lapping compound.

FAILED CYLINDERS — 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 linkrod to ascertain whether or not it has been bent or damaged. Make visual check of all combustion chambers to determine whether or not they have been damaged in any way. Examine the pushrods 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 compression 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 a recommended run-in schedule.

ASSEMBLY — ROCKER AND SHAFT — Install the rocker bearings in the rockers, using PWA-614 Drift and Base. Make sure the oil holes in the bearings line up with the oil holes in the rockers. Place each rocker in position and insert the shaft through the bushings and rocker. Install the oil seal, washer, and nut on the small end of the shaft; then, holding the large end of the shaft with a wrench, tighten the nut to the recommended torque. Install the oil seal, gasket, and nut on the large end of the shaft, and tighten the nut to the recommended torque. Cotterpin the nuts.

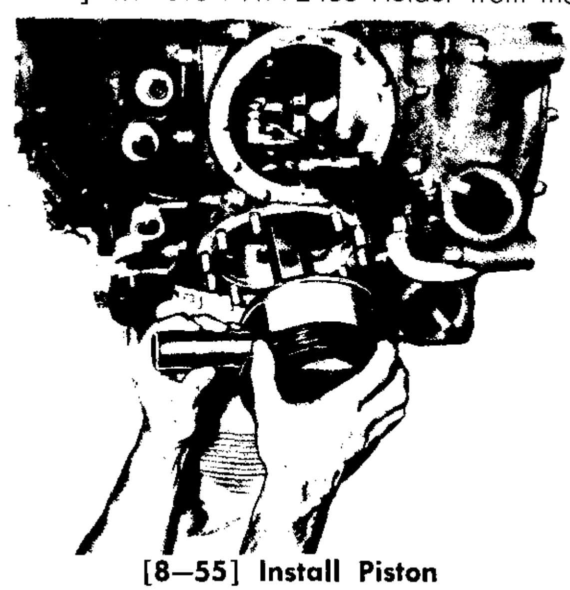
If improvement of the oil sealing characteristics at the inner end of the rockershaft is necessitated by excessive oil leakage, replace the oil seal, gasket, and the nut on the large end of the shaft with the improved type "O" ring seal, Part No. AN123867, and the nut, Part No. 343986, and tighten to the recommended torque. This replacement must be accomplished in sets only as the parts are not interchangeable.

VALVES — Clean and oil the 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. Install the lower valve spring washer, inner and outer valve springs, and the upper valve spring washer. Compress the valve springs, using PWA-459 Compressor, and install the split locks.

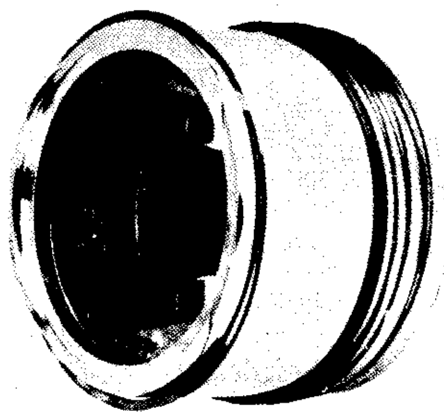
INSTALLATION OF CYLINDER AND PISTON

Before reusing any cylinders see Cylinder Removal and Inspection paragraphs in this chapter.

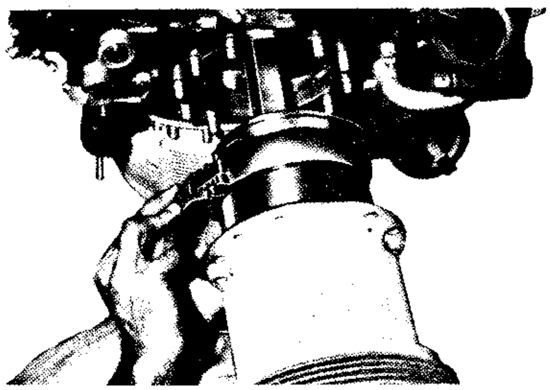
If masterod cylinder (No. 5) has been removed, it must be installed first. Coat the cylinder walls, pistonpin, piston, and pistonrings with oil. Install a new rubber oil seal ring under the hold-down flange of the cylinder. Rotate the crankshaft until the masterod or linkrod of the cylinder is at the full outward position. Each piston, pistonpin, and cylinder has a number denoting its proper position. Install the piston and pin with their numbered sides toward the front of the engine **[Figure 8—55]**. Remove PWA-2488 Holder from the



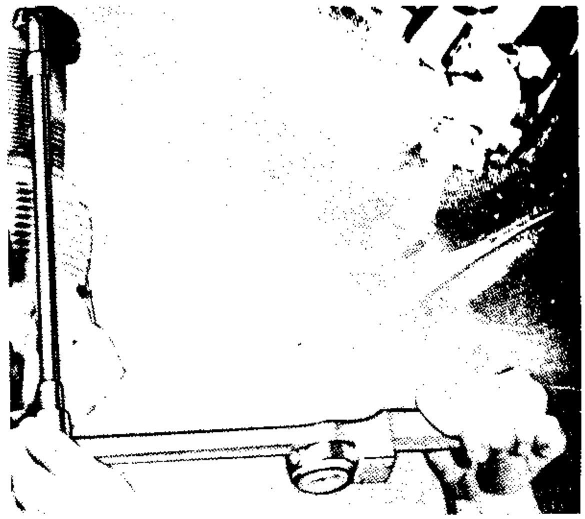
[8—55] Install Piston



[8—56] Ring Gaps



[8—57] Installing Cylinder



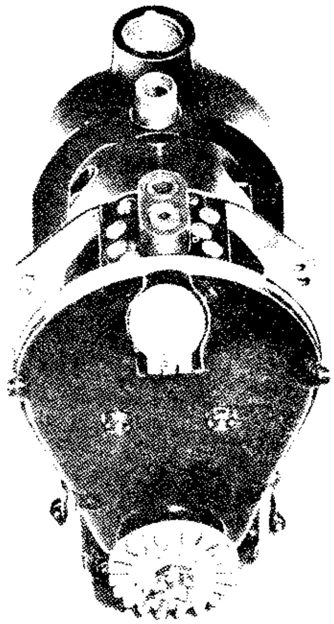
[8—58] Hold-down Nuts

linkrod (or masterod). Stagger the ring gaps **[Figure 8—56]** and apply a generous coating of oil to the rings; then compress the outer rings, using PWA-249 Clamp for Wasp Jr. engines or PWA-13 Clamp for Wasp engines, and slide the cylinder over the rings **[Figure 8—57]**. Compress the scraper ring with the clamp; then slide the cylinder over the ring and into place against the mounting pad. Install washers and nuts on the studs. Using PWA-2006, PWA-2397, or PWA-2399 Wrench, and PWA-2398 or PWA-2411 Handle, tighten the hold-down nuts evenly to ensure even load distribution around the cylinder flange; then using PWA-2239 Wrench and PWA-2240 Adapter **[Figure 8—58]** tighten the hold-down nuts to the recommended torque. Install palnuts over the hold-down nuts, running them down finger tight; then tighten ¼ turn.

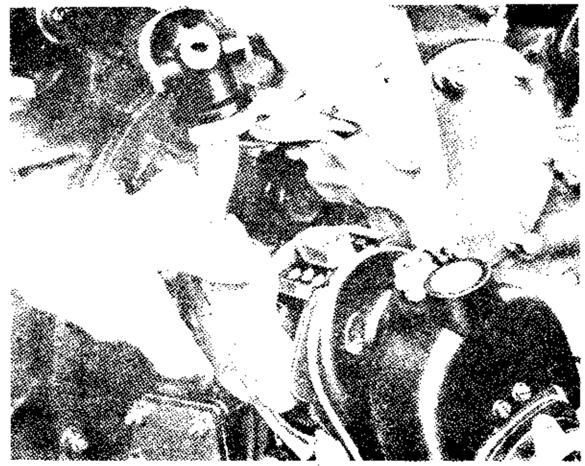
Because of the necessarily special design of cylinder hold-down nut wrenches, particular care should be exercised in tightening hold-down nuts. See that the cylinder hold-down nut wrench, the extension, and the torque indicating handle are so assembled that the handle is directly opposite the box end of the wrench, and apply torque by rotating the assembly as a unit. Do not let the shaft of the wrench twist to one side.

Install the pushrods and rockerbox covers; then check the valve stem to rocker clearance. Refer to Valve Clearance Adjustment, Adjustments chapter.

Regardless of the number of cylinders being replaced, the engine is to be run-in for ½ hour at 1000 RPM, ½ hour at 1400 RPM, and ½ hour in short spurts to 2000 RPM. During this run-in the cylinder head temperature should not exceed 205°C (400°F).



[8—59] **Magneto**



[8—60] **Remove Distributor Blocks**

[8—61] **Internal Timing**

Magnetos [**Figure 8—59**]

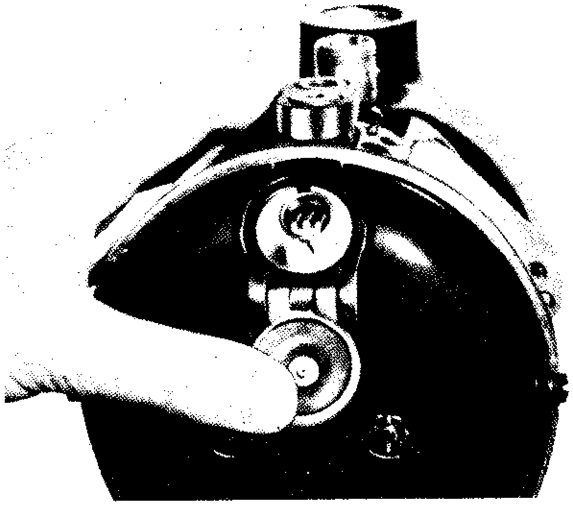
REMOVAL — Loosen the knurled coupling which secures the flexible conduit to the distributor block cover elbow using PWA-1886 Wrench. Remove the screws which secure the elbow to the distributor block cover.

Remove the screw which secures the distributor block cover halves of the magneto. Remove the safety pin, disengage the two spring locks on the distributor block cover; then remove the cover halves. Lift out the distributor blocks [**Figure 8—60**] and wrap each block in oiled paper.

Remove the three bolts which secure the magneto to its mounting pad and lift off the magneto and rubber coupling.

INSTALLATION — Before installing a magneto on the engine, the internal timing of the magneto should be checked. To do this, remove the breaker compartment cover. Attach the red wire of PWA-2417 Indicator to the breaker points and ground the black wire to the magneto housing. Place a straightedge against the step on the breaker can [**Figure 8—61**] and turn the magneto drive shaft in the normal direction of rotation. The light of the indicator should flash on just as the straightedge comes into alignment with the timing marks on the magneto housing. The timing marks shown through the timing window should align at this point [**Figure 8—62**]. If this check indicates that the magneto is not properly timed, the breaker points should be adjusted as follows: With PWA-2417 still connected and the straightedge aligned, loosen the contact bracket screws and turn the eccentric adjusting screw until the indicator light just flashes on, indicating that the points are just opening. Tighten the contract bracket screws.

After the internal timing has been found to be correct, position the No. 1 Piston 25 degrees before top center of its compression stroke as follows: Remove one sparkplug



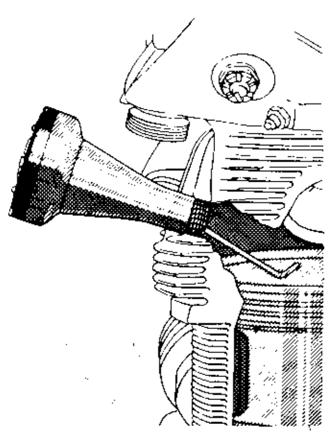
[8—62] Timing Window

from each cylinder and install PWA-3252 Vent Plugs in the sparkplug holes. Turn the engine crankshaft by means of the cooling fan or the propeller until the piston of No. 1 cylinder is at the beginning of the compression stroke. Install PWA-4142 Indicator in the top or front sparkplug hole of No. 1 cylinder [**Figure 8—63**]

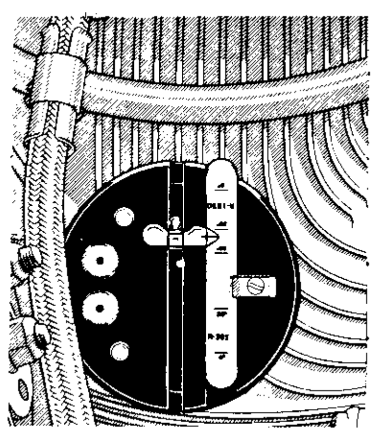
Use pivot arm "A" with hook end up for Wasp Jr. engines. Use pivot arm "A" with hook end down for Wasp engines.

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 at the top of the slot. Push the Slide pointer up close to the pivot arm [**Figure 8—64**]. Turn the propeller shaft in the direction of rotation until the pivot arm pushes the slide pointer to its farthest point [**Figure 8—65**]. 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-985 or R-1340) so that the zero degree mark on the scale aligns with the reference mark on the slide pointer [**Figure 8—66**]. Move the slide pointer up to align with the 25 degree mark on the scale [**Figure 8—67**]. Turn the propeller shaft in the normal direction of rotation until the pivot arm just contacts the slide [**Figure 8—68**]. At this point the lower light on the indicator should flash on. The No. 1 piston is now positioned 25 degrees before top center.

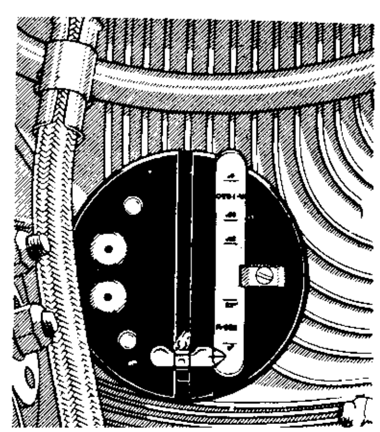
Mount the magneto on the engine without installing the rubber coupling Measure the distance between the magneto drive shaft and the magneto shaft couplings, making sure that the two shafts are at their maximum distance apart. Rubber couplings are provided 1/32 inch oversize, identified by "B + 1/32 inch" moulded on the face. The rubber coupling used should be .020 inch to .030 inch less in thickness than the distance between the two metal couplings. Remove the magneto from the engine.



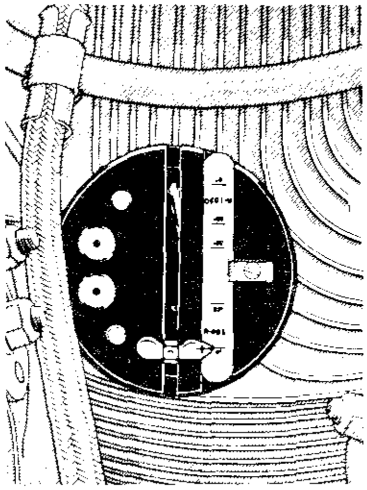
[8—63] Indicator



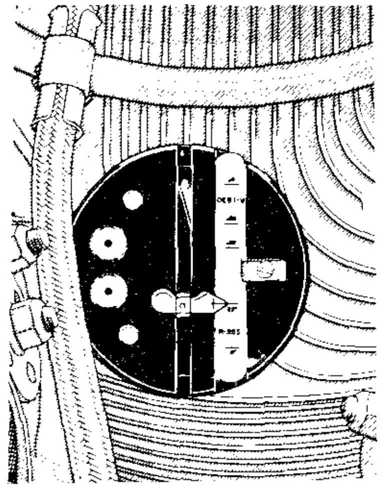
[8—64] Slide Pointer



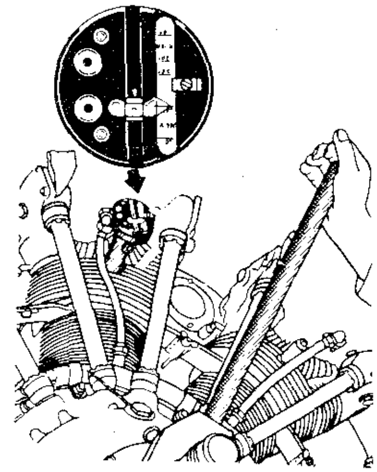
[8—65] Pivot Arm



[8—66] Align Scale

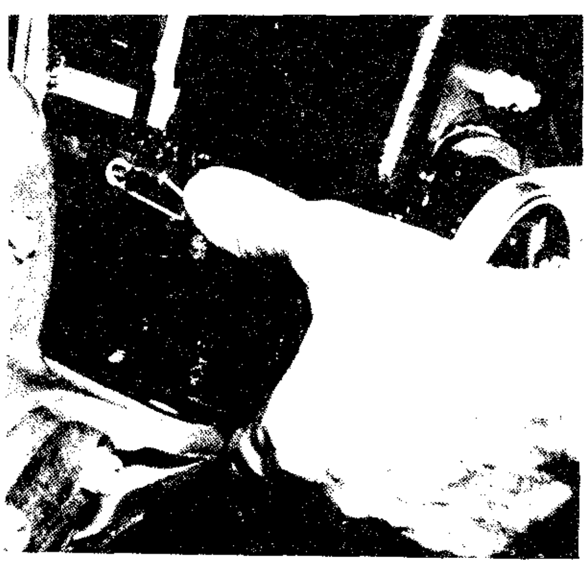


[8—67] Move Pointer Up

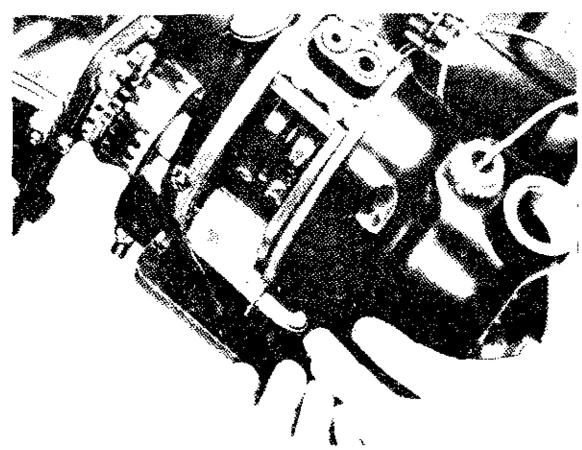


[8—68] Pivot Arm Contacts Side

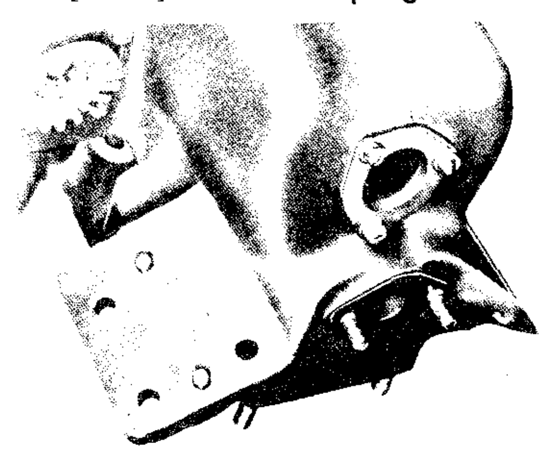
With the straightedge in exact alignment and with the rubber coupling in place, rest the magneto on the magneto mounting pad [**Figure 8—69**]. Hold the magneto in place and rotate the rubber coupling between the two metal couplings until the rubber coupling can be engaged with the metal couplings without causing the magneto shaft to turn [**Figure 8—70**]. Fit the magneto over the two dowel pins on the mounting pad [**Figure 8—71**]. Secure the magneto with the three bolts. Install the distributor blocks, [**Figure 8—72**], the distributor cover halves [**Figure 8—73**] and tighten the knurled coupling. Check to see that the magnetos are properly timed to the engine, and are synchronized to each other. Refer to Timing and Synchronizing



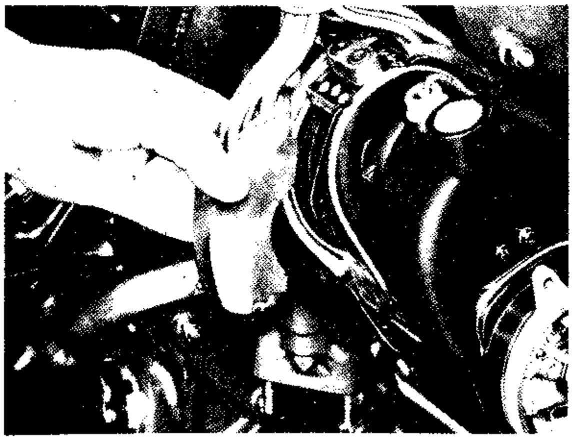
[8—69] Magneto Pad



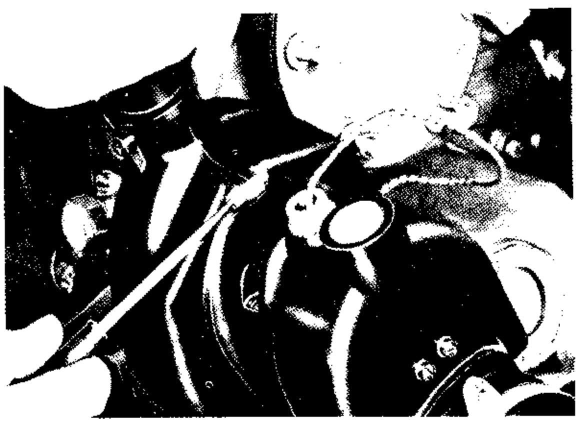
[8—70] Rubber Coupling



[8—71] Pad Dowel Pins



[8–72] Distributor Blocks



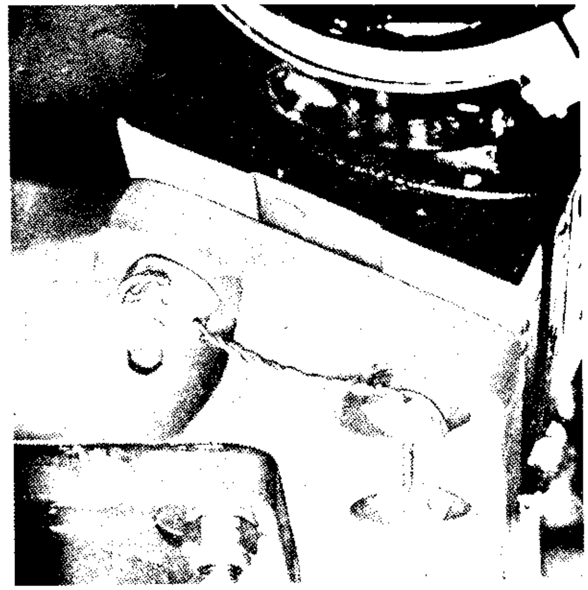
[8–73] Distributor Cover

Magnetos, Adjustments chapter. After this check has been completed, lockwire the three magneto retaining bolts [**Figure 8–74**].

Replacing Ignition Conduit Lead

Replace all ignition leads presenting evidence of chafing or deterioration of insulation. Remove the magneto flexible conduit to the distributor block cover elbow, the elbow from the distributor block cover, the distributor block cover halves, and lift the distributor blocks from the magneto. Refer to Magnetos, this chapter.

Remove the connector at the sparkplug end of the lead, and the sparkplug lead conduit from the ignition cable assembly. Loosen the coupling nut on the conduit and slide the



[8–74] Retaining Bolts

conduit towards the rear. Remove the lead from the distributor block. Determine in which direction the lead will pull the easiest; then splice and solder the new lead onto the opposite end of the old lead. Dust the lead with talc or soapstone to prevent friction. Push the new lead through as the old lead is slowly pulled out. When the new lead is through far enough, cut it off to the proper length.

Remove ½ inch of insulation from the distributor block end of the lead, being careful not to cut any of the lead strands. Separate the strands and bend them back along the insulation. Mark a new copper ferrule with the proper number, using a metal stamp; then install the ferrule and secure it with a crimping tool. Place the lead in its proper hole in the distributor block, and secure it with the piercing screw. Push the wire through the sparkplug lead conduit; then secure the conduit to the manifold.

Remove ⅛ inch of insulation from the lead, being careful not to cut any of the lead strands. The insulation must bear firmly against the brass disk inside the sparkplug connector. Treat the ends of the insulation with an insulating lacquer. After the lacquer has dried, slide the connector into position on

TABLES OF LEAD LENGTHS IN INCHES

	Wasp Engines Equipped with SB9R Magnetos			
No. of Distributor Block	Total Length Front Conduit	Total Length Rear Conduit	Wire Length from Rear Conduit to Left Magneto	Wire Length from Front Conduit Right Magneto
No. 1	57″	37″	18″	32½″
No. 2	51″	55″	19″	33½″
No. 3	62″	66″	17½″	32″
No. 4	75″	46″	18″	32½″
No. 5	62″	32″	19″	33½″
No. 6	50″	46″	17½″	32″
No. 7	57″	59″	18½″	33″
No. 8	83″	55″	20″	34½″
No. 9	73″	40″	19″	33½″

Wasp Jr. Engines
Equipped with SB9RN Magnetos

No. of Distributor Block	Total Length Front Conduit	Total Length Rear Conduit	Wire Length from Rear Conduit to Left Magneto	Wire Length from Front Conduit to Right Magneto
No. 1	53″	37″	18″	29″
No. 2	47″	55″	19″	30″
No. 3	58″	66″	17½″	28½″
No. 4	71″	46″	18″	29″
No. 5	58″	32″	19″	30″
No. 6	46″	46″	17½″	28½″
No. 7	53″	59″	18½″	29½″
No. 8	82″	55″	29″	31″
No. 9	66″	40″	19″	30″

the wire. Bend the strands back over the lead opening in a radial pattern. Do not solder the lead.

Oil Pressure Relief Valve

REMOVAL — Remove the acorn shaped cap from the oil pressure relief valve. Remove the oil pressure relief valve body, then withdraw the spring and plunger. Use PWA-671 Wrench **[Figure 8—75]** to remove the valve seat from the rear case **[Figure 8—76]**.

INSPECTION — Check the tension of the relief valve spring. Note the condition of the valve in the valve seat. Lap these parts with a very fine grade of lapping compound to form a perfect seat. The guide surfaces of the valve should have a free sliding fit in the seat. Polish the guide surfaces with crocus cloth and oil.

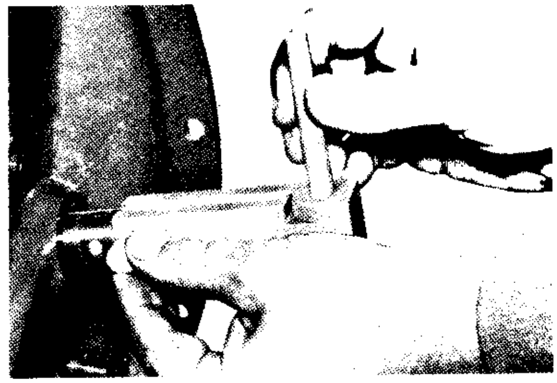
INSTALLATION — Install the valve seat in the rear-case, using PWA-671 Wrench. Insert the plunger and spring into the oil pressure relief valve body. Fit a new gasket under the flange on the valve body and screw the body into the rear case. Adjust the engine oil pressure. Refer to Oil Pressure Limits, Ground Checks chapter. Install a gasket and screw the acorn shaped cap on the outer end of the valve body. Lockwire the cap to the adjacent squarehead plug **[Figure 8—77]**.

Oil Pump [Figure 8—78].

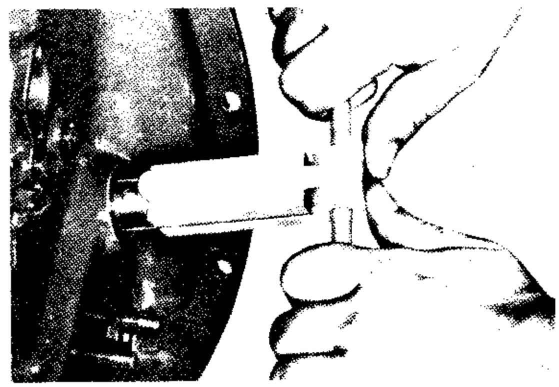
REMOVAL — Remove the nuts attaching the oil pump to the rear case. Attach PWA-1327 Puller to the oil inlet port studs and pull the pump from the rear case.

INSPECTION — Inspect the teeth for pitting and uneven contact. The gears should turn freely and show no indication of interference with the pump body. Oil passages must be clean.

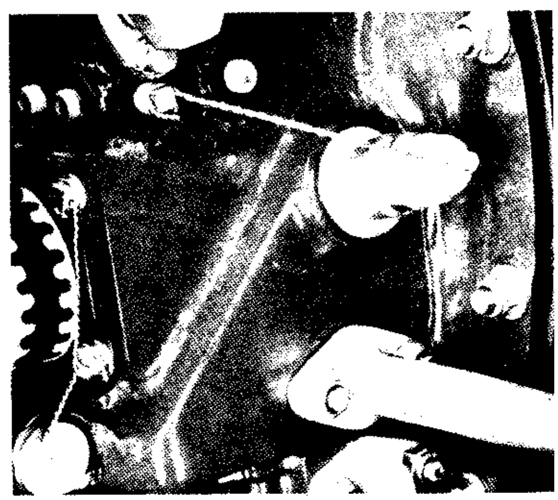
Inspect the body for cracks, scoring, and condition of paint. Check the oil seal rings for scoring and loss of tension.



[8—75] PWA-671 Wrench

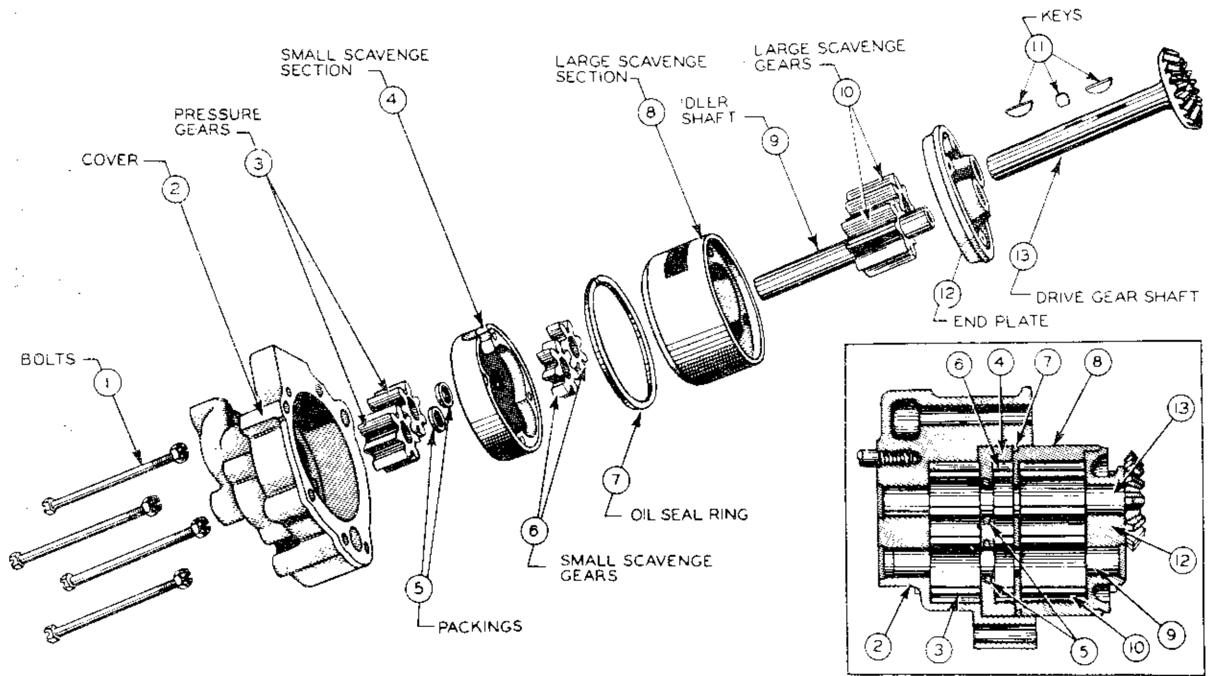


[8—76] Remove Valve Seat



[8—77] Lockwire Cap

INSTALLATION — Install the oil seal rings in position on the OD of the pump body. Fit a new gasket over the mounting flange on the oil pump housing. Install the oil pump in the rear case, engaging the drive gear with the accessory intermediate drive gear. Attach the pump to the rear case with washers and nuts.



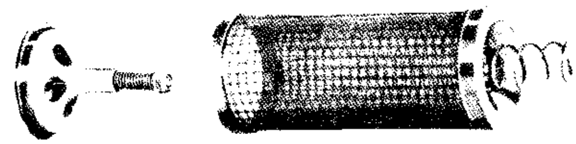
[8—78] **Oil Pump**

Pressure Oil Screen [Figure 8—79]

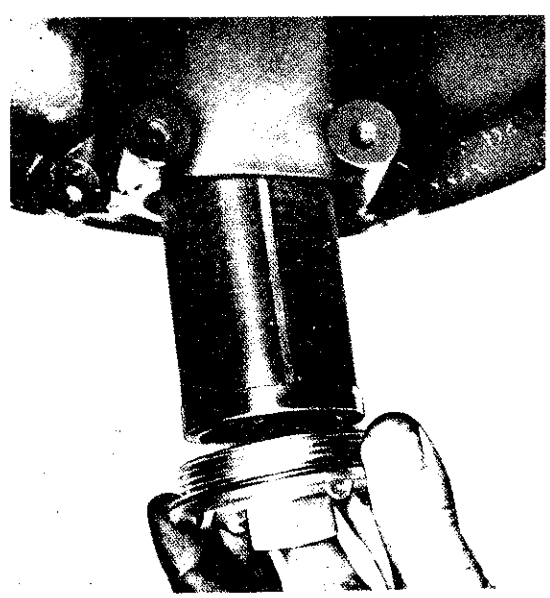
REMOVAL — Using PWA-228 Wrench, unfasten the oil screen cover nut; then remove the cover, spring, oil screen and check valve assembly **[Figure 8—80]**.

INSPECTION — Examine the screen for the presence of metal chips or foreign matter which may indicate a failure or some other unsatisfactory condition in the engine. Inspect the oil screen for distortion or splits at the soldered joints. Check the fit of the screen in its chamber in the rear case. Inspect the oil check valve to see that it is free and seats properly. Check the spring pressure and examine the cover for cracks and condition of paint.

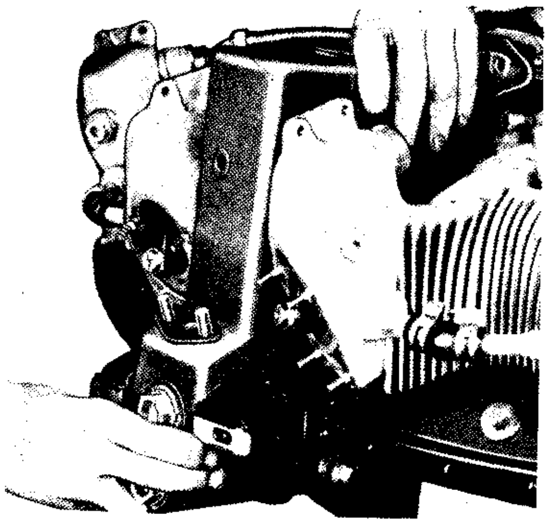
INSTALLATION — Insert the check valve assembly, oil seal and oil screen into the chamber in the rear case. Install the gasket and cover. Tighten the cover with PWA-228 Wrench. Lockwire the cover.



[8—79] **Pressure Oil Screen**



[8—80] Remove Screen Assembly



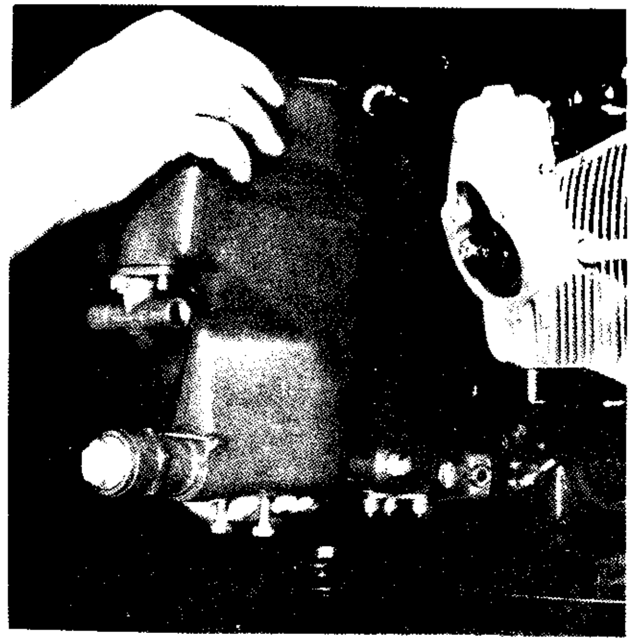
[8—81] Oil Sump

Oil Sump [Figure 8—81]

REMOVAL — Unscrew the elastic stop nuts which secure the rockerbox covers of cylinders No. 5 and No. 6 which are next to the sump. Disconnect the hose connecting them to the sump and remove the covers and hose. Remove the suction tubes from the rear of the sump. Remove the nuts wihch fasten the upper ends of the tubes to the right hand side of the rear section. Unfasten the clamps and remove the tubes. Unscrew the four nuts securing the oil sump to the engine. Pull the sump from the engine [**Figure 8—82**], taking care not to damage the oil pressure tubes which fit into the sump.

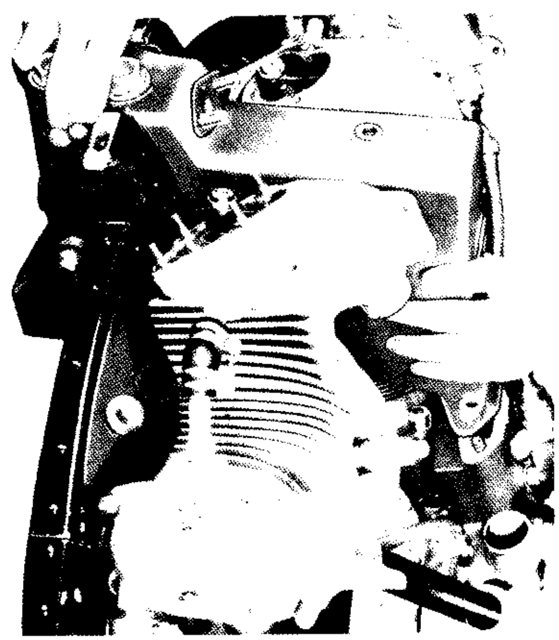
INSPECTION — Inspect the sump for cracks and condition of the paint. Seating surfaces must be clean and smooth. Check scavenge screen for distortion and condition of soldered joints. Make sure that the screen is thoroughly cleaned before it is reinstalled.

INSTALLATION — Place the intercylinder sump deflector on the sump while the latter is still on the bench and secure it. Screw the oil drain plugs into the bottom of the sump and tighten them to the recommended torque.

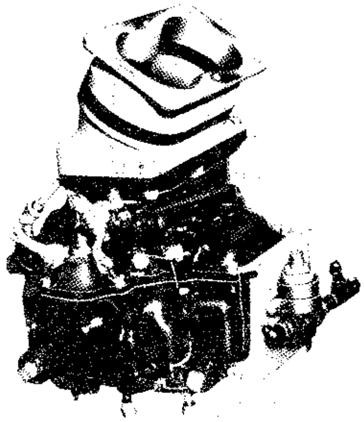


[8—82] Remove Sump

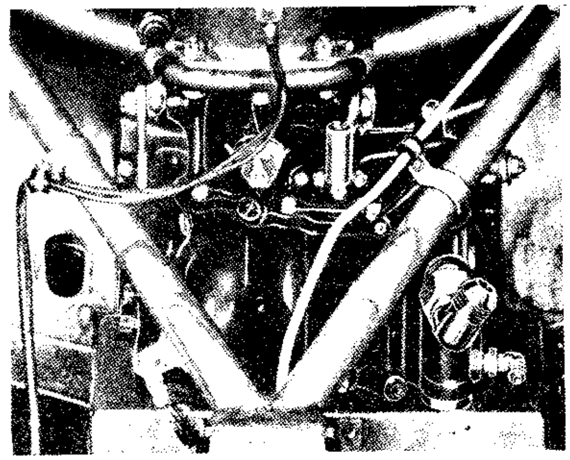
Place a new gasket on each mounting flange of the sump. Install the sump on its mounting pads [**Figure 8—83**]. Secure the two oil suction tubes to the sump and rear case, and install the tube clamps. Reinstall rockerbox covers and hose connections.



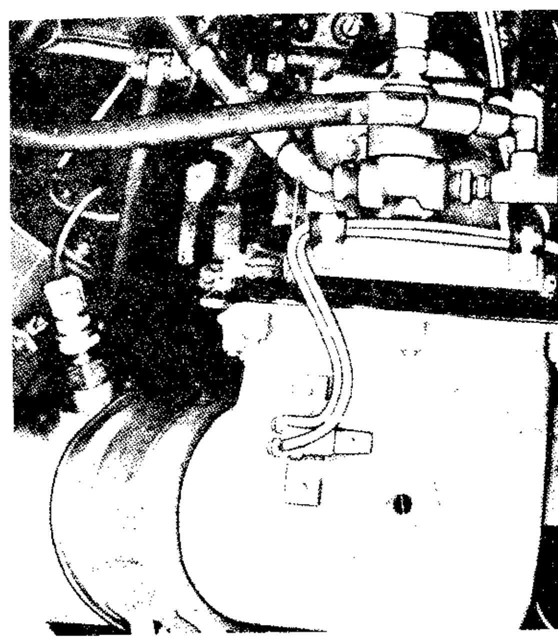
[8—83] Install Sump



[8—84] Carburetor and Adapter



[8—85] Install Carburetor



[8—86] Air Scoop Installed

Carburetor Replacement [Figure 8—84]

Depending upon the particular installation, remove the carburetor air scoop and disconnect the throttle control linkage and mixture control linkage. Remove the four nuts which secure the carburetor to the adapter and lift out the carburetor. Install the new carburetor **[Figure 8—85]** and secure it with the four nuts. Connect the control linkages and reinstall the carburetor air scoop **[Figure 8—86]**. Adjust the throttle stop and idle mixture strength. Refer to Carburetor Idling Adjustment, Adjustments chapter.

Propeller Governor Replacement

Remove the governor and governor mounting pad gasket. Inspect the surfaces of both the mounting pad and the governor base for foreign particles which might cause oil leakage or get into the governor and foul the operating mechanism.

If any stud in the governor mounting pad is found to be broken, replace all four studs.

Refer to Studs, this chapter, if replacement is necessary. Replace the governor mounting pad gasket and the governor in accordance with the applicable manufacturers, recommendations.

It is essential that the governor mounting pad nuts be drawn down evenly and then tightened to the recommended torque as excessive tightening may cause displacement of the gasket material in the vicinity of the mounting studs resulting in warpage of the governor base, subsequent oil leakage, or possible mounting stud failure.

If interference results between the governor mounting nuts and the governor replace the drilled studs P/N 43613 with undrilled studs P/N 20493 (1.078 inches) to a minimum projection length of .782 inch.

If interference results between the collector case stud (P/N 625) and the governor at the 11 or 1 o'clock positions because of the .875 inch stud projection length, it is permissible to drive the stud to a minimum projection length of .825 inch to obtain the necessary clearance.

Studs

GENERAL — The projection length of a stud is measured from the mounting surface to the side of the hole facing the mounting surface of drilled studs, and to the end of undrilled studs.

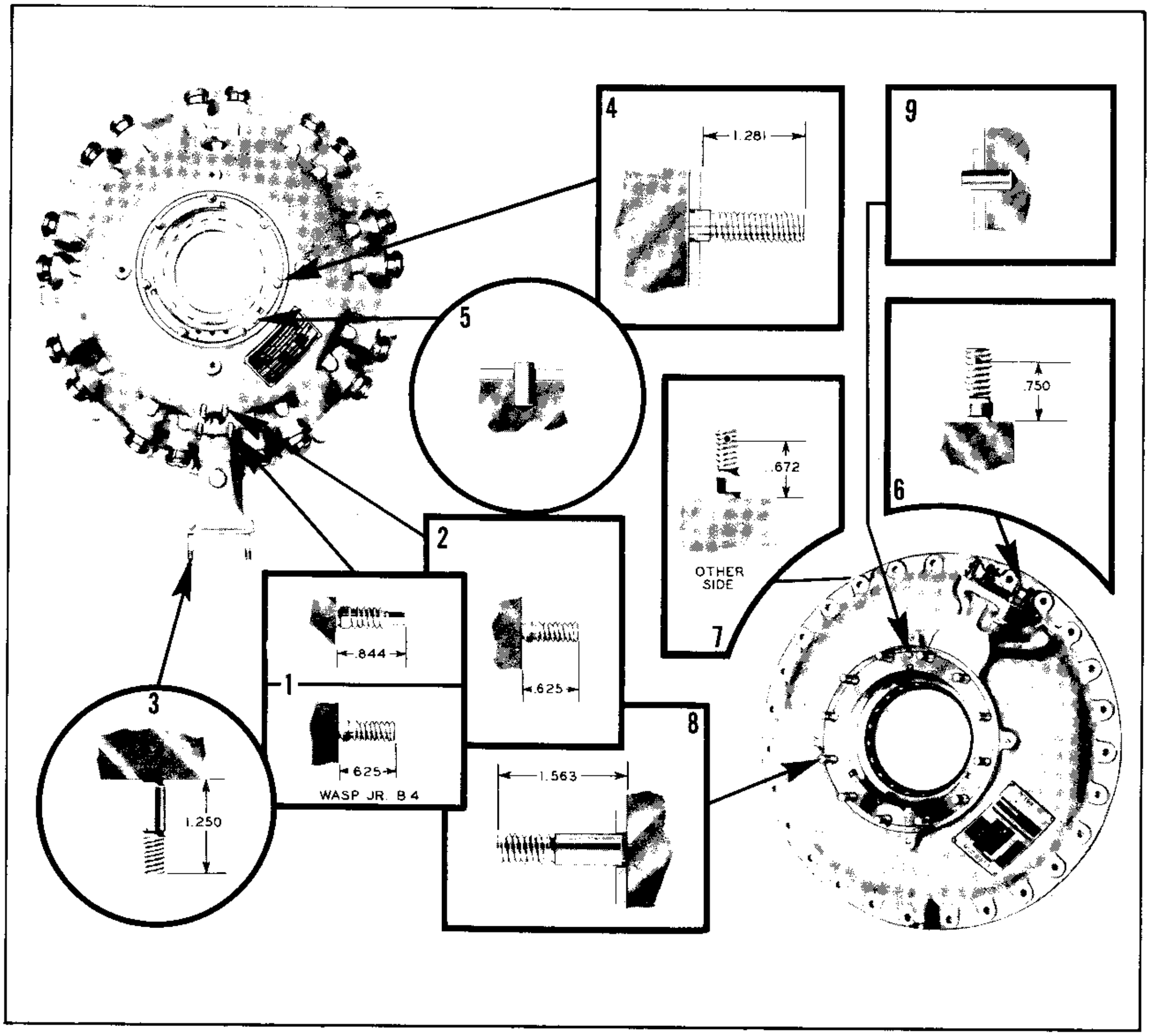
REMOVAL — Remove loose or broken studs which project above the mounting surface with an appropriate size stud extractor. Portions of broken studs remaining below the mounting surface generally may be extracted by utilizing the mounting hole in the mating part as a drill guide. Using a drill the same size as the hole in the mating part, spot drill the broken stud; then using the prescribed drill size for the type steel extractor being utilized, drill out the center portion of the stud. Drive the extractor into the drilled center of the stud and turn out the broken stud with a wrench or handle on the extractor. To facilitate stud removal heat may be applied to the particular locality.

INSTALLATION — If the stud hole is not damaged or worn replace the broken stud with a standard stud of the same size to the recommended torque (refer to Standard Studs, Limits chapter) and to the required projection length.

If the hole is worn or damaged, tap the hole with the appropriate oversize tap, and install a stepped stud to the recommended torque (refer to Stepped Studs, Limits chapter) and to the required projection length.

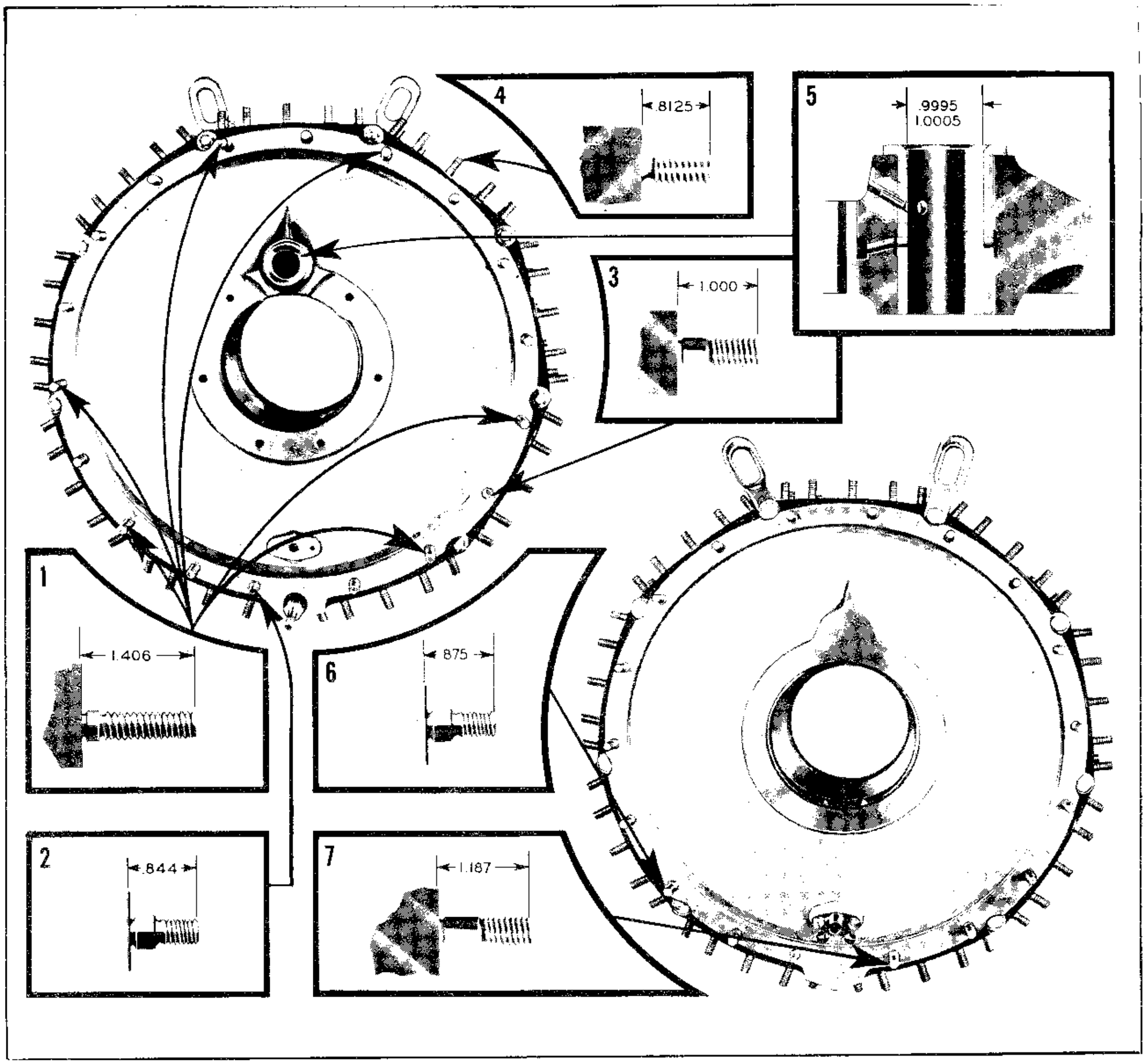
> *When installing an oversize stud in a stud hole which goes completely through a part, make sure that the anchor end of the stud does not project beyond the hole sufficiently to cause interference with other parts. If necessary, file off the anchor end enough to insure against such interference.*

THREADED INSERTS — If a threaded insert requires replacement, drill out any lockpins then remove the insert, using the proper tools. Install new inserts with the proper driver; drill new lockpin holes if necessary and install new lockpins. Refer to the Overhaul Manual for detailed instructions.



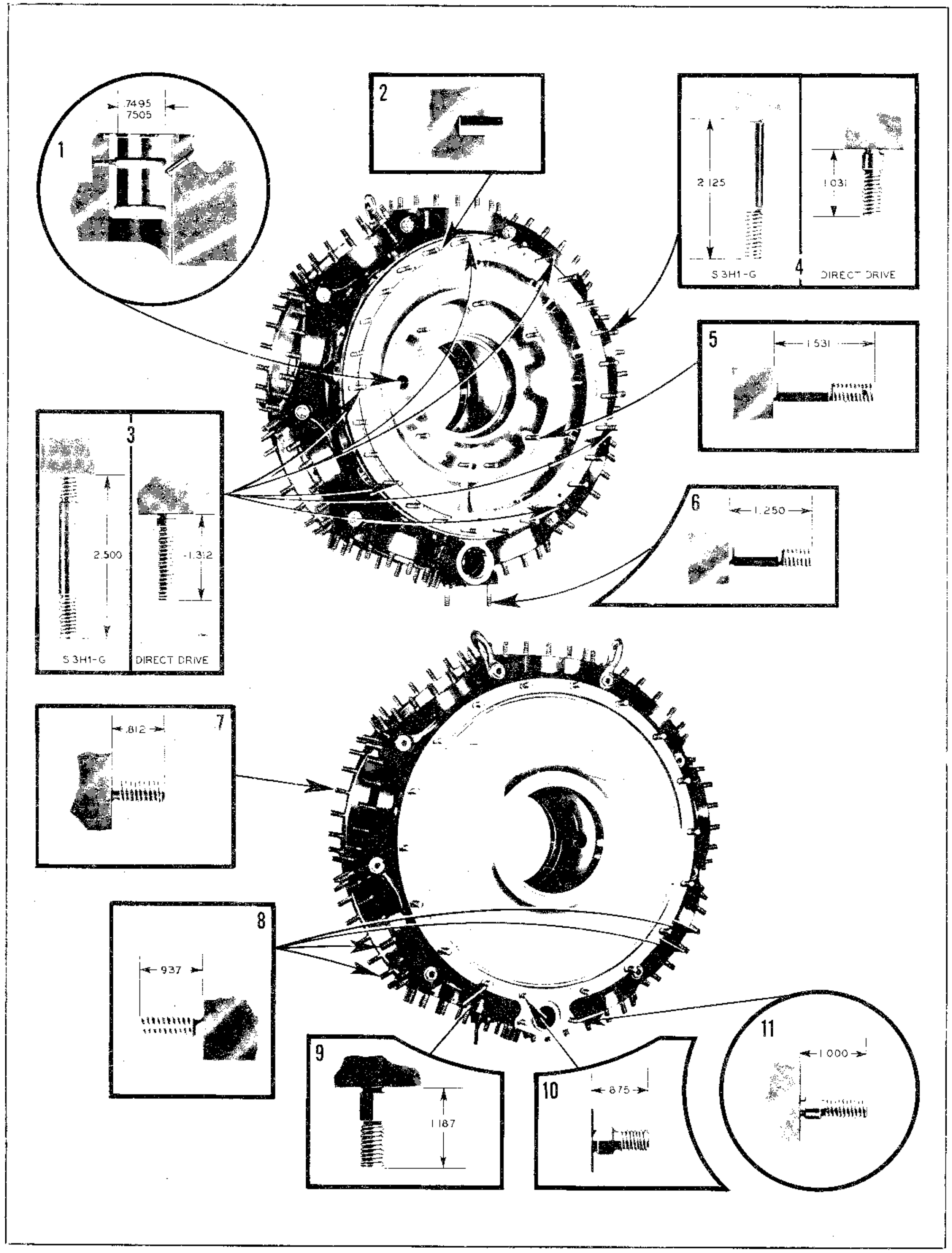
Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
1	Propeller Regulator Valve Stud	12088	2	1/4-28 Stud Driver	See "Studs"
2	Propeller Regulator Valve Stud	12089	2	1/4-28 Stud Driver	See "Studs"
1 and 2	Propeller Control Valve Cover Stud	28255	4	1/4-28 Stud Driver	See "Studs"
3	Sump Attaching Stud	12055	2	5/16-24 Stud Driver	See "Studs"
4	Thrust Cover Stud	42419	7	3/8-24 Stud Driver	See "Studs"
6	Governor Pad Stud	34919	4	5/16-24 Stud Driver	See "Studs"
8	Thrust Cover Stud	42418	12	3/8-24 Stud Driver	See "Studs"

Front Case Stud Replacement
(Direct Drive Engines)



Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
1	Front Crankcase Fastening Stud	38300	6	3/8-24 Stud Driver	See "**Studs**"
2	Front Crankcase Fastening Stud	42422	1	3/8-24 Stud Driver	See "**Studs**"
4	Cylinder Hold-Down Stud	12081	90	3/8-24 Stud Driver	See "**Studs**"
6	Blower Case Fastening Stud	12085	1	3/8-24 Stud Driver	See "**Studs**"
7	Blower Case Fastening Stud	12057	17	3/8-24 Stud Driver	See "**Studs**"

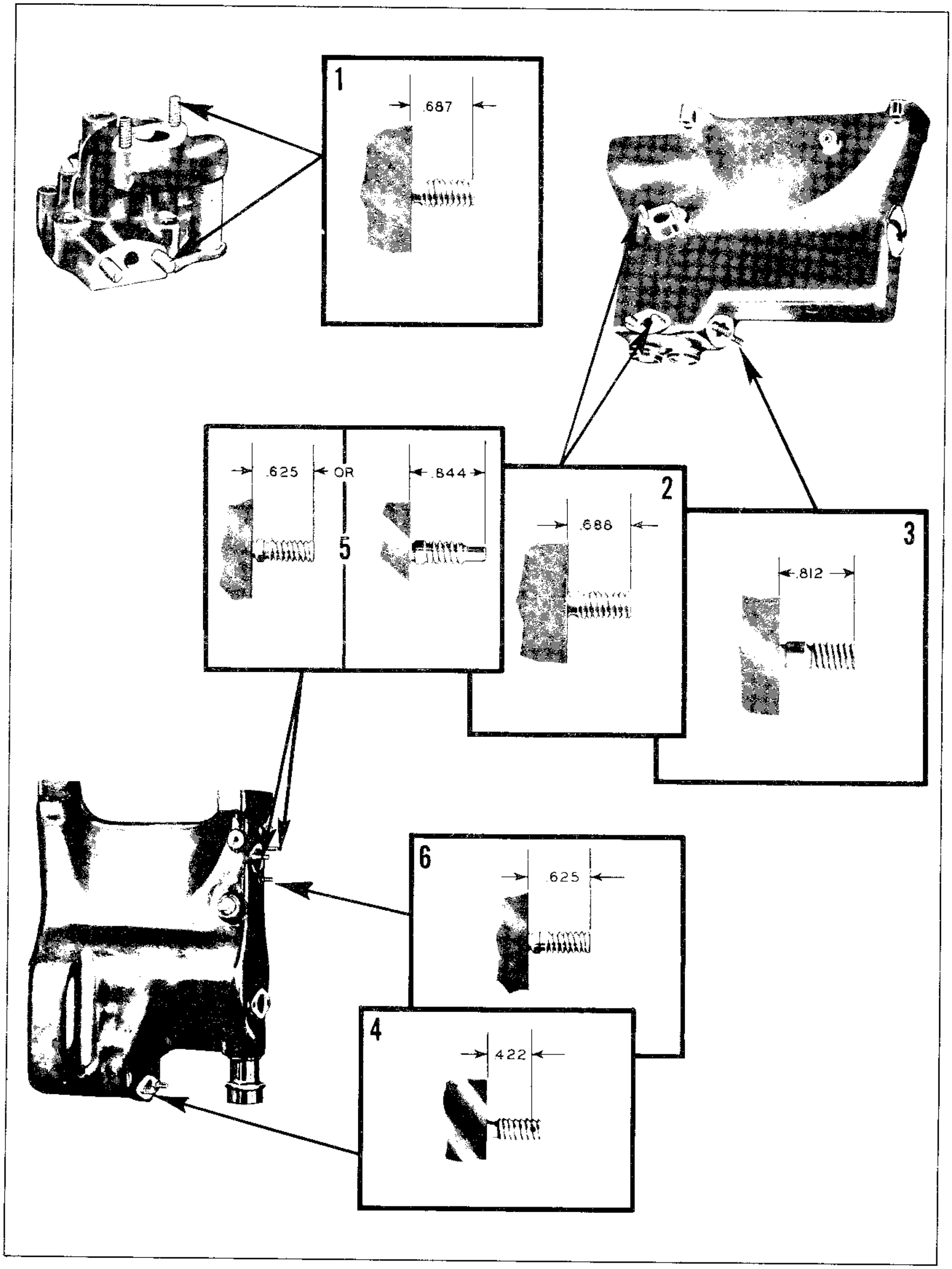
Crankcase Stud Replacement
(Wasp Jr. Engines)



Crankcase Stud Replacement (Wasp Engines)
(Sheet 1 of 2 Sheets)

Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
3	Front Case to Crankcase Stud	12052	6	5/16-24 Stud Driver	See "**Studs**"
	Front Case to Crankcase Stud	658	6		Used on Wasp H1-G only.
4	Front Case to Crankcase Stud	14782	21	5/16-24 Stud Driver	See "**Studs**"
	Front Case to Crankcase Stud	54611	21		Used on Wasp H1 only.
6	Sump Attaching Stud	12055	7	5/16-24 Stud Driver	See "**Studs**"
7	Cylinder Hold-Down Stud	12081	140-144	3/8-24 Stud Driver	See "**Studs**"
8	Cylinder Hold-Down Stud	23583	0-4	3/8-24 Stud Driver	See "**Studs**"
9	Blower to Crankcase Stud	12057	17	3/8-24 Stud Driver	See "**Studs**"
10	Blower to Crankcase Stud	12085	1	5/16-24 Stud Driver	See "**Studs**"
11	Blower to Crankcase Stud	656	2	5/16-24 Stud Driver	See "**Studs**"

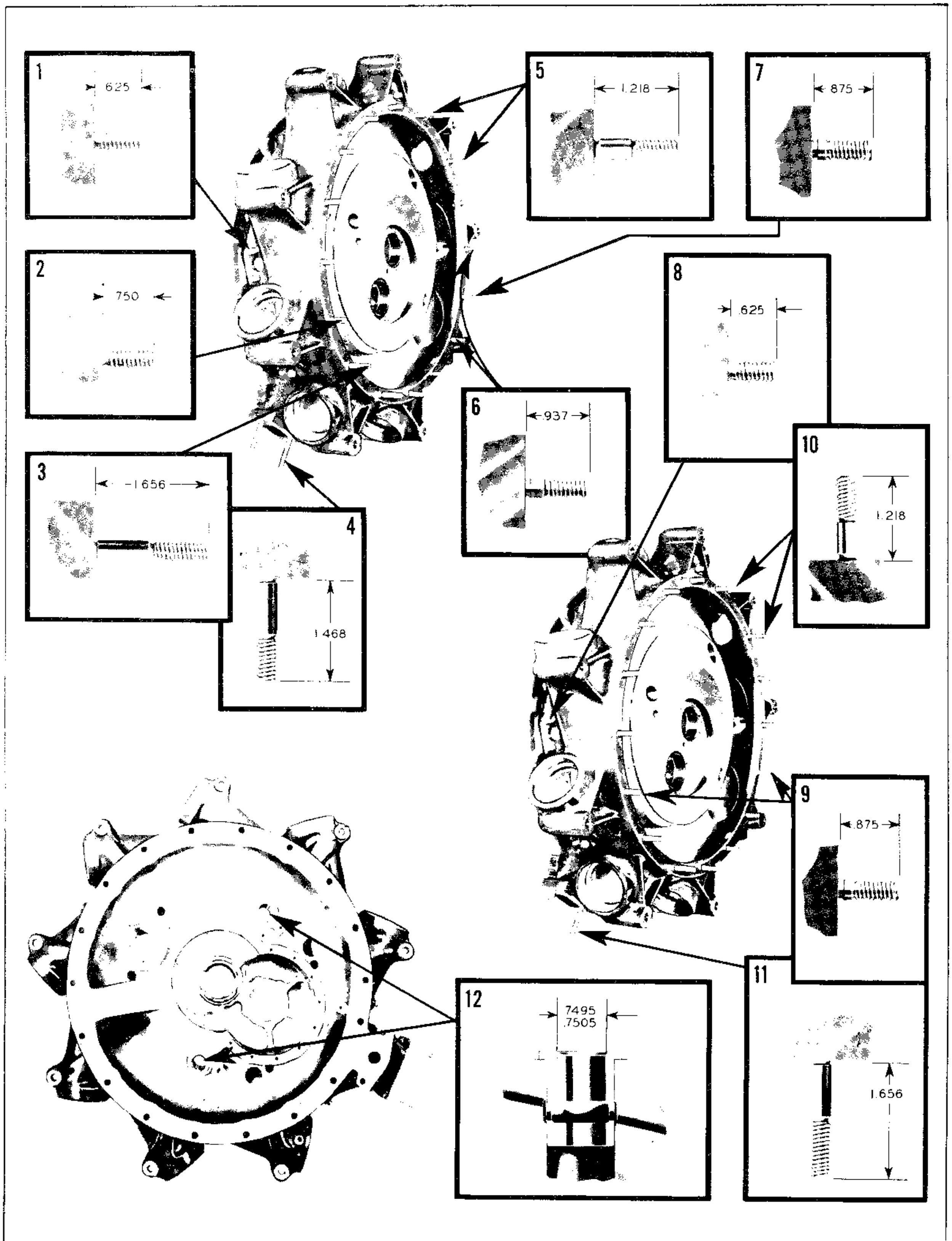
Crankcase Stud Replacement (Wasp Engines)
(Sheet 2 of 2 Sheets)



Oil Pump and Sump Stud Replacement (Sheet 1 of 2 Sheets)

Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
1	Oil Tube Flange Stud	12317	4	5/16-24 Stud Driver	See "**Studs**"
2	Scavenge Tube Stud	12317	4	5/16-24 Stud Driver	See "**Studs**"
3	Scavenge Tube Stud	39079	2	5/16-24 Stud Driver	See "**Studs**"
4	Scavenge Tube Stud	621	2	5/16-24 Stud Driver	See "**Studs**"
5	Propeller Control Valve Flange Stud	12088	2	1/4-28 Stud Driver	Used on sumps incorporating propeller control valve.
	Propeller Control Valve Flange Stud	12089	2	1/4-28 Stud Driver	Used on sumps not incorporating propeller control valve
6	Propeller Control Valve Flange Stud	12089	1	1/4-28 Stud Driver	See "Studs"

Oil Pump and Sump Stud Replacement (Sheet 2 of 2 Sheets)

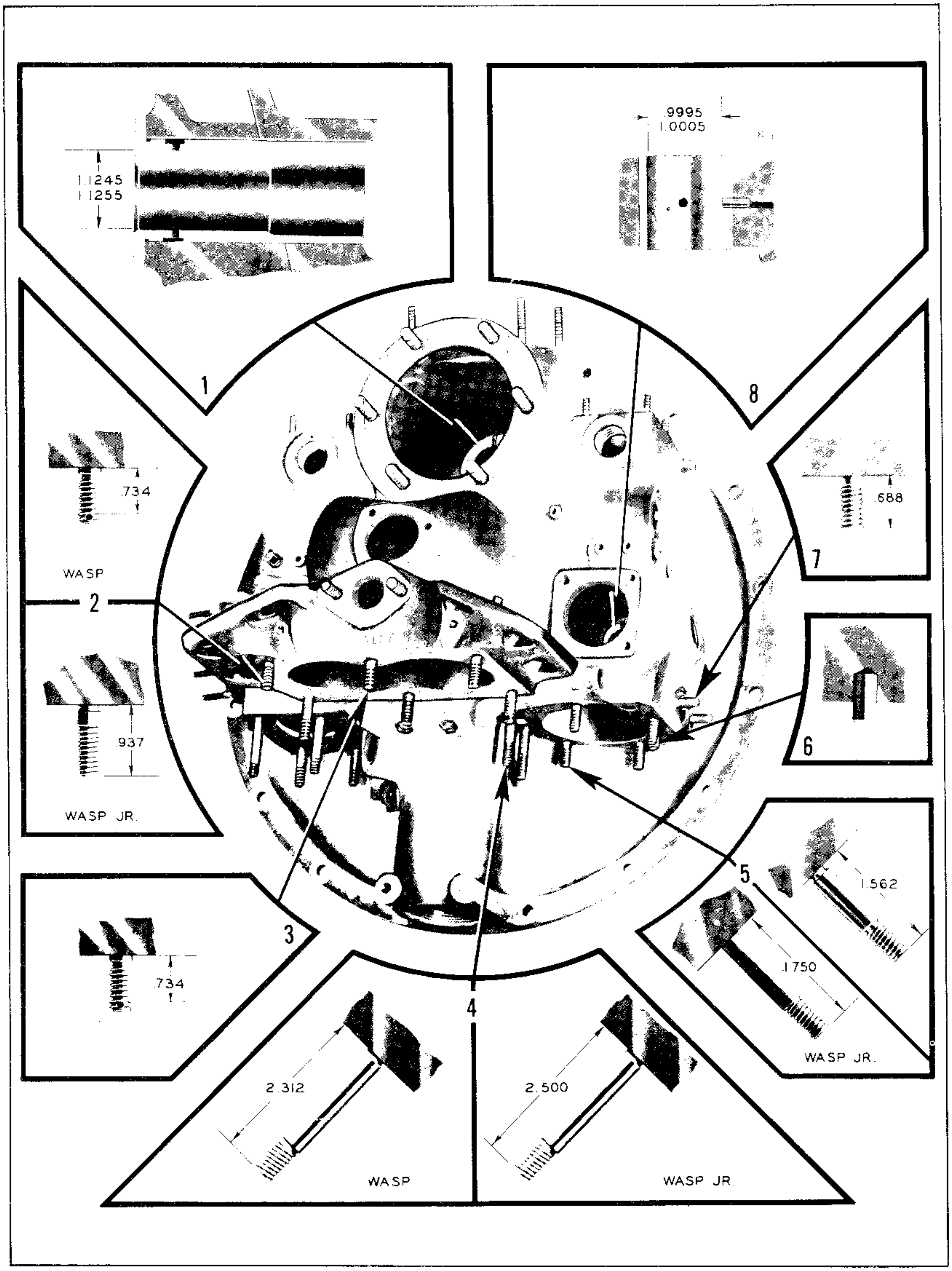


Blower Case Stud Replacement (All Models)
(Sheet 1 of 2 Sheets)

Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
			WASP JR. ENGINES		
1	Oil Drain Tube Stud	12054	2	5/16-24 Stud Driver	See "Studs"
2	Blower to Rear Case Stud	9085	1	5/16-24 Stud Driver	See "Studs"
3	Blower to Rear Case Stud	9385	1	5/16-24 Stud Driver	See "Studs"
4	Oil Sump Attaching Stud	9252	2	5/16-24 Stud Driver	See "Studs"
5	Blower to Rear Case Stud	7959	3	5/16-24 Stud Driver	See "Studs"
6	Blower to Rear Case Stud	11345	2*	5/16-24 Stud Driver	See "Studs" *Use 4 on Wasp Jr. B5
7	Blower to Rear Case Stud	625	9*	5/16-24 Stud Driver	See "Studs" *Use 4 on Wasp Jr. B5 May be driven to .825 inch minimum projection length to avoid interference with the propeller governor.
			WASP ENGINES		
8	Oil Drain Tube Stud	12054	2	5/16-24 Stud Driver	See "Studs"
9	Blower to Rear Case Stud	625	12	5/16-24 Stud Driver	See "Studs"
10	Blower to Rear Case Stud	7959	4	5/16-24 Stud Driver	See "Studs"
11	Oil Sump Attaching Stud	9385	2	5/16-24 Stud Driver	See "Studs"

Blower Case Stud Replacement (All Models)
(Sheet 2 of 2 Sheets)

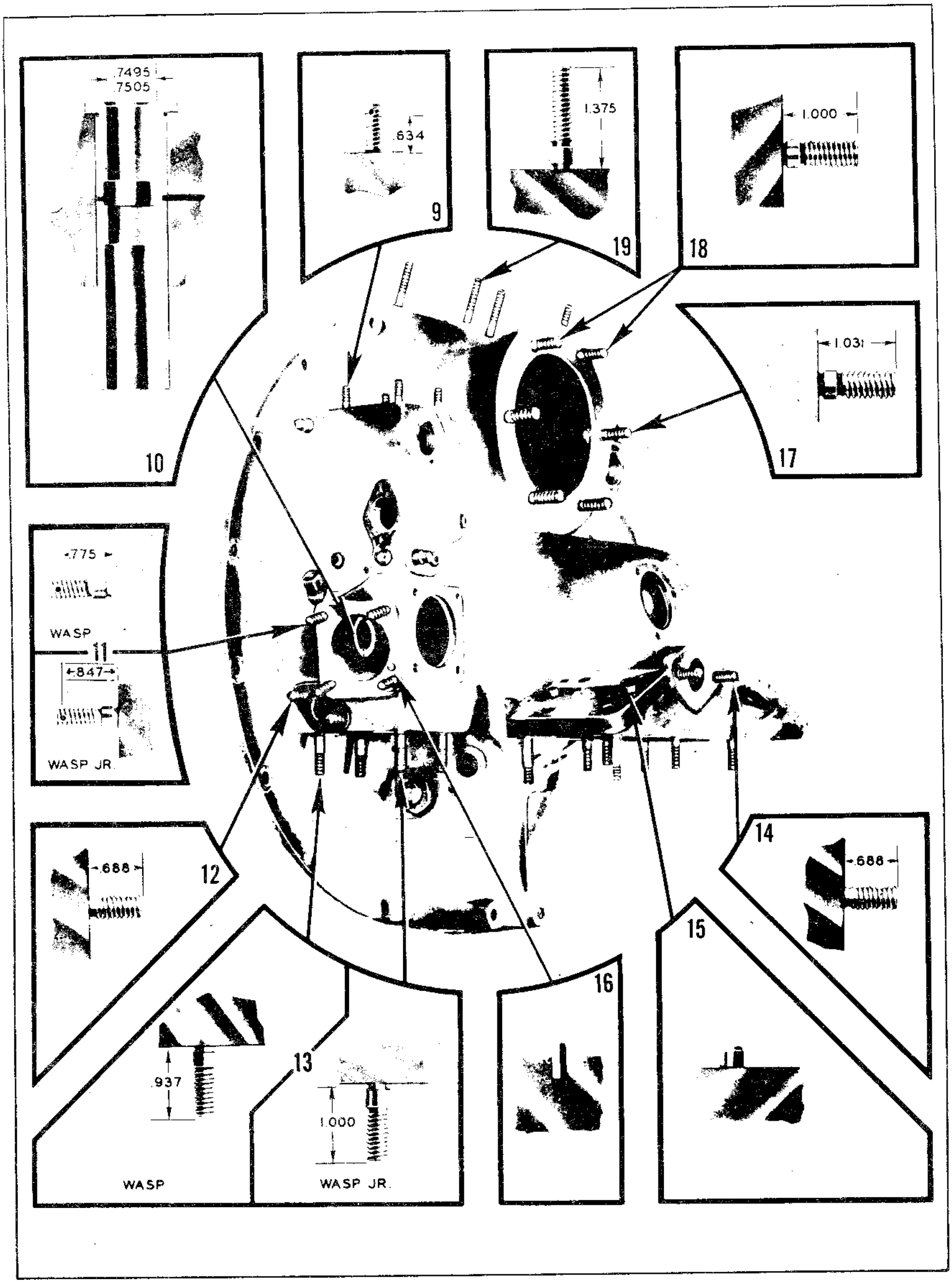
REPAIR AND REPLACEMENT



Rear Case Stud Replacement (Sheet 1 of 4 Sheets)

Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
	WASP JR. ENGINES				
2	Carburetor Adapter Stud	11345	4	5/16-24 Stud Driver	See "Studs"
3	Carburetor Adapter Stud	626	2	5/16-24 Stud Driver	See "Studs"
4	Oil Pump Stud	23299	2	5/16-24 Stud Driver	See "Studs"
5	Oil Pump Stud	19868	4	5/16-24 Stud Driver	See "Studs"
7	Oil Scavenge Tube Stud	12317	2	5/16-24 Stud Driver	See "Studs"
	WASP ENGINES				
2-3	Carburetor Adapter	626	6	5/16-24 Stud Driver	See "Studs"
4	Oil Pump Stud	12102	2	5/16-24 Stud Driver	See "Studs"
5	Oil Pump Stud	12101	4	5/16-24 Stud Driver	See "Studs"
7	Oil Scavenge Tube Stud	12317	2	5/16-24 Stud Driver	See "Studs"

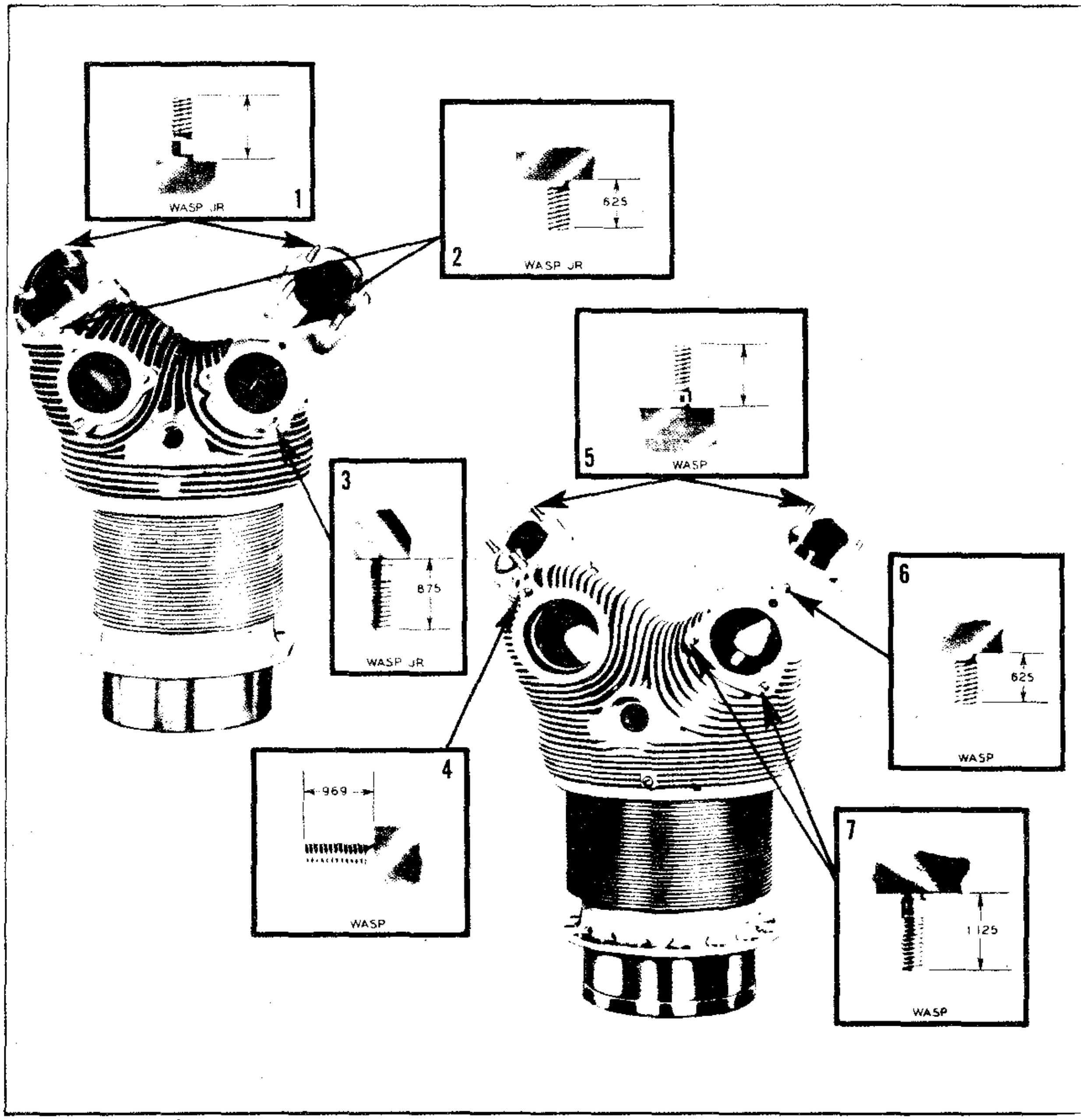
Rear Case Stud Replacement (Sheet 2 of 4 Sheets)



Rear Case Stud Replacement (Sheet 3 of 4 Sheets)

Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
	WASP JR. ENGINES				
9	Vertical Accessory Drive Pad Stud	43613*	8	1/4-28 Stud Driver	See "Studs" *20493 undrilled (optional). Drive to .782 inch minimum projection length to avoid interference with the propeller governor.
11	Vacuum Pump Pad Stud	35142	4	1/4-28 Stud Driver	See "Studs"
12	Oil Scavenge Tube Stud	12317	2	5/16-24 Stud Driver	See "Studs"
13	Fuel Pump Pad Stud	656	4	5/16-24 Stud Driver	See "Studs"
14	Oil Scavenge Tube Stud	12317	2	5/16-24 Stud Driver	See "Studs"
17	Starter Pad Stud	12091	4	3/8-24 Stud Driver	See "Studs"
18	Starter Pad Stud	12082	2	3/8-24 Stud Driver	See "Studs"
19	Generator Pad Stud	12086	4	5/16-24 Stud Driver	See "Studs"
	WASP ENGINES				
9	Vertical Accessory Drive Pad Stud	43613*	8	1/4-28 Stud Driver	See "Studs" *20493 undrilled (optional). Drive to .782 inch minimum projection length to avoid interference with the propeller governor.
11	Vacuum Pump Pad Stud	7418	4	1/4-28 Stud Driver	See "Studs"
12	Oil Scavenge Tube Stud	12317	2	5/16-24 Stud Driver	See "Studs"
13	Fuel Pump Pad Stud	11345	4	5/16-24 Stud Driver	See "Studs"
14	Oil Scavenge Tube Stud	12317	2	5/16-24 Stud Driver	See "Studs"
17	Starter Pad Stud	12091	4	3/8-24 Stud Driver	See "Studs"
18	Starter Pad Stud	12082	2	3/8-24 Stud Driver	See "Studs"
19	Generator Pad Stud	12086	4	5/16-24 Stud Driver	See "Studs"

Rear Case Stud Replacement (Sheet 4 of 4 Sheets)



Index No.	Part Name	Part No.	Units Per Ass'y	Tools Required	Notes and References
1	Rocker Cover Pad - Stud Projection 0.656 Inch	15072	8	1/4-28 Stud Driver	See "Studs"
2	Deflector Fastening Stud	12054	2	5/16-24 Stud Driver	See "Studs"
3	Intake and Exhaust Flange Stud	625	5	5/16-24 Stud Driver	See "Studs"
4	Exhaust Flange Stud	13212	1	5/16-24 Stud Driver	See "Studs"
*5	Rocker Cover Stud - Stud Projection 0.656 Inch	15072	6	1/4-28 Stud Driver	See "Studs"
6	Deflector Fastening Stud	12054	1	5/16-24 Stud Driver	See "Studs"
7	Intake Flange Stud	7545	2	5/16-24 Stud Driver	See "Studs"

*Screws are used at this location on the #5 Cylinder

Cylinder Stud Replacement

CHAPTER 9 . . EXTREME WEATHER MAINTENANCE

CONTENTS

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EXTREME WEATHER MAINTENANCE

COLD WEATHER MAINTENANCE

Cold weather operation of an aircraft engine involves conditions that require special preparations and precautions as compared to normal weather operation. Vaporization of the fuel becomes difficult, and the high viscosity of the oil causes reduced cranking speed with accompanying high loads on the starter. Often the accessories fail because of congealed oil. Excessive priming washes the oil from the piston rings and cylinder wall causing piston scuffing and scoring of the cylinders, while fuel may collect in the bottom intake pipes causing hydraulicking.

Cold Weather Problems

The main problems of cold weather operations and maintenance may be classified as follows:

a. *Moisture Freezing* — The introduction of water and moisture into the lubricating system is a potential hazard to be guarded against. Moisture or water collecting and freezing in such low points as the Y-drains, and engine sump sections, will cause blocking of oil flow, with consequent engine damage.

b. *Oil Lines and Fittings* — When these components are subjected to extreme cold weather, about —29°C (—20°F) and below, leaks will often develop in the seals and seating areas. All fittings should be properly torqued and the seals replaced where required.

c. *Instruments and Indicators* — In order to preclude malfunctioning of instruments and indicators, the flight deck should be thoroughly warmed before attempting a start. Instruments having remote transmitters may malfunction; therefore fluid used for transmitting pressure indications should be non-congealing.

d. *Accessories* — To ensure proper operation in extremely cold weather, it is essential that all lubricants used in the various accessories in the power plant installation be suitable low temperature lubricants. The engine starter, generator, electric tachometer heads, electric governor heads, engine control pulley bearings, cowl flap mechanism and the like, are examples of mechanisms in which low temperature lubricants must be used.

e. *Lubricating Oil* — To ensure proper fluidity of the engine oil at low temperatures, either oil dilution or thorough preheating of the engine is required. At −18°C (0°F) regular engine oil is in a practically congealed state. An attempted start with the oil in this condition would most certainly result in damage to the engine.

Preparation of Engines for Exposure to Extreme Cold Weather

Proper advanced planning, to cope with cold weather operational and maintenance problems, will greatly minimize the difficulties that are sure to be encountered. It is recommended that the following preparations be made.

a. Winterize the aircraft in accordance with the aircraft manufacturer's recommendations.

b. Keep fuel screens and filters free of water.

c. Drain the carburetor of accumulated moisture and water.

d. Drain instrument lines to transmitters and replace with a non-congealing fluid.

e. Ensure that the oil dilution system is in proper working order.

f. Ensure that engines are clean prior to using oil dilution, or that proper safe-guards are in effect to prevent clogging of the oil screens.

g. Tighten all fuel and oil line fittings, and accessory hold down nuts to the proper torque. Replace any seal or gasket showing evidence of leakage.

h. Inspect the Y-drains, oil sump, and fuel tank drains for evidence of water.

Effect of Cold on Fuel

Aviation fuels will normally contain little or no water, but the percentage of water is governed to a great extent by storage and handling conditions of the fuel. Fuels exposed to dampness or ordinary atmospheric conditions naturally contain a larger percentage of water than those kept in tightly sealed containers. This water content may, under poor conditions, average as high as several gallons in every thousand gallons of fuel.

As temperatures are reduced, the solubility of water in the fuel is also markedly reduced, which results in the water's separating from the fuel, seeking the lowest point in the tank, system or accessory concerned, and freezing there if the temperature goes low enough. Under these conditions it will also freeze in the fuel, forming tiny needle-shaped crystals which may be found impinged on the fuel screens, restricting fuel flow and, in severe cases clogging the screens entirely. Should this condition occur it will be evidenced by a drop in, or loss of, fuel pressure to the engine. The only remedy is heat applied to the engine and fuel system components.

It is most important that all sumps, screens and filters be thoroughly inspected on all preflight checks under these conditions. So long as fuel will flow freely from the drain valves in the tank sumps and screens, it can be surmised that the system is free of ice. Any indication that the flow is restricted is cause for the application of heat.

In the event that water has collected in the sumps or screens and frozen there, heat should be applied liberally and the drain valve opened frequently, drawing the water off as the ice melts.

Do not be misled by assuming that all the ice has melted if it is possible to drain fuel from the drain valve after several minutes of heat applied to the exterior of the affected component. The ice adjacent to the interior of the affected unit may melt and allow some water and fuel to flow from the drain, but a lump of ice may still remain in the fuel creating a serious hazard to any flight operation.

The flow of fuel to the outlet, on engine starting, may cause this block of ice to slip over the outlet and restrict or plug the opening creating a dangerous situation. If fuel does flow from the drain valve, continue to apply heat for a short time, checking the drain valve flow frequently. This fuel should be caught in a container and inspected for globules of water until it is evident that it is all removed from the area.

It is well to note that a similar situation may exist in the lubrication system, with the water coming from condensation of air in the tank or engine case area. When a hot engine is shut down in the open under low temperature conditions and allowed to stand for a period of time or possibly overnight in the open, the chances of ice in the fuel and lubrication systems are much more prevalent and extra precautions should be observed to prevent such accumulation and to check the system for ice during the preflight inspection.

When starting an engine which has been exposed to low temperatures overnight, carefully observe the fuel and oil pressures. The lack of any indication of either fuel or oil pressure, or a pressure indication below the normal operating limits, is cause for immediate engine shut-down. Inspect for ice in the system or move the aircraft indoors and apply heat before attempting another start.

During cold weather operation it is possible that cold water oil sludge may also form in the oil system, particularly if the oil has quite a number of operating hours on it. Therefore during these operations the oil screens should be checked frequently and if sludge accumulations are noted, the oil system should be completely drained while the engine is warm. This sludge generally has the consistency of mayonnaise, and if not removed can effectively clog or restrict the screens when the water content is frozen.

Successful operations during cold weather are more dependent upon careful inspection and good maintenance than under normal conditions. At the same time it must be realized that maintenance of aircraft and engines under cold weather conditions is far more difficult than under temperate conditions. The time required for all maintenance will be substantially increased and must be taken into account when scheduling operations.

Effect of Cold on Batteries

When batteries are exposed to temperature variations, there is a considerable lag in the change of their internal temperature. The best protection is in a heated storage place. Once batteries have been exposed to extreme cold, they should be warmed up thoroughly before using. This practice will prolong their service life and usefulness. In addition to low output in cold weather, storage batteries will charge at a slow rate. The charging rate at a temperature of −29°C (−20°F) is less than one-sixth that at normal temperature.

Partially discharged lead-acid batteries will freeze if left exposed to low temperatures; therefore, any lead-acid battery that may be in other than a fully charged condition should be kept in a warm place until charging facilities are available or until the battery is required in the aircraft. Water should not be added to batteries without operating them through a period of charging immediately thereafter in order to ensure that the acid water solution is mixed thoroughly. The following table indicates the freezing point of battery electrolyte at various values of specific gravity. A curve of these values can be drawn to determine intermediate points if desired:

Specific Gravity	Freezing Temperature
1.000	0°C (32°F)
1.050	—4°C (26°F)
1.100	—8°C (18°F)
1.150	—15°C (5°F)
1.200	—27°C (—17°F)
1.250	—52°C (—61°F)
1.300	—70°C (—95°F)

It is important that the condition of the battery be determined at the end of each flight to ensure an adequate state of charge and that the generator voltage is proper for battery charging. The condition of the battery can be determined by taking the specific gravity of each cell with an accurate hydrometer, returning the electrolyte to the cell from which it was removed.

If the specific gravity of any cell is below 1.150, the battery should be removed for recharge and replaced with a fully charged battery.

If it is repeatedly found that the specific gravity of the battery is not proper, the generator voltage regulator may require adjustments up to the maximum. Under conditions of cold-weather operation, it may not be possible to keep the battery charged by adjustment of the voltage regulator. Under these conditions, the battery should be removed and placed in the battery shop for charging and renewal of electrolyte. Batteries should be inspected to ensure that battery hold-down devices are adequate for securely mounting the battery in its compartment. Inspect the battery leads for condition of insulation. Inspect battery for evidence of leakage. Do not take hydrometer readings immediately after adding water. Do not add water to battery in sub-freezing temperature and permit to stand without charging. The water will mix with the electrolyte after approximately a thirty minute charge. When an aircraft located in below-freezing temperature is not in use, its battery should be removed and kept in a warm place or heated in the aircraft by plugging in external power, turning on the battery switch and charging the battery at a trickle rate.

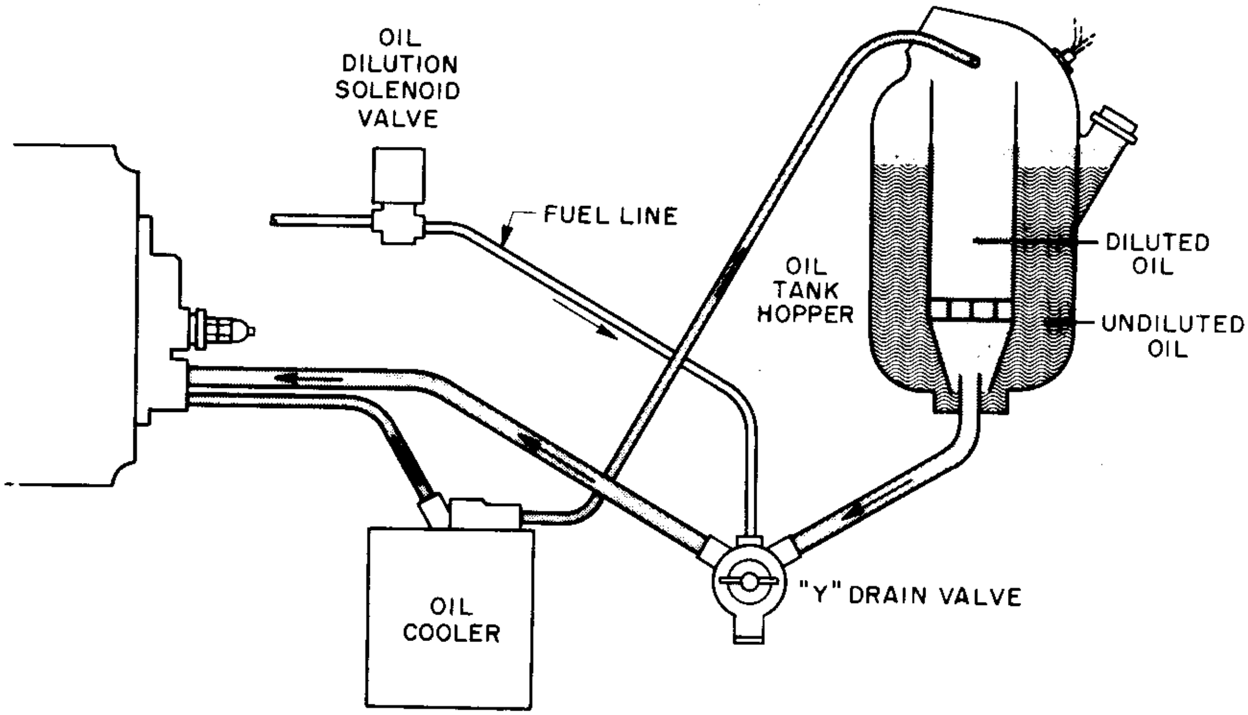
Care should be exercised when external power is plugged in for battery charging, that circuit breakers of equipment which do not have "On-Off" switches are disengaged.

The success of low temperature operation depends also upon the preparations made during the POST-FLIGHT inspection, in anticipation of the requirements for operation on the following day.

OIL DILUTION

Oil Dilution Systems

There are several types of oil dilution systems. The different types are usually identified with the configuration of the oil tank in the installation. The function of the oil dilution system is to supply raw fuel to the oil system, thereby reducing the viscosity of the oil. A typical oil dilution system is illustrated in **Figure 9—1** and its operation may be explained as follows:



[9—1] Typical Oil Dilution System

a. Engine idling at 800 to 1000 rpm.

b. Actuate oil dilution solenoid valve by means of the cockpit switch.

c. Observe a slight drop in fuel pressure.

d. Oil dilution valve supplies fuel pressure to Y-drain valve section.

e. Fuel and oil become thoroughly mixed passing through engine oil pump.

f. Diluted oil passes through oil screen and the engine and then to the hopper in the oil tank.

The hopper type oil tank permits only part of the total oil supply to be diluted, thus eliminating a long dilution period.

Oil Dilution Procedures

To accomplish satisfactory starting in cold weather, each engine oil system should be diluted in accordance with the following procedure.

a. Idle engine until oil temperature falls below 50°C (122°F) and cylinder head temperature approximates 150°C (302°F).

Service oil tanks, if required, (from central oil tank, if installed), prior to commencing dilution, allowing space for the fuel added.

b. With engine running at 800 to 1000 rpm, actuate the oil dilution switch.

c. Hold switch to ON position for the dilution time required by the dilution time table specified by the aircraft manufacturer. The dilution time for a given percent dilution will vary depending on the size of orifice installed in the fuel line to the Y-drain.

Observe for a slight drop in fuel pressure which indicates the oil dilution system is operating.

d. Exercise the propeller (if operating off engine oil system), through several pitch change cycles at 1500 to 1600 rpm.

Do not allow engine oil pressure to drop below 15 psi during dilution. If oil temperature rises above 50°C (122°F) during dilution, stop the engines and allow oil to cool.

e. Shut down engines when dilution time has elapsed by closing the throttles and moving the mixture control to IDLE CUTOFF.

f. Hold oil dilution switch ON until propeller stops turning. This will prevent undiluted oil from entering the engine.

Precautions When Using Oil Dilution

When the engine oil is diluted with fuel the violent desluding or purging action of the diluted oil releases the normal carbon and sludge deposits within the engine. In engines which have not been desludged prior to the use of oil dilution, this problem can be quite severe. Large carbon particles and slugs of sludge will be flushed through the oil system. These masses can clog the pressure oil screen causing the oil bypass valve to open releasing unfiltered oil direct to the engine. The contaminated oil contains a wide variety of deposits, including abrasive carbon particles and large slugs of sludge which can cause bearing damage and also block oil passages. This will cause troubles ranging from a maintenance nuisance to complete engine failure. Oil coolers and other oil system components can be plugged or restricted by these deposits, and may tend to serve as storage reservoirs for these harmful residues.

When oil dilution is first used, with the advent of cold weather, remove, inspect, and thoroughly clean the pressure oil screen after one to two hours of engine operation. A thorough inspection of the screen assembly cannot be made unless the screens are disassembled. Repeat the inspection frequently during the periods when oil dilution is being used. The sump plugs should also be removed to drain sludge accumulations. Drain a small amount of oil from any low points or natural sludge traps in the aircraft oil system such as from the hopper tank, the Y-drain, and the oil cooler.

Before flight is attempted, when diluted oil is in the engine, extreme care must be exercised to ensure that adequate burn-off of the diluent is obtained. It is recommended that no more than 10 per cent diluent fuel remain in the oil system prior to take-off. When extreme dilution has been used (20 to 35 percent) and when warm-up and diluent boil-off has not been thorough, some fuel will remain in the system until take-off has started. During take-off, the fuel is evaporated extremely rapidly, with a tendency to discharge oil from the breather. If a discharge from the breather occurs it can usually be stopped if engine speed is reduced to 2000 rpm or less.

The oil dilution valve should not be actuated in flight. A sudden fluctuation of oil pressure or discharge of oil from the engine breather during flight can be caused by a leaking dilution valve. Momentarily actuating the dilution switch on and off may assist in correcting the difficulty. If the condition continues, effect a landing as soon as possible and check the dilution valve mechanism. If excessive dilution of the oil supply has occurred, change the oil and examine the sump plugs and screens for the presence of metal particles. Refer to Foreign Material In The Oil System, Periodic Inspection Chapter.

Over dilution can also occur due to several dilutions without adequate boil-off. When at least a half hour flight is not made after the start and warmup, it is necessary to limit the dilution interval to allow for fuel remaining in the oil system from the previous dilution.

Any time the engine is started, after a dilution has been used, the engine must be rotated by use of the starter for a count of 20 blades before ignition and fuel are applied. Oil dilution has a double effect in causing a dry start: lowering of the oil viscosity resulting in a faster drain-off period, and the evaporation of the fuel reducing the residual oil film separating bearing surfaces.

GROUND OPERATION

Use of Preheat for Starting

If oil dilution was not employed when the engine was previously shut down, external heat generally will be necessary at temperatures below 5°C (40°F). Past experience, stiffness of the engine, and fluidity of the oil at the drain valve will be the best indications of the necessity for preheat.

The most important region to apply preheat is the engine accessory section. The second region in the nacelle which must be heated is forward of the fireseal.

The minimum time required for heating an engine is dependent upon the capacity of the heater, the outside air temperature, and the amount of oil dilution used prior to the previous shutdown. When using preheat, care must be exercised not to burn the insulation of the ignition system if the temperature of the preheat air exceeds 107°C (225°F). The heater discharge temperatures will increase with the warmer outside air temperatures or when the discharge air is restricted by blocking one or more of the outlet ducts.

The successful completion of preheating can best be determined by turning the propeller occasionally and noting engine stiffness. This is particularly effective if no, or insufficient oil dilution has been used.

Do not actuate cowl flaps until assured they are not frozen.

With extreme oil dilution, an engine will be free at a temperature as low as —40°C (—40°F) but preheating can be used to great advantage at the accessory section and induction system in aiding vaporization of the fuel.

For extreme cold weather operations, —29°C (—20°F) and below, preheat the central oil tank (if installed) to ensure a supply of make-up oil to the individual engine oil tanks. Diluted oil often causes rapid loss of oil quantity during take-off and climb.

Starting Instructions

Normal starting instructions (Refer to the Ground Checks Chapter) may be used in starting an engine properly diluted and/or preheated.

Warm-Up

Refer to the Ground Checks chapter for Warm-up Control Positions.

In cold weather, engine operation immediately after starting is frequently rough, with back firing and after firing. This is due principally to a lean mixture because of reduced vaporization of the fuel. Fouled or iced sparkplugs will result in the same actions. Turn on carburetor preheat about one minute after starting. This will tend to enrich the fuel-air ratio (in the idling range) by improving vaporization of the fuel, providing smoother operation. After the engine has warmed up, operation may be satisfactory with cold air, and carburetor preheat can be used as required.

No attempt must be made to heat the engine rapidly by closing the cowl flaps.

Be sure that the cowl flaps are free before attempting to operate them.

As in normal weather, keep the cowl flaps fully open during all ground operation. Under extremely cold conditions it may be necessary to partially close the cowl flaps for satisfactory warm-up. Satisfactory warm-up is indicated by an oil temperature of approximately 60°C (140°F). At normal ground warm-up speed, oil temperature will rise very slowly during cold weather. Do not advance throttle beyond ground warm-up speed until minimum oil temperature of 40°C (104°F) is obtained.

If backfiring occurs at ground warm-up speed, initial warm-up may have to begin at a lower speed.

Run-Up and Ground Checks

Refer to Specific Ground Checks in the Ground Checks chapter for applicable ground checks. In addition, observe the following precautions.

a. Ensure oil temperature is at least 40°C (104°F); 60°C (140°F) is to be preferred.

b. Exercise the propellers (if operating off engine oil system) through several pitch changes with engine speed brought up to 1500 — 1600 rpm.

Ensure that adequate boil-off of the diluent fuel is obtained before attempting flight. Serious oil spewing could result from too much diluent fuel remaining in the oil.

Shutdown of Engines

Use the engine shutdown procedure described in the Ground Checks chapter except as noted below.

a. If the engine oil is to be diluted, follow the Oil Dilution Procedure described in this chapter.

b. When the engine is shut down, close the throttle and leave closed. If the throttle is opened it will permit very cold air to enter the cylinders, possibly causing icing of the spark-plugs and valve warpage.

DESLUDGING OF AIRCRAFT ENGINES

General

Many operators realize that there is a growing need for engine operating and maintenance procedures based on year-round, all climate, global-flight schedules, and the increasing traffic along Arctic routes. The overlapping function of oil dilution for desludging and for cold weather starting is significant.

Oil dilution has always been considered as a necessary evil associated with cold weather starting. General experience accumulated over the years includes many epidemics of engine trouble associated directly with its misuse. These troubles have been mainly due to the violent desludging or purging action of diluted oil on normal carbon and sludge accumulations in the engine. The total accumulation of such deposits is a function of engine time and depends also on other variables such as operating temperatures, oil change frequency, and aircraft oil system design.

If an engine is operated for an extended period of time and is then diluted, these deposits may be flushed through the oil system. The larger particles and sludge masses can be trapped in the sumps and oil screens and can cause almost immediate clogging of the main oil screen. If this occurs, the oil bypass valve will open and the engine will be supplied with dirty unscreened oil. On engines not incorporating a bypass valve, the screen may collapse, starving the engine of oil. The contaminated oil includes a wide variety of deposits ranging from fine abrasive carbon particles to large slugs of sludge which can plug pressure or scavenge oil passages, such as rockerbox interconnect lines or tappet guide drains, and in turn can cause troubles which may vary from a maintenance or operational nuisance to an engine failure. Oil coolers and other oil system components can be plugged or restricted by these deposits and may tend to serve as storage reservoirs for these harmful residues.

Until all engines being operated by the using activity can be considered clean, they will have two categories of engines in the activity.

a. Clean Engines
All engines with less than 100 hours of flying time will be considered as clean engines.

b. Dirty Engines
Nondiluted engines with more than 100 hours of flying time will be considered as DIRTY engines. Diluted engines which have accumulated over 50 hours of operation since last dilution will also be considered dirty engines. Special desludging procedures are required on dirty engines before they can be considered as clean engines.

The following factors relating to oil dilution demand careful attention:

a. Typical cold weather dilution influences each phase of engine operation including technique for shutdown, starting, warm-up, run-up, take-off, and flight conditions.

b. There have been instances when overdilution or repeated dilution by error is believed to have caused engine failures. Careful control of run-up procedures is required to ensure adequate burn-off of the diluent fuel prior to take-off to avoid oil spewing and possible oil starvation during the take-off operating condition. The use of oil dilution requires definite and specific instructions.

c. Where an individual aircraft or a fleet is exposed to occasional or intermittent operation in cold weather conditions, the use of regular, year-round, periodic dilution procedures for desludging purposes is preferable to the hazards of suddenly introducing oil dilution on high-time engines. The details of any such procedure depend upon such variables as aircraft type, engine time, operating conditions, and the commitments of the individual organization. The simplest situation involves treatment of new engines, but it is obvious that provisions must also be made for cleaning up high-time engines since the practical application of the idea is on a fleet basis.

d. The importance of proper use of the engine oil dilution system cannot be overemphasized. Prevention of troubles associated with misuse of oil dilution involves diligent use of a specific oil dilution procedure and careful attention to maintenance and inspection procedures at frequent intervals for a considerable time after the engine is first diluted. Trouble is generally associated with lack of adequate control over such procedures.

Procedure

The purpose of this procedure is to provide a means of preventing excess amounts of deposits from breaking loose within the engine when low ambient temperature conditions require dilution for starting.

This procedure is applicable to all aircraft utilizing Pratt & Whitney reciprocating engines having less than 100 hours operating time since new or newly overhauled (Clean engines). Once periodic oil dilution is adopted, its use may be continuous throughout the life of the engine. If an engine has over 100 hours of operation since new or newly overhauled, and over 50 hours of operation has elapsed since the last oil dilution (either periodic or for cold weather starting), the engine will be considered as a Dirty engine and use of periodic oil dilution may be applied only after the engine is desludged in accordance with instructions contained herein.

Periodic oil dilution for sludge control, is not necessary during cold weather operation when the engine oil system is diluted in accordance with the seasonal operating oil dilution procedures outlined in paragraphs "Oil Dilution Procedures" and "Oil Dilution Precautions".

Prior to operation of engines with over 100 hours operation (Dirty engine) in cold areas where dilution is required for starting, adequate measures must be taken unless the engine is desludged in accordance with this manual.

Procedural Steps

a. Periodic dilution may be accomplished at preflight or postflight as outlined in paragraphs b through f.

The time period between applications and the personnel who will perform the dilution will be as required by the using activity. If the time period between applications is less than 25 hours, the procedures outlined in paragraphs b and c will be accomplished.

If the time period between applications exceeds 25 hours, the procedures outlined in paragraphs b through e will be accomplished.

Engines which have over 100 hours of operation since new or newly overhauled and have over a 50 hour period of operation without being diluted (Dirty engines), may be periodically diluted after following all procedures in paragraphs b through f.

b. Using the dilution procedures outlined under "Oil Dilution" in this Chapter, dilute the oil ten percent. Where dilution is not expressed in terms of percentage, dilute the oil in the amount specified for an ambient temperature of —12°C (10°F) (approximately ten percent).

Do not allow the engine oil pressure to fall below 15 psi during dilution.

c. Upon completion of the above and prior to takeoff or high power operation, operate the engine a minimum of ten minutes at an oil temperature above 50°C (122°F).

d. On aircraft incorporating a diverter-segregator oil system, care should be taken to ensure that the main oil tank and hopper are filled in accordance with instructions contained in paragraph "Oil Dilution Procedures".

e. The following additional procedures will be adhered to on engines which are periodically diluted at intervals greater than 25 hours:

1. On engines equipped with propellers using engine oil, cycle the propeller through three cycles.

2. Upon completion of the preceding operations, remove, disassemble, inspect, and clean, where applicable, the following:

(a) Engine inlet screen.

(b) Sump plugs.

3. If, during the screen examination, excessive deposits are noted, the engine should be run an additional ten minutes and the inspection given under paragraph e step 2 repeated.

4. After shutdown (preferably an hour or two), drain one gallon of oil from the Y-drain, hopper tank, and oil cooler drain to eliminate sludge which may have accumulated at these points.

5. Reservice the oil tank hopper to the full normal level on engines using the diverter-segregator system.

f. Engines which have over 100 hours of operation since new or newly overhauled and have over a 50 hour period of operation since last dilution (Dirty engines) require the following procedures be accomplished in addition to those outlined in paragraphs b through e.

1. In place of the oil draining required by paragraph e, step 4, drain and replace all oil from the engine oil tank.

2. Remove, inspect, clean and reinstall (lockwire as required), the propeller dome and propeller governor oil screen on propellers which use engine oil.

3. Carefully inspect the main oil screen and sump plugs, where applicable, at 10-hour operating intervals (or as close thereto as possible), for 100 hours after this desludging dilution.

HOT WEATHER MAINTENANCE

Hot weather maintenance of the aircraft engine will present no problems over those encountered during the summer season in a temperate climate, except as noted below.

Starting The Engines

a. Use normal starting procedure as described in the Ground Checks chapter except a more open throttle may be required.

b. Be careful not to overprime the engines.

Warm-Up And Ground Checks

a. Perform all checks, as described in the Ground Checks chapter, in a minimum length of time.

b. Do not exceed cylinder head, carburetor air temperature and oil temperature limits.

c. Guard against sand and dust entering the engine.

Consult the aircraft manufacturer's operating instructions for further information regarding hot weather operation, and operations in sandy or dusty areas.

Engine Shutdown

a. Stop the engines as soon as possible using normal procedure.

b. Keep the engine cowl flaps open until the engine has cooled.

c. When the engines have cooled sufficiently the cowl flaps may be closed.

d. Use dust plugs and engine covers to protect the power plant against sand and dust.

e. Prevent sand and dust from entering the fuel and oil tanks.

f. Inspect and clean any air filters that may be installed.

During desert operations always protect the aircraft against the effects of blowing sand.

CHAPTER 10 .... PRESERVATION

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PRESERVATION

ENGINES INACTIVE FROM TWO TO TEN DAYS

When it is known that an aircraft will be idle for more than two days but less than ten days, rotate engine on alternate days, at least 20 propeller blades, by means of the starter. Run-up engine on fifth day at 1000 rpm until oil temperature reaches 65°C (149°F). If, due to circumstances, it is not possible to rotate or run-up engine during this ten day period, pre-oil engine prior to starting.

The corrosion preventive mixture referred to in the following instructions, (Exxon Rust-Ban 632 or MIL-C-6529C, Type II. See Note), is composed of a blend of three parts engine lubricating oil 1100 or 1120 and one part corrosion preventive compound, Exxon Rust-Ban 631, MIL-C-6529C, Type I is the oil additive, or concentrate, to make Exxon Rust-Ban 632 (or equivalent), using standard lubricating oil (reference SB 1183). Heating mixture to a temperature of 38° to 104° (100° to 220°F) is desired to remove moisture and facilitate application. Use only dry filtered air when spraying.

NOTE: For details on Exxon Rust-Ban 631 or 632, contact Exxon Co., U.S.A. P.O. Box 2180, Houston, Texas, 77001, for brochure entitled "Lubetext' DG-4C."

ENGINES INACTIVE OVER TEN DAYS

OPERATION	PROCEDURE	Engines Installed		Engines Not In-stalled
		10 to 30 Days	Over 30 Days	
Cleaning Engine	Before washing engine look for oil leaks which may indicate loose connections, packings, or nuts. Wash engine externally with a cleaning solvent, removing all oil, grease, and dirt. Keep cleaning fluid away from magnetos and ignition manifolds.			✓

ENGINES INACTIVE OVER TEN DAYS (Continued)

OPERATION	PROCEDURE	Engines Installed 10 to 30 Days	Engines Installed Over 30 Days	Engines Not In-stalled
Preliminary Preservation	While the engine is still warm, drain the oil from the engine and the oil tank. Remove the pressure oil screen; thoroughly clean and reinstall all parts removed to facilitate draining. Fill the oil tank with enough corrosion preventive mixture to ensure adequate lubrication during the preservation run plus the quantity needed to preserve the induction system. Prepare the engine for preservation of the induction system as follows: join together two separate 10 foot lengths of number 6 hydraulic hose by means of a suitable two-way valve. Remove the pressure oil screen cover drain plug, and install a suitable adapter in the drain plug hole and in an appropriate opening in the supercharger case (such as the alternate manifold pressure gage connection). Connect the hydraulic hose between the two fittings. If desired, the control valve may be located in the cockpit and be manipulated by the operator or his assistant. (This method affords the use of the same preservative compound contained in the engine oil system during the preservation run and thus eliminates the need of a supplementary tank for preserving the induction system.) Make sure that the control valve is in the closed position. Block off or by-pass the oil cooler to produce a minimum oil inlet temperature of 95°C (203°F) during the preservation run. ***Do not exceed 120°C (250°F) oil inlet temperature.***		✓	✓
Preservation Run	Start the engine and then continue to run (on normal service fuel) at idling speed for at least 15 minutes, using the corrosion preventive mixture as a lubricant. At the end of the run, open the throttle to attain a speed of 1500 rpm to ensure propeller rotation of approximately 30 revolutions after the mixture control is moved to idle-cut-off. ***Do not operate in excess of 1500 rpm when engine is serviced with preservative oil.***		✓	✓

ENGINES INACTIVE OVER TEN DAYS (Continued)

OPERATION	PROCEDURE	Engines Installed		Engines Not In-stalled
		10 to 30 Days	Over 30 Days	
Preservation Run (continued)	With the throttle advanced as described, and with the oil temperature at not less than 95°C (203°F) open the control valve to allow the engine preservation mixture to be introduced into the induction system. When the exhaust stacks are smoking profusely, move the mixture control to idle cut-off position to stop the engine. After the engine has stopped, close the control valve within five seconds.			
Mixture Drainage	While the engine is still warm, drain the corrosion preventive mixture from the engine, the lines, and the oil tank. Remove the pressure and scavenge oil screens; thoroughly clean and reinstall all parts removed to facilitate draining.		✓	✓
Sparkplugs	Disconnect the sparkplug leads and remove the sparkplugs. Install protector caps on the sparkplug lead connectors. Clean the sparkplugs in clear, unleaded gasoline and dry them with compressed air. Coat the sparkplug 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.	✓	✓	✓
Exhaust Valves	Thoroughly spray each exhaust valve with corrosion preventive mixture through the sparkplug holes or the exhaust ports. Be sure each exhaust valve is fully open when it is being sprayed. Rotate the propeller shaft at least four revolutions in the normal direction of rotation to work the mixture into the exhaust valve guides. Install the exhaust port covers.	✓	✓	✓
Rockerboxes	It will not be necessary to remove the rockerbox covers and spray the rockers if the engine was preserved at the specified oil temperatures. Engines preserved under low temperature, or if the alternate method of treating cylinder bores is used, must have the rockerbox covers removed and the rockers, valve springs, washers, and valves sprayed with corrosion preventive mixture.	✓	✓	✓

PRESERVATION

ENGINES INACTIVE OVER TEN DAYS (Continued)

OPERATION	PROCEDURE	Engines Installed		Engines Not Installed
		10 to 30 Days	Over 30 Days	
Thrust Bearings	Remove any parts of the installation that prevent access to the thrust bearing cover. Preserve the thrust bearings of engines incorporating a drilled passage through the thrust bearing cover plate by removing the pipe plug, installing a suitable tapered thread connector, and pumping corrosion preventive mixture (at room temperature) into the passage at 80 psi minimum pressure for at least 15 seconds. Remove the connector and reinstall the pipe plug. On those engines not incorporating a drilled passage in the thrust bearing cover plate, remove the thrust bearing cover plate; thoroughly spray the exposed portion of the thrust bearings with the preservative mixture; then reinstall the cover plate and tighten to the recommended torque.		✓	✓
Cylinder Treatment	With the piston at the bottom of its intake stroke, spray hot, 99° to 140°C (210° to 220°F), corrosion preventive mixture into the front sparkplug hole of each cylinder and in the same sequence as the firing order. This spray should be deposited on the inlet valves and the cylinder walls. Rotate the propeller shaft at least six revolutions to ensure pistonring 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. ***Do not apply excessive amounts of material. All that is necessary is a uniform thin coating on all surfaces. Excessive amounts of material do not contribute to the preservation; they cause difficulty at the time of depreservation and increase the chances of hydraulic lock.*** It is of the utmost importance that personnel entrusted with the cylinder spray operation be properly trained in the techniques required. It is recommended that the operator practice on dummy cylinders until the	✓	✓	✓

ENGINES INACTIVE OVER TEN DAYS (Continued)

OPERATION	PROCEDURE	Engines Installed		Engines Not In-stalled
		10 to 30 Days	Over 30 Days	
Cylinder Treatment (continued)	desired even coat can be applied. The type of spray pattern formed can be observed by spraying into a suitable receptacle. The recommended procedure to be used by the operator is as follows: a. Place the preservation mixture in the reservoir; heat to the correct operating temperature; and mix thoroughly. Premixing and preheating the compound prior to placing it in the reservoir will be a timesaver. b. Close the vessel and connect the gun and all lines. c. Discharge the gun into a clean container until a fine uniform spray is produced at the nozzle. The mixture discharged during this operation should be retained for the final operation. d. Insert the discharge tube of the gun into the cylinder and determine the position of the piston. Use the free hand to mark the distance the gun will travel into the cylinder to come to a point just short of the piston. Withdraw the gun tube until the nozzle is at the sparkplug opening. e. Start spraying. As soon as the trigger is pressed move the gun so that the nozzle will travel slowly from the sparkplug opening to the piston, but without touching the piston head, then back to the sparkplug opening where the trigger should be released immediately. f. Proceed at once to spray each of the remaining cylinders in the same manner. If the spray gun will be idle more than one minute, repeat step (c) to ensure that a slug of cold preservation compound is not ejected, and that a fine even spray is obtained.			

PRESERVATION

ENGINES INACTIVE OVER TEN DAYS (Continued)

OPERATION	PROCEDURE	Engines Installed 10 to 30 Days	Engines Installed Over 30 Days	Engines Not Installed
Dehydrator Plugs	Install dehydrator plugs in the sparkplug holes of all cylinders and tighten them to the recommended torque. Do not remove the moisture seals from the plugs until ready to install. On those engines incorporating a front crankcase breather, disconnect the breather and install a dehydrator plug in the case. On those engines not incorporating a front crankcase breather, remove the governor, install a governor pad shipping gasket and cover; then install a dehydrator plug in the cover. Install dehydrator plugs in all suitable openings in the main, collector and rear crankcases.	✓	✓	✓
Propeller Shaft	Clean the exposed surfaces of the propeller shaft with dry cleaning solvent, Stoddard Solvent or equivalent; then follow with an application of finger print neutralizer, and dry. Coat the surfaces with soft film corrosion preventive compound. After the compound has set, protect the surfaces by wrapping with a suitable acid free waxed paper and secure with tape. Install a propeller thread protector. If the hoisting eye is installed, which will be needed to place the engine in the shipping container, installation of the shipping cap should be delayed until after the engine is secured to the base of the packing box.			✓
Carburetor	When a carburetor is to be out of service for a period exceeding 10 days, prepare for storage in accordance with one of the methods outlined in the following instructions. Use Naphtha for cleaning. Use only oil Grade 1065 for preservation purposes. Remove the carburetor from the engine; then remove the drain plug in the bottom of the float bowl, and drain all gasoline from the carburetor through this opening and the carburetor fuel inlet. A few strokes of the throttle lever will pump out any gasoline that may have collected in the accelerating pump system.	✓	✓	✓

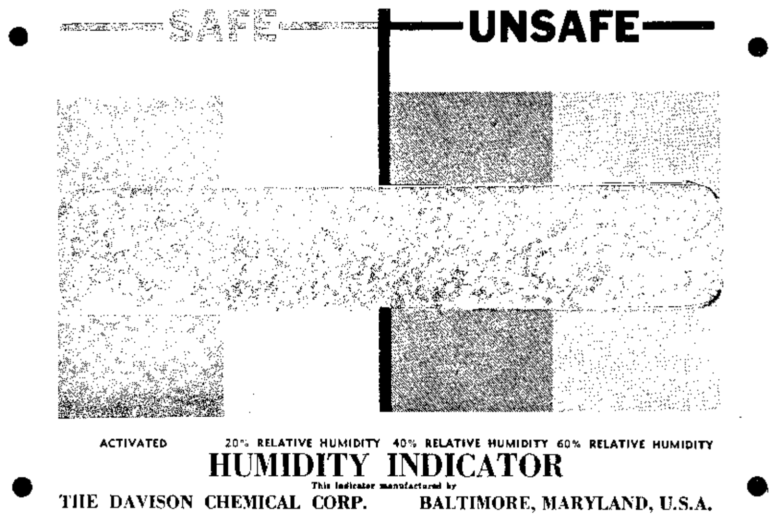
ENGINES INACTIVE OVER TEN DAYS (Continued)

OPERATION	PROCEDURE	Engines Installed		Engines Not In-stalled
		10 to 30 Days	Over 30 Days	
Carburetor (continued)	After the carburetor has been drained thoroughly, place the carburetor on its top flange. Install a fitting in the carburetor drain and attach an oil line. Pump in slushing oil (Grade 1065) until the oil flows from the discharge nozzle. The slushing oil pressure applied to the carburetor should not exceed 3 to 4 pounds per square inch. If a pump is not available, the oil may be poured in providing precautions are take to ensure complete slushing. When the oil flows from the discharge nozzle, disconnect the oil line and replace the drain plug. Set the carburetor in an upright position and operate the throttle lever until oil is discharged from the accelerating pump discharge nozzle. Place the throttle valve in the closed position and adjust the throttle stop to obtain the maximum throttle opening; then lockwire the throttle valve in this position against the stop.			
Carburetor Opening in the Rear Case	When the carburetor is removed from the engine, secure two ½ pound bags 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.	✓	✓	✓
Accessories	Drain the fuel from the engine drive fuel pump and the oil from the propeller governor and flush with corrosion preventive mixture while rotating the crankshaft to ensure complete preservation of all internal parts. All accessories not attached to the engine should be treated for proper storage preparation. Drain the excess oil and wrap these accessories in acid-free waxed paper.		✓	✓
Accessory Drives	Remove all accessory drive cover plates. Cover the drive ends with corrosion preventive mixture; then reinstall the cover plates.			✓

PRESERVATION

ENGINES INACTIVE OVER TEN DAYS (Continued)

OPERATION	PROCEDURE	Engines Installed		Engines Not Installed
		10 to 30 Days	Over 30 Days	
Openings	Seal all engine breathers and blast tube lines to the accessories with moisture resisting plugs and covers. Seal the magneto vents, all oil inlet and outlet connections, and other openings not otherwise covered by plates or covers with moisture resisting sealing tape. Install dehydrating agent in the exhaust stacks and then seal with moisture resistant sealing tape; or install exhaust port covers between the cylinder exhaust ports and the exhaust stacks.		✓	✓
External Inspection	Inspect the engine carefully, checking all nuts and bolts 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.		✓	✓
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 seven days and the color of the dehydrating agent compared with that on the humidity indicator [**Figure 10-1**]. 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 pipes and in the carburetor mounting flange cover 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.	✓	✓	✓



[10—1] Humidity Indicator

Preservation of Engines Removed from Service Because of Mechanical Difficulty

Engines which are inoperative because of mechanical difficulty should be preserved as directed in the preceding chart under "Engines Not Installed." However, to prevent further engine damage in cases of suspected or determined engine failure, "Preliminary Preservation" should be accomplished without engine run-up as follows:

With the engine in flight position, drain the oil from the engine. Connect a line from a pre-oiling pump or some other pressure source to the oil pressure gage connection. Pump corrosion preventive mixture into the engine at 45 to 65 pounds per square inch pressure until clean fluid flows from the oil sump drain plug hole. Remove one cylinder and spray the cylinder barrels and all the internal parts of the power section with the corrosion preventive mixture. Spray the cylinder that was removed and reinstall it. Carefully inspect all exterior surfaces of the engine, and seal all openings with plugs or moisture resistant sealing tape.

Preservation of Engines Subjected to Salt Water Immersion

Engines which have been removed from salt water should be cleaned with steam or fresh hot water as soon as possible after recovery. Disassemble the engine at least as far as removal of all the cylinders. Clean and preserve the crankshaft, crankcases and cam reduction gearing through the cylinder pad holes. Clean miscellaneous parts, subassemblies and accessories with steam or hot water. If an oven is available, bake parts at approximately 93°C (200°F) until thoroughly dry. After parts are dry, coat them with grease or corrosion preventive mixture. Reassemble the engine utilizing any parts which will assist in sealing the engine as completely as possible. Wrap the remaining parts and accessories in acid-free waxed paper and pack in an appropriate box.

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 sparkplug 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 sparkplug holes. If a band of corrosion is observed at the top of the cylinder barrel, remove one cylinder and inspect for further corrosion. Remove the rust and respray. If significant corrosion is present other than in a band at the top of the cylinder, or if there is corrosion in the power section, turn in the engine for overhaul.

CHAPTER 11 .... LIMITS

TABLE OF CONTENTS

LIMITS

These tables should be used in conjunction with the Limits and Lubrication Charts for the Wasp Jr. and the Wasp series engines. The letter "T" indicates a tight fit. The symbol "*" indicates that worn parts should be replaced if any looseness is found. The symbol "[illegible]" in the Replace column indicates that, contrary to the column heading, the spring should be replaced when its rate is less than the limit. 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. The figures in the limits column should be interpreted as follows: torques in pound-inches, spring pressures in pounds, and all other limits in inches. Unless otherwise specified, all fits between circular parts are diametrical; spline fits are calculated from chordal dimensions. Reference numbers not listed in the following table but appearing in the Limits, and Lubrication Charts are required only in overhaul procedures, and are covered in the Overhaul Manual, Part No. 123440.

TABLE FOR WASP JR. ENGINES

Ref. No.	Name	Min.	Max.	Replace
7	Propeller Shaft Thrust Bearing Spacer Pinch—Thrust Bearing Cover (Fit To)	.004T	.008T	*
35	Pushrod Ball Socket—Valve Rocker	.000	.0025T	*
36	Pushrod Ballend—Pushrod	.0015T	.0035T	*
37	Inside Inlet Valve Spring Pressure (Dia. of Wire .154) at 1½ in.	53	56	48

LIMITS

Ref. No.	Name	Min.	Max.	Replace
38	Outside Inlet Valve Spring Pressure (Dia. of Wire .183) at 1 1/2 in.	68.5	72.5	64
39	Inlet Valve Guide — Valve	.0015	.004	.010
42	Valve Adjusting Screw Ball-Socket	.0005	.007	.020
43	Cold Valve Clearance (Inlet and Exhaust)	.010	.010	
44	Spring (Inside) Exhaust Valve (Dia. of Wire .162) at 1 1/2 in.	62.25	65.25	58
45	Spring (Outside) Exhaust Valve (Dia. of Wire .192) at 1 1/2 in.	79.5	83.5	75
46	Exhaust Valve Guide — Valve (-B-5 engines)	.0030	.0055	.010
49	Rocker Bearing — Valve Rocker	.0005T	.0015T	*
50	Rocker Bearing — Rocker Shaft	.000	.0008	.0015
301	Pistonring — End Clearance Five Groove Piston, Tapered Bore (Rectangular and Wedge-Type Rings).			
	Top Groove	.052	.062	
	2nd Groove	.051	.059	
	3rd Groove	.051	.059	
	4th Groove	.051	.059	
	5th Groove	.011	.018	
	(With Chrome-Moly Barrels Using Compression Ring in Place of Scraper Ring)			
	5th Groove	.051	.059	
302	Pistonring Side Clearance Five Groove Piston (Wedge-Type-Top Three Rings)			
	Top Groove	.002	.004	
	2nd Groove	.002	.004	
	3rd Groove	.002	.004	
	4th Groove	.0035	.007	

LIMITS

Ref. No.	Name	Min.	Max.	Replace
	5th Groove	.001	.0035	
	(Wedge-Type Ring Clearance is Measured with Outer Face of Ring Flush with Piston)			
303	Pistonpin—Piston			
	(Light Hand Push Fit When Parts are Oiled at Room Temperature)			.003
305	Cylinder Barrel—Piston	.018	.022	.028
306	Pistonpin Bushing—Pin	.0017	.0033	.005
347	Magneto Drive Oil Seal Housing—Rear Crankcase	.000	.012	
348	Magneto Drive Oil Seal Housing—Oil Seal			
	(P/N 164314)	.001T	.007T	*
	(P/N 383021)	.003T	.009T	*
652	Oil Return Check Valve—Valve Guide	.0005	.0035	
653	Oil Return Check Valve Spring Pressure at 13/16 in.	2.25	2.75	<1.75
654	Oil Strainer Retaining Spring Pressure at 1-3/32 in.	9	13	<5
703	Oil Pressure Relief Valve Spring Pressure at 1-7/16 in. (P/N 6091)	19	21	<15
737	Vacuum Pump Drive Shaft Oil Seal—Pump Adapter	.0015L	.0065T	*
738	Vacuum Pump Drive Adapter—Rear Case	.000	.003	
743	Fuel Pump Drive Shaft Oil Seal—Pump Bracket	.0015L	.0065T	*

TABLE FOR DIRECT DRIVE WASP ENGINES

Ref. No.	Name	Min.	Max.	Replace
7	Valve, Oil Strainer Check—Guide, Valve	.0005	.0035	.006
43	Cold Valve Clearance (Inlet and Exhaust)	.010	.010	
44	Valve Adjusting Screw Ball—Socket (Fit To)	.0005	.007	.020
61	Guide, Inlet—Valve, Inlet	.0015	.004	.010
63	Piston—Cylinder Barrel	.020	.024	.030

LIMITS

Ref. No.	Name	Min.	Max.	Replace
66	Pistonpin—Bushing, Linkrod	.0017	.0033	.005
67	Pistonpin—Piston .... Light Hand Push Fit When Parts Are at Room Temperature and Oiled			.003
85	End Clearance—Pistonrings—With Tapered Cylinder Bore			
	Top Groove	.067	.077	
	2nd Groove	.0665	.0735	
	3rd Groove	.0665	.0735	
	4th Groove	.0665	.0735	
	5th Groove	.0265	.0335	
86	Side Clearance—Piston—Pistonring			
	Top Groove	*.007	.009	
	2nd Groove	*.005	.007	
	3rd Groove	*.003	.005	
	4th Groove	.0035	.007	
	5th Groove	.001	.0035	
	*Arrangement of the S1H2 engine rings differs only in the side clearances of the top 3 rings which are:			
	Top Compression	.007	.0095	
	2nd Compression	.005	.0075	
	3rd Compression	.003	.0055	
226	Rocker Arm Socket—Rocker Arm	.000	.0025T	*
316	Bushing, Valve Rocker Shaft—Shaft, Valve Rocker (Large End)	.000	.0013	.002
317	Shaft, Valve Rocker—Bearing, Valve Rocker Shaft	.000	.0008	.0015
319	Bearing, Valve Rocker—Rocker, Valve	.0005T	.0015T	.0005
320	Bushing, Valve Rocker Shaft—Shaft, Valve Rocker (Small End)	.000	.001	.002
347	Magneto Drive Oil Seal Housing—Rear Crankcase	.000	.012	

LIMITS

Ref. No.	Name	Min.	Max.	Replace
348	Magneto Drive Oil Seal Housing - Oil Seal (P/N 163314)	.001T	.007T	*
348	Magneto Drive Oil Seal Housing - Oil Seal (P/N 383201)	.003T	.009T	*
645	Exhaust Valve - Guide (Maximum allowance on Valve Stem Wear .010)	.003	.0055	.010
646	Cap Ball - Pushrod.	.0015T	.0035T	*
671	Splines - Gear, Generator Drive - Generator (On Width).	.001	.006	.030
902	Fuel Pump Drive Gear Bracket - Oil Seal.	.0015T	.0065T	*
906	Spring, Oil Return Check Valve Dia. Wire .038 . . . . At 13/16	2 1/4		< 1 3/4
908	Oil Pressure Relief Spring Dia. Wire .0625 (P/N 6091) . . . . At 1-7/16	19	21	< 15
953	Impeller Shaft Plain Bearing End Clearance	.003	.007	.014
963	Inlet and Exhaust Valves (Inner Spring at 1.450 in.)	91	99	< 83
964	Inlet and Exhaust Valves (Outer Spring at 1.450 in.).	101	109	< 93
966	Oil Return Check Valve Spring at .813 in.	2.25	2.75	< 1.75
967	Oil Screen Retaining Spring at 1.094 in.	9	13	< 5

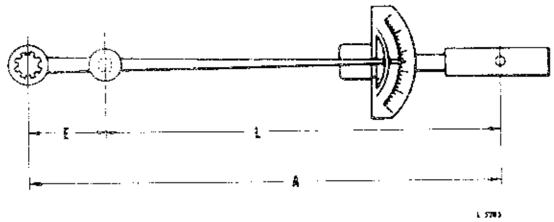
TORQUE RECOMMENDATIONS

Torque Wrenches

The specified torque limits apply only when Pratt & Whitney Aircraft wrenches, or wrenches of identical design are used.

Torque indicating devices should be checked daily and calibrated by means of weights and a measured arm to ensure accuracy. Checking one torque wrench against another is not sufficient. Some wrenches are quite sensitive as to the way they are supported during a tightening operation, and every effort should be made to adhere to the instructions furnished by the respective manufacturer. Tightening should be done slowly and evenly for consistency, and for the best possible accuracy.

On occasion, it is necessary to use a special extension or adapter wrench together with a standard torque wrench. In order to arrive at the resultant required torque limits, the following formula should be used in conjunction with Figure 11-1.



[11—1] **Torque Wrench and Extension**

T = Desired torque on the part.
E = Effective length of special extension or adapter.
L = Effective length of torque wrench.

> *The effective length of P&WA special extensions, adapters, and wrenches is stamped on the tool.*

R = Reading on scale or dial of torque wrench.
A = Distance through which force is applied to part.

$$R = \frac{LT}{A} = \frac{LT}{L+E}$$

Example: A torque of 1440 pound-inches is desired on a part, using a special extension having a length of 3 inches from center to center on its holes, and a torque wrench measuring 15 inches from center of handle or handle swivel pin to center of its square adapter.

$$\text{Then: } R = \frac{LT}{L+E} = \frac{15 \times 1440}{15+3} = 1200$$

With the axis of the extension or adapter and the torque wrench in a straight line, tightening to a wrench reading of 1200 pound-inches will provide the desired torque of 1440 pound-inches on the part.

General Torque Recommendations

The following torque values in pounds-inches, unless otherwise specified, and stretch values in inches, are recommended for use during maintenance of Pratt & Whitney Aircraft reciprocating engines.

Torques are based on the use of a thread lubricant, such as engine oil or the equivalent, except where otherwise specified by applicable instructions recommending a special lubricant or surface coating.

If a part has been heated or cooled prior to assembly, make sure that sufficient time has elapsed for the temperature of the part to reach that of the surrounding area before attempting a torque operation.

Torque requirements for interference fit applications such as studs and pipe plugs may be obtained with or without thread lubricant unless otherwise specified.

If the torque required to drive a stud to the correct projection length should not come up to the minimum or should exceed the maximum recommended, another stud should be selected.

There may be instances, other than those listed under Specific Torque Recommendations, where it is obvious that the torque recommended should not be used due to the kind of material or the design of the engine part involved. Common sense and good judgment should be exercised in such cases.

NUTS, BOLTS, AND SCREWS — All nut, bolt, and screw torques **[Figure 11—2]** are based on the use of a thread lubricant such as engine oil or the equivalent, except where otherwise specified by applicable instructions recommending a special lubricant or surface coating.

A standard nut has a height approximately equal to the diameter of the bolt. The torque on a nut that is shallower than standard should be reduced in proportion to the reduction in height of the nut from standard, therefore, unless otherwise specified, for thin nuts, where the height of the [illegible] approximately half the [illegible], reduce the listed [illegible] percent.

Thread Size	Limits		Thread Size	Limits	
	Min.	Max.		Min.	Max.
4-40	4	6			
6-32	8	10			
8-32	15	20	3/8-24	225	300
8-36	15	20	7/16-14	325	430
10-24	20	30	7/16-20	360	480
10-32	20	30	1/2-13	500	650
12-24	35	45	1/2-20	560	750
12-28	35	45	9/16-12	700	950
1/4-20	50	70	9/16-18	800	1050
1/4-28	65	85	5/8-11	1000	1300
5/16-18	110	150	5/8-18	1150	1500
5/16-24	125	170	3/4-10	1700	2300
3/8-16	200	270	3/4-16	2000	2600

[11—2] Nuts, Bolts, Screws

Castellations on a nut are additional and do not affect torque. However, after a castellated nut, or a drilled head bolt or screw, has been tightened to the proper torque, it should not be loosened to permit the insertion of lockwire or a cotterpin. If the slots in the nut, or the lockwire holes in the bolt or screw, are not properly aligned at the minimum torque limit, the nut should be further tightened to the next aligning position, but the maximum torque limit, if any, must not be exceeded. If this alignment cannot be accomplished without exceeding the maximum torque limit, back-off the nut, bolt or screw half a turn, then retighten. Occasionally it may be necessary to select a new part.

Tighten all palnuts snug, then an additional quarter turn.

STRAIGHT THREADED FLANGED PARTS — When installing straight threaded flanged parts such as hex head drive plugs and connectors, tighten until the hex flange just contacts its mating face, and then tighten further to a maximum of 50 pound-inches unless otherwise specified.

Excessive tightening may result in damage to the threads of the mating part.

STEEL PIPE PLUGS IN ALUMINUM AND MAGNESIUM CASES — If a pipe plug is found to leak after it has been tightened to the limits **[Figure 11—3]**, it should not be tightened further, but should be removed, and more sealing compound applied to the threads. The plug should then be reinstalled and tightened to the required torque.

Thread Size	Torque Limits	
	Minimum	Maximum
1/16 in. A.N.P.T.	30	40
1/8 in. A.N.P.T.	30	40
1/4 in. A.N.P.T.	70	85
3/8 in. A.N.P.T.	95	110
1/2 in. A.N.P.T.	140	160
3/4 in. A.N.P.T.	210	230
1 in. A.N.P.T.	285	315
1 1/4 in. A.N.P.T.	355	385

[11-3] Straight Threaded Flanged Parts

When plugs are tightened in a hot engine, the different expansion characteristics of the steel plugs and the aluminum or magnesium cases must be considered, and the recommended torque values should be reduced approximately twenty percent.

FLEXIBLE TYPE CONNECTORS — Tighten flexible type connectors to the recommended torque **[Figure 11—4]**. The tube must be properly aligned, and the seal wet with engine oil and bottomed prior to applying the recommended torque. It is to be expected that these flexible connections will experience a loss of torque over a period of time due to the seating of the seal in the mating parts.

Tube Size	Single and Double Wall Tubes Limits
1/8 in.	25 to 30
3/16 in.	25 to 30
1/4 in.	25 to 30
5/16 in.	30 to 35
3/8 in.	30 to 35
1/2 in.	55 to 60
5/8 in.	65 to 70
3/4 in.	70 to 80
7/8 in.	75 to 85
1 in.	100 to 110
1 1/8 in.	100 to 110
1 1/4 in.	100 to 110
1 1/2 in.	100 to 110

[11—4] Flexible Type Connectors

HOSE, TUBE, AND THREADED CONNECTORS—Tighten the nut on all hose fittings and tubes (not listed in Figure 11—4) to the recommended torque **[Figure 11—5]**. If either of the mating sealing surfaces are aluminum, the recommended torque limits for aluminum fittings apply. All jamnuts or locknuts on connectors, elbows, and fittings should be tightened to the minimum values listed. Thread size should be used for determining torque rather than the listed tubing sizes.

No attempt should be made to correct any leakage of a joint by overtightening. Disassemble the fitting, inspect for nicks, burrs and dirt, replace damaged parts if necessary, and then retighten to the required torque.

CRUSH TYPE ASBESTOS FILLED GASKETS—Install all crush gaskets except the self centering type, with the unbroken surface against the flange of the plug or part being installed. Tighten the part being installed until its flanged surface contacts the gasket, and then tighten to the recommended angle of turn **[Figure 11—6]** for the appropriate thread pitch.

Hose	Tube	Thread	Aluminum Fittings (Liquid or Air) Steel Fittings (Air)	Steel Fittings (Liquids)
Size	O.D.	Size	Limits	Limits
3	3/16 in.	3/8-24	30 to 50	70 to 80
4	1/4 in.	7/16-20	40 to 65	90 to 100
5	5/16 in.	1/2-20	60 to 80	135 to 150
6	3/8 in.	9/16-18	75 to 125	270 to 300
6	3/8 in.	5/8-18	100 to 175	320 to 350
—	1/2 in.	11/16-24	— —	300 to 350
8	1/2 in.	3/4-16	150 to 250	450 to 500
10	5/8 in.	7/8-14	200 to 350	650 to 700
10	5/8 in.	7/8-16	200 to 350	650 to 700
12	3/4 in.	1-14	275 to 450	800 to 900
12	3/4 in.	1 1/16-12	300 to 500	900 to 1000
16	1 in.	1 1/4-12	400 to 650	1150 to 1300
16	1 in.	1 5/16-12	500 to 700	2200 to 2400
18	1 1/8 in.	1 1/2-12	600 to 900	2200 to 2400
20	1 1/4 in.	1 5/8-12	600 to 900	2200 to 2400
24	1 1/2 in.	1 7/8-12	600 to 900	2200 to 2400

[11—5] Hose, Tube, and Threaded Connectors

Thread Pitch on Part to be Tightened	Angle of Turn: Aluminum Asbestos	Angle of Turn: Asbestos Copper
8 Threads per Inch	135°	67°
10 Threads per Inch	135°	67°
12 Threads per Inch	180°	90°
14 Threads per Inch	180°	90°
16 Threads per Inch	270°	135°
18 Threads per Inch	270°	135°
20 Threads per Inch	270°	135°
24 Threads per Inch	360°	180°
28 Threads per Inch	360°	180°

[11—6] Crush Type Asbestos Filled Gaskets

HOSE CLAMPS—Tighten the thumb-screw type hose clamps to 10 pound-inches minimum to 20 pound-inches maximum. Retighten after a period of one hour or immediately following the next operation of the engine.

STANDARD STUDS [**Figure 11—7**].

STEPPED STUDS [**Figure 11—8**].

PLAIN NECKED
STANDARD STUDS

PLAIN NECKED
STEPPED STUDS

PLAIN **NECKED**

Thread Size	Driving Torque Limits		
	Minimum	Maximum	
	Plain and Necked	Plain	Necked
8-32	10	30	30
10-24	15	45	40
12-24	20	70	65
¼-20	40	105	95
5/16-18	85	230	210
⅜-16	160	425	375
7/16-14	200	675	600
½-13	250	1050	950
9/16-12	425	1500	1400
⅝-11	625	2100	1900
¾-10	1100	3800	3500

[11—7] **Standard Studs**

PLAIN **NECKED**

Thread Size (Nut End)	Driving Torque Limits		
	Minimum	Maximum	
	Plain and Necked	Plain	Necked
8-36	10	30	30
10-32	15	50	45
12-28	20	75	65
¼-28	40	125	115
5/16-24	85	260	240
⅜-24	160	500	450
7/16-20	200	800	700
½-20	250	1300	1150
9/16-18	425	1800	1600
⅝-18	625	2600	2400
¾-16	1100	4600	4200

[11—8] **Stepped Studs**

SPECIFIC TORQUE RECOMMENDATIONS

Nomenclature	Recommended Torque
Cylinder Flange Nuts	300 with lubricant
Dehydrating Plugs —	20 to 25
Cylinder Crankcase and Sump, ¾ and 1 in. dia. thread	35 to 45
Pushrod Cover Gland Nuts (P/N 121839 and P/N 559886)	125 to 150
Pushrod Cover Gland Nuts (P/N 161707)	65 to 75
Propeller Governor Attaching Nuts (wasp engine only)	160 to 180

SPECIFIC TORQUE RECOMMENDATIONS

Nomenclature	Recommended Torque
Propeller Shaft Thrust Bearing Nut	Tighten to 250 pounds-feet, then turn to tighten through an angle of 15° to 20°. Pencil mark the nut and the thrust plate and allow to set for five to ten minutes. Loosen the nut to zero pound-feet, retorque to 250 pound-feet and turn to tighten through an angle of 15° to 20°. The pencil mark on the nut must meet or pass the mark on the plate.
Propeller Shaft Thrust Bearing Cover Nuts	100 to 150
Rigid Bracket Mounting Nuts	400 to 450
Rockerbox Cover Nuts	60 to 75
Rocker Shaft Nuts (P/N 343986)	Tighten snug against the bushing; then tighten to the next cotterpin hole.
Rocker Shaft Nuts (P/N 16405)	65 to 100
Rocker Shaft Nuts (P/N 532)	200 to 250
Sparkplugs	300 to 360
Sparkplug Lead Coupling Nut	
Couplings having ⅝-24 thread	100 to 120
Couplings having ¾-20 thread	140 to 160
Starter and Starter Cover Nuts (Two Top Nuts Only)	175 to 200
Valve Adjusting Screw Locknut	300 to 350

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.

CONVERSION FACTORS

Multiply	By	To Obtain
Acres	43,560	Square feet
	4,047	Square meters
	1.562×10^{3}	Square miles
Atmospheres	76.0	Cm mercury
	29.921	Inches mercury
	33.899	Feet of water
	10,332	Kilogm per sq m
	14.696	Pounds per sq in.
	2,116.2	Pounds per sq ft
	1.0133	Bars
Bars	75.01	Cm mercury
	14.5	Pounds per sq in.
British thermal unit	778.2	Foot pounds
	$.3930 \times 10^{-3}$	Horsepower hour
	$.2930 \times 10^{-3}$	Kilowatt hour
	.2520	Kilogram calorie
	107.6	Kilogram meters
	1055	Joules
Centimeters (cm)	.39370	Inches
	.03281	Feet
Cm of mercury	5.3524	Inches of water
	.44603	Feet of water
	.19337	Pounds per sq in.
	27.845	Pounds per sq ft
	135.95	Kilogm per sq m
Cm per second	.03281	Feet per sec
Circular mils	7.854×10^{-7}	Square inches
	5.067×10^{-4}	Sq millimeters
	.7854	Square mils
Cubic centimeters	10^{-3}	Liters
	.06102	Cubic inches
Cubic feet	28,317	Cu centimeters
	1,728	Cubic inches
	.02831	Cubic meters
	.03704	Cubic yards
	7.4805	Gallons
	28.316	Liters
Cu feet per min.	.47170	Liters per second
	.02832	Cu m per minute
Cu feet of water	62.428	Pounds
Cubic inches	16.387	Cu centimeters
	.01639	Liters
	4.329×10^{-3}	Gallons
	.01732	Quarts
Cubic meters	61,023	Cubic inches
	35.314	Cubic feet
	264.17	Gallons
Cubic yards	27	Cubic feet
	.7646	Cubic meters
	202	U. S. gallons
Degrees (arc)	.01745	Radians
Dynes	1.020×10^{-3}	Grams
	2.248×10^{-6}	Pounds
	7.233×10^{-5}	Poundals
Ergs	$.9478 \times 10^{-10}$	BTU
	1	Dyne cm
	7.376×10^{-8}	Foot pounds
	1.020×10^{-3}	Gram cm
	10^{-7}	Joules
	2.388×10^{-4}	Kilogram calories
Feet	.30480	Meters
Feet of water	.02950	Atmospheres
	.43353	Pounds per sq in.
	62.378	Pounds per sq ft
	304.80	Kilogm per sq m
	.88367	In. of mercury
	.24199	Cm of mercury
Feet per minute	.01136	Miles per hour
	.01829	Km per hour
	.50800	Cm per second
Feet per second	.68182	Miles per hour
	1.0973	Km per hour
	30.480	Cm per second
	.30480	Meters per sec
	.59209	Knots
Foot-pounds	.13826	Meter-kilograms
Foot-pounds/min	.1092	Horsepower
Foot-pounds/sec	.00182	Horsepower
Gallons, imperial	277.4	Cubic inches
	1.201	U. S. gallons
	4.546	Liters
Gallons, U. S. dry	268.8	Cubic inches
	.1556	Cubic feet
	1.164	U. S. gals, liquid
	4.405	Liters
Gallons, U.S. liquid	231	Cubic inches
	.13368	Cubic feet
	3.7853	Liters
	.83268	Imperial gallons
	128	Liquid ounces
Grams	15.432	Grains
	.03527	Ounces
	.00220	Pounds
	1,000	Milligrams
	.001	Kilograms
	980.67	Dynes
Gram calories	.00397	BTU

CONVERSION FACTORS

Multiply	By	To Obtain
Grams per cm	0.1	Kilograms per m
	.06720	Pounds per foot
	.00559	Pounds per inch
Grams per cu cm	1,000	Kilogms per cm
	62.428	Pounds per cu ft
Horsepower	33,000	Ft-pounds/min
	550	Ft-pounds/sec
	76,040	Kg-meters/sec
	1.0139	Metric hp
Horsepower, metric	75	Kilogm-m/sec
	.98632	Horsepower
Horsepower-hours	2,545.1	BTU
	1,980,000	Foot-pounds
	273,745	Kilogm-meters
Inches	2.5400	Centimeters
Inches of mercury	.03342	Atmosphere
	13.595	Inches of water
	1.1329	Feet of water
	.49116	Pounds per sq in.
	70.727	Pounds per sq ft
	345.32	Kilogm per sq m
Inches of water	.07356	Ins. of mercury
	.18683	Cm of mercury
	.03613	Pounds per sq in.
	5.1981	Pounds per sq ft
	25.400	Kilogm per sq m
Joules	$.9478 \times 10^{-3}$	BTU
	.7376	Foot-pounds
	$.2388 \times 10^{-3}$	Kilogm calories
	.10179	Kilogm meters
	$.2777 \times 10^{-3}$	Watt hours
	$.3725 \times 10^{-6}$	Horsepower hrs
Kilograms	2.2046	Pounds
	32.274	Ounces
	1,000	Grams
Kilogram-calories	3.9685	BTU
	3,087.4	Foot-pounds
	426.85	Kilogm-meters
Kilogram-meters	7.2330	Foot-pounds
	9.8067×10^{-7}	Ergs
Kilogram per cu m	06243	Pounds per cu ft
	.001	Grams per cu cm
Kilogram per meter	.67197	Pounds per ft
Kilogram per sq m	.00142	Pounds per sq in.
	.20482	Pounds per sq ft
	.00290	Ins. of mercury
	.00328	Feet of water
	0.1	Grams per sq cm
Kilometers	3,280.8	Feet
	.62137	Miles
	.53956	Nautical miles
Kilometers per hr	.91134	Feet per second
	.53955	Knots
	.62137	Miles per hour
	.2777	Meters per sec
Kilowatts	.9480	BTU per sec
	737.7	Ft-pounds per sec
	1.341	Horsepower
	.2389	Kg-cal per sec
Knots	1.0	Nautical miles/hr
	1.6889	Feet per second
	1.1516	Miles per hour
	1.8532	Kilometers per hr
	.51479	Meters per sec
Liters	1,000	Cu centimeters
	61.025	Cubic inches
	.03532	Cubic feet
	.26418	Gallons
	.21998	Imperial gallons
Meters	39.37	Inches
	3.2808	Feet
	1.0936	Yards
Meters per second	3.2808	Feet per second
	2.2369	Miles per hour
	3.600	Kilometers per hr
Miles	5,280	Feet
	1.6093	Kilometers
	.86839	Nautical miles
Miles per hour	1.4667	Feet per second
	.44704	Meters per sec
	1.6093	Kilometers per hr
	.86839	Knots
Miles/hr squared	2.1511	Feet/sec squared
Nautical Miles	6080.2	Feet
Ounces, avdp	.0625	Pounds, avdp
	28.350	Grams
	437.5	Grains
Ounces, fluid	29.57	Cu centimeters
	1.805	Cubic inches
Pounds	453.59	Grams
	7000	Grains
	16.0	Ounces
	32.174	Poundals
Pounds per cu ft	16.018	Kilogm per cu m
	.01602	Grams per cu cm

CONVERSION FACTORS

Multiply	By	To Obtain
Pounds per cu in.	1,728.0	Pounds per cu ft
	27.680	Grams per cu cm
Pounds per sq in.	2.0361	Ins. of mercury
	2.3066	Feet of water
	.06805	Atmospheres
	703.07	Kilogm per sq m
	.07036	Kilogm per sq cm
Radians	57.296	Degrees (arc)
Radians per sec	57.296	Degrees per sec
	.15916	Rev per sec
	9.8493	Rev per min
Revolutions	6.2832	Radians
Revolutions per min	.10472	Radians per sec
Slugs	32.174	Pounds
Square centimeters	.15500	Sq inch
	.00108	Sq feet
Square feet	929.03	Sq centimeters
	144	Sq inches
	.09290	Sq meters
	.111	Sq yards
Square inches	645.16	Sq millimeters
	6.4516	Sq centimeters
Square kilometers	.38610	Sq miles
Square meters	10.764	Sq feet
	1.1960	Sq yards
Square miles	2.5900	Sq kilometers
	640	Acres
Square yards	.83613	Sq meters
Yards	.9144	Meters

INTERNATIONAL STANDARDS

	English	Metric
Gravity — g	32.1739 ft/sec^2	9.80665 m/sec^2
Absolute zero	-459.4 F	-273 C
π	3.14159	3.14159

STANDARD ATMOSPHERE

Standard Values at Sea Level			
Pressure, Po		29.92 in. Hg	760 mm Hg
Pressure, Po		2116 lb/ft^2	10332 kg/m^2
Temperature,	NACA	59 F	15 C
	Army & CAA	100.4 F	38 C
	Navy	89.6 F	32 C
Absolute temp, T_o		518.4 F abs, R	288 C abs, K
Specific weight, $g\rho_o$		.07651 lb/ft^3	1.2255 kg/m^3
Density, ρ_o		.002378 lb sec^2/ft^4	.124966 kg sec^2/m^4

Standard Values at Altitude			
Isothermal Level		35332 ft	10769 m
Isothermal temp.		-67 F	-55 C
Temp. gradient	NACA	.00356 F/ft	.0065 C/m
	Navy	.0036 F/ft	.0066
	Army & CAA	.0036 F/ft	.0066

WEIGHTS AND MEASURES

LENGTH

12 inches = 1 foot
9 inches = 1 span
4 inches = 1 hand
3 feet = 1 yard
5½ yards = 16½ feet = 1 rod or pole
40 rods = 220 yd = 1 furlong
8 furlongs = 5280 ft = 1 mile
3 miles = 1 league

Nautical

6080.2 ft = 1 nautical mile
1 nautical mile per hour = 1 knot
6 feet = 1 fathom

Surveyor's

7.92 inches = 1 link
100 links = 66 ft = 1 chain
80 chains = 1 mile

WEIGHTS

Avoirdupois

16 drams = 437.5 grains = 1 ounce
16 ounces = 7000 grains = 1 pound
112 pounds = 1 hundredweight
2240 pounds = 1 long ton
2000 pounds = 1 short ton

Troy

24 grains = 1 pennyweight
20 pennyweights = 1 ounce
12 ounces = 5760 grains = 1 pound

Apothecaries

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 5760 grains = 1 pound

VOLUME

1728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard
128 cubic feet = 1 cord of wood

Liquid

4 gills = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
7.4805 gallons = 1 cubic foot

Dry

2 pints = 1 quart
8 quarts = 1 peck
4 pecks = 1 bushel

Apothecaries

60 minim = 1 liquid dram
8 drams = 1 liquid ounce
16 ounces = 1 pint

Shipping

100 cubic feet = 1 Register ton
40 cubic feet = 1 U. S. shipping ton

AREA

144 square inches = 1 square foot
9 square feet = 1 square yard
30¼ square yards = 1 square rod
160 square rods = 43,560 square feet = 1 acre
640 acres = 1 square mile

ENGLISH — METRIC EQUIVALENTS

Length

1 centimeter = 0.3937 inches
2.54 centimeters = 1 inch
0.3048 meters = 1 foot
1 meter = 3.278 feet
1 kilometer = 0.6214 miles
1.61 kilometers = 1 mile

Area

1 sq cm = .1550 sq in.
6.452 sq cm = 1.0 sq in.
0.093 sq meters = 1 sq ft
1 sq meter = 10.76 sq ft
4047 sq meters = 1 acre
1 hectare = 10,000 sq meters = 2.471 acres

Volume

1 cu cm = 0.061 cu in.
16.39 cu cm = 1 cu in.
0.0283 cu meter = 1 cu ft
1 cu meter = 35.31 cu ft
1 cu meter = 1.308 cu yd

Weight

0.648 gram = 1 grain
1.0 gram = 15.43 grains
28.35 grams = 1 oz
1 kilogram = 2.205 pounds

Liquid Measure

29.57 cu cm = 1 fluid ounce
1 liter = 33.81 fluid oz = 1.057 qt
3.8 liters = 1 gal

INCH FRACTION CONVERSIONS
Decimals, Area of Circles, and Millimeters

Inch Fraction		Decimal Equiv.	Area Sq. In.	Mm. Equiv.	Inch Fraction		Decimal Equiv.	Area Sq. In.	Mm. Equiv.
	1/64	.0156	.0002	.397		33/64	.5156	.2088	13.097
1/32		.0312	.0008	.794	17/32		.5312	.2217	13.494
	3/64	.0469	.0016	1.191		35/64	.5469	.2349	13.891
1/16		.0625	.0031	1.587	9/16		.5625	.2485	14.288
	5/64	.0781	.0048	1.984		37/64	.5781	.2624	14.684
3/32		.0937	.0069	2.381	19/32		.5937	.2769	15.081
	7/64	.1094	.0093	2.778		39/64	.6094	.2916	15.479
1/8		.125	.0123	3.175	5/8		.625	.3068	15.875
	9/64	.1406	.0154	3.572		41/64	.6406	.3223	16.272
5/32		.1562	.0192	3.969	21/32		.6562	.3382	16.669
	11/64	.1719	.0231	4.366		43/64	.6719	.3545	17.065
3/16		.1875	.0276	4.762	11/16		.6875	.3712	17.462
	13/64	.2031	.0323	5.159		45/64	.7031	.3883	17.859
7/32		.2187	.0376	5.556	23/32		.7187	.4057	18.256
	15/64	.2344	.0431	5.953		47/64	.7344	.4235	18.653
1/4		.25	.0491	6.350	3/4		.75	.4418	19.050
	17/64	.2656	.0553	6.747		49/64	.7656	.4604	19.447
9/32		.2812	.0621	7.144	25/32		.7812	.4794	19.844
	19/64	.2969	.0691	7.540		51/64	.7969	.4987	20.241
5/16		.3125	.0767	7.937	13/16		.8125	.5185	20.637
	21/64	.3281	.0845	8.334		53/64	.8281	.5386	21.034
11/32		.3437	.0928	8.731	27/32		.8437	.5591	21.431
	23/64	.3594	.1013	9.128		55/64	.8594	.5800	21.828
3/8		.375	.1105	9.525	7/8		.875	.6013	22.225
	25/64	.3906	.1198	9.922		57/64	.8906	.6229	22.622
13/32		.4062	.1296	10.319	29/32		.9062	.6450	23.019
	27/64	.4219	.1398	10.716		59/64	.9219	.6675	23.416
7/16		.4375	.1503	11.112	15/16		.9375	.6903	23.812
	29/64	.4531	.1612	11.509		61/84	.9531	.7134	24.209
15/32		.4687	.1726	11.906	31/32		.9687	.7371	24.606
	31/64	.4844	.1842	12.303		63/64	.9844	.7610	25.003
1/2		.5	.1964	12.700	1		1.	.7854	25.400

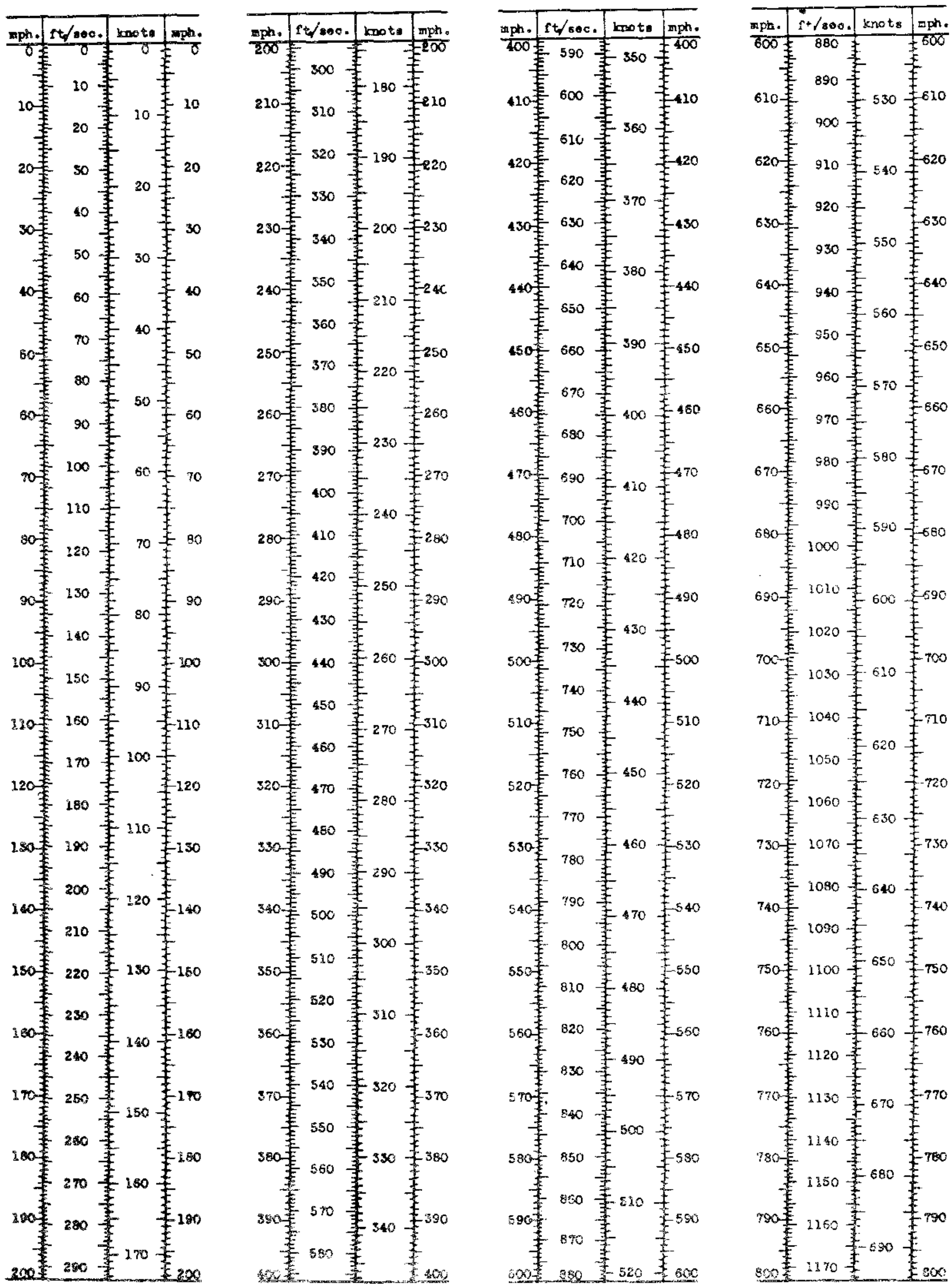
DRILL SIZE — DECIMAL EQUIVALENTS

Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.
1	.2280	19	.1660	37	.1040	55	.0520	73	.0240	I	.272
2	.2210	20	.1610	38	.1015	56	.0465	74	.0225	J	.277
3	.2130	21	.1590	39	.0995	57	.0430	75	.0210	K	.281
4	.2090	22	.1570	40	.0980	58	.0420	76	.0200	L	.290
5	.2055	23	.1540	41	.0960	59	.0410	77	.0180	M	.295
6	.2040	24	.1520	42	.0935	60	.0400	78	.0160	N	.302
7	.2010	25	.1495	43	.0890	61	.0390	79	.0145	O	.316
8	.1990	26	.1470	44	.0860	62	.0380	80	.0135	P	.323
9	.1960	27	.1440	45	.0820	63	.0370			Q	.332
10	.1935	28	.1405	46	.0810	64	.0360			R	.339
11	.1910	29	.1360	47	.0785	65	.0350	A	.234	S	.348
12	.1890	30	.1285	48	.0760	66	.0330	B	.238	T	.358
13	.1850	31	.1200	49	.0730	67	.0320	C	.242	U	.368
14	.1820	32	.1160	50	.0700	68	.0310	D	.246	V	.377
15	.1800	33	.1130	51	.0670	69	.0292	E	.250	W	.386
16	.1770	34	.1110	52	.0635	70	.0280	F	.257	X	.397
17	.1730	35	.1100	53	.0595	71	.0260	G	.261	Y	.404
18	.1695	36	.1065	54	.0550	72	.0250	H	.266	Z	.413

VELOCITY CONVERSION CHART

Conversion factors from: The Handbook of Chemistry and Physics, 23rd. Edition

1 mph. = 1.4667 ft./sec.
1 mph. = .8684 knots



TEMPERATURE CONVERSION TABLE

Conversion Constants

The following table gives the conversion of Fahrenheit and centigrade temperatures from -100° to +249° in units of 1° and from +250° to +2645° in units of 5°. The readings are based on the standard temperature scale. Conversion of any value to the absolute temperature scale may be made as follows:

Degrees Kelvin (K) = degrees centigrade + 273.16
Degrees Rankine (R) = degrees Fahrenheit + 459.69

If F and C denote readings on the Fahrenheit and centigrade standard scales, respectively, for the same, then

$$C = 5/9\ (F - 32), \qquad F = (9/5)\ C + 32.$$

Use of the Table

Look up reading in middle column; if in degrees centigrade, read Fahrenheit equivalent in right-hand column, if in degrees Fahrenheit, read centigrade equivalent in left-hand column.

Conversion of Centigrade and Fahrenheit Temperatures from -100° to +249°

C		F	C		F	C		F	C		F	C		F	C		F	C		F
-73.3	-100	-148.0	-45.6	-50	-58.0	-17.8	0	32.0	10.0	50	122.0	37.8	100	212.0	65.6	150	302.0	93.3	200	392.0
-72.8	-99	-146.2	-45.0	-49	-56.2	-17.2	1	33.8	10.6	51	123.8	38.3	101	213.8	66.1	151	303.8	93.9	201	393.8
-72.2	-98	-144.4	-44.4	-48	-54.4	-16.7	2	35.6	11.1	52	125.6	38.9	102	215.6	66.7	152	305.6	94.4	202	395.6
-71.7	-97	-142.6	-43.9	-47	-52.6	-16.1	3	37.4	11.7	53	127.4	39.4	103	217.4	67.2	153	307.4	95.0	203	397.4
-71.1	-96	-140.8	-43.3	-46	-50.8	-15.6	4	39.2	12.2	54	129.2	40.0	104	219.2	67.8	154	309.2	95.6	204	399.2
-70.6	-95	-139.0	-42.8	-45	-49.0	-15.0	5	41.0	12.8	55	131.0	40.6	105	221.0	68.3	155	311.0	96.1	205	401.0
-70.0	-94	-137.2	-42.2	-44	-47.2	-14.4	6	42.8	13.3	56	132.8	41.1	106	222.8	68.9	156	312.8	96.7	206	402.8
-69.4	-93	-135.4	-41.7	-43	-45.4	-13.9	7	44.6	13.9	57	134.6	41.7	107	224.6	69.4	157	314.6	97.2	207	404.6
-68.9	-92	-133.6	-41.1	-42	-43.6	-13.3	8	46.4	14.4	58	136.4	42.2	108	226.4	70.0	158	316.4	97.8	208	406.4
-68.3	-91	-131.8	-40.6	-41	-41.8	-12.8	9	48.2	15.0	59	138.2	42.8	109	228.2	70.6	159	318.2	98.3	209	408.2
-67.8	-90	-130.0	-40.0	-40	-40.0	-12.2	10	50.0	15.6	60	140.0	43.3	110	230.0	71.1	160	320.0	98.9	210	410.0
-67.2	-89	-128.2	-39.4	-39	-38.2	-11.7	11	51.8	16.1	61	141.8	43.9	111	231.8	71.7	161	321.8	99.4	211	411.8
-66.7	-88	-126.4	-38.9	-38	-36.4	-11.1	12	53.6	16.7	62	143.6	44.4	112	233.6	72.2	162	323.6	100.0	212	413.6
-66.1	-87	-124.6	-38.3	-37	-34.6	-10.6	13	55.4	17.2	63	145.4	45.0	113	235.4	72.8	163	325.4	100.6	213	415.4
-65.6	-86	-122.8	-37.8	-36	-32.8	-10.0	14	57.2	17.8	64	147.2	45.6	114	237.2	73.3	164	327.2	101.1	214	417.2
-65.0	-85	-121.0	-37.2	-35	-31.0	- 9.4	15	59.0	18.3	65	149.0	46.1	115	239.0	73.9	165	329.0	101.7	215	419.0
-64.4	-84	-119.2	-36.7	-34	-29.0	- 8.9	16	60.8	18.9	66	150.8	46.7	116	240.8	74.4	166	330.8	102.2	216	420.8
-63.9	-83	-117.4	-36.1	-33	-27.4	- 8.3	17	62.6	19.4	67	152.6	47.2	117	242.6	75.0	167	332.6	102.8	217	422.6
-63.3	-82	-115.6	-35.6	-32	-25.6	- 7.8	18	64.4	20.0	68	154.4	47.8	118	244.4	75.6	168	334.4	103.3	218	424.4
-62.8	-81	-113.8	-35.0	-31	-23.8	- 7.2	19	66.2	20.6	69	156.2	48.3	119	246.2	76.1	169	336.2	103.9	219	426.2
-62.2	-80	-112.0	-34.4	-30	-22.0	- 6.7	20	68.0	21.1	70	158.0	48.9	120	248.0	76.7	170	338.0	104.4	220	428.0
-61.7	-79	-110.2	-33.9	-29	-20.2	- 6.1	21	69.8	21.7	71	159.8	49.4	121	249.8	77.2	171	339.8	105.0	221	429.8
-61.1	-78	-108.4	-33.3	-28	-18.4	- 5.6	22	71.6	22.2	72	161.6	50.0	122	251.6	77.8	172	341.6	105.6	222	431.6
-60.6	-77	-106.6	-32.8	-27	-16.6	- 5.0	23	73.4	22.8	73	163.4	50.6	123	253.4	78.3	173	343.4	106.1	223	433.4
-60.0	-76	-104.8	-32.2	-26	-14.8	- 4.4	24	75.2	23.3	74	165.2	51.1	124	255.2	78.9	174	345.2	106.7	224	435.2
-59.4	-75	-103.0	-31.7	-25	-13.0	- 3.9	25	77.0	23.9	75	167.0	51.7	125	257.0	79.4	175	347.0	107.2	225	437.0
-58.9	-74	-101.2	-31.1	-24	-11.2	- 3.3	26	78.8	24.4	76	168.8	52.2	126	258.8	80.0	176	348.8	107.8	226	438.8
-58.3	-73	- 99.4	-30.6	-23	- 9.4	- 2.8	27	80.6	25.0	77	170.6	52.8	127	260.6	80.6	177	350.6	108.3	227	440.6
-57.8	-72	- 97.6	-30.0	-22	- 7.6	- 2.2	28	82.4	25.6	78	172.4	53.3	128	262.4	81.1	178	352.4	108.9	228	442.4
-57.2	-71	- 95.8	-29.4	-21	- 5.8	- 1.7	29	84.2	26.1	79	174.2	53.9	129	264.2	81.7	179	354.2	109.4	229	444.2
-56.7	-70	- 94.0	-28.9	-20	- 4.0	- 1.1	30	86.0	26.7	80	176.0	54.4	130	266.0	82.2	180	356.0	110.0	230	446.0
-56.1	-69	- 92.2	-28.3	-19	- 2.2	- 0.6	31	87.8	27.2	81	177.8	55.0	131	267.8	82.8	181	357.8	110.6	231	447.8
-55.6	-68	- 90.4	-27.8	-18	- 0.4	0.0	32	89.6	27.8	82	179.6	55.6	132	269.6	83.3	182	359.6	111.1	232	449.6
-55.0	-67	- 88.6	-27.2	-17	1.4	0.6	33	91.4	28.3	83	181.4	56.1	133	271.4	83.9	183	361.4	111.7	233	451.4
-54.4	-66	- 86.8	-26.7	-16	3.2	1.1	34	93.2	28.9	84	183.2	56.7	134	273.2	84.4	184	363.2	112.2	234	453.2
-53.9	-65	-85.0	-26.1	-15	5.0	1.7	35	95.0	29.4	85	185.0	57.2	135	275.0	85.0	185	365.0	112.8	235	455.0
-53.3	-64	-83.2	-25.6	-14	6.8	2.2	36	96.8	30.0	86	186.8	57.8	136	276.8	85.6	186	366.8	113.3	236	456.8
-52.8	-63	-81.4	-25.0	-13	8.6	2.8	37	98.6	30.6	87	188.6	58.3	137	278.6	86.1	187	368.6	113.9	237	458.6
-52.2	-62	-79.6	-24.4	-12	10.4	3.3	38	100.4	31.1	88	190.4	58.9	138	280.4	86.7	188	370.4	114.4	238	460.4
-51.7	-61	-77.8	-23.9	-11	12.2	3.9	39	102.2	31.7	89	192.2	59.4	139	282.2	87.2	189	372.2	115.0	239	462.2
-51.1	-60	-76.0	-23.3	-10	14.0	4.4	40	104.0	32.2	90	194.0	60.0	140	284.0	87.8	190	374.0	115.6	240	464.0
-50.6	-59	-74.2	-22.8	- 9	15.8	5.0	41	105.8	32.8	91	195.8	60.6	141	285.8	88.3	191	375.8	116.1	241	465.8
-50.0	-58	-72.4	-22.2	- 8	17.6	5.6	42	107.6	33.3	92	197.6	61.1	142	287.6	88.9	192	377.6	116.7	242	467.6
-49.4	-57	-70.6	-21.7	- 7	19.4	6.1	43	109.4	33.9	93	199.4	61.7	143	289.4	89.4	193	379.4	117.2	243	469.4
-48.9	-56	-68.8	-21.1	- 6	21.2	6.7	44	111.2	34.4	94	201.2	62.2	144	291.2	90.0	194	381.2	117.8	244	471.2
-48.3	-55	-67.0	-20.6	- 5	23.0	7.2	45	113.0	[illegible]	95	203.0	62.8	145	293.0	90.6	195	383.0	118.3	245	473.0
-47.8	-54	-65.2	-20.0	- 4	24.8	7.8	46	114.8	35.6	96	204.8	63.3	146	294.8	91.1	196	384.8	118.9	246	474.8
-47.2	-53	-63.4	-19.4	- 3	26.6	8.3	47	116.6	36.1	97	206.6	63.9	147	296.6	91.7	197	386.6	119.4	247	476.6
-46.7	-52	-61.6	-18.9	- 2	28.4	8.9	48	118.4	36.7	98	208.4	64.4	148	298.4	92.2	198	388.4	120.0	248	478.4
-46.1	-51	-59.8	-18.3	- 1	30.2	9.4	49	120.2	[illegible]	99	[illegible]	65.0	149	300.2	92.8	199	390.2	120.6	249	480.2

 Conversion of Centigrade and Fahrenheit Temperatures form +250° to +2645°

C		F
121.1	250	482.0
123.9	255	491.0
126.7	260	500.0
129.4	265	509.0
132.2	270	518.0
135.0	275	527.0
137.8	280	536.0
140.6	285	545.0
143.3	290	554.0
146.1	295	563.0
148.9	300	572.0
151.7	305	581.0
154.4	310	590.0
157.2	315	599.0
160.0	320	608.0
162.8	325	617.0
165.6	330	626.0
168.3	335	635.0
171.1	340	644.0
173.9	345	653.0
176.7	350	662.0
179.4	355	671.0
182.2	360	680.0
185.0	365	689.0
187.8	370	698.0
190.6	375	707.0
193.3	380	716.0
196.1	385	725.0
198.9	390	734.0
201.7	395	743.0
204.4	400	752.0
207.2	405	761.0
210.0	410	770.0
212.8	415	779.0
215.6	420	788.0
218.3	425	797.0
221.1	430	806.0
223.9	435	815.0
226.7	440	824.0
229.4	445	833.0
232.2	450	842.0
235.0	455	851.0
237.8	460	860.0
240.6	465	869.0
243.3	470	878.0
246.1	475	887.0
248.9	480	896.0
251.7	485	905.0
254.4	490	914.0
257.2	495	923.0
260.0	500	932.0
262.8	505	941.0
265.6	510	950.0
268.3	515	959.0
271.1	520	968.0
273.9	525	977.0
276.7	530	986.0
279.4	535	995.0
282.2	540	1004.0
285.0	545	1013.0
287.8	550	1022.0
290.6	555	1031.0
293.3	560	1040.0
296.1	565	1049.0
298.9	570	1058.0
301.7	575	1067.0
304.4	580	1076.0
307.2	585	1085.0
310.0	590	1094.0
312.8	595	1103.0
315.6	600	1112.0
318.3	605	1121.0
321.1	610	1130.0
323.9	615	1139.0
326.7	620	1148.0
329.4	625	1157.0
332.2	630	1166.0
335.0	635	1175.0
337.8	640	1184.0
340.6	645	1193.0

C		F
343.3	650	1202.0
346.1	655	1211.0
348.9	660	1220.0
351.7	665	1229.0
354.4	670	1238.0
357.2	675	1247.0
360.0	680	1256.0
362.8	685	1265.0
365.6	690	1274.0
368.3	695	1283.0
371.1	700	1292.0
373.9	705	1301.0
376.7	710	1310.0
379.4	715	1319.0
382.2	720	1328.0
385.0	725	1337.0
387.8	730	1346.0
390.6	735	1355.0
393.3	740	1364.0
396.1	745	1373.0
398.9	750	1382.0
401.7	755	1391.0
404.4	760	1400.0
407.2	765	1409.0
410.0	770	1418.0
412.8	775	1427.0
415.6	780	1436.0
418.3	785	1445.0
421.1	790	1454.0
423.9	795	1463.0
426.7	800	1472.0
429.4	805	1481.0
432.2	810	1490.0
435.0	815	1499.0
437.8	820	1508.0
440.6	825	1517.0
443.3	830	1526.0
446.1	835	1535.0
448.9	840	1544.0
451.7	845	1553.0
454.4	850	1562.0
457.2	855	1571.0
460.0	860	1580.0
462.8	865	1589.0
465.6	870	1598.0
468.3	875	1607.0
471.1	880	1616.0
473.9	885	1625.0
476.7	890	1634.0
479.4	895	1643.0
482.2	900	1652.0
485.0	905	1661.0
487.8	910	1670.0
490.6	915	1679.0
493.3	920	1688.0
496.1	925	1697.0
498.9	930	1706.0
501.7	935	1715.0
504.4	940	1724.0
507.2	945	1733.0
510.0	950	1742.0
512.8	955	1751.0
515.6	960	1760.0
518.3	965	1769.0
521.1	970	1778.0
523.9	975	1787.0
526.7	980	1796.0
529.4	985	1805.0
532.2	990	1814.0
535.0	995	1823.0
537.8	1000	1852.0
540.6	1005	1841.0
543.3	1010	1850.0
546.1	1015	1859.0
548.9	1020	1868.0
551.7	1025	1877.0
554.4	1030	1886.0
557.2	1035	1895.0
560.0	1040	1904.0
562.8	1045	1913.0

C		F
565.6	1050	1922.0
568.3	1055	1931.0
571.1	1060	1940.0
573.9	1065	1949.0
576.7	1070	1958.0
579.4	1075	1967.0
582.2	1080	1976.0
585.0	1085	1985.0
587.8	1090	1994.0
590.6	1095	2003.0
593.3	1100	2012.0
596.1	1105	2021.0
598.9	1110	2030.0
601.7	1115	2039.0
604.4	1120	2048.0
607.2	1125	2057.0
610.0	1130	2066.0
612.8	1135	2075.0
615.6	1140	2084.0
618.3	1145	2093.0
621.1	1150	2102.0
623.9	1155	2111.0
626.7	1160	2120.0
629.4	1165	2129.0
632.2	1170	2138.0
635.0	1175	2147.0
637.8	1180	2156.0
640.6	1185	2165.0
643.3	1190	2174.0
646.1	1195	2183.0
648.9	1200	2192.0
651.7	1205	2201.0
654.4	1210	2210.0
657.2	1215	2219.0
660.0	1220	2228.0
662.8	1225	2237.0
665.6	1230	2246.0
668.3	1235	2255.0
671.1	1240	2264.0
673.9	1245	2273.0
676.7	1250	2282.0
679.4	1255	2291.0
682.2	1260	2300.0
685.0	1265	2309.0
687.8	1270	2318.0
690.6	1275	2327.0
693.3	1280	2336.0
696.1	1285	2345.0
698.9	1290	2354.0
701.7	1295	2363.0
704.4	1300	2372.0
707.2	1305	2381.0
710.0	1310	2390.0
712.8	1315	2399.0
715.6	1320	2408.0
718.3	1325	2417.0
721.1	1330	2426.0
723.9	1335	2435.0
726.7	1340	2444.0
729.4	1345	2453.0
732.2	1350	2462.0
735.0	1355	2471.0
737.8	1360	2480.0
740.6	1365	2489.0
743.3	1370	2498.0
746.1	1375	2507.0
748.9	1380	2516.0
751.7	1385	2525.0
754.4	1390	2534.0
757.2	1395	2543.0
760.0	1400	2552.0
762.8	1405	2561.0
765.6	1410	2570.0
768.3	1415	2579.0
771.1	1420	2588.0
773.9	1425	2597.0
776.7	1430	2606.0
779.4	1435	2615.0
782.2	1440	2624.0
785.0	1445	2633.0

C		F
787.8	1450	2642.0
790.6	1455	2651.0
793.3	1460	2660.0
796.1	1465	2669.0
798.9	1470	2678.0
801.7	1475	2687.0
804.4	1480	2696.0
807.2	1485	2705.0
810.0	1490	2714.0
812.8	1495	2723.0
815.6	1500	2732.0
818.3	1505	2741.0
821.1	1510	2750.0
823.9	1515	2759.0
826.7	1520	2768.0
829.4	1525	2777.0
832.2	1530	2786.0
835.0	1535	2795.0
837.8	1540	2804.0
840.6	1545	2813.0
843.3	1550	2822.0
846.1	1555	2831.0
848.9	1560	2840.0
851.7	1565	2849.0
854.4	1570	2858.0
857.2	1575	2867.0
860.0	1580	2876.0
862.8	1585	2885.0
865.6	1590	2894.0
868.3	1595	2903.0
871.1	1600	2912.0
873.9	1605	2921.0
876.7	1610	2930.0
879.4	1615	2939.0
882.2	1620	2948.0
885.0	1625	2957.0
887.8	1630	2966.0
890.6	1635	2975.0
893.3	1640	2984.0
896.1	1645	2993.0
898.9	1650	3002.0
901.7	1655	3011.0
904.4	1660	3020.0
907.2	1665	3029.0
910.0	1670	3038.0
912.8	1675	3047.0
915.6	1680	3056.0
918.3	1685	3065.0
921.1	1690	3074.0
923.9	1695	3083.0
926.7	1700	3092.0
929.4	1705	3101.0
932.2	1710	3110.0
935.0	1715	3119.0
937.8	1720	3128.0
940.6	1725	3137.0
943.3	1730	3146.0
946.1	1735	3155.0
948.9	1740	3164.0
951.7	1745	3173.0
954.4	1750	3182.0
957.2	1755	3191.0
960.0	1760	3200.0
962.8	1765	3209.0
965.6	1770	3218.0
968.3	1775	3227.0
971.1	1780	3236.0
973.9	1785	3245.0
976.7	1790	3254.0
979.4	1795	3263.0
982.2	1800	3272.0
985.0	1805	3281.0
987.8	1810	3290.0
990.6	1815	3299.0
993.3	1820	3308.0
996.1	1825	3317.0
998.9	1830	3326.0
1001.7	1835	3335.0
1004.4	1840	3344.0
1007.2	1845	3353.0

C		F
1010.0	1850	3362.0
1012.8	1855	3371.0
1015.6	1860	3380.0
1018.3	1865	3389.0
1021.1	1870	3398.0
1023.9	1875	3407.0
1026.9	1880	3416.0
1029.4	1885	3425.0
1032.2	1890	3434.0
1035.0	1895	3443.0
1037.8	1900	3452.0
1040.6	1905	3461.0
1043.3	1910	3470.0
1046.1	1915	3479.0
1048.9	1920	3488.0
1051.7	1925	3497.0
1054.4	1930	3506.0
1057.2	1935	3515.0
1060.0	1940	3524.0
1062.8	1945	3533.0
1065.6	1950	3542.0
1068.3	1955	3551.0
1071.1	1960	3560.0
1073.9	1965	3569.0
1076.7	1970	3578.0
1079.4	1975	3587.0
1082.2	1980	3596.0
1085.0	1985	3605.0
1087.8	1990	3614.0
1090.6	1995	3623.0
1093.6	2000	3632.0
1096.1	2005	3641.0
1098.9	2010	3650.0
1101.7	2015	3659.0
1104.4	2020	3668.0
1107.2	2025	3677.0
1110.0	2030	3686.0
1112.8	2035	3695.0
1115.6	2040	3704.0
1118.3	2045	3713.0
1121.1	2050	3722.0
1123.9	2055	3731.0
1126.7	2060	3740.0
1129.4	2065	3749.0
1132.2	2070	3758.0
1135.0	2075	3767.0
1137.8	2080	3776.0
1140.6	2085	3785.0
1143.3	2090	3794.0
1146.1	2095	3803.0
1148.9	2100	3812.0
1151.7	2105	3821.0
1154.4	2110	3830.0
1157.2	2115	3839.0
1160.0	2120	3848.0
1162.8	2125	3857.0
1165.6	2130	3866.0
1168.3	2135	3875.0
1171.1	2140	3884.0
1173.9	2145	3893.0
1176.7	2150	3902.0
1179.4	2155	3911.0
1182.2	2160	3920.0
1185.0	2165	3929.0
1187.8	2170	3938.0
1190.6	2175	3947.0
1193.3	2180	3956.0
1196.1	2185	3965.0
1198.9	2190	3974.0
1201.7	2195	3983.0
1204.4	2200	3992.0
1207.2	2205	4001.0
1210.0	2210	4010.0
1212.8	2215	4019.0
1215.6	2220	4028.0
1218.3	2225	4037.0
1221.1	2230	4046.0
1223.9	2235	4055.0
1226.7	2240	4064.0
1229.4	2245	4073.0

C		F
1232.2	2250	4082.0
1235.0	2255	4091.0
1237.8	2260	4100.0
1240.6	2265	4109.0
1243.3	2270	4118.0
1246.1	2275	4127.0
1248.9	2280	4136.0
1251.7	2285	4145.0
1254.4	2290	4154.0
1257.2	2295	4163.0
1260.0	2300	4172.0
1262.8	2305	4181.0
1265.6	2310	4190.0
1268.3	2315	4199.0
1271.1	2320	4208.0
1273.9	2325	4217.0
1276.7	2330	4226.0
1279.4	2335	4235.0
1282.2	2340	4244.0
1285.0	2345	4253.0
1287.8	2350	4262.0
1290.6	2355	4271.0
1293.3	2360	4280.0
1296.1	2365	4289.0
1298.9	2370	4298.0
1301.7	2375	4307.0
1304.4	2380	4316.0
1307.2	2385	4325.0
1310.0	2390	4334.0
1312.8	2395	4343.0
1315.6	2400	4352.0
1318.3	2405	4361.0
1321.1	2410	4370.0
1323.9	2415	4379.0
1326.7	2420	4388.0
1329.4	2425	4397.0
1332.2	2430	4406.0
1335.0	2435	4415.0
1337.8	2440	4424.0
1340.6	2445	4433.0
1343.3	2450	4442.0
1346.1	2455	4451.0
1348.9	2460	4460.0
1351.7	2465	4469.0
1354.4	2470	4478.0
1357.2	2475	4487.0
1360.0	2480	4496.0
1362.8	2485	4505.0
1365.6	2490	4514.0
1368.3	2495	4523.0
1371.1	2500	4532.0
1373.9	2505	4541.0
1376.7	2510	4550.0
1379.4	2515	4559.0
1382.2	2520	4568.0
1385.0	2525	4577.0
1387.8	2530	4586.0
1390.6	2535	4595.0
1393.3	2540	4604.0
1396.1	2545	4613.0
1398.9	2550	4622.0
1401.7	2555	4631.0
1404.4	2560	4640.0
1407.2	2565	4649.0
1410.0	2570	4658.0
1412.8	2575	4667.0
1415.6	2580	4676.0
1418.3	2585	4685.0
1421.1	2590	4694.0
1423.9	2595	4703.0
1426.7	2600	4712.0
1429.4	2605	4721.0
1432.2	2610	4730.0
1435.0	2615	4739.0
1437.8	2620	4748.0
1440.6	2625	4757.0
1443.3	2630	4766.0
1446.1	2635	4775.0
1448.9	2640	4784.0
1451.7	2645	4793.0

AERODYNAMIC RELATIONSHIPS

b = Span — ft
c = Chord — ft
D = Drag — lb
L = Lift — lb
L = Rolling Moment — lb-ft
M = Pitching Moment — lb-ft
N = Yawing Moment — lb-ft

q = Dynamic Pressure — lb/sq ft
S = Area — sq ft
V = Velocity — ft/sec
ϵ = Angle of downwash — deg.
α = Angle of attack — deg.
γ = Flight-path angle — deg.
ρ = Density — lb sec²/ft⁴

Lift coef $C_L = \frac{L}{qS}$

Drag coef $C_D = \frac{D}{qS}$

Pitching moment coef $C_m = \frac{M}{qcS}$

Rolling moment coef $C_l = \frac{L}{qbS}$

Yawing moment coef $C_n = \frac{N}{qbS}$

Reynolds' Number

$$R = \rho \frac{Vc}{\mu} = \frac{Vc}{\nu}$$

Change in velocity with change in Power at Constant Air Density

$$V_2 = V_1 \sqrt[3]{\frac{Hp_2}{Hp_1}}$$

Change in velocity with change in Air Density at constant Thp

$$V_2 = V_1\sqrt{\frac{\rho_1}{\rho_2}} \text{ and } V_{true} = \sqrt{\frac{\rho_o}{\rho}} \quad V_{ind}$$

Approximate Reynolds' Number for Airfoils

$$R = 10{,}000\ cV_{mph}$$

Values of ν at Standard Altitudes

Altitude	0	10,000	20,000	30,000
$\nu \times 10^6$	157	202	264	354

PROPELLER RELATIONSHIPS

D = Diameter — ft
N = Propeller speed — rpm
n = Propeller speed — rps
Q = Torque — lb ft

P = Power — ft-lb/sec
T = Thrust — lb
J = Progression Factor
η = Propeller efficiency

Power coef $C_P = \frac{P}{\rho n^3 D^5}$

Thrust coef $C_T = \frac{T}{\rho n^2 D^4}$

Torque coef $C_Q = \frac{Q}{\rho n^2 D^5}$

Speed power coef $C_S = \sqrt[5]{\frac{\rho V^5}{P n^2}}$

Progression factor $J = \frac{1.467 V_{mph}}{n D}$

Propeller efficiency $\eta = \frac{C_T}{C_P} J$

EQUATIONS RELATING TO ENGINE POWER

Power Corrections

Corrected hp = Observed hp x correction factor

$$\text{Correction factor} = \sqrt{\frac{459.6 + t}{518.4}} \times \frac{29.92}{P} \text{ at sea level}$$

$$= \sqrt{\frac{459.6 + t}{T}} \times \frac{B}{P} \text{ at altitude}$$

t = Dry bulb temp at carb—F

B = Corrected barometric pressure—in. Hg

T = Standard air temperature —F abs

P = Dry carburetor pressure—in. Hg abs

Propeller Load Curve

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

$$\text{Torque, } T = \frac{63025\ hp}{rpm} \text{ lb in.} = \frac{5252\ hp}{rpm} \text{ lb ft}$$

Indicated Horsepower, ihp = bhp + friction hp

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

Thermal Efficiency,

$$\text{percent} = \frac{2545}{Sfc \times Btu/lb\ fuel} \times 100$$

Brake Mean Effective Pressure — lb/sq in

$$bmep = \frac{792{,}000 \times bhp}{Displacement \times rpm} = constant \times \frac{bhp}{rpm}$$

Displacement Constant for each engine

R-985 — 805
R-1340 — 591
R-1830 — 432
R-2000 — 396
R-2180 — 364
R-2800 — 283
R-4360 — 182

GENERAL PROPERTIES OF AIR

P = Absolute pressure — lb/sq ft
P_o = Standard absolute pressure — lb/sq ft
T = Absolute temperature
T_o = Standard absolute temperature
V = Velocity — ft/sec
g = Acceleration of gravity — ft/sec^2

$$P = \rho g R T$$

$$\frac{P}{P_o} = \frac{\rho}{\rho_o}\frac{T}{T_o} = \left(\frac{\rho}{\rho_o}\right)^n = \left(\frac{V_o}{V}\right)^n$$

Specific Weight of Air in lb/ft^3

$$g\rho = .07651\ \frac{P}{P_o}\ \frac{T_o}{T} = 1.325\ \frac{\text{P in in. Hg}}{\text{T in } F_{abs}}$$

Density of Air in lb sec^2/ft^4 or slugs/ft^3

$$\rho = .002378\ \frac{P}{P_o}\ \frac{T_o}{T} = .041187\ \frac{\text{P in in. Hg}}{\text{T in } F_{abs}}$$

Air Density Ratio

$$\rho/\rho_o = \frac{P}{P_o}\ \frac{T_o}{T} = 17.32\ \frac{\text{P in in. Hg}}{\text{T in } F_{abs}}$$

Impact Pressure

for incompressible flow $q = \frac{1}{2}\rho V^2$

for compressible flow $qc = \left(\frac{P_r}{P_{am}} - 1\right)^{P_{am}}$

$$T_r = \left(\frac{T_r}{T_{am}} - 1\right)^{T_{am}}$$

Approximate value (at sea level)

$$q = 25\left(\frac{V}{100}\right)^2 \text{lb/sq ft}$$

$$= 5\left(\frac{V}{100}\right)^2 \text{in. water}$$

Where V is in mph

n = Exponent of compression
q = Impact pressure — lb/ft^2
ρ = Density — lb sec^2/ft^4
μ = Absolute viscosity lb sec/ft^2
ν = Kinematic viscosity — ft^2/sec
σ = Density ratio — ρ/ρ_o

$$\frac{T}{T_o} = \left(\frac{P}{P_o}\right)^{\frac{n-1}{n}} = \left(\frac{V_o}{V}\right)^{n-1}$$

$$\frac{\rho}{\rho_o} = \left(\frac{T}{T_o}\right)^{\frac{1}{n-1}}$$

For adiabatic change
$n = 1.39$

Specific Heat of Air in Btu per lb per degree F

at constant pressure, $C_p = .240$
at constant volume, $C_v = .1715$
for atmospheric temperature range
$\gamma = C_p/C_v = 1.40$

Gas Constant for Air

$$R = 53.345 \text{ ft-lb/lb F}_{abs}$$

$$= \frac{1545.4 \text{ ft-lb/lb - mole F}_{abs}}{\text{mol wt}}$$

Molecular weight of air = 28.97

Speed of Sound in Air in mph

$$C = 33.5\sqrt{T}$$

Where T = air temperature in F_{abs}

C_{SL} = 762 mph = 1118 fps = 662 knots

Absolute Viscosity for Air

$$\mu = \rho\nu$$

$$10^{10}\mu = 3583 + 9.870 \text{ t in degrees C}$$

$$= 3408 + 5.483 \text{ t in degrees F}$$

Temperature rise resulting from adiabatic compression at impact

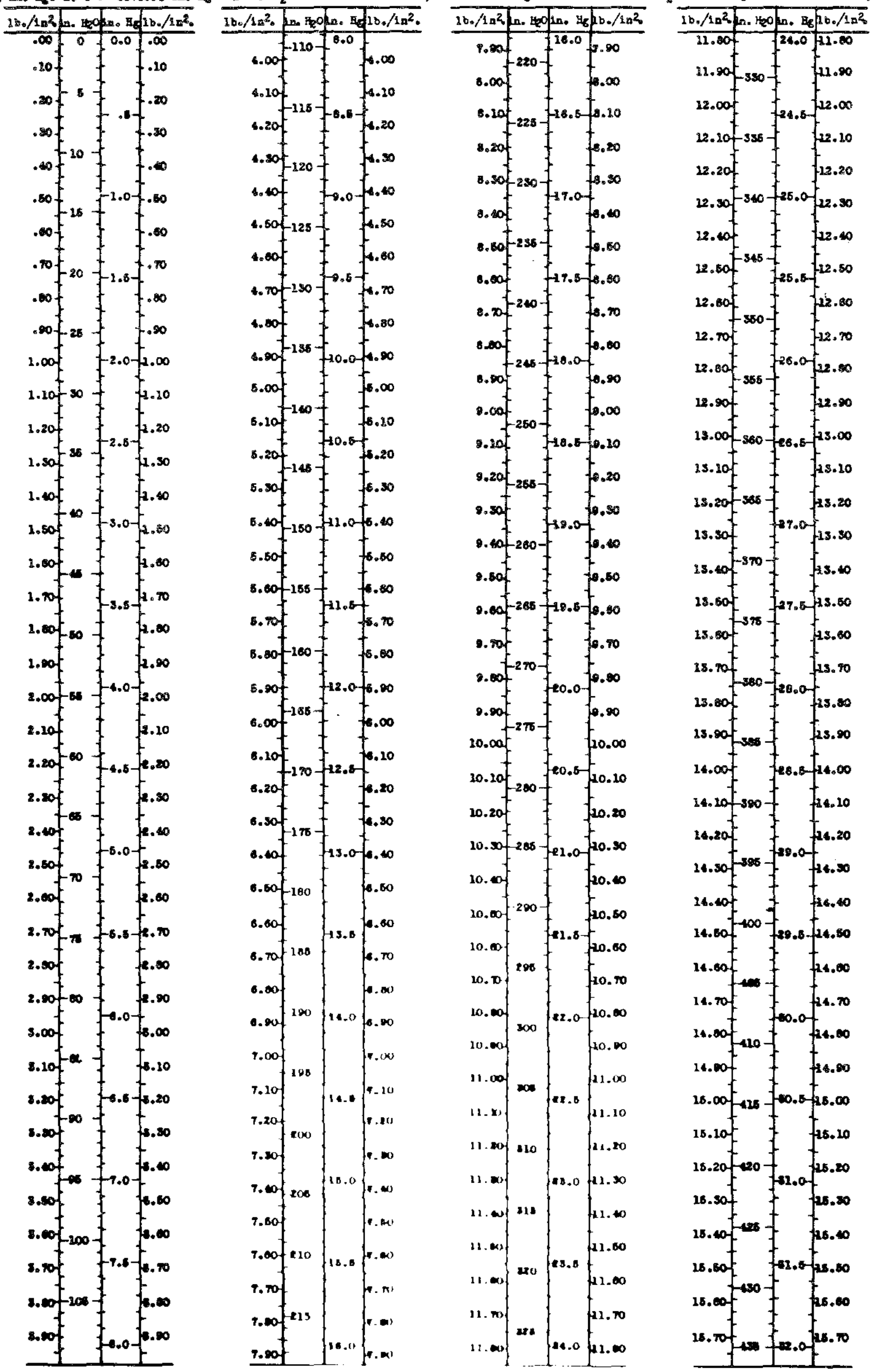
$$T = 1.792\left(\frac{V}{100}\right)^2 \text{ in degrees F}$$

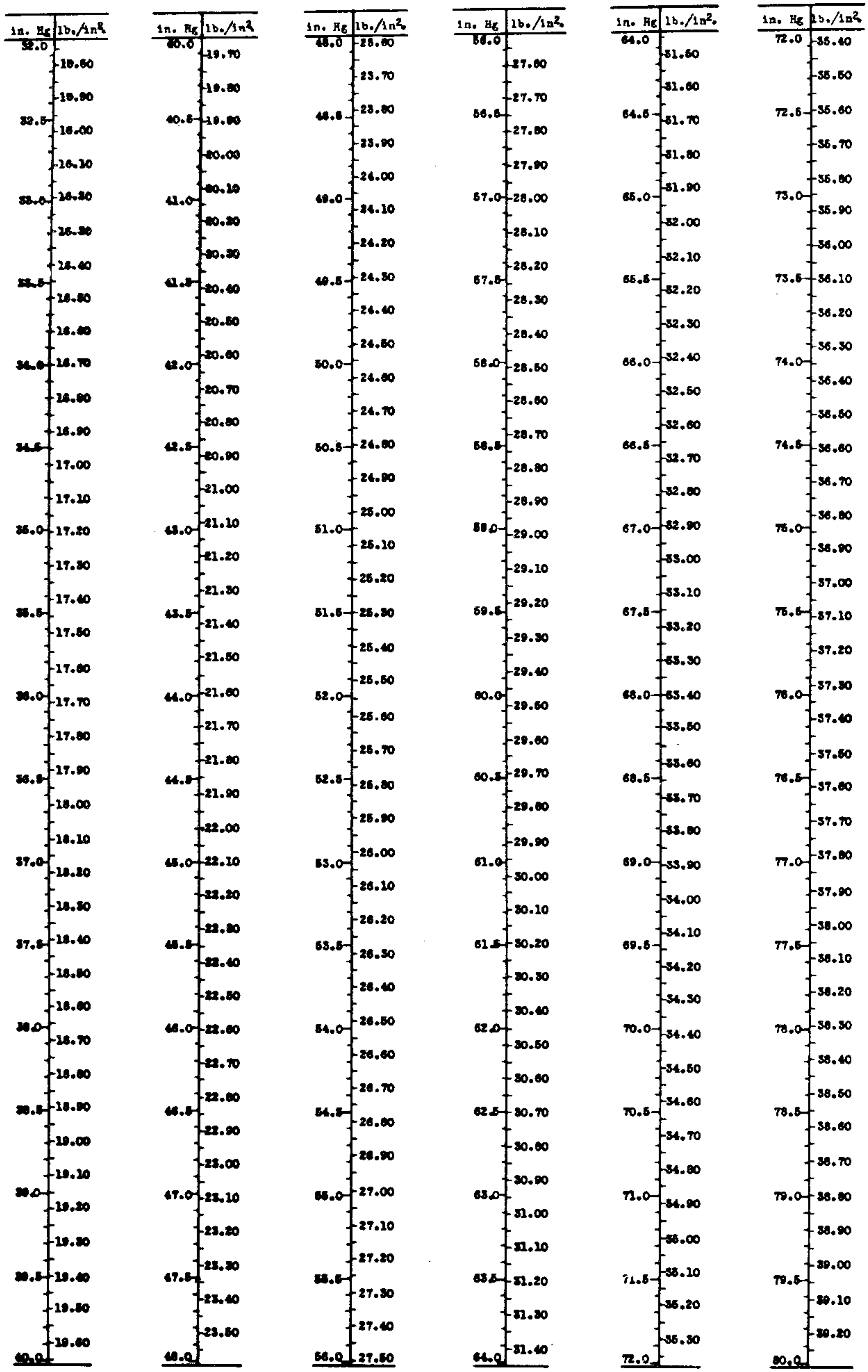
Where V = True air speed in mph

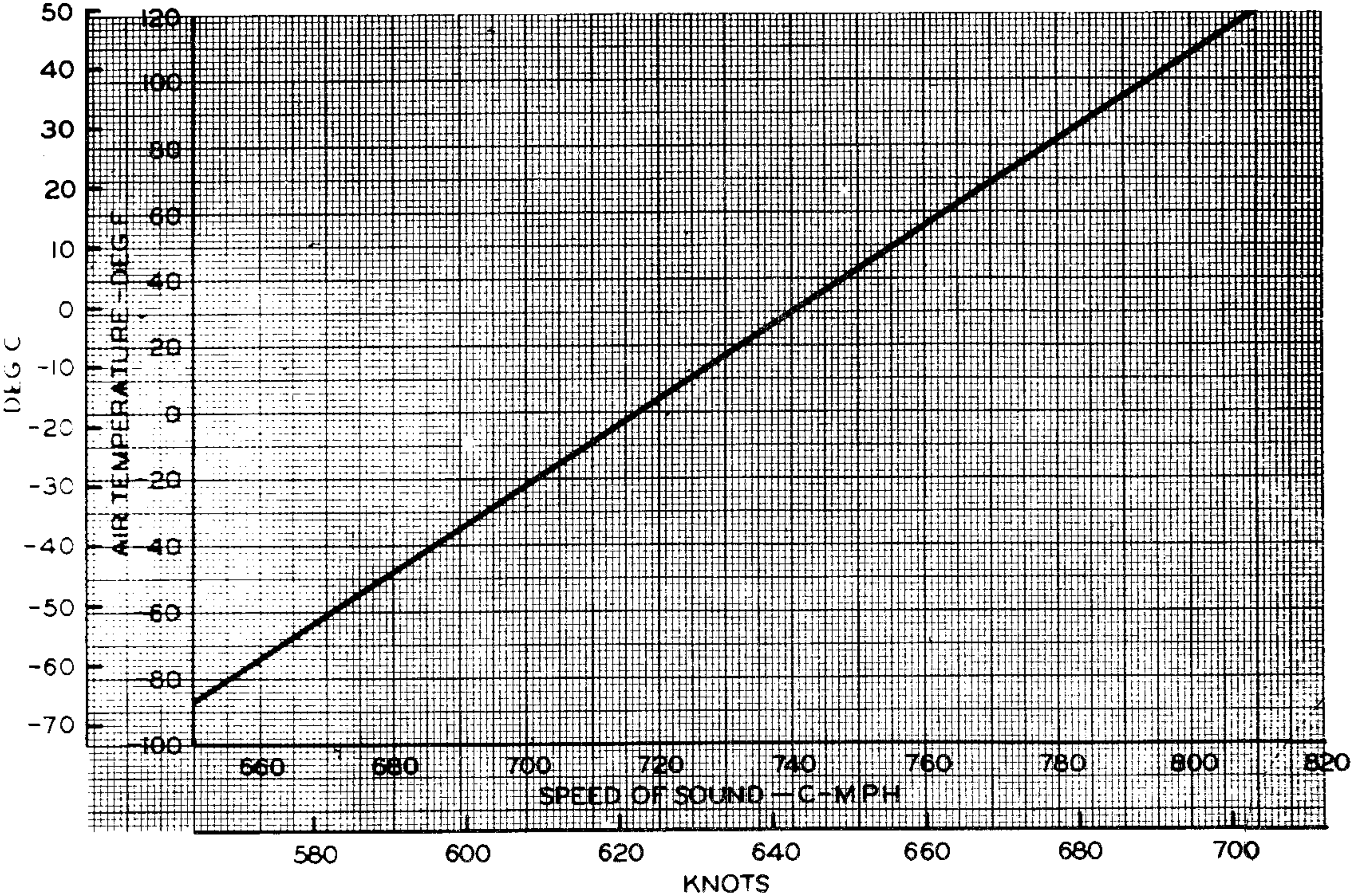
PRESSURE CONVERSION CHART

Conversion factors taken from the Handbook of Chemistry and Physics

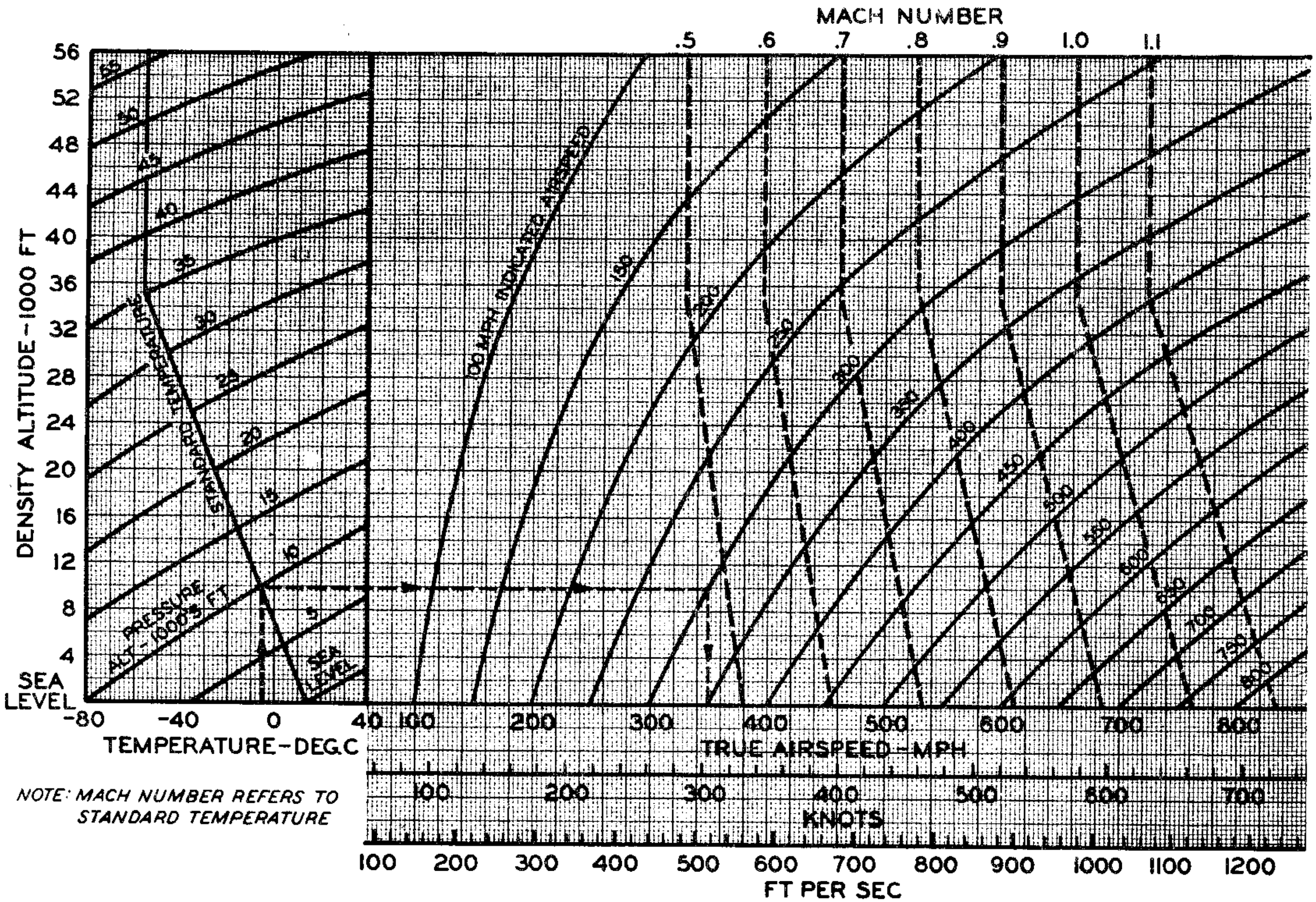
1 in. H_2O at 4°C = .073554 in. Hg — 1 in. H_2O at 4°C = .036136 lb./in.^{2} — 1 in. Hg at 0°C = 13.595 in. H_2O — 1 in. Hg at 0°C = .49116 lb./in.^{2}




in. Hg
lb./in²
32.0 32.5 33.0 33.5 34.0 34.5 35.0 35.5 36.0 36.5 37.0 37.5 38.0 38.5 39.0 39.5 40.0
15.80 15.90 16.00 16.10 16.20 16.30 16.40 16.50 16.60 16.70 16.80 16.90 17.00 17.10 17.20 17.30 17.40 17.50 17.60 17.70 17.80 17.90 18.00 18.10 18.20 18.30 18.40 18.50 18.60 18.70 18.80 18.90 19.00 19.10 19.20 19.30 19.40 19.50 19.60
in. Hg
lb./in²
40.0 40.5 41.0 41.5 42.0 42.5 43.0 43.5 44.0 44.5 45.0 45.5 46.0 46.5 47.0 47.5 48.0
19.70 19.80 19.90 20.00 20.10 20.20 20.30 20.40 20.50 20.60 20.70 20.80 20.90 21.00 21.10 21.20 21.30 21.40 21.50 21.60 21.70 21.80 21.90 22.00 22.10 22.20 22.30 22.40 22.50 22.60 22.70 22.80 22.90 23.00 23.10 23.20 23.30 23.40 23.50
in. Hg
lb./in²
48.0 48.5 49.0 49.5 50.0 50.5 51.0 51.5 52.0 52.5 53.0 53.5 54.0 54.5 55.0 55.5 56.0
23.60 23.70 23.80 23.90 24.00 24.10 24.20 24.30 24.40 24.50 24.60 24.70 24.80 24.90 25.00 25.10 25.20 25.30 25.40 25.50 25.60 25.70 25.80 25.90 26.00 26.10 26.20 26.30 26.40 26.50 26.60 26.70 26.80 26.90 27.00 27.10 27.20 27.30 27.40 27.50
in. Hg
lb./in²
56.0 56.5 57.0 57.5 58.0 58.5 59.0 59.5 60.0 60.5 61.0 61.5 62.0 62.5 63.0 63.5 64.0
27.60 27.70 27.80 27.90 28.00 28.10 28.20 28.30 28.40 28.50 28.60 28.70 28.80 28.90 29.00 29.10 29.20 29.30 29.40 29.50 29.60 29.70 29.80 29.90 30.00 30.10 30.20 30.30 30.40 30.50 30.60 30.70 30.80 30.90 31.00 31.10 31.20 31.30 31.40
in. Hg
lb./in².
64.0 64.5 65.0 65.5 66.0 66.5 67.0 67.5 68.0 68.5 69.0 69.5 70.0 70.5 71.0 71.5 72.0
31.50 31.60 31.70 31.80 31.90 32.00 32.10 32.20 32.30 32.40 32.50 32.60 32.70 32.80 32.90 33.00 33.10 33.20 33.30 33.40 33.50 33.60 33.70 33.80 33.90 34.00 34.10 34.20 34.30 34.40 34.50 34.60 34.70 34.80 34.90 35.00 35.10 35.20 35.30
in. Hg
lb./in²
72.0 72.5 73.0 73.5 74.0 74.5 75.0 75.5 76.0 76.5 77.0 77.5 78.0 78.5 79.0 79.5 80.0
35.40 35.50 35.60 35.70 35.80 35.90 36.00 36.10 36.20 36.30 36.40 36.50 36.60 36.70 36.80 36.90 37.00 37.10 37.20 37.30 37.40 37.50 37.60 37.70 37.80 37.90 38.00 38.10 38.20 38.30 38.40 38.50 38.60 38.70 38.80 38.90 39.00 39.10 39.20

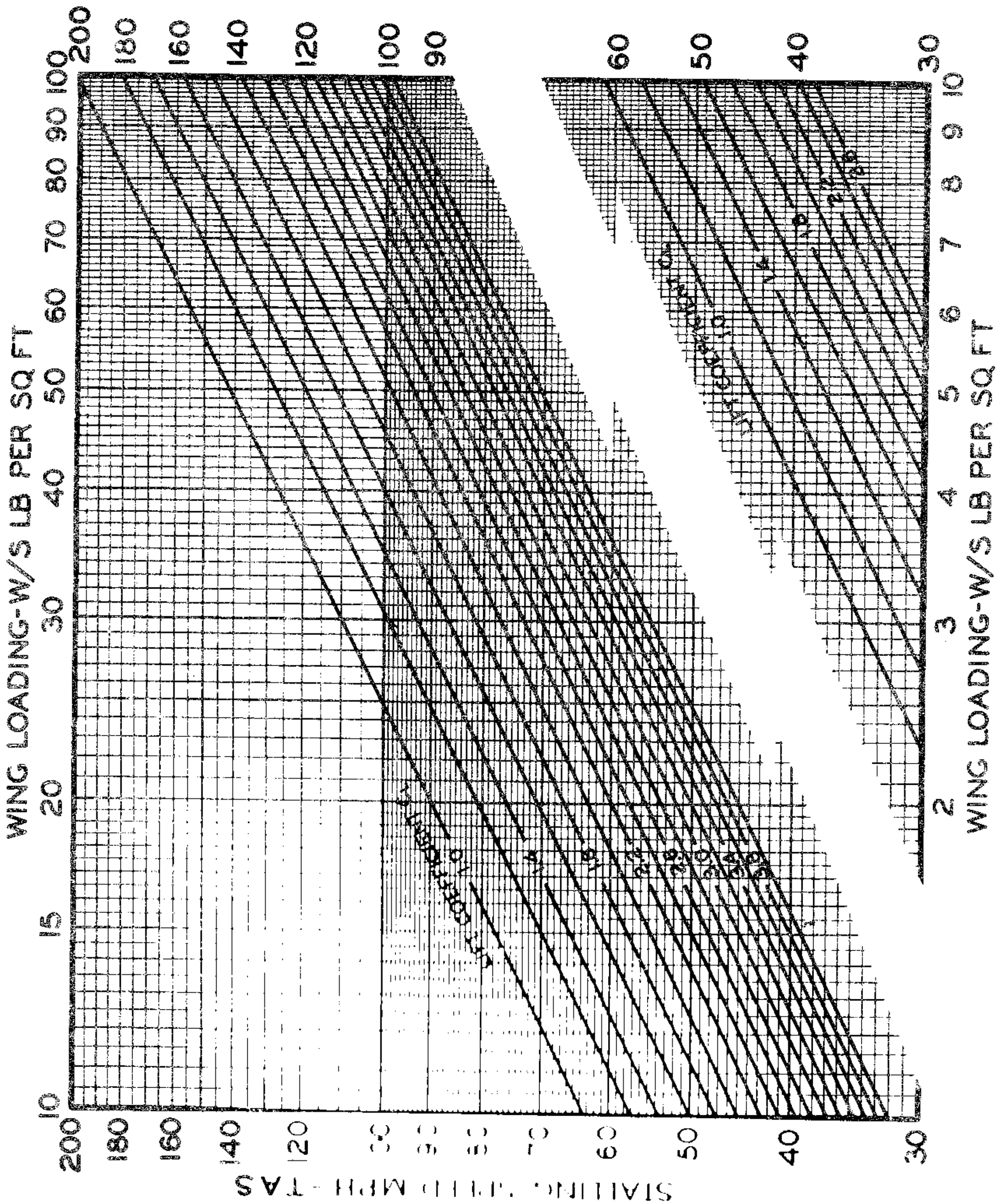


Variation of Speed of Sound with Temperature

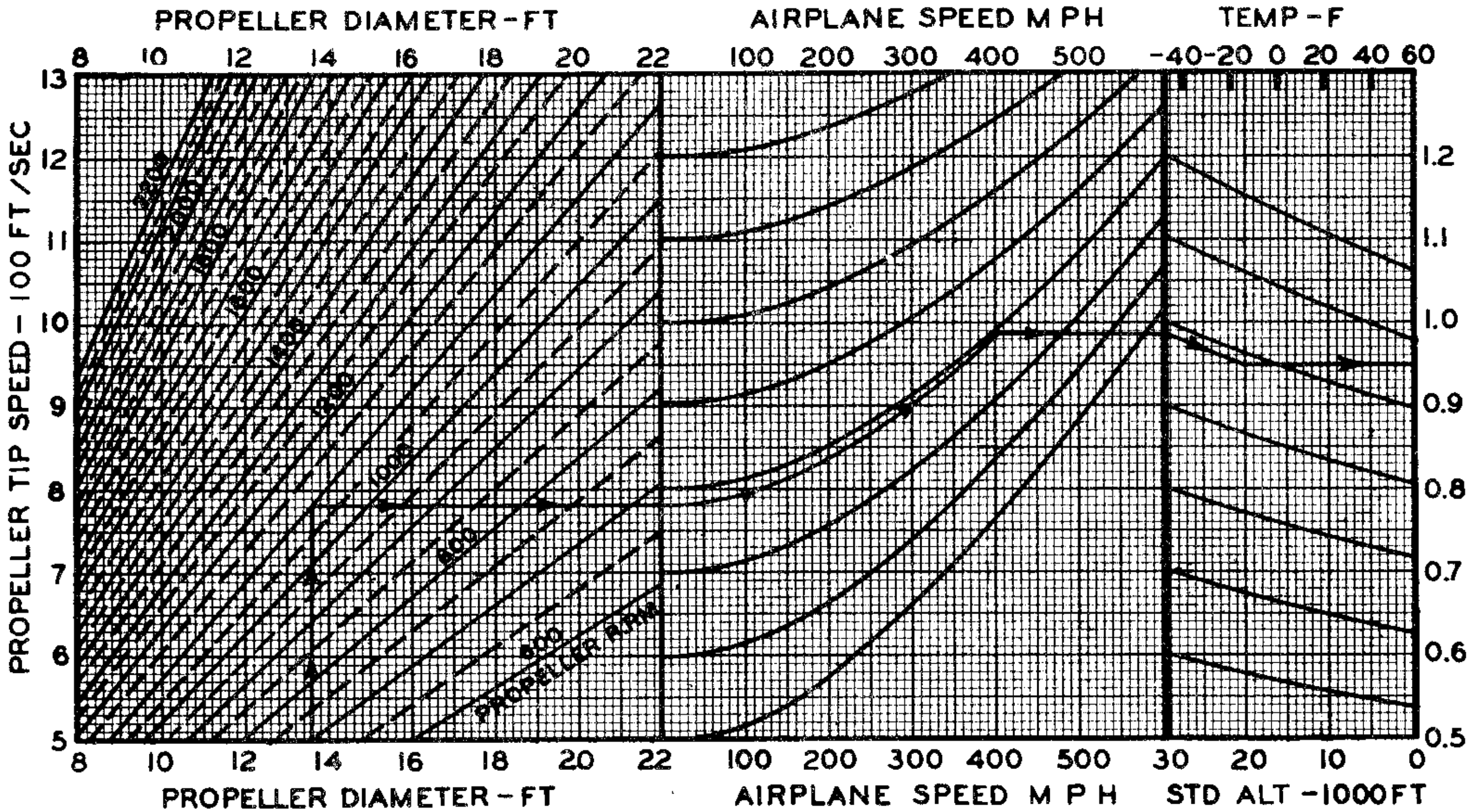


Air Speed Chart

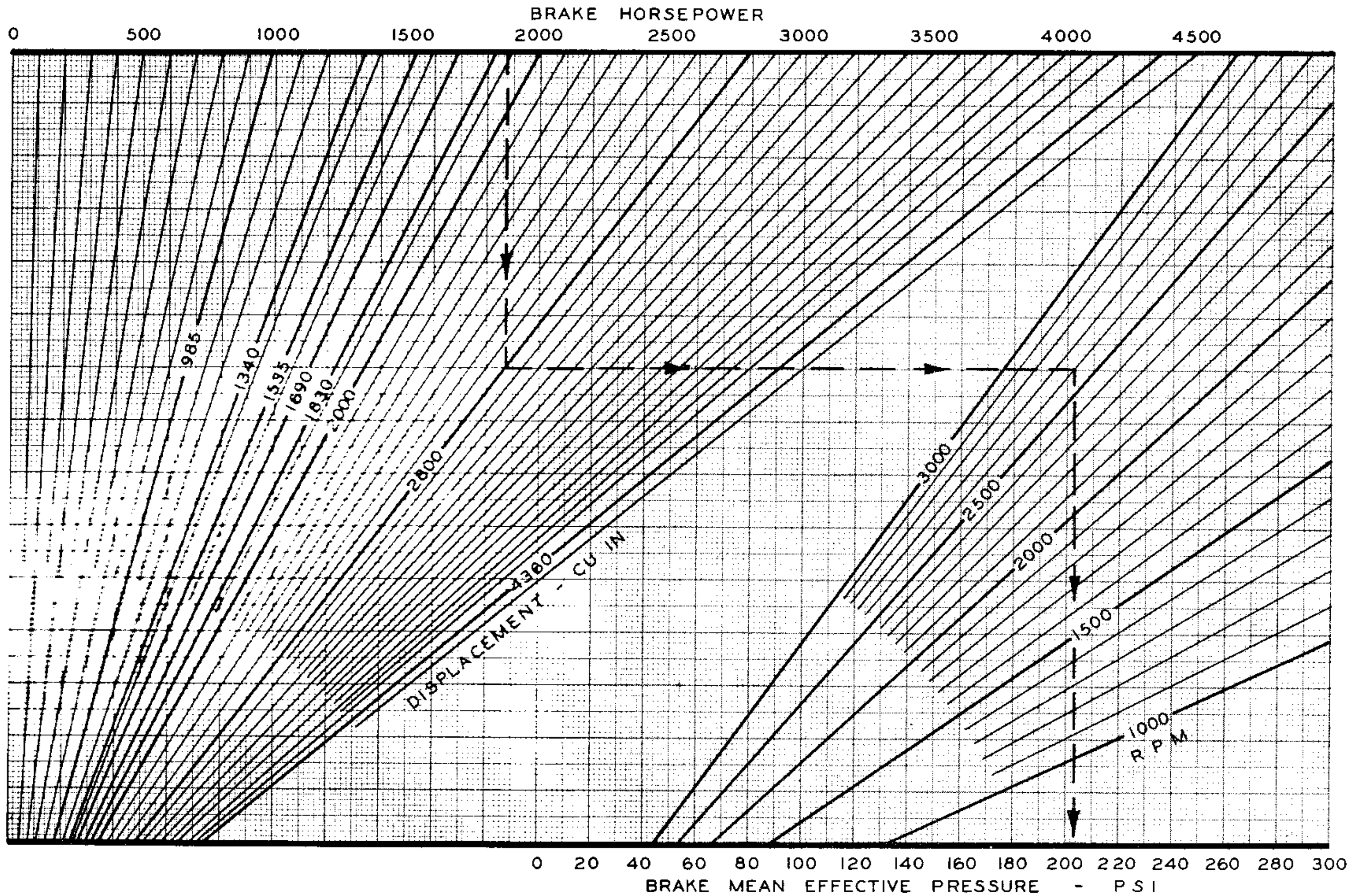
REFERENCE TABLES AND CHARTS



Stalling Speed Chart

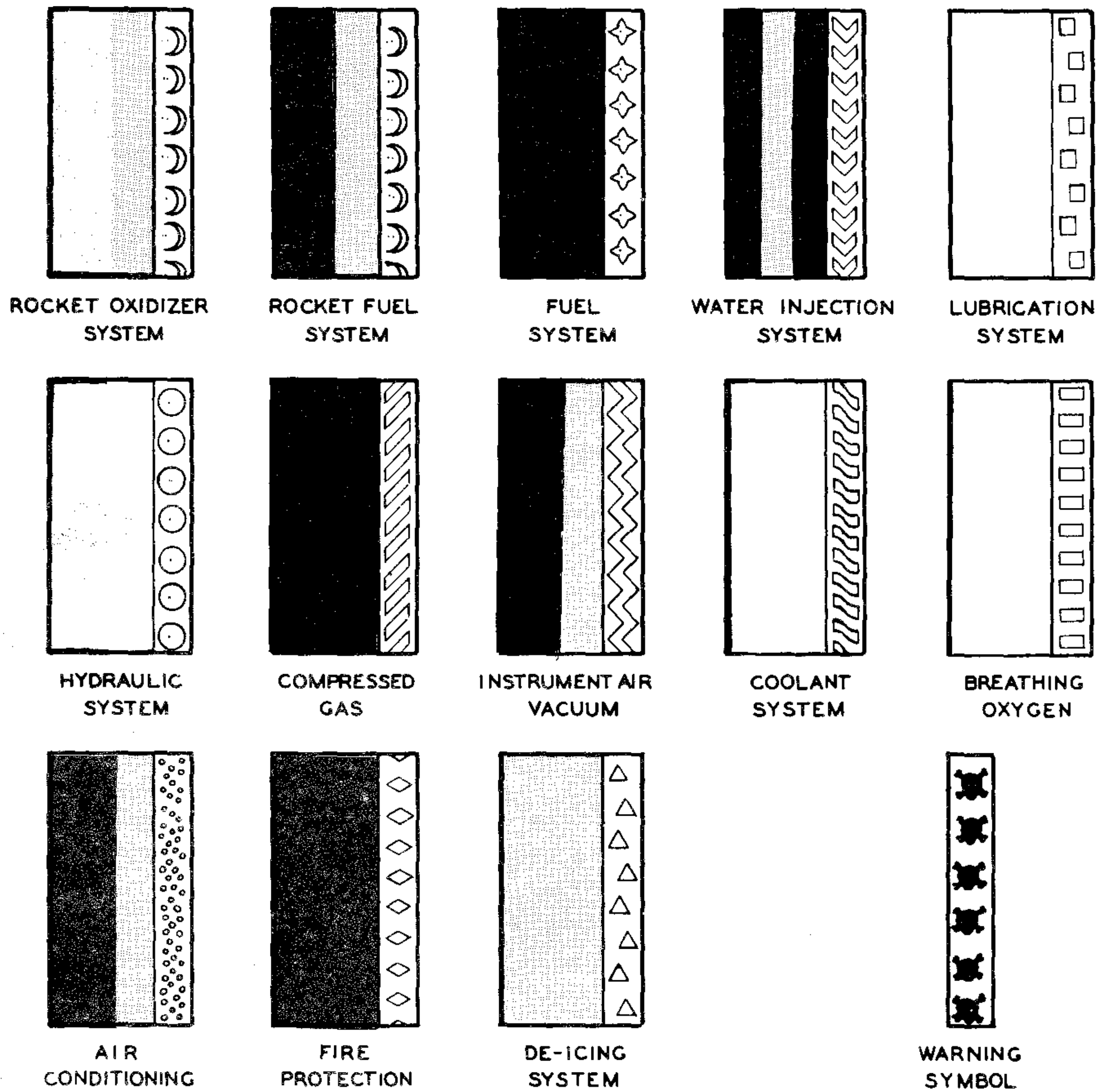


Propeller Tip Speed Chart



BMEP Chart for all Engine Desplacements

REFERENCE TABLES AND CHARTS



THE ABOVE COLOR CODES REPRESENT DESIGNATIONS FOR SYSTEMS ONLY. TO CODE LINES WHICH DO NOT FALL INTO ONE OF THESE SYSTEMS THE CONTENTS SHALL BE DESIGNATED BY BLACK LETTERING ON WHITE TAPE.

PRESSURE TRANSMITTER LINES SHALL BE IDENTIFIED BY THE SAME COLORS AS THE LINES FROM WHICH THE PRESSURE IS BEING TRANSMITTED.

FILLER LINES, VENT LINES AND DRAIN LINES FROM FUNCTIONS OR RELATED FUNCTIONAL EQUIPMENT SPECIFIED HEREON SHALL BE IDENTIFIED BY THE SAME COLORS AS THE FUNCTION LINES.

COLOR CODE FOR AIRCRAFT PIPING

REFERENCE TABLES AND CHARTS

U. S. AIRFORCE AIRCRAFT DESIGNATIONS

Fundamental Types (Denoting Basic Unit)		Prefix Symbols (Modification for Current Use)	
Amphibian	A		
Bombardment	B	B	Bombardment
Cargo	C	C	Cargo
		D	Director
Fighter	F	F	Fighter
Glider	G	G	Glider
Helicopter	H		
Liaison	L	L	Liaison
		M	Missile Aircraft
Targets & Drones	Q	Q	Target or Drone
Reconnaissance	R	R	Reconnaissance
Search & Rescue	S	S	Sea Search
Trainers	T	T	Training
		V	Staff Administrative Transports
Special Research or Experimental	X		
General Classification		X	Experimental
		Y	Service Test
		Z	Obsolete

Example: C -54 B -1 -DC

Type — C
Model — 54
Series — B
Block Number — 1
Manufacturer — DC

NAVAL AIRCRAFT DESIGNATIONS

Type Designations

Heavier than air (fixed wing)	V (Usually omitted)
Heavier than air (rotary)	H
Pilotless Drones	K
Guided Missiles	M
Lighter than air	Z

Class Designations (Basic Mission)

Attack	A
Fighter	F
Glider	G
Patrol	P
Observation	O
Transport	R
Training	T
Utility	U

Prefix Letter

Experimental	X
Service Test	Y
Obsolete	Z

Suffix Letter

A	Amphibian
B	Special armament
C	Carrier version
D	Drone control
E	Special electronic gear
G	Search and rescue
H	Hospital
J	Target tow
K	Target drone
L	Searchlight
M	Weather reconnaissance
N	Night operating
P	Photographic
Q	Countermeasures
R	Transport
S	Anti-submarine
T	Training
U	Utility
W	Air warning
Z	Administrative

Example: X -F 9 F- 2

Prefix — X
Type (V omitted)
Class — F
Series No. — 9
Designer's Letter — F
Modification No. — 2

DESIGNER'S IDENTIFICATION LETTERS — NAVY

B	Boeing
C	Curtiss-Wright
D	Douglas
E	Piper
F	Grumman
G	Goodyear
H	McDonnell
J	North American
K	Kaiser
L	Bell
M	Glenn L. Martin
N	Naval Aircraft Factory
O	Lockheed (Factory B)
P	Piasecki
Q	Fairchild
R	Ryan
S	Sikorsky
T	Northrop
U	Chance Vought
Y	Consolidated Vultee

REFERENCE TABLES AND CHARTS

AIRCRAFT NATIONALITY MARKS

YA	Afghanistan	LR*	Lebanon
LV	Argentina	LI*	Liberia
VH	Australia	LX	Luxembourg
OO	Belgium and Colonies	XA, XB	Mexico
CB, CP	Bolivia	CN	Morocco
PP, PT	Brazil	PH	Netherlands
VP, VQ, VR	British Colonies and Protectorates	PK	Netherlands East Indies
XY	Burma	PJ	Netherlands West Indies
CF	Canada	VO	Newfoundland
CC	Chile	YJ	New Hebrides
XT	China	ZK	New Zealand
HK	Colombia	AN	Nicaragua
TI	Costa Rica	LN	Norway
CU	Cuba	RX	Panama
OK	Czechoslovakia	ZP	Paraguay
OY	Denmark	OB	Peru
HI	Dominican Republic	PI	Philippines Commonwealth
HC	Ecuador	SP	Poland
SU	Egypt	CS	Portugal
YS	El Salvador	CR	Portuguese Colonies
ET*	Ethiopia	**	Saudi Arabia
F	France, Colonies and Protectorates except Morocco	HS	Siam
SX	Greece	EC	Spain
LG	Guatemala	PZ	Surinam
HH	Haiti	SE	Sweden
XH	Honduras	HB	Switzerland
TF	Iceland	**	Syria
VT	India	TC	Turkey
EP	Iran	URSS	Union of Soviet Socialist Republic
YI	Iraq	ZS	Union of South Africa
EI	Ireland	G	United Kingdom
		N	United States of America
		CX	Uruguay
		YV	Venezuela
		YU	Yugoslavia

*Indicates that the nationality mark is provisional.
**Indicates that the nationality mark will be selected at a future date.

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.

CONVERSION FACTORS

Multiply	By	To Obtain
Acres	43,560	Square feet
	4,047	Square meters
	1.562×10^{3}	Square miles
Atmospheres	76.0	Cm mercury
	29.921	Inches mercury
	33.899	Feet of water
	10,332	Kilogm per sq m
	14.696	Pounds per sq in.
	2,116.2	Pounds per sq ft
	1.0133	Bars
Bars	75.01	Cm mercury
	14.5	Pounds per sq in.
British thermal unit	778.2	Foot pounds
	$.3930 \times 10^{-3}$	Horsepower hour
	$.2930 \times 10^{-3}$	Kilowatt hour
	.2520	Kilogram calorie
	107.6	Kilogram meters
	1055	Joules
Centimeters (cm)	.39370	Inches
	.03281	Feet
Cm of mercury	5.3524	Inches of water
	.44603	Feet of water
	.19337	Pounds per sq in.
	27.845	Pounds per sq ft
	135.95	Kilogm per sq m
Cm per second	.03281	Feet per sec
Circular mils	7.854×10^{-7}	Square inches
	5.067×10^{-4}	Sq millimeters
	.7854	Square mils
Cubic centimeters	10^{-3}	Liters
	.06102	Cubic inches
Cubic feet	28,317	Cu centimeters
	1,728	Cubic inches
	.02831	Cubic meters
	.03704	Cubic yards
	7.4805	Gallons
	28.316	Liters
Cu feet per min.	.47170	Liters per second
	.02832	Cu m per minute
Cu feet of water	62.428	Pounds
Cubic inches	16.387	Cu centimeters
	.01639	Liters
	4.329×10^{-3}	Gallons
	.01732	Quarts
Cubic meters	61,023	Cubic inches
	35.314	Cubic feet
	264.17	Gallons
Cubic yards	27	Cubic feet
	.7646	Cubic meters
	202	U. S. gallons

Multiply	By	To Obtain
Degrees (arc)	.01745	Radians
Dynes	1.020×10^{-3}	Grams
	2.248×10^{-6}	Pounds
	7.233×10^{-5}	Poundals
Ergs	$.9478 \times 10^{-10}$	BTU
	1	Dyne cm
	7.376×10^{-8}	Foot pounds
	1.020×10^{-3}	Gram cm
	10^{-7}	Joules
	2.388×10^{-4}	Kilogram calories
Feet	.30480	Meters
Feet of water	.02950	Atmospheres
	.43353	Pounds per sq in.
	62.378	Pounds per sq ft
	304.80	Kilogm per sq m
	.88367	In. of mercury
	.24199	Cm of mercury
Feet per minute	.01136	Miles per hour
	.01829	Km per hour
	.50800	Cm per second
Feet per second	.68182	Miles per hour
	1.0973	Km per hour
	30.480	Cm per second
	.30480	Meters per sec
	.59209	Knots
Foot-pounds	.13826	Meter-kilograms
Foot-pounds/min	.1092	Horsepower
Foot-pounds/sec	.00182	Horsepower
Gallons, imperial	277.4	Cubic inches
	1.201	U. S. gallons
	4.546	Liters
Gallons, U. S. dry	268.8	Cubic inches
	.1556	Cubic feet
	1.164	U. S. gals, liquid
	4.405	Liters
Gallons, U.S. liquid	231	Cubic inches
	.13368	Cubic feet
	3.7853	Liters
	.83268	Imperial gallons
	128	Liquid ounces
Grams	15.432	Grains
	.03527	Ounces
	.00220	Pounds
	1,000	Milligrams
	.001	Kilograms
	980.67	Dynes
Gram calories	.00397	BTU

CONVERSION FACTORS

Multiply	By	To Obtain
Grams per cm	0.1	Kilograms per m
	.06720	Pounds per foot
	.00559	Pounds per inch
Grams per cu cm	1,000	Kilogms per cm
	62.428	Pounds per cu ft
Horsepower	33,000	Ft-pounds/min
	550	Ft-pounds/sec
	76,040	Kg-meters/sec
	1.0139	Metric hp
Horsepower, metric	75	Kilogm-m/sec
	.98632	Horsepower
Horsepower-hours	2,545.1	BTU
	1,980,000	Foot-pounds
	273,745	Kilogm-meters
Inches	2.5400	Centimeters
Inches of mercury	.03342	Atmosphere
	13.595	Inches of water
	1.1329	Feet of water
	.49116	Pounds per sq in.
	70.727	Pounds per sq ft
	345.32	Kilogm per sq m
Inches of water	.07356	Ins. of mercury
	.18683	Cm of mercury
	.03613	Pounds per sq in.
	5.1981	Pounds per sq ft
	25.400	Kilogm per sq m
Joules	$.9478 \times 10^{-3}$	BTU
	.7376	Foot-pounds
	$.2388 \times 10^{-3}$	Kilogm calories
	.10179	Kilogm meters
	$.2777 \times 10^{-3}$	Watt hours
	$.3725 \times 10^{-6}$	Horsepower hrs
Kilograms	2.2046	Pounds
	32.274	Ounces
	1,000	Grams
Kilogram-calories	3.9685	BTU
	3,087.4	Foot-pounds
	426.85	Kilogm-meters
Kilogram-meters	7.2330	Foot-pounds
	9.8067×10^{-7}	Ergs
Kilogram per cu m	06243	Pounds per cu ft
	.001	Grams per cu cm
Kilogram per meter	.67197	Pounds per ft
Kilogram per sq m	.00142	Pounds per sq in.
	.20482	Pounds per sq ft
	.00290	Ins. of mercury
	.00328	Feet of water
	0.1	Grams per sq cm

Multiply	By	To Obtain
Kilometers	3,280.8	Feet
	.62137	Miles
	.53956	Nautical miles
Kilometers per hr	.91134	Feet per second
	.53955	Knots
	.62137	Miles per hour
	.2777	Meters per sec
Kilowatts	.9480	BTU per sec
	737.7	Ft-pounds per sec
	1.341	Horsepower
	.2389	Kg-cal per sec
Knots	1.0	Nautical miles/hr
	1.6889	Feet per second
	1.1516	Miles per hour
	1.8532	Kilometers per hr
	.51479	Meters per sec
Liters	1,000	Cu centimeters
	61.025	Cubic inches
	.03532	Cubic feet
	.26418	Gallons
	.21998	Imperial gallons
Meters	39.37	Inches
	3.2808	Feet
	1.0936	Yards
Meters per second	3.2808	Feet per second
	2.2369	Miles per hour
	3.600	Kilometers per hr
Miles	5,280	Feet
	1.6093	Kilometers
	.86839	Nautical miles
Miles per hour	1.4667	Feet per second
	.44704	Meters per sec
	1.6093	Kilometers per hr
	.86839	Knots
Miles/hr squared	2.1511	Feet/sec squared
Nautical Miles	6080.2	Feet
Ounces, avdp	.0625	Pounds, avdp
	28.350	Grams
	437.5	Grains
Ounces, fluid	29.57	Cu centimeters
	1.805	Cubic inches
Pounds	453.59	Grams
	7000	Grains
	16.0	Ounces
	32.174	Poundals
Pounds per cu ft	16.018	Kilogm per cu m
	.01602	Grams per cu cm

CONVERSION FACTORS

Multiply	By	To Obtain	Multiply	By	To Obtain
Pounds per cu in.	1,728.0	Pounds per cu ft	Square centimeters	.15500	Sq inch
	27.680	Grams per cu cm		.00108	Sq feet
Pounds per sq in.	2.0361	Ins. of mercury	Square feet	929.03	Sq centimeters
	2.3066	Feet of water		144	Sq inches
	.06805	Atmospheres		.09290	Sq meters
	703.07	Kilogm per sq m		.111	Sq yards
	.07036	Kilogm per sq cm	Square inches	645.16	Sq millimeters
Radians	57.296	Degrees (arc)		6.4516	Sq centimeters
Radians per sec	57.296	Degrees per sec	Square kilometers	.38610	Sq miles
	.15916	Rev per sec	Square meters	10.764	Sq feet
	9.8493	Rev per min		1.1960	Sq yards
Revolutions	6.2832	Radians	Square miles	2.5900	Sq kilometers
				640	Acres
Revolutions per min	.10472	Radians per sec	Square yards	.83613	Sq meters
Slugs	32.174	Pounds	Yards	.9144	Meters

INTERNATIONAL STANDARDS

	English	Metric
Gravity — g	32.1739 ft/sec^2	9.80665 m/sec^2
Absolute zero	-459.4 F	-273 C
π	3.14159	3.14159

STANDARD ATMOSPHERE

Standard Values at Sea Level			
Pressure, Po		29.92 in. Hg	760 mm Hg
Pressure, Po		2116 lb/ft^2	10332 kg/m^2
Temperature,	NACA	59 F	15 C
	Army & CAA	100.4 F	38 C
	Navy	89.6 F	32 C
Absolute temp, T_o		518.4 F abs, R	288 C abs, K
Specific weight, $g\rho_o$		.07651 lb/ft^3	1.2255 kg/m^3
Density, ρ_o		.002378 lb sec^2/ft^4	.124966 kg sec^2/m^4

Standard Values at Altitude			
Isothermal Level		35332 ft	10769 m
Isothermal temp.		-67 F	-55 C
Temp. gradient	NACA	.00356 F/ft	.0065 C/m
	Navy	.0036 F/ft	.0066
	Army & CAA	.0036 F/ft	.0066

WEIGHTS AND MEASURES

LENGTH

12 inches = 1 foot
9 inches = 1 span
4 inches = 1 hand
3 feet = 1 yard
5½ yards = 16½ feet = 1 rod or pole
40 rods = 220 yd = 1 furlong
8 furlongs = 5280 ft = 1 mile
3 miles = 1 league

Nautical

6080.2 ft = 1 nautical mile
1 nautical mile per hour = 1 knot
6 feet = 1 fathom

Surveyor's

7.92 inches = 1 link
100 links = 66 ft = 1 chain
80 chains = 1 mile

WEIGHTS

Avoirdupois

16 drams = 437.5 grains = 1 ounce
16 ounces = 7000 grains = 1 pound
112 pounds = 1 hundredweight
2240 pounds = 1 long ton
2000 pounds = 1 short ton

Troy

24 grains = 1 pennyweight
20 pennyweights = 1 ounce
12 ounces = 5760 grains = 1 pound

Apothecaries

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 5760 grains = 1 pound

VOLUME

1728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard
128 cubic feet = 1 cord of wood

Liquid

4 gills = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
7.4805 gallons = 1 cubic foot

Dry

2 pints = 1 quart
8 quarts = 1 peck
4 pecks = 1 bushel

Apothecaries

60 minim = 1 liquid dram
8 drams = 1 liquid ounce
16 ounces = 1 pint

Shipping

100 cubic feet = 1 Register ton
40 cubic feet = 1 U. S. shipping ton

AREA

144 square inches = 1 square foot
9 square feet = 1 square yard
30¼ square yards = 1 square rod
160 square rods = 43,560 square feet = 1 acre
640 acres = 1 square mile

ENGLISH — METRIC EQUIVALENTS

Length

1 centimeter = 0.3937 inches
2.54 centimeters = 1 inch
0.3048 meters = 1 foot
1 meter = 3.278 feet
1 kilometer = 0.6214 miles
1.61 kilometers = 1 mile

Area

1 sq cm = .1550 sq in.
6.452 sq cm = 1.0 sq in.
0.093 sq meters = 1 sq ft
1 sq meter = 10.76 sq ft
4047 sq meters = 1 acre
1 hectare = 10,000 sq meters = 2.471 acres

Volume

1 cu cm = 0.061 cu in.
16.39 cu cm = 1 cu in.
0.0283 cu meter = 1 cu ft
1 cu meter = 35.31 cu ft
1 cu meter = 1.308 cu yd

Weight

0.648 gram = 1 grain
1.0 gram = 15.43 grains
28.35 grams = 1 oz
1 kilogram = 2.205 pounds

Liquid Measure

29.57 cu cm = 1 fluid ounce
1 liter = 33.81 fluid oz = 1.057 qt
3.8 liters = 1 gal

INCH FRACTION CONVERSIONS
Decimals, Area of Circles, and Millimeters

Inch Fraction	Decimal Equiv.	Area Sq. In.	Mm. Equiv.	Inch Fraction	Decimal Equiv.	Area Sq. In.	Mm. Equiv.
1/64	.0156	.0002	.397	33/64	.5156	.2088	13.097
1/32	.0312	.0008	.794	17/32	.5312	.2217	13.494
3/64	.0469	.0016	1.191	35/64	.5469	.2349	13.891
1/16	.0625	.0031	1.587	9/16	.5625	.2485	14.288
5/64	.0781	.0048	1.984	37/64	.5781	.2624	14.684
3/32	.0937	.0069	2.381	19/32	.5937	.2769	15.081
7/64	.1094	.0093	2.778	39/64	.6094	.2916	15.479
1/8	.125	.0123	3.175	5/8	.625	.3068	15.875
9/64	.1406	.0154	3.572	41/64	.6406	.3223	16.272
5/32	.1562	.0192	3.969	21/32	.6562	.3382	16.669
11/64	.1719	.0231	4.366	43/64	.6719	.3545	17.065
3/16	.1875	.0276	4.762	11/16	.6875	.3712	17.462
13/64	.2031	.0323	5.159	45/64	.7031	.3883	17.859
7/32	.2187	.0376	5.556	23/32	.7187	.4057	18.256
15/64	.2344	.0431	5.953	47/64	.7344	.4235	18.653
1/4	.25	.0491	6.350	3/4	.75	.4418	19.050
17/64	.2656	.0553	6.747	49/64	.7656	.4604	19.447
9/32	.2812	.0621	7.144	25/32	.7812	.4794	19.844
19/64	.2969	.0691	7.540	51/64	.7969	.4987	20.241
5/16	.3125	.0767	7.937	13/16	.8125	.5185	20.637
21/64	.3281	.0845	8.334	53/64	.8281	.5386	21.034
11/32	.3437	.0928	8.731	27/32	.8437	.5591	21.431
23/64	.3594	.1013	9.128	55/64	.8594	.5800	21.828
3/8	.375	.1105	9.525	7/8	.875	.6013	22.225
25/64	.3906	.1198	9.922	57/64	.8906	.6229	22.622
13/32	.4062	.1296	10.319	29/32	.9062	.6450	23.019
27/64	.4219	.1398	10.716	59/64	.9219	.6675	23.416
7/16	.4375	.1503	11.112	15/16	.9375	.6903	23.812
29/64	.4531	.1612	11.509	61/84	.9531	.7134	24.209
15/32	.4687	.1726	11.906	31/32	.9687	.7371	24.606
31/64	.4844	.1842	12.303	63/64	.9844	.7610	25.003
1/2	.5	.1964	12.700	1	1.	.7854	25.400

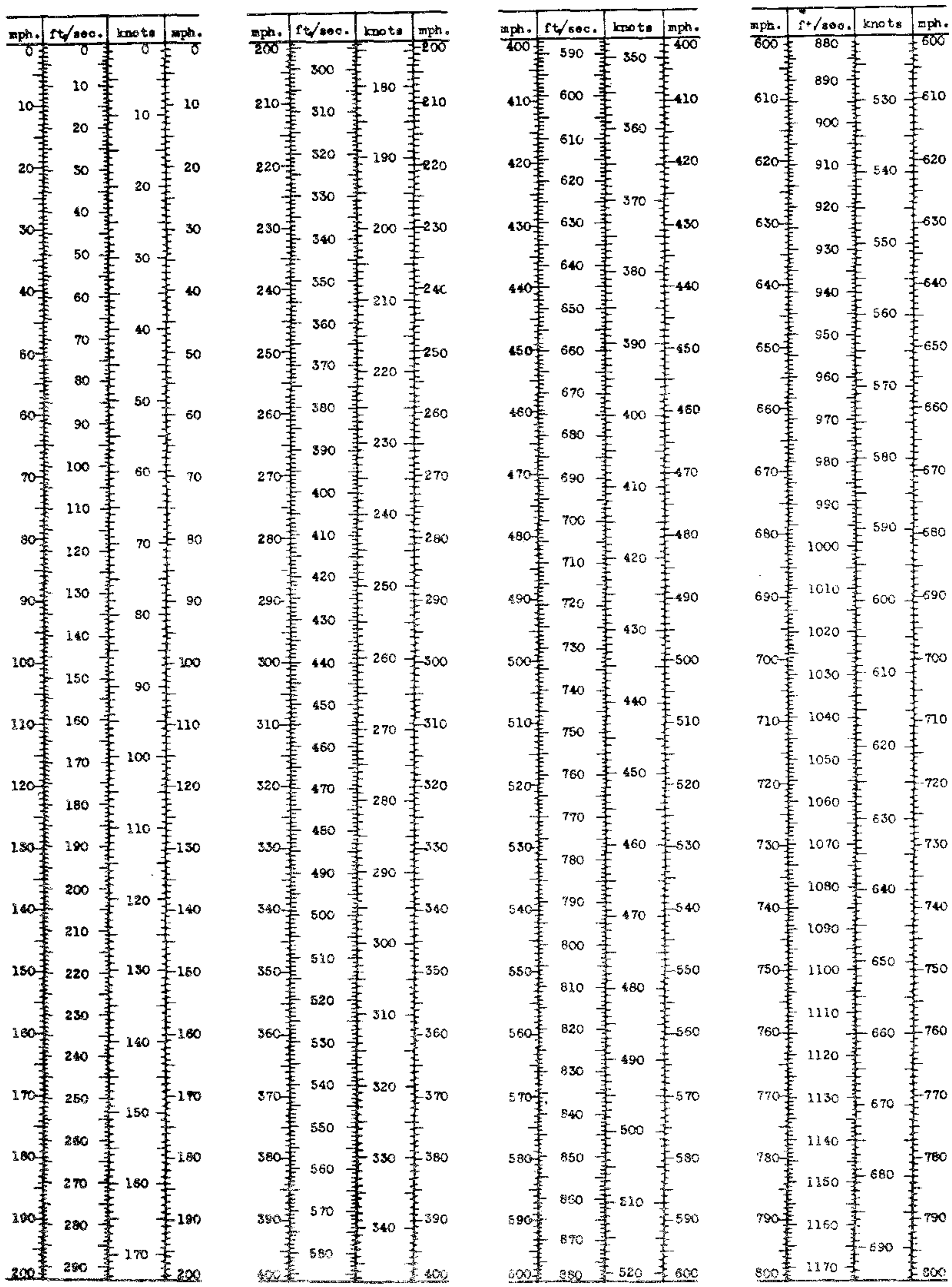
DRILL SIZE — DECIMAL EQUIVALENTS

Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.	Drill No.	Diam. In.
1	.2280	19	.1660	37	.1040	55	.0520	73	.0240	I	.272
2	.2210	20	.1610	38	.1015	56	.0465	74	.0225	J	.277
3	.2130	21	.1590	39	.0995	57	.0430	75	.0210	K	.281
4	.2090	22	.1570	40	.0980	58	.0420	76	.0200	L	.290
5	.2055	23	.1540	41	.0960	59	.0410	77	.0180	M	.295
6	.2040	24	.1520	42	.0935	60	.0400	78	.0160	N	.302
7	.2010	25	.1495	43	.0890	61	.0390	79	.0145	O	.316
8	.1990	26	.1470	44	.0860	62	.0380	80	.0135	P	.323
9	.1960	27	.1440	45	.0820	63	.0370			Q	.332
10	.1935	28	.1405	46	.0810	64	.0360			R	.339
11	.1910	29	.1360	47	.0785	65	.0350	A	.234	S	.348
12	.1890	30	.1285	48	.0760	66	.0330	B	.238	T	.358
13	.1850	31	.1200	49	.0730	67	.0320	C	.242	U	.368
14	.1820	32	.1160	50	.0700	68	.0310	D	.246	V	.377
15	.1800	33	.1130	51	.0670	69	.0292	E	.250	W	.386
16	.1770	34	.1110	52	.0635	70	.0280	F	.257	X	.397
17	.1730	35	.1100	53	.0595	71	.0260	G	.261	Y	.404
18	.1695	36	.1065	54	.0550	72	.0250	H	.266	Z	.413

VELOCITY CONVERSION CHART

Conversion factors from: The Handbook of Chemistry and Physics, 23rd. Edition

1 mph. = 1.4667 ft./sec.
1 mph. = .8684 knots



TEMPERATURE CONVERSION TABLE

Conversion Constants

The following table gives the conversion of Fahrenheit and centigrade temperatures from -100° to +249° in units of 1° and from +250° to +2645° in units of 5°. The readings are based on the standard temperature scale. Conversion of any value to the absolute temperature scale may be made as follows:

Degrees Kelvin (K) = degrees centigrade + 273.16
Degrees Rankine (R) = degrees Fahrenheit + 459.69

If F and C denote readings on the Fahrenheit and centigrade standard scales, respectively, for the same, then

$$C = 5/9\ (F - 32), \qquad F = (9/5)\ C + 32.$$

Use of the Table

Look up reading in middle column; if in degrees centigrade, read Fahrenheit equivalent in right-hand column, if in degrees Fahrenheit, read centigrade equivalent in left-hand column.

Conversion of Centigrade and Fahrenheit Temperatures from -100° to +249°

C		F	C		F	C		F	C		F	C		F	C		F	C		F
-73.3	-100	-148.0	-45.6	-50	-58.0	-17.8	0	32.0	10.0	50	122.0	37.8	100	212.0	65.6	150	302.0	93.3	200	392.0
-72.8	-99	-146.2	-45.0	-49	-56.2	-17.2	1	33.8	10.6	51	123.8	38.3	101	213.8	66.1	151	303.8	93.9	201	393.8
-72.2	-98	-144.4	-44.4	-48	-54.4	-16.7	2	35.6	11.1	52	125.6	38.9	102	215.6	66.7	152	305.6	94.4	202	395.6
-71.7	-97	-142.6	-43.9	-47	-52.6	-16.1	3	37.4	11.7	53	127.4	39.4	103	217.4	67.2	153	307.4	95.0	203	397.4
-71.1	-96	-140.8	-43.3	-46	-50.8	-15.6	4	39.2	12.2	54	129.2	40.0	104	219.2	67.8	154	309.2	95.6	204	399.2
-70.6	-95	-139.0	-42.8	-45	-49.0	-15.0	5	41.0	12.8	55	131.0	40.6	105	221.0	68.3	155	311.0	96.1	205	401.0
-70.0	-94	-137.2	-42.2	-44	-47.2	-14.4	6	42.8	13.3	56	132.8	41.1	106	222.8	68.9	156	312.8	96.7	206	402.8
-69.4	-93	-135.4	-41.7	-43	-45.4	-13.9	7	44.6	13.9	57	134.6	41.7	107	224.6	69.4	157	314.6	97.2	207	404.6
-68.9	-92	-133.6	-41.1	-42	-43.6	-13.3	8	46.4	14.4	58	136.4	42.2	108	226.4	70.0	158	316.4	97.8	208	406.4
-68.3	-91	-131.8	-40.6	-41	-41.8	-12.8	9	48.2	15.0	59	138.2	42.8	109	228.2	70.6	159	318.2	98.3	209	408.2
-67.8	-90	-130.0	-40.0	-40	-40.0	-12.2	10	50.0	15.6	60	140.0	43.3	110	230.0	71.1	160	320.0	98.9	210	410.0
-67.2	-89	-128.2	-39.4	-39	-38.2	-11.7	11	51.8	16.1	61	141.8	43.9	111	231.8	71.7	161	321.8	99.4	211	411.8
-66.7	-88	-126.4	-38.9	-38	-36.4	-11.1	12	53.6	16.7	62	143.6	44.4	112	233.6	72.2	162	323.6	100.0	212	413.6
-66.1	-87	-124.6	-38.3	-37	-34.6	-10.6	13	55.4	17.2	63	145.4	45.0	113	235.4	72.8	163	325.4	100.6	213	415.4
-65.6	-86	-122.8	-37.8	-36	-32.8	-10.0	14	57.2	17.8	64	147.2	45.6	114	237.2	73.3	164	327.2	101.1	214	417.2
-65.0	-85	-121.0	-37.2	-35	-31.0	- 9.4	15	59.0	18.3	65	149.0	46.1	115	239.0	73.9	165	329.0	101.7	215	419.0
-64.4	-84	-119.2	-36.7	-34	-29.0	- 8.9	16	60.8	18.9	66	150.8	46.7	116	240.8	74.4	166	330.8	102.2	216	420.8
-63.9	-83	-117.4	-36.1	-35	-27.4	- 8.3	17	62.6	19.4	67	152.6	47.2	117	242.6	75.0	167	332.6	102.8	217	422.6
-63.3	-82	-115.6	-35.6	-32	-25.6	- 7.8	18	64.4	20.0	68	154.4	47.8	118	244.4	75.6	168	334.4	103.3	218	424.4
-62.8	-81	-113.8	-35.0	-31	-23.8	- 7.2	19	66.2	20.6	69	156.2	48.3	119	246.2	76.1	169	336.2	103.9	219	426.2
-62.2	-80	-112.0	-34.4	-30	-22.0	- 6.7	20	68.0	21.1	70	158.0	48.9	120	248.0	76.7	170	338.0	104.4	220	428.0
-61.7	-79	-110.2	-33.9	-29	-20.2	- 6.1	21	69.8	21.7	71	159.8	49.4	121	249.8	77.2	171	339.8	105.0	221	429.8
-61.1	-78	-108.4	-33.3	-28	-18.4	- 5.6	22	71.6	22.2	72	161.6	50.0	122	251.6	77.8	172	341.6	105.6	222	431.6
-60.6	-77	-106.6	-32.8	-27	-16.6	- 5.0	23	73.4	22.8	73	163.4	50.6	123	253.4	78.3	173	343.4	106.1	223	433.4
-60.0	-76	-104.8	-32.2	-26	-14.8	- 4.4	24	75.2	23.3	74	165.2	51.1	124	255.2	78.9	174	345.2	106.7	224	435.2
-59.4	-75	-103.0	-31.7	-25	-13.0	- 3.9	25	77.0	23.9	75	167.0	51.7	125	257.0	79.4	175	347.0	107.2	225	437.0
-58.9	-74	-101.2	-31.1	-24	-11.2	- 3.3	26	78.8	24.4	76	168.8	52.2	126	258.8	80.0	176	348.8	107.8	226	438.8
-58.3	-73	- 99.4	-30.6	-23	- 9.4	- 2.8	27	80.6	25.0	77	170.6	52.8	127	260.6	80.6	177	350.6	108.3	227	440.6
-57.8	-72	- 97.6	-30.0	-22	- 7.6	- 2.2	28	82.4	25.6	78	172.4	53.3	128	262.4	81.1	178	352.4	108.9	228	442.4
-57.2	-71	- 95.8	-29.4	-21	- 5.8	- 1.7	29	84.2	26.1	79	174.2	53.9	129	264.2	81.7	179	354.2	109.4	229	444.2
-56.7	-70	- 94.0	-28.9	-20	- 4.0	- 1.1	30	86.0	26.7	80	176.0	54.4	130	266.0	82.2	180	356.0	110.0	230	446.0
-56.1	-69	- 92.2	-28.3	-19	- 2.2	- 0.6	31	87.8	27.2	81	177.8	55.0	131	267.8	82.8	181	357.8	110.6	231	447.8
-55.6	-68	- 90.4	-27.8	-18	- 0.4	0.0	32	89.6	27.8	82	179.6	55.6	132	269.6	83.3	182	359.6	111.1	232	449.6
-55.0	-67	- 88.6	-27.2	-17	1.4	0.6	33	91.4	28.3	83	181.4	56.1	133	271.4	83.9	183	361.4	111.7	233	451.4
-54.4	-66	- 86.8	-26.7	-16	3.2	1.1	34	93.2	28.9	84	183.2	56.7	134	273.2	84.4	184	363.2	112.2	234	453.2
-53.9	-65	-85.0	-26.1	-15	5.0	1.7	35	95.0	29.4	85	185.0	57.2	135	275.0	85.0	185	365.0	112.8	235	455.0
-53.3	-64	-83.2	-25.6	-14	6.8	2.2	36	96.8	30.0	86	186.8	57.8	136	276.8	85.6	186	366.8	113.3	236	456.8
-52.8	-63	-81.4	-25.0	-13	8.6	2.8	37	98.6	30.6	87	188.6	58.3	137	278.6	86.1	187	368.6	113.9	237	458.6
-52.2	-62	-79.6	-24.4	-12	10.4	3.3	38	100.4	31.1	88	190.4	58.9	138	280.4	86.7	188	370.4	114.4	238	460.4
-51.7	-61	-77.8	-23.9	-11	12.2	3.9	39	102.2	31.7	89	192.2	59.4	139	282.2	87.2	189	372.2	115.0	239	462.2
-51.1	-60	-76.0	-23.3	-10	14.0	4.4	40	104.0	32.2	90	194.0	60.0	140	284.0	87.8	190	374.0	115.6	240	464.0
-50.6	-59	-74.2	-22.8	- 9	15.8	5.0	41	105.8	32.8	91	195.8	60.6	141	285.8	88.3	191	375.8	116.1	241	465.8
-50.0	-58	-72.4	-22.2	- 8	17.6	5.6	42	107.6	33.3	92	197.6	61.1	142	287.6	88.9	192	377.6	116.7	242	467.6
-49.4	-57	-70.6	-21.7	- 7	19.4	6.1	43	109.4	33.9	93	199.4	61.7	143	289.4	89.4	193	379.4	117.2	243	469.4
-48.9	-56	-68.8	-21.1	- 6	21.2	6.7	44	111.2	34.4	94	201.2	62.2	144	291.2	90.0	194	381.2	117.8	244	471.2
-48.3	-55	-67.0	-20.6	- 5	23.0	7.2	45	113.0	35.0	95	203.0	62.8	145	293.0	90.6	195	383.0	118.3	245	473.0
-47.8	-54	-65.2	-20.0	- 4	24.8	7.8	46	114.8	35.6	96	204.8	63.3	146	294.8	91.1	196	384.8	118.9	246	474.8
-47.2	-53	-63.4	-19.4	- 3	26.6	8.3	47	116.6	36.1	97	206.6	63.9	147	296.6	91.7	197	386.6	119.4	247	476.6
-46.7	-52	-61.6	-18.9	- 2	28.4	8.9	48	118.4	36.7	98	208.4	64.4	148	298.4	92.2	198	388.4	120.0	248	478.4
-46.1	-51	-59.8	-18.3	- 1	30.2	9.4	49	120.2	37.2	99	210.2	65.0	149	300.2	92.8	199	390.2	120.6	249	480.2

C		F	C		F	C		F	C		F	C		F	C		F
121.1	250	482.0	343.3	650	1202.0	565.6	1050	1922.0	787.8	1450	2642.0	1010.0	1850	3362.0	1232.2	2250	4082.0
123.9	255	491.0	346.1	655	1211.0	568.3	1055	1931.0	790.6	1455	2651.0	1012.8	1855	3371.0	1235.0	2255	4091.0
126.7	260	500.0	348.9	660	1220.0	571.1	1060	1940.0	793.3	1460	2660.0	1015.6	1860	3380.0	1237.8	2260	4100.0
129.4	265	509.0	351.7	665	1229.0	573.9	1065	1949.0	796.1	1465	2669.0	1018.3	1865	3389.0	1240.6	2265	4109.0
132.2	270	518.0	354.4	670	1238.0	576.7	1070	1958.0	798.9	1470	2678.0	1021.1	1870	3398.0	1243.3	2270	4118.0
135.0	275	527.0	357.2	675	1247.0	579.4	1075	1967.0	801.7	1475	2687.0	1023.9	1875	3407.0	1246.1	2275	4127.0
137.8	280	536.0	360.0	680	1256.0	582.2	1080	1976.0	804.4	1480	2696.0	1026.9	1880	3416.0	1248.9	2280	4136.0
140.6	285	545.0	362.8	685	1265.0	585.0	1085	1985.0	807.2	1485	2705.0	1029.4	1885	3425.0	1251.7	2285	4145.0
143.3	290	554.0	365.6	690	1274.0	587.8	1090	1994.0	810.0	1490	2714.0	1032.2	1890	3434.0	1254.4	2290	4154.0
146.1	295	563.0	368.3	695	1283.0	590.6	1095	2003.0	812.8	1495	2723.0	1035.0	1895	3443.0	1257.2	2295	4163.0
148.9	300	572.0	371.1	700	1292.0	593.3	1100	2012.0	815.6	1500	2732.0	1037.8	1900	3452.0	1260.0	2300	4172.0
151.7	305	581.0	373.9	705	1301.0	596.1	1105	2021.0	818.3	1505	2741.0	1040.6	1905	3461.0	1262.8	2305	4181.0
154.4	310	590.0	376.7	710	1310.0	598.9	1110	2030.0	821.1	1510	2750.0	1043.3	1910	3470.0	1265.6	2310	4190.0
157.2	315	599.0	379.4	715	1319.0	601.7	1115	2039.0	823.9	1515	2759.0	1046.1	1915	3479.0	1268.3	2315	4199.0
160.0	320	608.0	382.2	720	1328.0	604.4	1120	2048.0	826.7	1520	2768.0	1048.9	1920	3488.0	1271.1	2320	4208.0
162.8	325	617.0	385.0	725	1337.0	607.2	1125	2057.0	829.4	1525	2777.0	1051.7	1925	3497.0	1273.9	2325	4217.0
165.6	330	626.0	387.8	730	1346.0	610.0	1130	2066.0	832.2	1530	2786.0	1054.4	1930	3506.0	1276.7	2330	4226.0
168.3	335	635.0	390.6	735	1355.0	612.8	1135	2075.0	835.0	1535	2795.0	1057.2	1935	3515.0	1279.4	2335	4235.0
171.1	340	644.0	393.3	740	1364.0	615.6	1140	2084.0	837.8	1540	2804.0	1060.0	1940	3524.0	1282.2	2340	4244.0
173.9	345	653.0	396.1	745	1373.0	618.3	1145	2093.0	840.6	1545	2813.0	1062.8	1945	3533.0	1285.0	2345	4253.0
176.7	350	662.0	398.9	750	1382.0	621.1	1150	2102.0	843.3	1550	2822.0	1065.6	1950	3542.0	1287.8	2350	4262.0
179.4	355	671.0	401.7	755	1391.0	623.9	1155	2111.0	846.1	1555	2831.0	1068.3	1955	3551.0	1290.6	2355	4271.0
182.2	360	680.0	404.4	760	1400.0	626.7	1160	2120.0	848.9	1560	2840.0	1071.1	1960	3560.0	1293.3	2360	4280.0
185.0	365	689.0	407.2	765	1409.0	629.4	1165	2129.0	851.7	1565	2849.0	1073.9	1965	3569.0	1296.1	2365	4289.0
187.8	370	698.0	410.0	770	1418.0	632.2	1170	2138.0	854.4	1570	2858.0	1076.7	1970	3578.0	1298.9	2370	4298.0
190.6	375	707.0	412.8	775	1427.0	635.0	1175	2147.0	857.2	1575	2867.0	1079.4	1975	3587.0	1301.7	2375	4307.0
193.3	380	716.0	415.6	780	1436.0	637.8	1180	2156.0	860.0	1580	2876.0	1082.2	1980	3596.0	1304.4	2380	4316.0
196.1	385	725.0	418.3	785	1445.0	640.6	1185	2165.0	862.8	1585	2885.0	1085.0	1985	3605.0	1307.2	2385	4325.0
198.9	390	734.0	421.1	790	1454.0	643.3	1190	2174.0	865.6	1590	2894.0	1087.8	1990	3614.0	1310.0	2390	4334.0
201.7	395	743.0	423.9	795	1463.0	646.1	1195	2183.0	868.3	1595	2903.0	1090.6	1995	3623.0	1312.8	2395	4343.0
204.4	400	752.0	426.7	800	1472.0	648.9	1200	2192.0	871.1	1600	2912.0	1093.6	2000	3632.0	1315.6	2400	4352.0
207.2	405	761.0	429.4	805	1481.0	651.7	1205	2201.0	873.9	1605	2921.0	1096.1	2005	3641.0	1318.3	2405	4361.0
210.0	410	770.0	432.2	810	1490.0	654.4	1210	2210.0	876.7	1610	2930.0	1098.9	2010	3650.0	1321.1	2410	4370.0
212.8	415	779.0	435.0	815	1499.0	657.2	1215	2219.0	879.4	1615	2939.0	1101.7	2015	3659.0	1323.9	2415	4379.0
215.6	420	788.0	437.8	820	1508.0	660.0	1220	2228.0	882.2	1620	2948.0	1104.4	2020	3668.0	1326.7	2420	4388.0
218.3	425	797.0	440.6	825	1517.0	662.8	1225	2237.0	885.0	1625	2957.0	1107.2	2025	3677.0	1329.4	2425	4397.0
221.1	430	806.0	443.3	830	1526.0	665.6	1230	2246.0	887.8	1630	2966.0	1110.0	2030	3686.0	1332.2	2430	4406.0
223.9	435	815.0	446.1	835	1535.0	668.3	1235	2255.0	890.6	1635	2975.0	1112.8	2035	3695.0	1335.0	2435	4415.0
226.7	440	824.0	448.9	840	1544.0	671.1	1240	2264.0	893.3	1640	2984.0	1115.6	2040	3704.0	1337.8	2440	4424.0
229.4	445	833.0	451.7	845	1553.0	673.9	1245	2273.0	896.1	1645	2993.0	1118.3	2045	3713.0	1340.6	2445	4433.0
232.2	450	842.0	454.4	850	1562.0	676.7	1250	2282.0	898.9	1650	3002.0	1121.1	2050	3722.0	1343.3	2450	4442.0
235.0	455	851.0	457.2	855	1571.0	679.4	1255	2291.0	901.7	1655	3011.0	1123.9	2055	3731.0	1346.1	2455	4451.0
237.8	460	860.0	460.0	860	1580.0	682.2	1260	2300.0	904.4	1660	3020.0	1126.7	2060	3740.0	1348.9	2460	4460.0
240.6	465	869.0	462.8	865	1589.0	685.0	1265	2309.0	907.2	1665	3029.0	1129.4	2065	3749.0	1351.7	2465	4469.0
243.3	470	878.0	465.6	870	1598.0	687.8	1270	2318.0	910.0	1670	3038.0	1132.2	2070	3758.0	1354.4	2470	4478.0
246.1	475	887.0	468.3	875	1607.0	690.6	1275	2327.0	912.8	1675	3047.0	1135.0	2075	3767.0	1357.2	2475	4487.0
248.9	480	896.0	471.1	880	1616.0	693.3	1280	2336.0	915.6	1680	3056.0	1137.8	2080	3776.0	1360.0	2480	4496.0
251.7	485	905.0	473.9	885	1625.0	696.1	1285	2345.0	918.3	1685	3065.0	1140.6	2085	3785.0	1362.8	2485	4505.0
254.4	490	914.0	476.7	890	1634.0	698.9	1290	2354.0	921.1	1690	3074.0	1143.3	2090	3794.0	1365.6	2490	4514.0
257.2	495	923.0	479.4	895	1643.0	701.7	1295	2363.0	923.9	1695	3083.0	1146.1	2095	3803.0	1368.3	2495	4523.0
260.0	500	932.0	482.2	900	1652.0	704.4	1300	2372.0	926.7	1700	3092.0	1148.9	2100	3812.0	1371.1	2500	4532.0
262.8	505	941.0	485.0	905	1661.0	707.2	1305	2381.0	929.4	1705	3101.0	1151.7	2105	3821.0	1373.9	2505	4541.0
265.6	510	950.0	487.8	910	1670.0	710.0	1310	2390.0	932.2	1710	3110.0	1154.4	2110	3830.0	1376.7	2510	4550.0
268.3	515	959.0	490.6	915	1679.0	712.8	1315	2399.0	935.0	1715	3119.0	1157.2	2115	3839.0	1379.4	2515	4559.0
271.1	520	968.0	493.3	920	1688.0	715.6	1320	2408.0	937.8	1720	3128.0	1160.0	2120	3848.0	1382.2	2520	4568.0
273.9	525	977.0	496.1	925	1697.0	718.3	1325	2417.0	940.6	1725	3137.0	1162.8	2125	3857.0	1385.0	2525	4577.0
276.7	530	986.0	498.9	930	1706.0	721.1	1330	2426.0	943.3	1730	3146.0	1165.6	2130	3866.0	1387.8	2530	4586.0
279.4	535	995.0	501.7	935	1715.0	723.9	1335	2435.0	946.1	1735	3155.0	1168.3	2135	3875.0	1390.6	2535	4595.0
282.2	540	1004.0	504.4	940	1724.0	726.7	1340	2444.0	948.9	1740	3164.0	1171.1	2140	3884.0	1393.3	2540	4604.0
285.0	545	1013.0	507.2	945	1733.0	729.4	1345	2453.0	951.7	1745	3173.0	1173.9	2145	3893.0	1396.1	2545	4613.0
287.8	550	1022.0	510.0	950	1742.0	732.2	1350	2462.0	954.4	1750	3182.0	1176.7	2150	3902.0	1398.9	2550	4622.0
290.6	555	1031.0	512.8	955	1751.0	735.0	1355	2471.0	957.2	1755	3191.0	1179.4	2155	3911.0	1401.7	2555	4631.0
293.3	560	1040.0	515.6	960	1760.0	737.8	1360	2480.0	960.0	1760	3200.0	1182.2	2160	3920.0	1404.4	2560	4640.0
296.1	565	1049.0	518.3	965	1769.0	740.6	1365	2489.0	962.8	1765	3209.0	1185.0	2165	3929.0	1407.2	2565	4649.0
298.9	570	1058.0	521.1	970	1778.0	743.3	1370	2498.0	965.6	1770	3218.0	1187.8	2170	3938.0	1410.0	2570	4658.0
301.7	575	1067.0	523.9	975	1787.0	746.1	1375	2507.0	968.3	1775	3227.0	1190.6	2175	3947.0	1412.8	2575	4667.0
304.4	580	1076.0	526.7	980	1796.0	748.9	1380	2516.0	971.1	1780	3236.0	1193.3	2180	3956.0	1415.6	2580	4676.0
307.2	585	1085.0	529.4	985	1805.0	751.7	1385	2525.0	973.9	1785	3245.0	1196.1	2185	3965.0	1418.3	2585	4685.0
310.0	590	1094.0	532.2	990	1814.0	754.4	1390	2534.0	976.7	1790	3254.0	1198.9	2190	3974.0	1421.1	2590	4694.0
312.8	595	1103.0	535.0	995	1823.0	757.2	1395	2543.0	979.4	1795	3263.0	1201.7	2195	3983.0	1423.9	2595	4703.0
315.6	600	1112.0	537.8	1000	1832.0	760.0	1400	2552.0	982.2	1800	3272.0	1204.4	2200	3992.0	1426.7	2600	4712.0
318.3	605	1121.0	540.6	1005	1841.0	762.8	1405	2561.0	985.0	1805	3281.0	1207.2	2205	4001.0	1429.4	2605	4721.0
321.1	610	1130.0	543.3	1010	1850.0	765.6	1410	2570.0	987.8	1810	3290.0	1210.0	2210	4010.0	1432.2	2610	4730.0
323.9	615	1139.0	546.1	1015	1859.0	768.3	1415	2579.0	990.6	1815	3299.0	1212.8	2215	4019.0	1435.0	2615	4739.0
326.7	620	1148.0	548.9	1020	1868.0	771.1	1420	2588.0	993.3	1820	3308.0	1215.6	2220	4028.0	1437.8	2620	4748.0
329.4	625	1157.0	551.7	1025	1877.0	773.9	1425	2597.0	996.1	1825	3317.0	1218.3	2225	4037.0	1440.6	2625	4757.0
332.2	630	1166.0	554.4	1030	1886.0	776.7	1430	2606.0	998.9	1830	3326.0	1221.1	2230	4046.0	1443.3	2630	4766.0
335.0	635	1175.0	557.2	1035	1895.0	779.4	1435	2615.0	1001.7	1835	3335.0	1223.9	2235	4055.0	1446.1	2635	4775.0
337.8	640	1184.0	560.0	1040	1904.0	782.2	1440	2624.0	1004.4	1840	3344.0	1226.7	2240	4064.0	1448.9	2640	4784.0
340.6	645	1193.0	562.8	1045	1913.0	785.0	1445	2633.0	1007.2	1845	3353.0	1229.4	2245	4073.0	1451.7	2645	4793.0

AERODYNAMIC RELATIONSHIPS

b = Span — ft
c = Chord — ft
D = Drag — lb
L = Lift — lb
L = Rolling Moment — lb-ft
M = Pitching Moment — lb-ft
N = Yawing Moment — lb-ft

q = Dynamic Pressure — lb/sq ft
S = Area — sq ft
V = Velocity — ft/sec
ϵ = Angle of downwash — deg.
α = Angle of attack — deg.
γ = Flight-path angle — deg.
ρ = Density — lb sec²/ft⁴

Lift coef $C_L = \frac{L}{qS}$

Drag coef $C_D = \frac{D}{qS}$

Pitching moment coef $C_m = \frac{M}{qcS}$

Rolling moment coef $C_l = \frac{L}{qbS}$

Yawing moment coef $C_n = \frac{N}{qbS}$

Reynolds' Number

$$R = \rho \frac{Vc}{\mu} = \frac{Vc}{\nu}$$

Change in velocity with change in Power at Constant Air Density

$$V_2 = V_1 \sqrt[3]{\frac{Hp_2}{Hp_1}}$$

Change in velocity with change in Air Density at constant Thp

$$V_2 = V_1\sqrt{\frac{\rho_1}{\rho_2}} \text{ and } V_{true} = \sqrt{\frac{\rho_o}{\rho}} \quad V_{ind}$$

Approximate Reynolds' Number for Airfoils

$$R = 10{,}000\ cV_{mph}$$

Values of ν at Standard Altitudes

Altitude	0	10,000	20,000	30,000
$\nu \times 10^6$	157	202	264	354

PROPELLER RELATIONSHIPS

D = Diameter — ft
N = Propeller speed — rpm
n = Propeller speed — rps
Q = Torque — lb ft

P = Power — ft-lb/sec
T = Thrust — lb
J = Progression Factor
η = Propeller efficiency

Power coef $C_P = \frac{P}{\rho n^3 D^5}$

Thrust coef $C_T = \frac{T}{\rho n^2 D^4}$

Torque coef $C_Q = \frac{Q}{\rho n^2 D^5}$

Speed power coef $C_S = \sqrt[5]{\frac{\rho V^5}{Pn^2}}$

Progression factor $J = \frac{1.467 V_{mph}}{n D}$

Propeller efficiency $\eta = \frac{C_T}{C_P} J$

EQUATIONS RELATING TO ENGINE POWER

Power Corrections

Corrected hp = Observed hp x correction factor

$$\text{Correction factor} = \sqrt{\frac{459.6 + t}{518.4}} \times \frac{29.92}{P} \text{ at sea level}$$

$$= \sqrt{\frac{459.6 + t}{T}} \times \frac{B}{P} \text{ at altitude}$$

t = Dry bulb temp at carb—F

B = Corrected barometric pressure—in. Hg

T = Standard air temperature —F abs

P = Dry carburetor pressure—in. Hg abs

Propeller Load Curve

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

$$\text{Torque, } T = \frac{63025\ hp}{rpm} \text{ lb in.} = \frac{5252\ hp}{rpm} \text{ lb ft}$$

Indicated Horsepower, ihp = bhp + friction hp

Mechanical Efficiency, percent $= \frac{bhp}{ihp} \times 100$

Thermal Efficiency,

$$\text{percent} = \frac{2545}{\text{Sfc x Btu/lb fuel}} \times 100$$

Brake Mean Effective Pressure — lb/sq in

$$bmep = \frac{792{,}000 \times bhp}{\text{Displacement} \times rpm} = \text{constant} \times \frac{bhp}{rpm}$$

Displacement Constant for each engine

R-985 — 805
R-1340 — 591
R-1830 — 432
R-2000 — 396
R-2180 — 364
R-2800 — 283
R-4360 — 182

GENERAL PROPERTIES OF AIR

P = Absolute pressure — lb/sq ft
P_o = Standard absolute pressure — lb/sq ft
T = Absolute temperature
T_o = Standard absolute temperature
V = Velocity — ft/sec
g = Acceleration of gravity — ft/sec^2

n = Exponent of compression
q = Impact pressure — lb/ft^2
ρ = Density — lb sec^2/ft^4
μ = Absolute viscosity lb sec/ft^2
ν = Kinematic viscosity — ft^2/sec
σ = Density ratio — ρ/ρ_o

$$P = \rho g R T$$

$$\frac{P}{P_o} = \frac{\rho}{\rho_o}\frac{T}{T_o} = \left(\frac{\rho}{\rho_o}\right)^n = \left(\frac{V_o}{V}\right)^n$$

$$\frac{T}{T_o} = \left(\frac{P}{P_o}\right)^{\frac{n-1}{n}} = \left(\frac{V_o}{V}\right)^{n-1}$$

$$\frac{\rho}{\rho_o} = \left(\frac{T}{T_o}\right)^{\frac{1}{n-1}}$$

For adiabatic change $n = 1.39$

Specific Weight of Air in lb/ft^3

$$g\rho = .07651\,\frac{P}{P_o}\,\frac{T_o}{T} = 1.325\,\frac{P \text{ in in. Hg}}{T \text{ in } F_{abs}}$$

Density of Air in lb sec^2/ft^4 or slugs/ft^3

$$\rho = .002378\,\frac{P}{P_o}\,\frac{T_o}{T} = .041187\,\frac{P \text{ in in. Hg}}{T \text{ in } F_{abs}}$$

Air Density Ratio

$$\rho/\rho_o = \frac{P}{P_o}\,\frac{T_o}{T} = 17.32\,\frac{P \text{ in in. Hg}}{T \text{ in } F_{abs}}$$

Impact Pressure

for incompressible flow $q = \frac{1}{2}\rho V^2$

for compressible flow $$qc = \left(\frac{P_r}{P_{am}} - 1\right)^{P_{am}}$$

$$T_r = \left(\frac{T_r}{T_{am}} - 1\right)^{T_{am}}$$

Approximate value (at sea level)

$$q = 25\left(\frac{V}{100}\right)^2 \text{lb/sq ft}$$

$$= 5\left(\frac{V}{100}\right)^2 \text{in. water}$$

Where V is in mph

Specific Heat of Air in Btu per lb per degree F

at constant pressure, $C_p = .240$
at constant volume, $C_v = .1715$
for atmospheric temperature range
$\gamma = C_p/C_v = 1.40$

Gas Constant for Air

$$R = 53.345 \text{ ft-lb/lb } F_{abs}$$

$$= \frac{1545.4 \text{ ft-lb/lb - mole } F_{abs}}{\text{mol wt}}$$

Molecular weight of air = 28.97

Speed of Sound in Air in mph

$$C = 33.5\sqrt{T}$$

Where T = air temperature in F_{abs}

C_{SL} = 762 mph = 1118 fps = 662 knots

Absolute Viscosity for Air

$$\mu = \rho\nu$$

$$10^{10}\mu = 3583 + 9.870\ t \text{ in degrees C}$$

$$= 3408 + 5.483\ t \text{ in degrees F}$$

Temperature rise resulting from adiabatic compression at impact

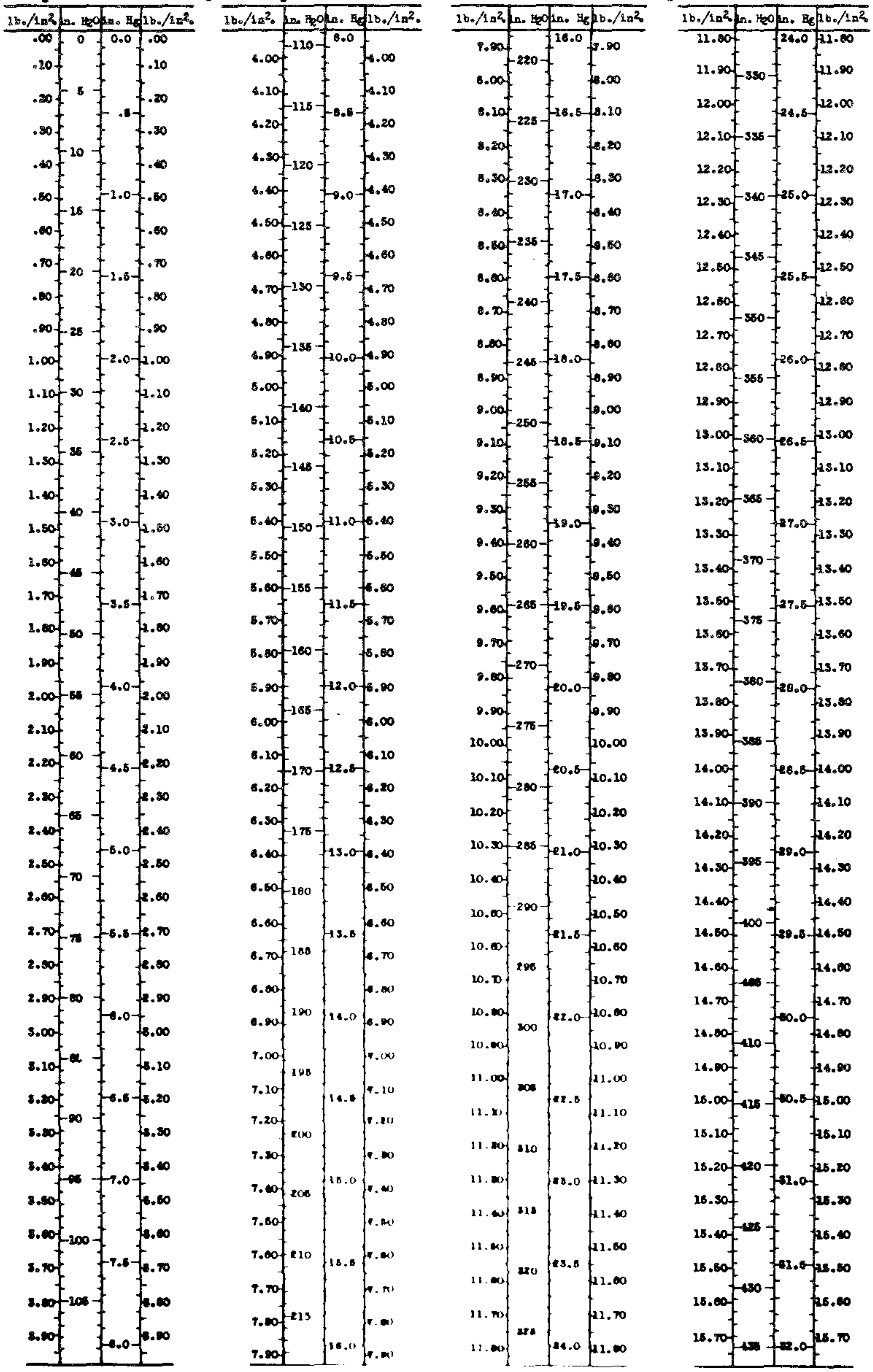
$$T = 1.792\left(\frac{V}{100}\right)^2 \text{ in degrees F}$$

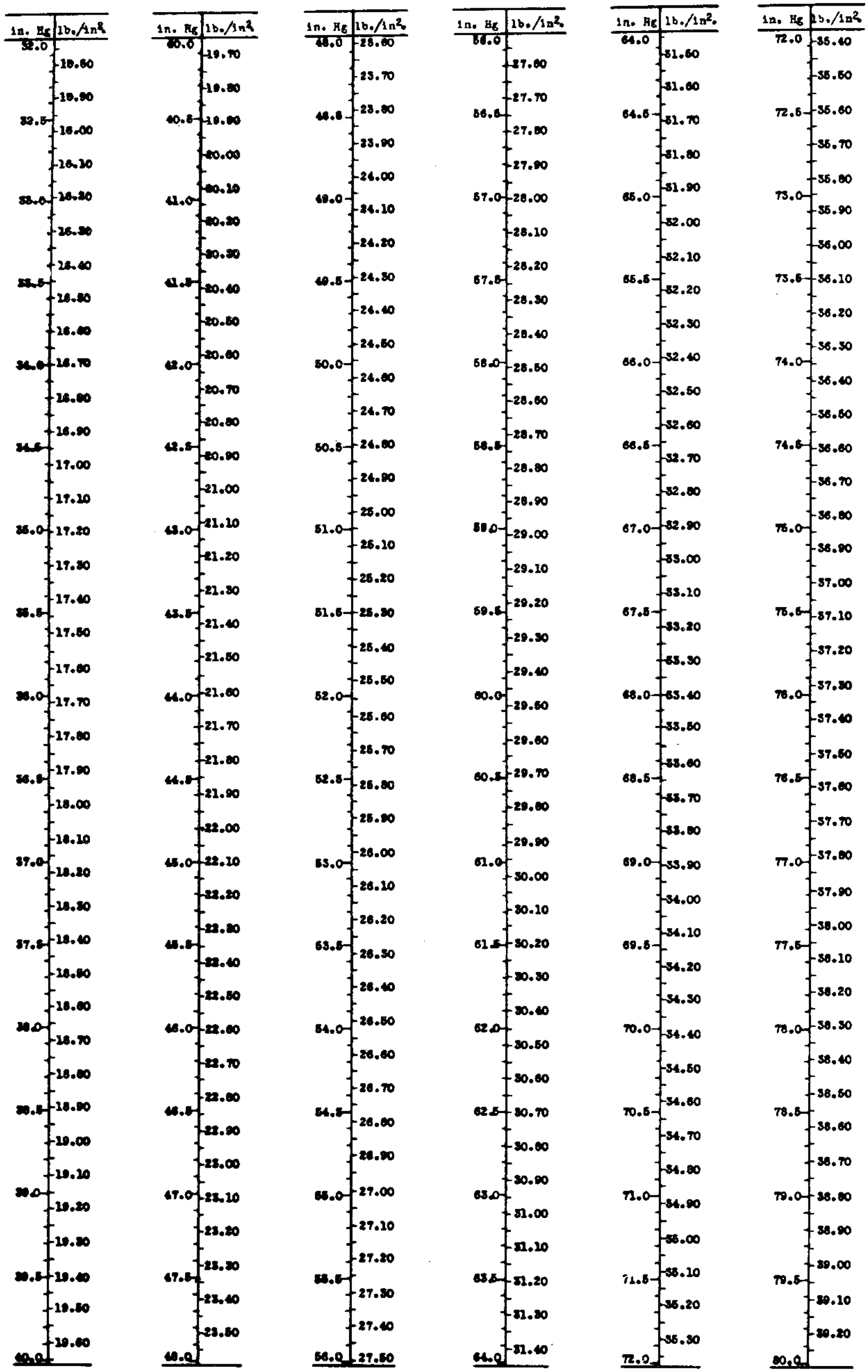
Where V = True air speed in mph

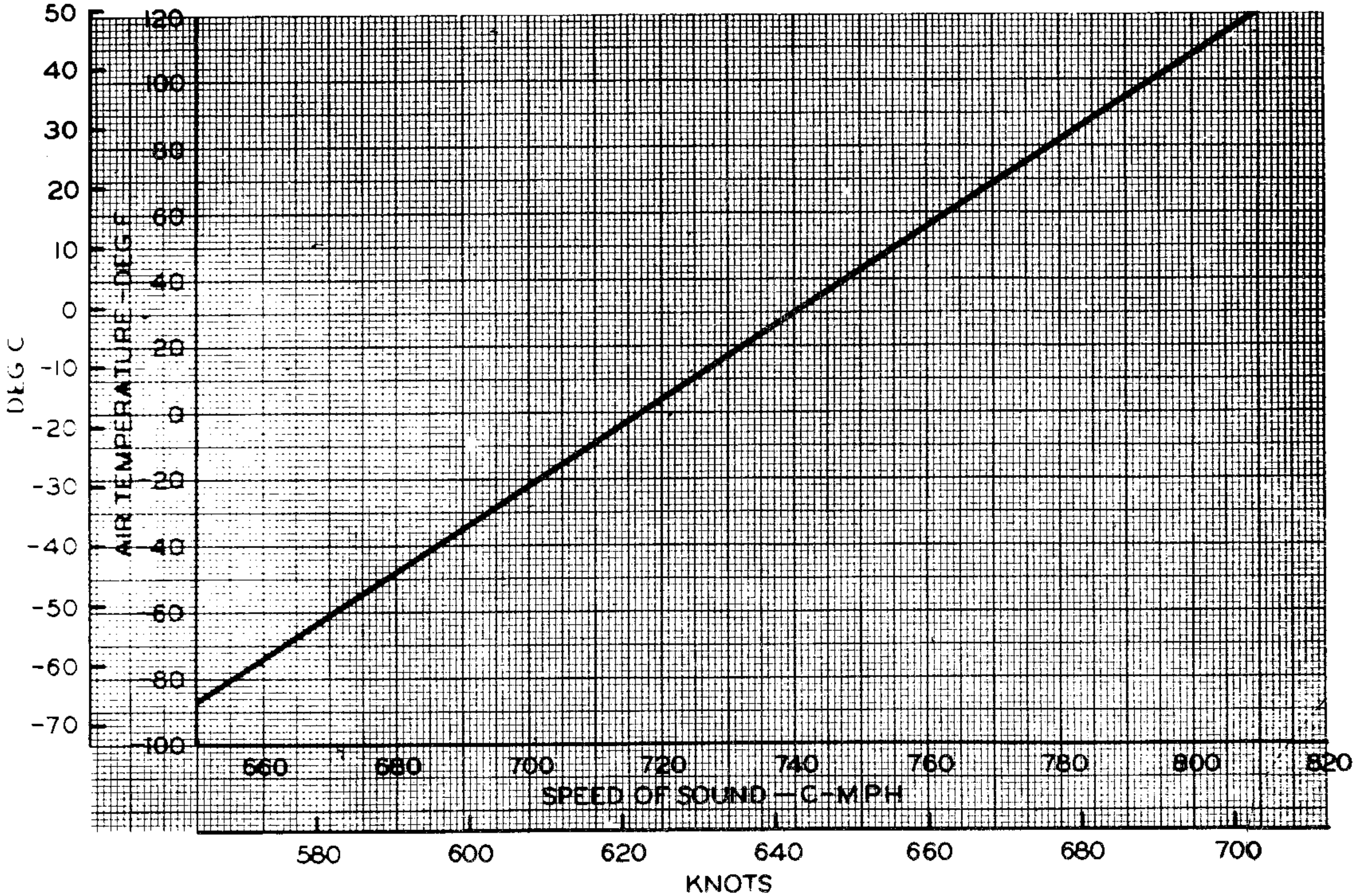
PRESSURE CONVERSION CHART

Conversion factors taken from the Handbook of Chemistry and Physics

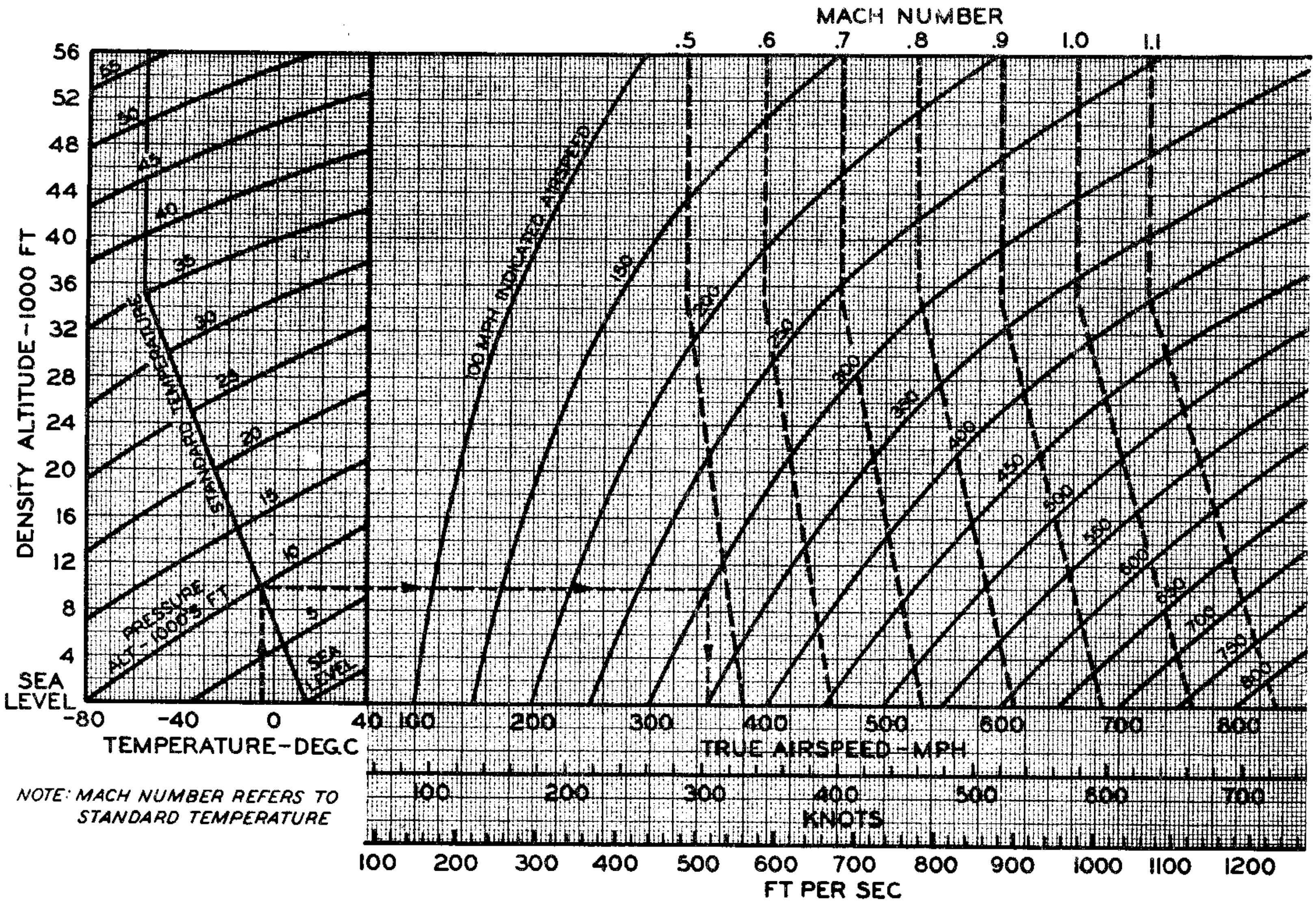
1 in. H_2O at 4°C = .073554 in. Hg 1 in. H_2O at 4°C = .036136 lb./in² 1 in. Hg at 0°C = 13.595 in. H_2O 1 in. Hg at 0°C = .49116 lb./in²




in. Hg | lb./in²
32.0 32.5 33.0 33.5 34.0 34.5 35.0 35.5 36.0 36.5 37.0 37.5 38.0 38.5 39.0 39.5 40.0
15.80 15.90 16.00 16.10 16.20 16.30 16.40 16.50 16.60 16.70 16.80 16.90 17.00 17.10 17.20 17.30 17.40 17.50 17.60 17.70 17.80 17.90 18.00 18.10 18.20 18.30 18.40 18.50 18.60 18.70 18.80 18.90 19.00 19.10 19.20 19.30 19.40 19.50 19.60
in. Hg | lb./in²
40.0 40.5 41.0 41.5 42.0 42.5 43.0 43.5 44.0 44.5 45.0 45.5 46.0 46.5 47.0 47.5 48.0
19.70 19.80 19.90 20.00 20.10 20.20 20.30 20.40 20.50 20.60 20.70 20.80 20.90 21.00 21.10 21.20 21.30 21.40 21.50 21.60 21.70 21.80 21.90 22.00 22.10 22.20 22.30 22.40 22.50 22.60 22.70 22.80 22.90 23.00 23.10 23.20 23.30 23.40 23.50
in. Hg | lb./in².
48.0 48.5 49.0 49.5 50.0 50.5 51.0 51.5 52.0 52.5 53.0 53.5 54.0 54.5 55.0 55.5 56.0
23.60 23.70 23.80 23.90 24.00 24.10 24.20 24.30 24.40 24.50 24.60 24.70 24.80 24.90 25.00 25.10 25.20 25.30 25.40 25.50 25.60 25.70 25.80 25.90 26.00 26.10 26.20 26.30 26.40 26.50 26.60 26.70 26.80 26.90 27.00 27.10 27.20 27.30 27.40 27.50
in. Hg | lb./in².
56.0 56.5 57.0 57.5 58.0 58.5 59.0 59.5 60.0 60.5 61.0 61.5 62.0 62.5 63.0 63.5 64.0
27.60 27.70 27.80 27.90 28.00 28.10 28.20 28.30 28.40 28.50 28.60 28.70 28.80 28.90 29.00 29.10 29.20 29.30 29.40 29.50 29.60 29.70 29.80 29.90 30.00 30.10 30.20 30.30 30.40 30.50 30.60 30.70 30.80 30.90 31.00 31.10 31.20 31.30 31.40
in. Hg | lb./in².
64.0 64.5 65.0 65.5 66.0 66.5 67.0 67.5 68.0 68.5 69.0 69.5 70.0 70.5 71.0 71.5 72.0
31.50 31.60 31.70 31.80 31.90 32.00 32.10 32.20 32.30 32.40 32.50 32.60 32.70 32.80 32.90 33.00 33.10 33.20 33.30 33.40 33.50 33.60 33.70 33.80 33.90 34.00 34.10 34.20 34.30 34.40 34.50 34.60 34.70 34.80 34.90 35.00 35.10 35.20 35.30
in. Hg | lb./in².
72.0 72.5 73.0 73.5 74.0 74.5 75.0 75.5 76.0 76.5 77.0 77.5 78.0 78.5 79.0 79.5 80.0
35.40 35.50 35.60 35.70 35.80 35.90 36.00 36.10 36.20 36.30 36.40 36.50 36.60 36.70 36.80 36.90 37.00 37.10 37.20 37.30 37.40 37.50 37.60 37.70 37.80 37.90 38.00 38.10 38.20 38.30 38.40 38.50 38.60 38.70 38.80 38.90 39.00 39.10 39.20

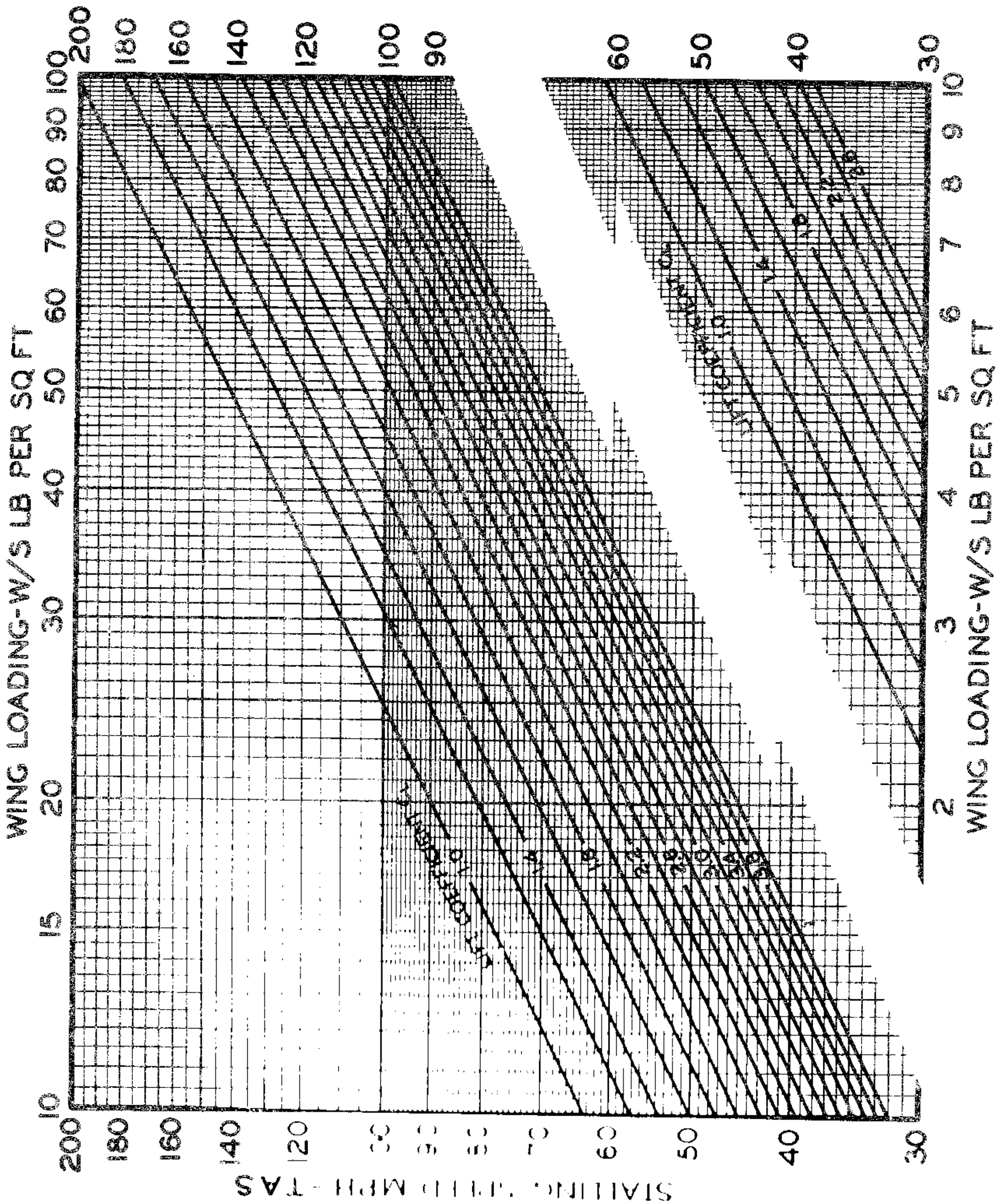


Variation of Speed of Sound with Temperature

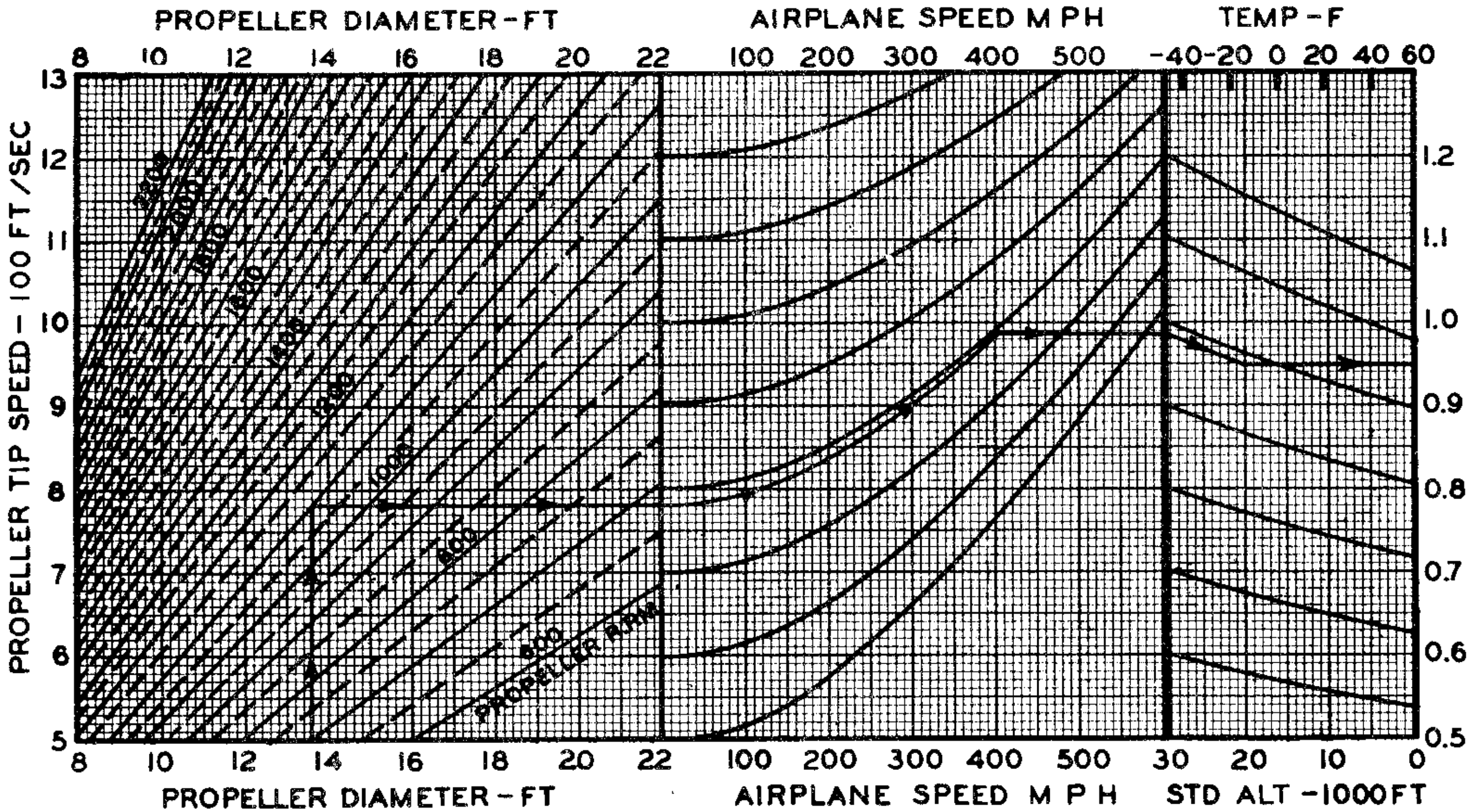


Air Speed Chart

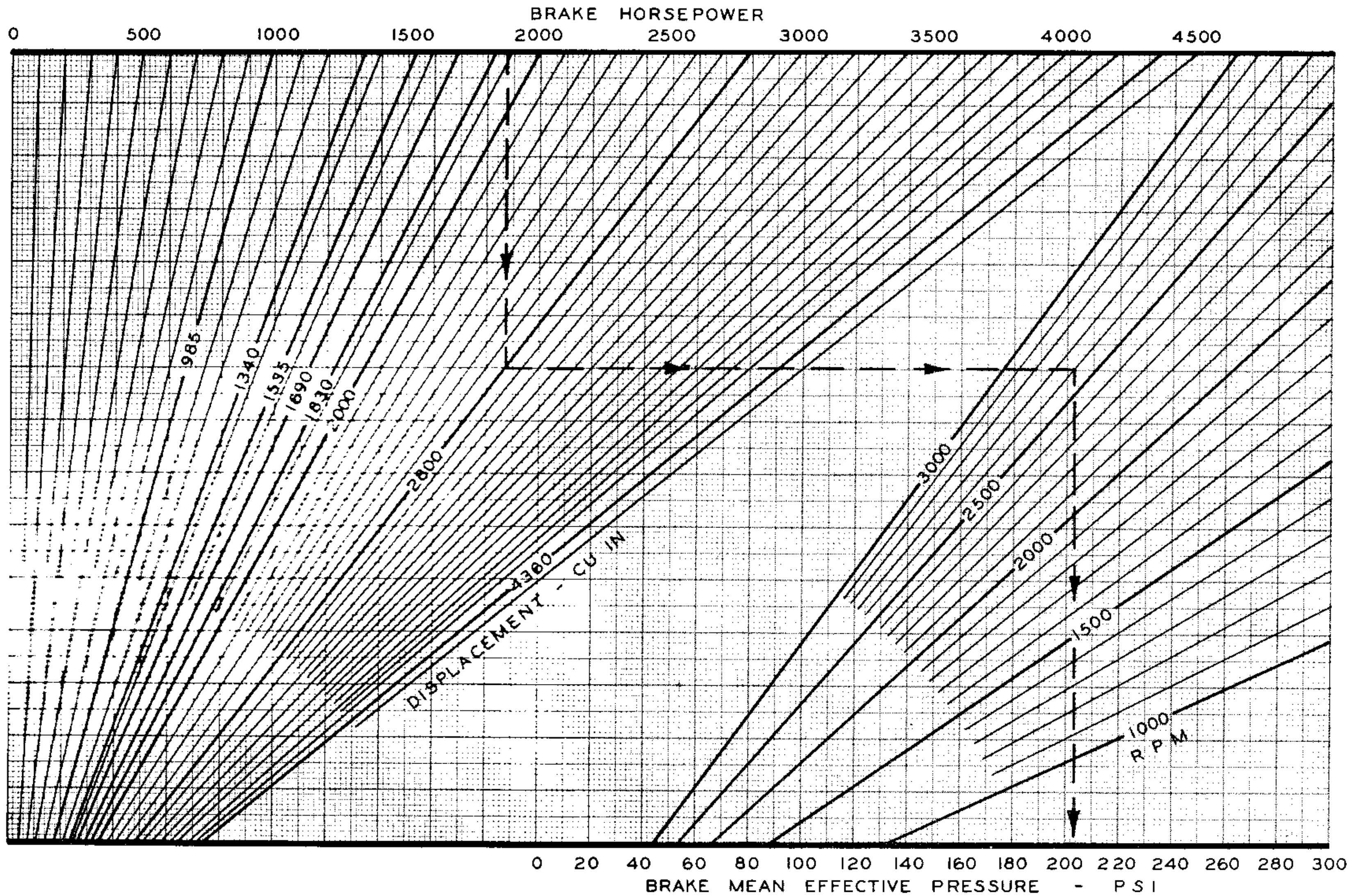
REFERENCE TABLES AND CHARTS



Stalling Speed Chart

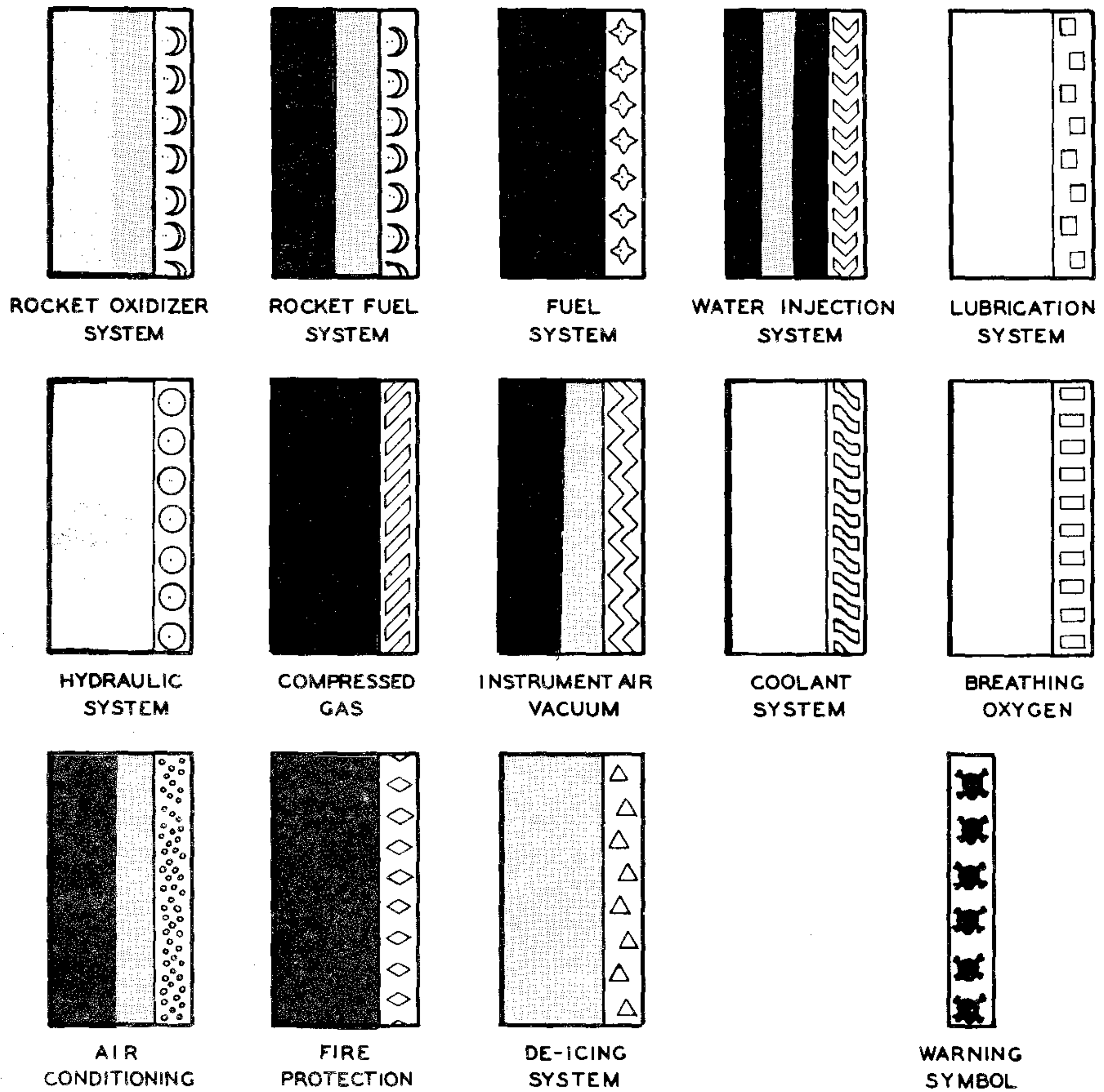


Propeller Tip Speed Chart



BMEP Chart for all Engine Desplacements

REFERENCE TABLES AND CHARTS



THE ABOVE COLOR CODES REPRESENT DESIGNATIONS FOR SYSTEMS ONLY. TO CODE LINES WHICH DO NOT FALL INTO ONE OF THESE SYSTEMS THE CONTENTS SHALL BE DESIGNATED BY BLACK LETTERING ON WHITE TAPE.

PRESSURE TRANSMITTER LINES SHALL BE IDENTIFIED BY THE SAME COLORS AS THE LINES FROM WHICH THE PRESSURE IS BEING TRANSMITTED.

FILLER LINES, VENT LINES AND DRAIN LINES FROM FUNCTIONS OR RELATED FUNCTIONAL EQUIPMENT SPECIFIED HEREON SHALL BE IDENTIFIED BY THE SAME COLORS AS THE FUNCTION LINES.

COLOR CODE FOR AIRCRAFT PIPING

REFERENCE TABLES AND CHARTS

U. S. AIRFORCE AIRCRAFT DESIGNATIONS

Fundamental Types
(Denoting Basic Unit)

Amphibian	A
Bombardment	B
Cargo	C
Fighter	F
Glider	G
Helicopter	H
Liaison	L
Targets & Drones	Q
Reconnaissance	R
Search & Rescue	S
Trainers	T
Special Research or Experimental	X

General Classification

Prefix Symbols
(Modification for Current Use)

B	Bombardment
C	Cargo
D	Director
F	Fighter
G	Glider
L	Liaison
M	Missile Aircraft
Q	Target or Drone
R	Reconnaissance
S	Sea Search
T	Training
V	Staff Administrative Transports
X	Experimental
Y	Service Test
Z	Obsolete

Example: C -54 B -1 -DC

Type — C
Model — 54
Series — B
Block Number — 1
Manufacturer — DC

NAVAL AIRCRAFT DESIGNATIONS

Type Designations

Heavier than air (fixed wing)	V (Usually omitted)
Heavier than air (rotary)	H
Pilotless Drones	K
Guided Missiles	M
Lighter than air	Z

Class Designations (Basic Mission)

Attack	A
Fighter	F
Glider	G
Patrol	P
Observation	O
Transport	R
Training	T
Utility	U

Prefix Letter

Experimental	X
Service Test	Y
Obsolete	Z

Suffix Letter

A	Amphibian
B	Special armament
C	Carrier version
D	Drone control
E	Special electronic gear
G	Search and rescue
H	Hospital
J	Target tow
K	Target drone
L	Searchlight
M	Weather reconnaissance
N	Night operating
P	Photographic
Q	Countermeasures
R	Transport
S	Anti-submarine
T	Training
U	Utility
W	Air warning
Z	Administrative

Example: X -F 9 F- 2

Prefix — X
Type (V omitted)
Class — F
Series No. — 9
Designer's Letter — F
Modification No. — 2

DESIGNER'S IDENTIFICATION LETTERS — NAVY

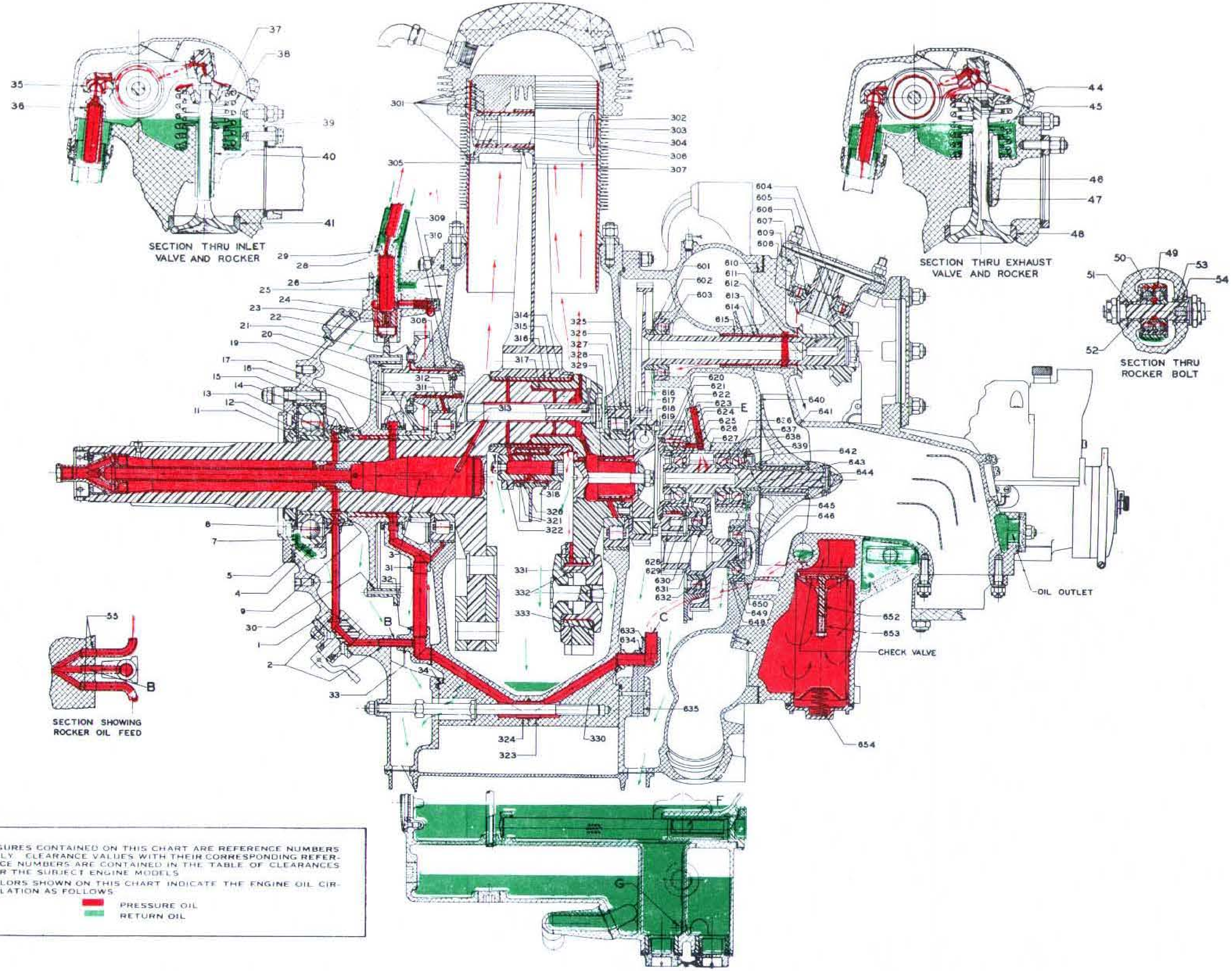
B	Boeing	M	Glenn L. Martin
C	Curtiss-Wright	N	Naval Aircraft Factory
D	Douglas	O	Lockheed (Factory B)
E	Piper	P	Piasecki
F	Grumman	Q	Fairchild
G	Goodyear	R	Ryan
H	McDonnell	S	Sikorsky
J	North American	T	Northrop
K	Kaiser	U	Chance Vought
L	Bell	Y	Consolidated Vultee

REFERENCE TABLES AND CHARTS

AIRCRAFT NATIONALITY MARKS

YA	Afghanistan
LV	Argentina
VH	Australia
OO	Belgium and Colonies
CB, CP	Bolivia
PP, PT	Brazil
VP, VQ, VR	British Colonies and Protectorates
XY	Burma
CF	Canada
CC	Chile
XT	China
HK	Colombia
TI	Costa Rica
CU	Cuba
OK	Czechoslovakia
OY	Denmark
HI	Dominican Republic
HC	Ecuador
SU	Egypt
YS	El Salvador
ET*	Ethiopia
F	France, Colonies and Protectorates except Morocco
SX	Greece
LG	Guatemala
HH	Haiti
XH	Honduras
TF	Iceland
VT	India
EP	Iran
YI	Iraq
EI	Ireland
LR*	Lebanon
LI*	Liberia
LX	Luxembourg
XA, XB	Mexico
CN	Morocco
PH	Netherlands
PK	Netherlands East Indies
PJ	Netherlands West Indies
VO	Newfoundland
YJ	New Hebrides
ZK	New Zealand
AN	Nicaragua
LN	Norway
RX	Panama
ZP	Paraguay
OB	Peru
PI	Philippines Commonwealth
SP	Poland
CS	Portugal
CR	Portuguese Colonies
**	Saudi Arabia
HS	Siam
EC	Spain
PZ	Surinam
SE	Sweden
HB	Switzerland
**	Syria
TC	Turkey
URSS	Union of Soviet Socialist Republic
ZS	Union of South Africa
G	United Kingdom
N	United States of America
CX	Uruguay
YV	Venezuela
YU	Yugoslavia

*Indicates that the nationality mark is provisional.
**Indicates that the nationality mark will be selected at a future date.



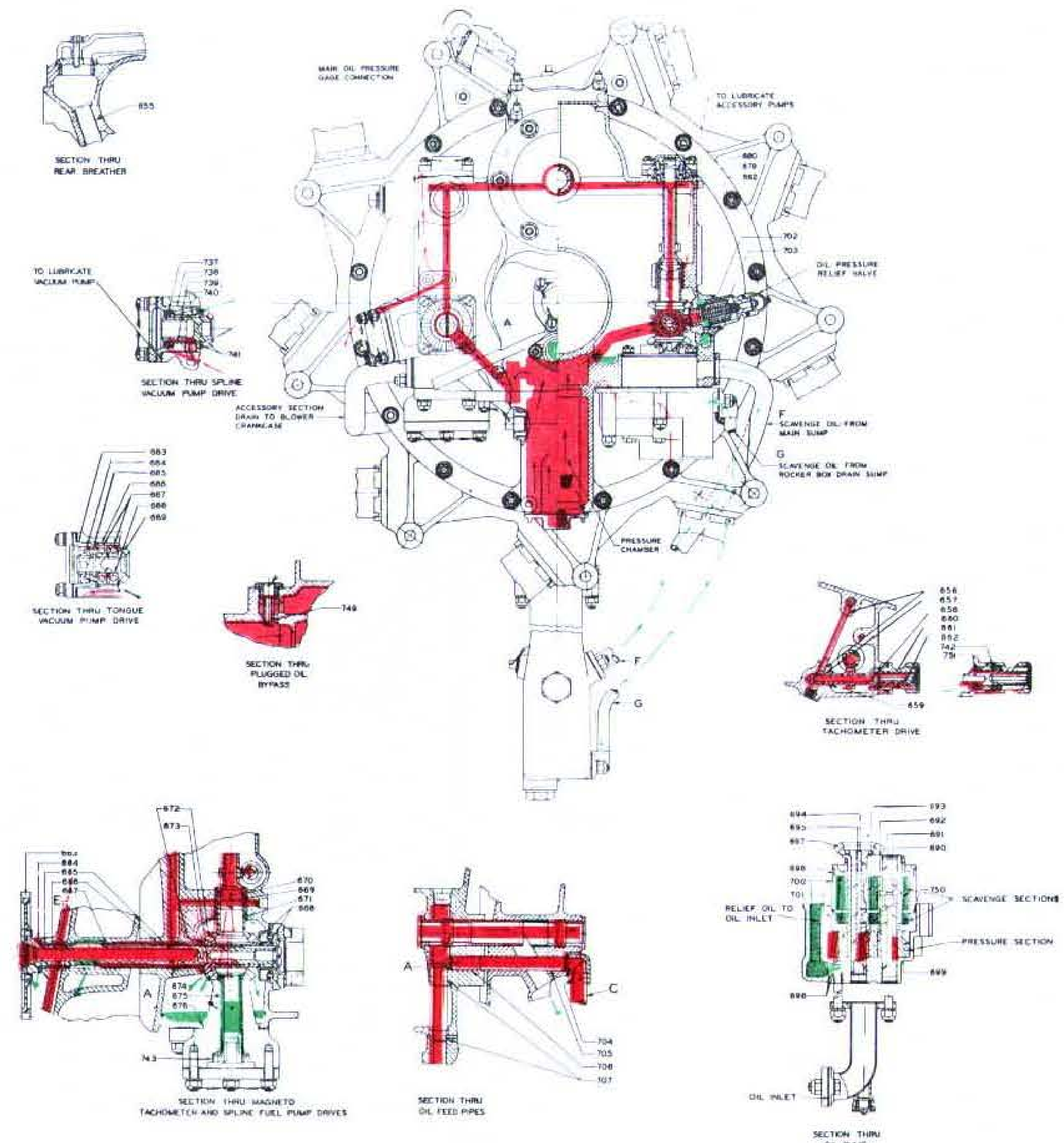
FIGURES CONTAINED ON THIS CHART ARE REFERENCE NUMBERS ONLY. CLEARANCE VALUES WITH THEIR CORRESPONDING REFERENCE NUMBERS ARE CONTAINED IN THE TABLE OF CLEARANCES FOR THE SUBJECT ENGINE MODELS

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

- PRESSURE OIL
- RETURN OIL

[11–9] Limits and Lubrication Chart for Front, Power and Accessory Sections — Wasp Jr. B5 Engines

[11-10] Limits and Lubrication Chart for Rear Section Wasp Jr. B5 Engines

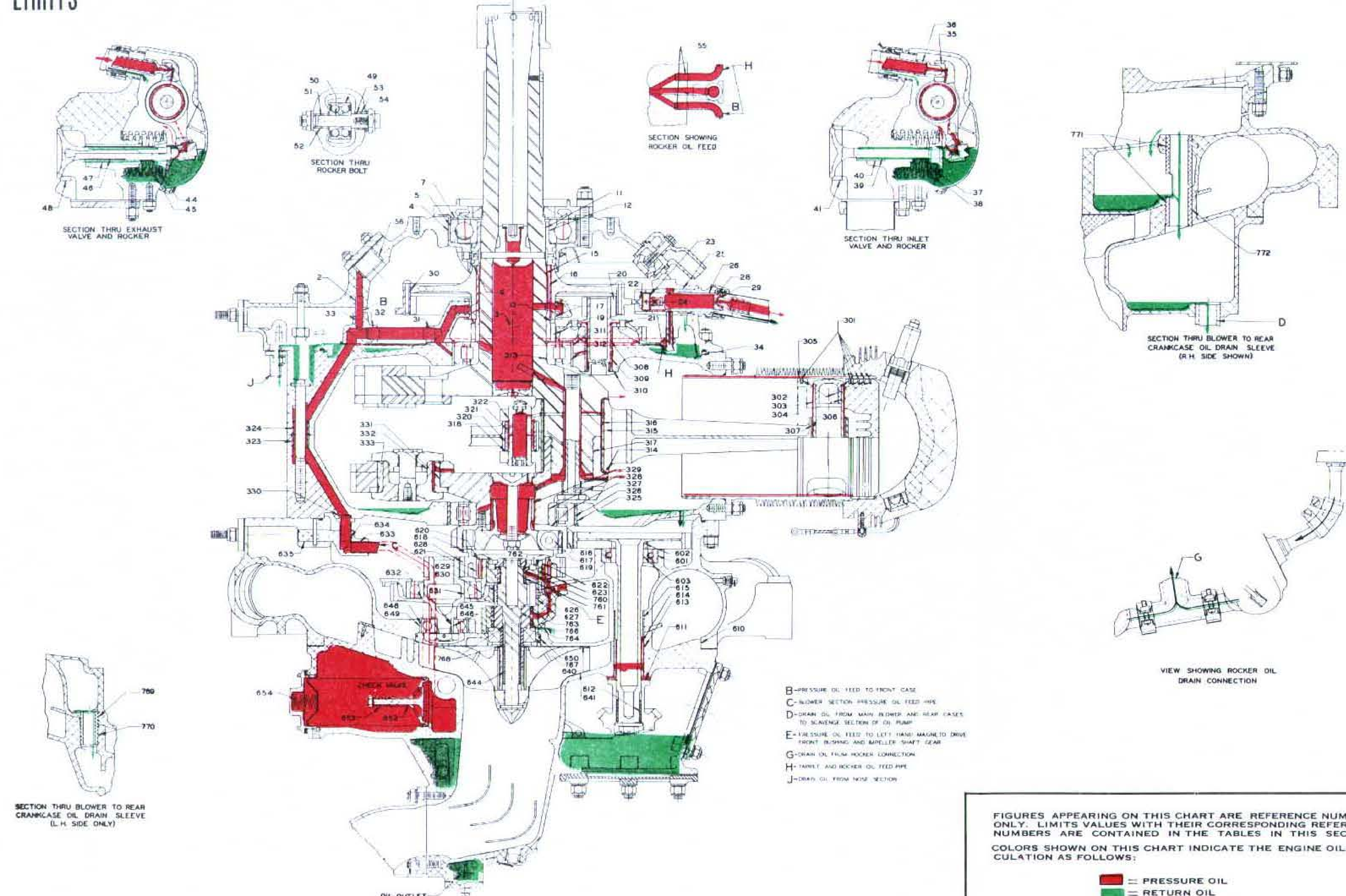


FIGURES CONTAINED ON THIS CHART ARE REFERENCE NUMBERS ONLY. CLEARANCE VALUES WITH THEIR CORRESPONDING REFERENCE NUMBERS ARE CONTAINED IN THE TABLE OF CLEARANCES FOR THE SUBJECT ENGINE MODELS

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

(red) = PRESSURE OIL
(green) = RETURN OIL

Limits and Lubrication Chart for Rear Section — B5 Engines
Figure 4

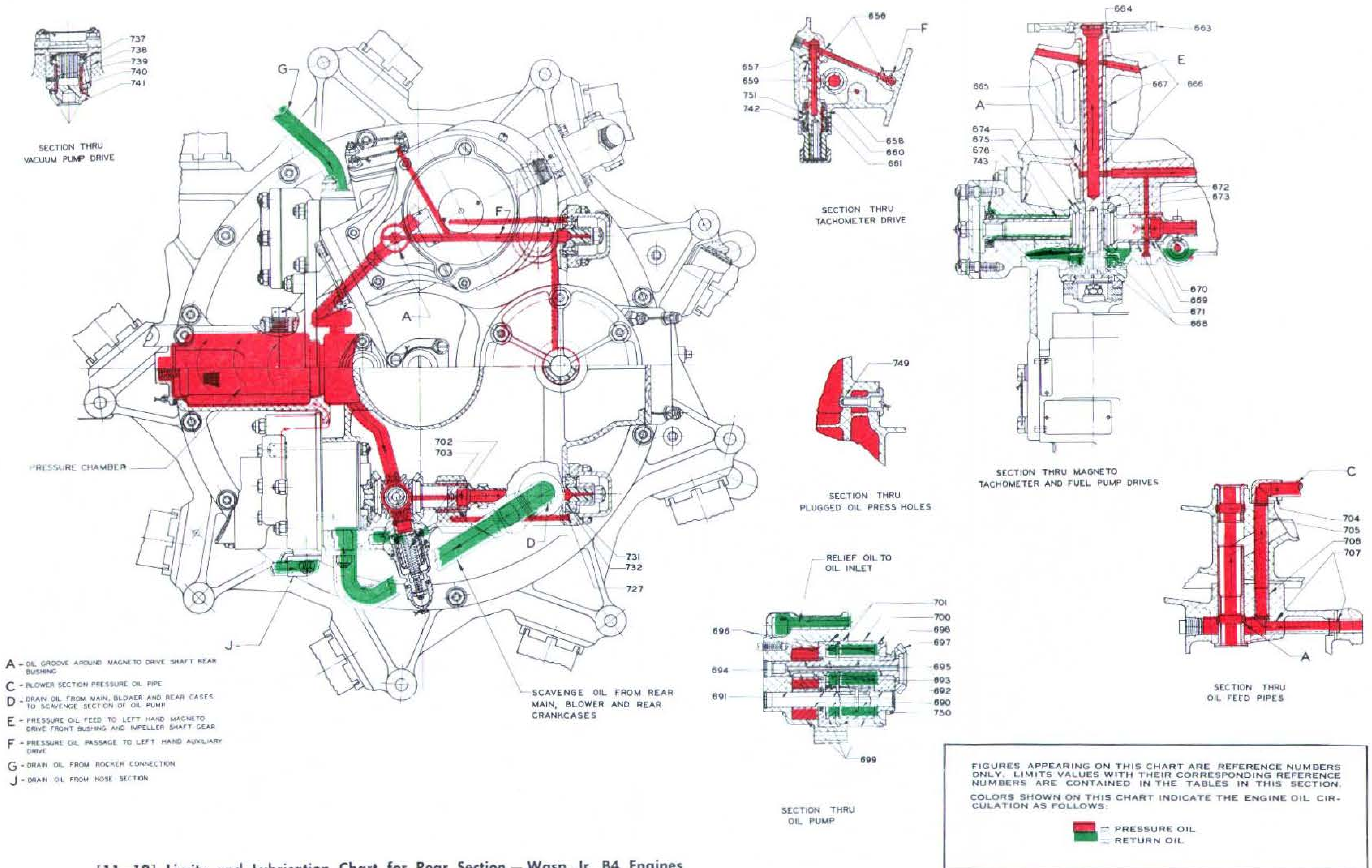


FIGURES APPEARING ON THIS CHART ARE REFERENCE NUMBERS ONLY. LIMITS VALUES WITH THEIR CORRESPONDING REFERENCE NUMBERS ARE CONTAINED IN THE TABLES IN THIS SECTION.

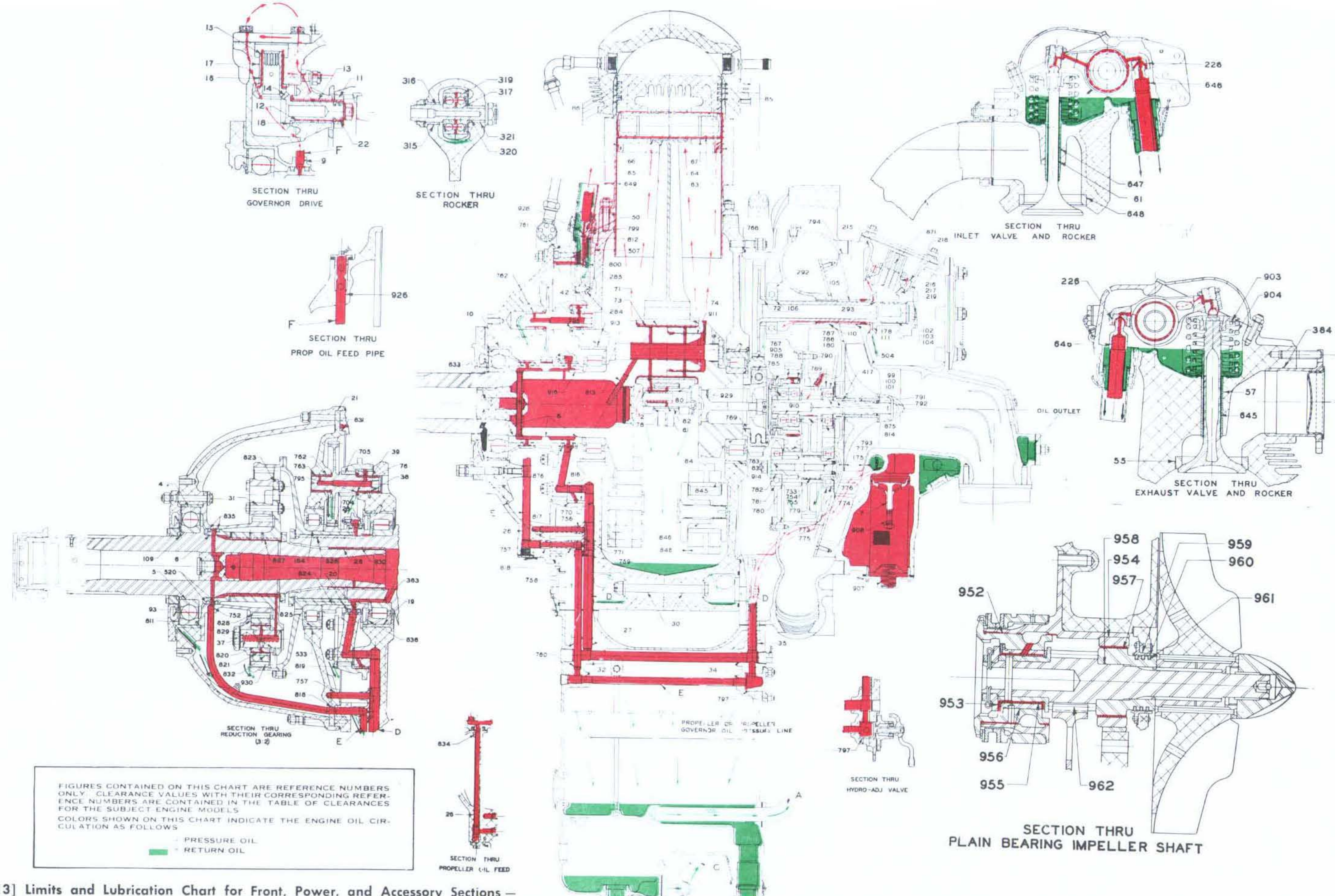
COLORS SHOWN ON THIS CHART INDICATE THE ENGINE OIL CIRCULATION AS FOLLOWS:

= PRESSURE OIL
= RETURN OIL

[11—11] Limits and Lubrication Chart for Front, Power and Accessory Sections — Wasp Jr. and B4 Engines

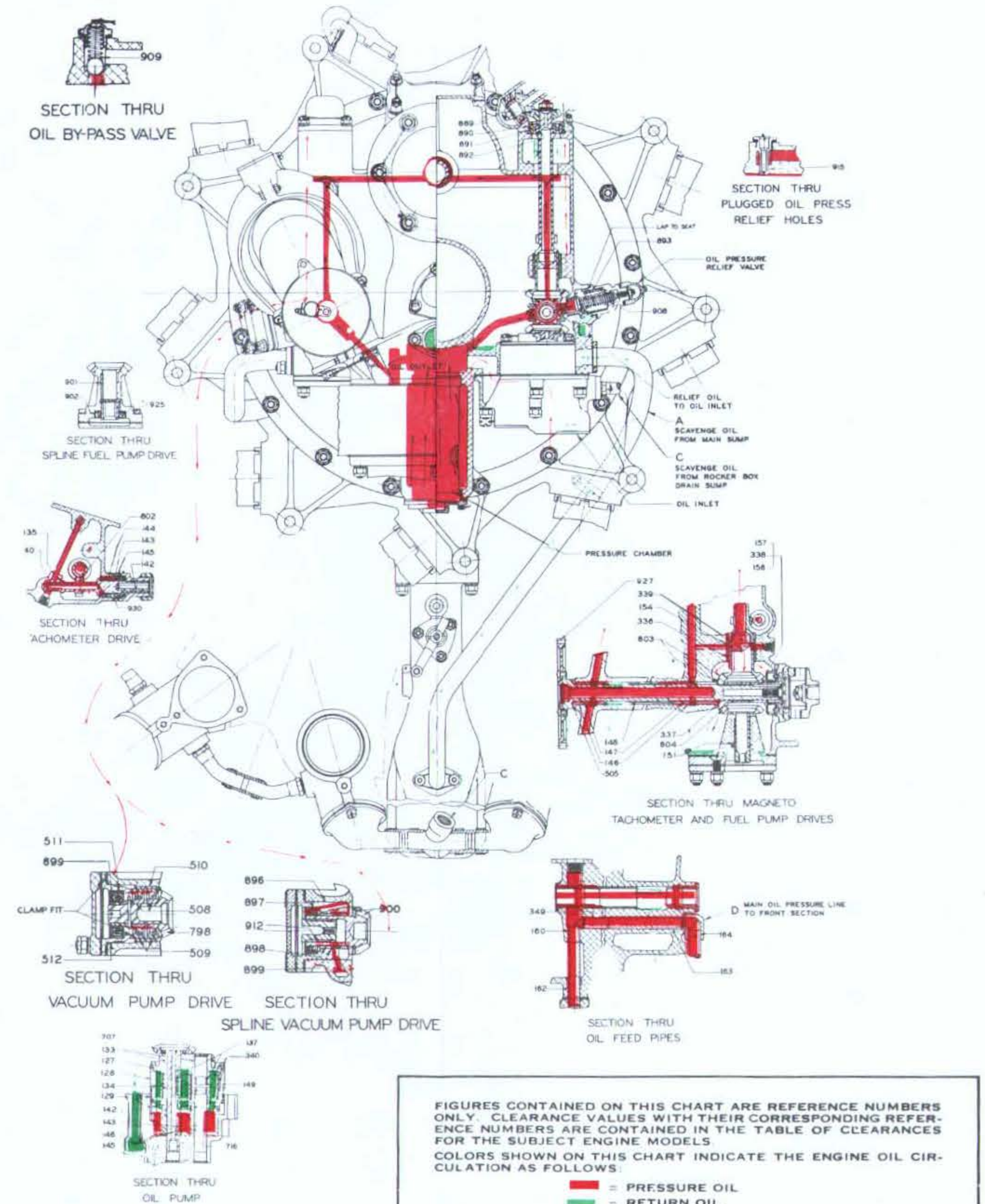


[11—12] Limits and Lubrication Chart for Rear Section — Wasp Jr. B4 Engines



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
- RETURN OIL

[11–13] Limits and Lubrication Chart for Front, Power, and Accessory Sections — Wasp S3H1, S3H1-G Engines



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.

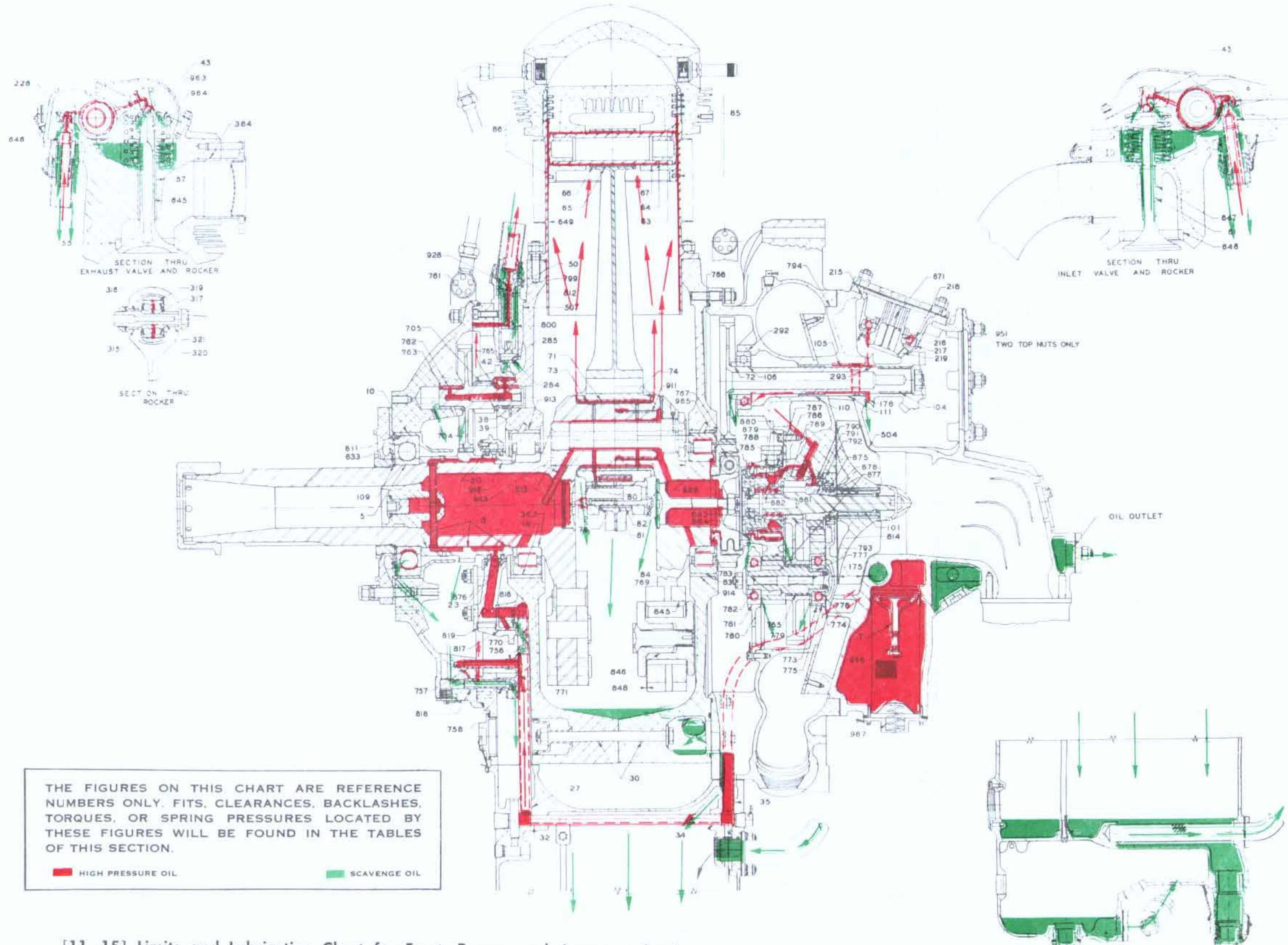
COLORS SHOWN ON THIS CHART INDICATE THE ENGINE OIL CIRCULATION AS FOLLOWS:

= PRESSURE OIL

= RETURN OIL

[11—14] Limits and Lubrication Chart for Rear Section — Wasp S3H1, S3H1-G Engines

Limits and Lubrication Chart for Rear Section — S1H1, S3H1, S3H1-G Engines
Figure 6

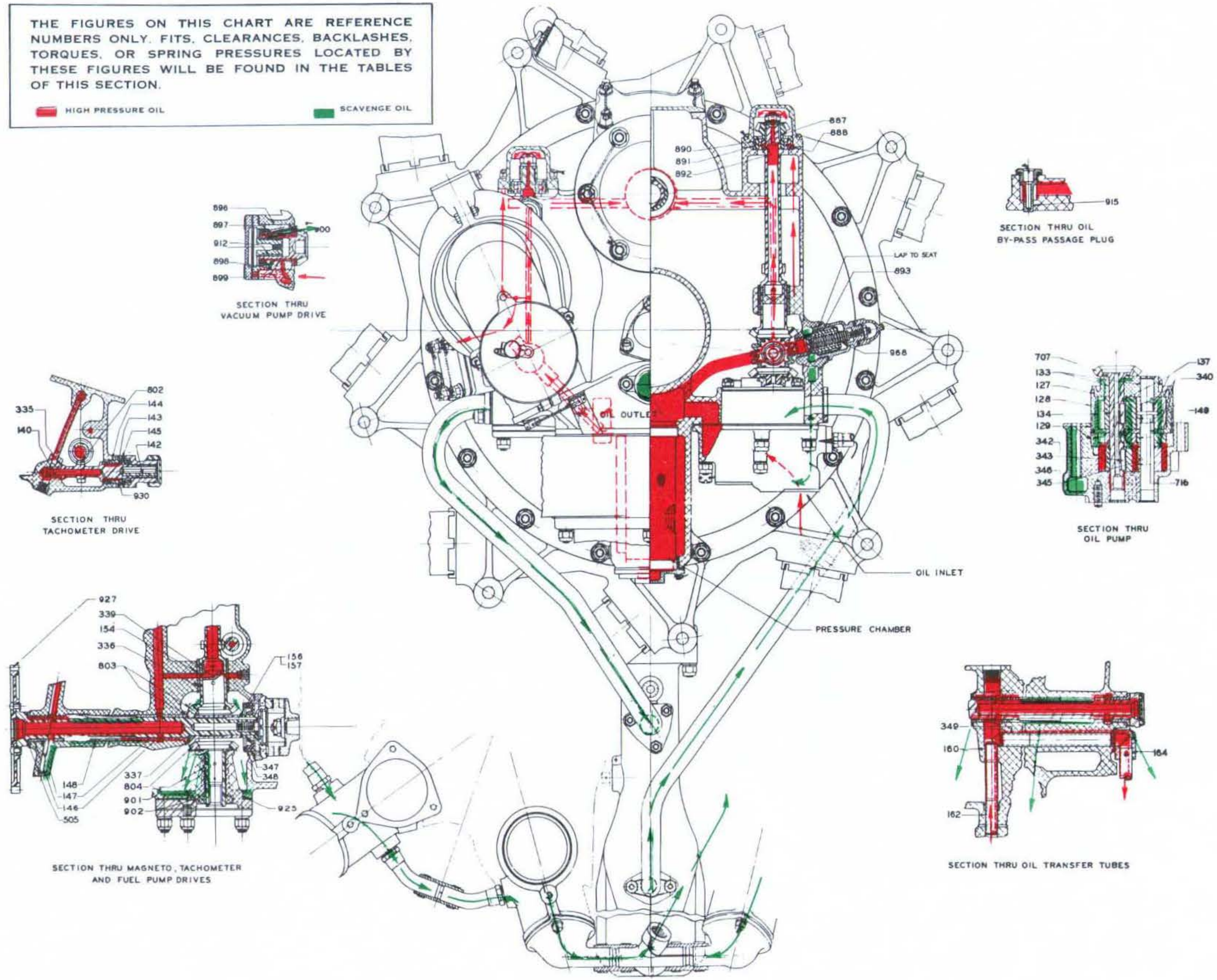


THE FIGURES ON THIS CHART ARE REFERENCE NUMBERS ONLY. FITS, CLEARANCES, BACKLASHES, TORQUES, OR SPRING PRESSURES LOCATED BY THESE FIGURES WILL BE FOUND IN THE TABLES OF THIS SECTION.

HIGH PRESSURE OIL

SCAVENGE OIL

[11—15] Limits and Lubrication Chart for Front, Power, and Accessory Sections — S1H2, S3H2 Engines



Limits and Lubrication Chart for Rear Section — S1H2, S3H2 Engines
Figure 8