OPERATORS HANDBOOK

Wasp Jr. B, Wasp H1
and
Hornet E Series Engines

SECOND EDITION

PRATT & WHITNEY AIRCRAFT
Division of
UNITED AIRCRAFT CORPORATION
EAST HARTFORD . CONNECTICUT

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OPERATORS HANDBOOK

(PART NO. 49130)

PRATT & WHITNEY U.S.A. DEPENDABLE ENGINES

Wasp Jr. B, Wasp H1 and Hornet E Series Engines

Second Edition

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PRATT & WHITNEY AIRCRAFT
Division of
UNITED AIRCRAFT CORPORATION
EAST HARTFORD . . . CONNECTICUT

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PREFACE

This second edition of the Wasp Jr. B, Wasp H1 and Hornet E Series Operators Handbook incorporates only minor revisions to the January, 1941 edition and does not necessarily supersede it.

INTRODUCTION

This Operator's Handbook is issued for the guidance of those operating Wasp Jr., Wasp and Hornet engines. Whereas it deals primarily with Wasp Jr. B3, Wasp H1 and Hornet E3-G engines, the operating and maintenance information contained herein, with the exception of specific operating instructions, is also applicable, for the most part, to earlier engines of these models.

The information in this book, covering the operation, routine servicing and making of minor adjustments, is the summation of experience in the operation of these engines under many varied service conditions. It is strongly recommended that these instructions be followed closely for all average operating conditions and that no deviation from them be made without first consulting the Pratt & Whitney Aircraft Service Department. Complete information in connection with overhaul of the engines is contained in the Overhaul Manual.

It has always been the object of Pratt & Whitney Aircraft to build engines which will render the maximum of satisfaction and dependability. We desire close cooperation with the users of our products. Suggestions for improvement of the engines, their equipment and the servicing thereof, are welcome and will be given careful consideration. We depend upon the cooperative efforts of our customers and our Research, Design, Engineering, Test, and Service Departments to enable our engines to maintain their position among the most successful aircraft engines of the world. It is earnestly requested that all problems concerning the operation and maintenance of our engines be submitted to our Service Department.

We extend to the users of our product an invitation to visit our factory at East Hartford, Connecticut, U.S.A. Those of this group who are not citizens of the United States should procure the necessary permission for such a visit through their embassies in Washington, D. C.

This book is divided into five major sections:

1. Description of the Engine
2. Installation of the Engine
3. Treatment of a New Engine
4. Operation
5. Maintenance

The table of contents on page 6 and the list of illustrations on page 5 provide a ready means of finding any desired subject.

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1. United Aircraft Corporation warrants its products for ninety days after the shipment thereof from its plants to be free from defects in material and workmanship. This warranty does not cover its product unless it is properly installed and unless it is maintained in accord with the then current recommendations of the Corporation as stated in its Overhaul Manuals, Service Bulletins, or otherwise, and unless it is used under normal operating conditions. Such warranty is limited to replacing or repairing at its shops any part or parts which have been returned to it, and which in its opinion are defective, provided that transportation charges and any and all sales taxes, duties, imposts or excises for such part or parts shall be paid by the purchaser, who shall be reimbursed by the Corporation for such transportation charges, if in the Corporation's opinion, such part or parts are defective and are covered by this warranty. The Corporation shall have the sole right to determine whether such defective parts shall be repaired or replaced. Such warranty does not cover any labor charges of the purchaser for replacement of parts, adjustments or repairs, or any other work, unless such charges be assumed or authorized by the Corporation. The said warranty is expressly in lieu of any and all other warranties or representations, expressed or implied, and of any other obligations or liabilities of the Corporation to the purchaser arising out of the use of the said product, and no agreement or understanding varying or extending the same will be binding upon the Corporation unless in writing, signed by a duly authorized officer or representative.

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Joint Resolution of the Congress of the United States of America, approved November 4, 1939, commonly known as the "Neutrality Resolution," and of any amendments thereto from time to time in effect and of any and all proclamations, regulations, rules and orders made and in force thereunder or pursuant thereto from time to time, and upon the understanding that the purchaser agrees to observe any and all such provisions insofar as they may apply to it. However, no proclamation of any embargo pursuant to the said Resolution or any amendment thereto shall give cause to the purchaser for the cancellation of any order theretofore placed by it with United Aircraft Corporation.

6. All contracts shall be interpreted in accordance with the plain English meaning of their terms, and the construction thereof shall be governed by the laws of the State of Connecticut.

Note: Unless otherwise specified in writing engines shipped by us are prepared for domestic shipments and short time storage only.

SERVICE

Authorized Service Stations—The emblem illustrated below is displayed by Authorized Service Stations.

AUTHORIZED

PARTS AND SERVICE

All stations displaying this sign have equipment and personnel for thoroughly and efficiently overhauling Pratt & Whitney engines. These stations use only Pratt & Whitney Aircraft parts which are sold at the published catalog prices.

Factory Service Department—Pratt & Whitney Aircraft maintains a Factory Service Department to assist its customers in the operation and maintenance of Pratt & Whitney Aircraft engines. The Service Department maintains contact with Operators and Overhaul activities by means of periodic visits of service representatives, who are also available for the investigation of any specific difficulty or problem. Any request for assistance should be addressed direct to the Service Department of the Pratt & Whitney Aircraft, East Hartford, Connecticut.

Ordering Parts—Whenever possible, parts should be ordered from a Parts Catalog. These catalogs are furnished to Operators and Service Stations and are available to other interested parties. In case a parts list is not available, give name of engine, model, and engine number, and a full description of the part wanted and where it is used. Whenever possible, parts should be ordered through the nearest Service Station.

Some parts are not furnished individually but must be purchased as assemblies. This is because they require special or expensive equipment for assembling and cannot be fabricated except in a shop especially equipped for this work. If an order is received for a unit of an assembly coming under this classification, the complete assembly will be shipped.

Spare parts for carburetors, magnetos, and special radio shielding, together with such accessories as propellers, hubs, vacuum pumps, starters, and generators, should be ordered direct from the manufacturer.

Returning Parts—Whenever possible, parts being returned for repairs, information, inspection or credit, should be returned through an authorized Service Station. In case it is not possible to send parts in through an authorized Service Station, it is necessary to first obtain the proper authority from the factory for their return. When requesting authority for return of parts or when returning parts to a Service Station, all information should be given as to:

1. Reason for return.
2. Engine Number.
3. Type of engine from which parts are taken.
4. Number of hours of service of the part and of the engine.

If the parts are being returned direct to the factory, proper notification of shipment must be forwarded so that it will arrive at least one day in advance of the parts.

When returning parts for repair only, it is unnecessary to obtain authority for return and, whereas desirable, it is not essential to have them sent through a Service Station. All factory repair work is handled by the United Airports Division, Rentschler Field, East Hartford, Connecticut. Strictly repair items should be sent to that address.

ENGINE DATA

Wasp Jr., SB3

Type	Air Cooled—Radial—9 Cylinder—Single Row of Cylinders	
Bore	5.1875 inches	131.8 mm
Stroke	5.1875 inches	131.8 mm
Total Displacement	985 cu. inches	16.14 liters
Compression Ratio	6:1	6:1
Blower Ratio	10:1	10:1
Propeller Gear Ratio	Direct Drive	Direct Drive
Propeller Shaft Rotation (viewed from rear)	Clockwise	Clockwise
Propeller Shaft Size — SAE	No. 30	No. 30
Overall Diameter	46.19 inches	1173 mm
Overall Length	42.38 inches	1077 mm
Center of Gravity —		
Forward of Mounting Flange	7.28 inches	185 mm
Below Crankshaft Center Line	.30 inches	8 mm
Dry Weight	668 lbs.	303 kg.

Grade of Fuel — See Section entitled, "Fuel."
Grade of Oil — See Section entitled, "Lubricating Oils."

Accessory Drives	*Type*	*Ratio to Crankshaft*	*Rotation Drive End*
Generator	Int. 6 Spline (Rect.)	1.500:1	Clockwise
Starter	3 Tooth Jaw	1.000:1	Counterclockwise
Fuel Pump	Int. 11 Spline	1.000:1	Counterclockwise
Tachometer	Left Hand	.500:1	Counterclockwise
Tachometer	Right Hand	.500:1	Clockwise
Dual Vertical Auxiliary	Int. Hex.	1.000:1	Counterclockwise
Vacuum Pump	Int. 12 Spline	1.500:1	Clockwise

ENGINE DATA

Wasp S3H1

Type	Air Cooled—Radial—9 Cylinder—Single Row of Cylinders	
Bore	5.75 inches	146 mm
Stroke	5.75 inches	146 mm
Total Displacement	1344 cu. inches	22.03 liters
Compression Ratio	6:1	6:1
Blower Ratio	10:1	10:1
Propeller Gear Ratio	Direct Drive	Direct Drive
Propeller Shaft Rotation (viewed from rear)	Clockwise	Clockwise
Propeller Shaft Size — SAE	No. 40	No. 40
Overall Diameter	51.75 inches	1314 mm
Overall Length	42.94 inches	1090 mm
Center of Gravity —		
Forward of Mounting Flange	7.91 inches	201 mm
Below Crankshaft Center Line	.38 inches	10 mm
Dry Weight	864 lbs.	392 kg.

Grade of Fuel — See Section entitled, "Fuel."
Grade of Oil — See Section entitled, "Lubricating Oils."

Accessory Drives	*Type*	*Ratio to Crankshaft*	*Rotation Drive End*
Generator	Int. 6 Spline (Rect.)	1.500:1	Clockwise
Starter	3 Tooth Jaw	1.000:1	Counterclockwise
Fuel Pump	Int. 11 Spline	1.000:1	Counterclockwise
Tachometer	Left Hand	.500:1	Counterclockwise
Tachometer	Right Hand	.500:1	Clockwise
Dual Vertical Auxiliary	Int. Hex.	1.000:1	Counterclockwise
Vacuum Pump	Int. 12 Spline	1.500:1	Clockwise
Propeller Governor	Int. 12 Spline	1.144:1	Clockwise

ENGINE DATA

Hornet S1E3-G

Type	Air Cooled—Radial—9 Cylinders—Single Row of Cylinders	
Bore	6.125 inches	155.5 mm
Stroke	6.375 inches	162.0 mm
Total Displacement	1690 cu. inches	27.7 liters
Compression Ratio	6.5:1	6.5:1
Blower Ratio	10:1	10:1
Propeller Gear Ratio	.667	.667
Propeller Shaft Rotation (viewed from rear)	Clockwise	Clockwise
Propeller Shaft Size — SAE	No. 50	No. 50
Overall Diameter	54.69 inches	1389 mm
Overall Length	50.52 inches	1283 mm
Center of Gravity —		
Forward of Mounting Flange	9.86 inches	251 mm
Below Crankshaft Center Line	.25 inches	6 mm
Dry Weight	1087 lbs.	493 kg.

Grade of Fuel — See Section entitled, "Fuel."

Grade of Oil — See Section entitled, "Lubricating Oils."

Accessory Drives	*Type*	*Ratio to Crankshaft*	*Rotation Drive End*
Generator	Int. 6 Spline (Rect.)	1.500:1	Clockwise
Starter	3 Tooth Jaw	1.000:1	Counterclockwise
Fuel Pump	Int. 11 Spline	1.000:1	Counterclockwise
Tachometer	Left Hand	.500:1	Counterclockwise
Tachometer	Right Hand	.500:1	Clockwise
Dual Vertical Auxiliary	Int. Hex.	1.000:1	Counterclockwise
Vacuum Pump	Int. 12 Spline	1.500:1	Clockwise
Propeller Governor	Int. 12 Spline	1.067:1	Counterclockwise

DESCRIPTION OF THE ENGINES

Wasp Jr. B, Wasp H1 and Hornet E Series engines are nine cylinder, radial air-cooled engines. The general features of these three models are alike, each incorporating a solid master rod and two-piece, split-pin crankshaft, a forged aluminum alloy main crankcase of two sections, a built-in supercharger, automatic valve gear lubrication and an updraft carburetor. The Wasp Jr. has been manufactured only as a direct drive engine, whereas the Wasp and Hornet have been manufactured both as direct and geared drive engines. The high standards followed throughout the manufacture of these engines insure the quality, dependability and fine performance which is characteristic of Pratt & Whitney Aircraft engines.

The following should be kept in mind when reading the ensuing description:

The cylinders are numbered consecutively in the direction of crankshaft rotation (anti-clockwise when viewing engine from propeller end), beginning with the top cylinder which is called No. 1. Reference to right and left sides of the engines will apply as viewed from the rear.

For descriptive purposes these engines may be segregated into five major groups of component parts: front or nose section, main crankcase section, cylinders, blower section and rear section. An assembled engine may be split at the blower and main crankcase sections if it should become desirable to perform work on one half of the engine without disturbing the other half.

GROUP I — FRONT (NOSE) SECTION

Direct Drive Engines—The front section housing of the Wasp Jr. B3 engine is a magnesium alloy casting and that of the Wasp H1 is an aluminum alloy forging. These housings support a deep groove ball bearing which transmits the thrust of the propeller from the crankshaft to the engine mounting via the main crankcase. There is provision for cowling support bracket studs at the front end and there are long studs for the same purpose where this housing attaches to the main crankcase.

On the Wasp Jr. B3, the front section houses piping for the 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). This section also carries the valve tappets, tappet rollers and guides, and incorporates an oil manifold ring which is a part of the automatic rocker box lubricating system.

Wasp H1 front sections incorporate provision for mounting and driving a propeller governor.

Geared Drive Engines—The front section housing of geared engines, which is frequently called the reduction gear housing, serves to house the propeller reduction gear assembly. It is an aluminum alloy forging for the Wasp H1-G engine and aluminum alloy casting for the Hornet E3-G engine. As with direct drive engines, the front section carries a propeller thrust bearing and has provision for attaching cowling support brackets.

Reduction Gearing—The Wasp H1-G and Hornet E3-G engines use the planetary type reduction gearing. A reduction drive gear (bell gear) with internal teeth is splined to the front end of the crankshaft. This gear is also supported by a roller bearing mounted in a bearing support plate (anchor plate) which is secured between the nose section and the front main crankcase section. A fixed gear is bolted to the inner side of the forward end of the nose section. Six pinions mesh with the bell gear and fixed gear and are mounted in a cage which is splined to the propeller shaft. Each pinion, mounted on a steel-backed lead bronze bearing, rotates around a special inner race on a concentric shaft. The propeller shaft is supported at the forward end by the thrust bearing carried in the nose section, and at the rear end in a steel-backed lead bronze bearing located inside the front end of the crankshaft.

All gear teeth for this reduction gearing are ground-finished to insure tooth alignment and even bearing surfaces. The pinion cage consists of two halves closely fitted for alignment and rigidity.

GROUP II — MAIN CRANKCASE SECTION

The main crankcase, made of forged aluminum alloy, is divided into two sections in the plane of the cylinders. They are united by nine through bolts between the cylinders, as well as by the cylinder flanges which are secured to the studs on the crankcase. With this type of construction, the explosion forces are equally distributed between the two main bearings, one of which is carried in each section of the case. The two sections of all main crankcases are machined together and are not interchangeable. A rubber seal is located between each cylinder flange and cylinder parting face.

Timing Gear — The cam which actuates all valves through two four-lobed tracks, is rotated opposite to crankshaft direction at 1/8 crankshaft speed by means of a train of spur gears and internal teeth on the cam. It is supported on a bronze bushing mounted on a shelf forged integral with the front main crankcase on the Wasp H1 and H1-G and Hornet E3-G. A cam reduction gear is mounted with bearing on each side, one in the main case and the other in the anchor plate on geared drive engines and in the nose section on direct drive engines. On the Wasp Jr. B3, the cam rotates on a sleeve supported on the crankshaft.

Crankshaft—The crankshaft is a single throw, two-piece split-pin type, supported by three bearings. Two roller bearings on each side of the crank throw are located in the front and rear main crankcase halves. A ball bearing housed in the nose section of direct drive engines supports the front end of the shaft and also takes the thrust of the propeller. In geared engines, a roller bearing mounted in the bearing support plate (between the front main crankcase and front section), directly supports the propeller reduction drive gear (bell gear), which is splined to the front end of the crankshaft. The front section of the crankshaft is splined to the rear and is united by a through bolt. The propeller shaft of geared engines is supported at the front end by a ball bearing, which also takes the propeller thrust, and at the rear by a pilot rotating in the bronze bearing shrunk inside the front end of the crankshaft.

The reciprocating and rotating parts are counterbalanced by weights which are riveted to the cheeks of the crankshaft. The crankshaft is precision-balanced, both statically and dynamically, against a master balance weight. With the two flyweights in the rear counterweight, these counterbalancers insure vibrationless performance at all speeds. The careful balancing provides interchangeablility of crankshafts between engines of the same types.

An oil jet in the crankshaft front half rear plug and another on the top of the rear cheek furnish spray lubrication to the pistons, piston pins and cylinder walls in addition to the oil thrown out from the master rod bearing and knuckle pin bushings.

Connecting Rods — The master rod is of one-piece construction, incorporating a pressed-in, steel-backed, leaded silver bearing. Eight "I" section link rods are attached to the master rod by knuckle pins. Piston and knuckle pin holes are bronze-bushed, with a dowel pin in the piston pin bushings to maintain alignment of the oil holes. Pressure oil from within the hollow chamber of the crankpin lubricates the master rod bearing and knuckle pin bushings through drilled passages in the crankpin, bearing, master rod and pins. The full floating piston pins are lubricated by the mist of oil from the master rod bearing, knuckle pin bushings and oil jets.

Pistons — All pistons are made of aluminum alloy forgings and are of the full skirt type. Each one includes five ring groves which contain three compression rings, a dual oil control ring and a scraper ring in Wasp Jr. and Wasp engines; the Hornet piston uses a special oil scraper ring rather than a dual oil ring in the fourth groove. The grooves for the three compression rings in Wasp Jr. B3 and Hornet E3-G pistons are wedge-shaped, which increases the thickness of the ring lands at their roots, thus resulting in greater land strength.

Oil Sump—The double decked oil sump is located betwen cylinders Nos. 5 and 6 and fastened at each end to the front and blower sections respectively, on Wasp Jr. B3 engines. On Wasp H1 and H1G and Hornet E3-G engines, the sump is connected to the front main crankcase and blower sections. An oil pipe, supported in the upper part of the sump, carries oil under pressure from the blower to the front of the engine in Wasp H1 and H1-G and Hornet E3-G engines, while in Wasp Jr. B3 engines the oil is transferred through the lower part of the main crankcase to the front of the engine. The two-way hydro-controllable valve (if used), is located in the nose of the Wasp Jr. B3 engine and in the rear of the oil sump in Wasp H1 and H1-G and Hornet E3-G engines. This valve is optional equipment. An additional pipe in the sump of these two latter types routes the necessary oil to the nose section passages for the hydro-controllable propeller. Two scavenge pipes attached to the bottom of the two sump compartments conduct drain oil to the scavenge sections of the oil pump. One scavenges the rocker section, the other the main section of the sump.

GROUP III — CYLINDERS

The cylinders are of steel and aluminum construction. The barrels, which incorporate integral cooling fins, are machined from steel forgings. The heads are machined from an aluminum alloy casting having closely spaced cooling fins and integral rocker boxes. Following the final machining operations, the head is screwed and shrunk onto the barrel. This forms a permanent joint, although rebarreling of a cylinder is possible under certain conditions. Each cylinder has one inlet and one exhaust valve, the inlet seating on a bronze insert and the exhaust on a steel insert, both of which are shrunk into the head. The cylinder head also incorporates bronze bushings for two spark plugs and four steel inserts for supporting the two rocker arm shafts. Since proper cooling of the exhaust valve is of great importance, fins are concentrated at the exhaust side of the hemispherical head, and also at the top of the head, where rapid heat dissipation is the most essential. Horizontal fins surround the lower portion.

Cylinder Baffles—Pressure type deflectors force a high velocity flow of cooling air through and over the finning on the cylinders. This flow is induced by the positive pressure in front of the cylinders and a negative pressure in the rear of the cylinders due to the forward speed of the airplane.

Valve Mechanism — All valve operating parts are enclosed. The rocker arms are housed in rocker boxes cast integral with the cylinder head and are supported on double row ball bearings. Eighteen tappets located in front main crankcase (nose section on Wasp Jr. B3), actuate the rocker arms through tubular push rods which have hardened steel ball ends. These rods are protected by removable oil tight cover tubes held in place by a packing nut at each end. Rocker box covers are secured by studs and self-locking nuts. The valve clearance adjusting screw, in the front end of the rocker arm, has a half ball for self-alignment, resulting in a minimum of friction between the valve tip and adjusting screw.

Two concentric valve springs are secured to each valve stem by a split cone and washer. These springs may be removed without taking out the rocker arm. A safety ring is installed on each valve stem to prevent valves from dropping into cylinders while split cones are being installed or removed. The exhaust valves are made of high heat resisting steel, are sodium-filled and have stellite seating faces.

The entire valve mechanism is pressure lubricated by oil which enters the tappets through the guides, thence through the push rods and rockers. The rocker boxes are inter-connected by pipes which drain the oil into a separate compartment in the sump which is scavenged by the oil pump. This fully automatic lubrication makes attention to valve mechanism unnecessary between overhauls.

GROUP IV — BLOWER SECTION

The blower section, which also serves as the mounting section, is attached to the rear of the main crankcase and supports the engine in the airplane. The supercharger, together with its gearing, is contained in this section. An annulus in this section receives the mixture from the impeller through a diffuser chamber and delivers it to the cylinders via tangential intake pipes.

The supercharger is of the high speed, centrifugal type. It is driven by the crankshaft through a spring coupling located inside the rear crankshaft gear which in turn couples with a floating gear in the blower section. By means of a pair of spur gears, the impeller is driven at a high rate of speed—ten times crankshaft speed in most instances. This spring coupling relieves the blower gears of sudden strains from rapid acceleration or deceleration.

GROUP V — REAR SECTION

The rear section, or accessory section, is attached to the blower section. This section carries all the auxiliaries, which include two magnetos, a carburetor, a generator, a starter, a fuel pump, oil pump, oil pressure relief valve, oil screen, vacuum pump drive, one or two tachometer drives and two accessory or gun synchronizer drives.

A check valve is provided in the oil pressure strainer to prevent oil from the engine supply tank draining into the engine while it is standing idle.

Vanes are incorporated in the elbow above the carburetor to aid in mixture distribution.

Accessory Drives—The accessories are driven by the three shafts which extend entirely through the blower and rear sections. Each shaft carries a spur gear at its forward end which engages a gear coupled to the rear of the crankshaft. The upper shaft provides a drive for the starter and generator. Each of the two lower shafts drives 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 two gun synchronizers, or 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.

LUBRICATION SYSTEM

Oil is circulated through the engine by a three-section gear pump mounted in the right-hand lower side of the rear section. 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 from where it is forced to the oil screen chamber, located directly forward of the carburetor. From here the oil is directed through the blower section to the front of the engine. An additional cored passage conducts oil to the oil pressure relief valve at the right side of the rear section, where the engine oil pressure is regulated. By-passed oil is returned to the inlet side of the oil pump pressure section.

Branch lines from the strainer chamber circulate oil for the lubrication of the accessory drive bushings, gears, and accessories in the rear section. Oil is furnished to the interior of the hollow magneto drive shafts to lubricate the bushings which carry the forward ends of these shafts in the blower section. An oil jet (in the blower section), which assists in the lubrication of the blower gears and bearings, is supplied with oil from the forward bushing of the left magneto shaft.

The oil directed through the blower section is transferred to a pipe in the top of the sump and is then conducted to the main oil transfer bracket in Wasp and Hornet engines. In Wasp Jr. engines the oil is conducted through the lower part of the main crankcase section and then to the main oil transfer bracket. At this point the oil is introduced into the crankshaft by means of the oil transfer bracket where a drilled passage in the crankshaft directs it to the crankpin for the lubrication of the master rod bearing, knuckle pins and bushings, piston pins and bushings, and cylinder walls. The cylinder walls and piston pins and bushings are lubricated by spray from the oil jets—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 master rod bearing and knuckle pin bushings.

In geared engines a portion of the oil which is introduced into 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 reduction gear parts.

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

In Wasp and Hornet engines, an additional pipe from the sump connects with a pipe in the nose section and conducts oil to the nose, then into the propeller shaft through an oil transfer, 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 in the Wasp and Hornet engines, 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.

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

In Wasp and Hornet engines, oil is distributed from the main transfer bracket to the tappets through a groove around the front main crankcase to internal passages drilled in the case. In Wasp Jr. B3 engines, an oil manifold ring fastened to the tappet bosses on the front section conducts the oil to the tappet guides. Oil is then fed into the tappets and through the push rods to the rocker arms, rocker arm bearings, and valve clearance adjusting screws.

The surplus oil in the engine proper drains into the main sump, oil from the rocker boxes drains through the push rod cover tubes to the crankcase or through a system of inter-cylinder drain pipes to an additional compartment in the sump from where it is pumped through the scavenging pump to the oil tank. Excess oil from the relief valve is routed through a cored passage to the inlet side of the pressure stage of the pump, as mentioned in the first paragraph of this section.

On these engines, a thermostatic oil temperature regulator, incorporated in the oil system of the airplane, is included as optional equipment. This device automatically regulates the oil entering the engine to the desired temperature, thus relieving the pilot of manually controlling the temperature. Warming up time is reduced about one-half. When starting or when engine is cold, the valve directs oil from the scavenging pumps to the bottom of the tank near the suction line. Consequently, the warm oil is immediately used over again. When the oil approaches the desired temperature, the automatic valve begins to direct the oil through the oil cooler to the top of the tank. In this way, the temperature of the oil entering the engine is automatically controlled.

Lubrication charts on pages 24a, 24b and 24c will assist the reader in visualizing the oil flow from the time it leaves the pump until it is returned to the scavenging pump.

INTAKE SYSTEM

The part of the induction system which feeds air to the carburetor varies in different airplane installations, but in general consists of a top or front air inlet (air scoop and duct) and a preheating stove with provision for manually adjusting the air temperature.

The gasoline-air mixture from the carburetor is passed through the entering vanes in the rear section to the diffuser chamber. (In some Wasp and Hornet installations, hot spots are used between the carburetor and rear section to improve mixture distribution and are available as optional equipment for these two engines.) After reaching the diffuser chamber the mixture is forced by an impeller into an annulus in the blower section, from which it passes through intake pipes into the cylinders.

HOT SPOT

The round type hot spot is furnished as optional equipment for Wasp and Hornet engines. Exhaust gases are circulated through a stainless steel manifold cast in an aluminum housing. The heated tube around which the mixture passes, produces excellent vaporization, resulting in favorable mixture distribution to the cylinders.

CARBURETORS

Wasp Jr. engines are equipped with Stromberg NA-R9B or NA-R9C2 carburetors, both of which are single barrel, updraft, float type carburetors. The former incorporates the needle type of mixture control mechanism, whereas the latter has the back suction type. The NA-R9C2 provides automatic mixture control, but the NA-R9B does not and the mixture must be adjusted manually.

Stromberg NA-Y9H and NA-Y9J carburetors are used on Wasp H1 engines. These are also updraft, float type carburetors, but are double barreled. Both have the back suction type of mixture control. The mixture must be adjusted manually with the NA-Y9H carburetor, but the NA-Y9J provides automatic mixture control.

All the above carburetors incorporate an integral priming feature, wherein the accelerating pump of the carburetor is utilized for priming the engine prior to starting. They also incorporate an "idle cut-off", which provides the best method of stopping an engine, through terminating fuel flow, when the mixture control lever is placed in the "full lean" position. The self-priming and idle cut-off features are also incorporated in the Hornet carburetors which will be discussed immediately following.

The Stromberg NA-Y9G, or NA-Y9G1, carburetor is normally used on the E Hornet engine. These are double barrel, updraft carburetors which are designed for use with the Pratt & Whitney Automatic Mixture and Power Control. They are also equipped with a back suction type of mixture control which may be manually operated if there is occasion for its use.

The Pratt & Whitney Automatic Mixture and Power Control unit is a device for maintaining the carburetor air scoop pressure at pre-determined constant values for climb and cruise operation and for automatically opening or closing the correct carburetor jets to give the desired mixture strength for climb and cruising horsepower. Bellows regulate air pressure control valves in the carburetor air scoop through an oil servo mechanism. The unit incorporates a selector valve which makes the three following positions available:

Manual Full Rich or Emergency Full Power Position—When in this position the carburetor functions independent of the automatic unit. The air pressure control valve is held wide open by both a spring and the servo control mechanism. Four fuel jets are in use to provide a mixture sufficiently rich for take-off or emergency operation. The mixture may be manually adjusted in this position.

Mid Position—In this position, the air pressure control valves are in operation, limiting the power to a predetermined value at a specified maximum engine speed. One fuel jet is automatically closed off to give the correct mixture strength for this power, which is normally used for climb operation. Power may be reduced to less than the maximum for this position by decreasing engine speed with the propeller control or by retarding the throttle. This is covered in detail in the "Operating" section.

Cruising Position—When in this position the air control valves maintain a carburetor air scoop pressure which limits horsepower to the maximum permissible for cruising operation at a specified maximum engine speed. A second fuel jet is closed off, leaving two jets in operation, to furnish a leaner mixture for economical fuel consumption at cruising powers. Here, again, the power may be reduced with the propeller control or by retarding the throttle. Refer to the "Operation" section for more specific information.

Note: The carburetor settings for the automatic cruising position are based on a carburetor air scoop temperature of 90°F. (32°C.). Refer to "Carburetor Air Temperature", page 66, for detailed information.

IGNITION

Ignition is furnished by two Scintilla SB9R or American Bosch SB9RU-3 magnetos located at the rear of the engine, each firing one of the two spark plugs in each of the nine cylinders, thus giving two independent sources of ignition. The right magneto fires the front spark plug and the left magneto fires the rear spark plug in each cylinder. The ignition harness and spark plugs are of the shielded types to prevent radio interference.

STARTER

An S.A.E. six inch aircraft starter flange is provided on the rear section for mounting any current standard starter.

PROPELLERS

These engines are equipped to mount two-position, constant speed and full feathering propellers of the hydraulically controlled type. The nose housing of the engine contains the oil passages and the oil transfer rings for introducing the oil into the propeller shaft and connections to the propeller. The governor for obtaining constant speed operation is mounted in a readily accessible location on the front (nose) section of Wasp H1 and Hornet E2-G and E3-G engines. On Wasp Jr. and Wasp H1-G engines the control may be mounted on the vertical accessory drive pad on the rear section.

The addition of special propeller control parts at the thrust bearing cover plate readily adapts the engine for the use of mechanically or electrically operated variable pitch or constant speed propellers.

All these types of propellers allow the engine to develop its full rated R.P.M. at the take-off. Constant speed propellers automatically hold the desired revolutions throughout the take-off and climb, and will hold the speed of the engine constant at any R.P.M. that the pilot may select, enabling him to maintain any combination of revolutions, manifold pressure and power (within the physical limitations of the engine or propeller) at any altitude.

The full feathering propeller combines the advantages of the constant speed propeller with the added feature that the propeller may be put in the full feathered position and the engine stopped in the air in the case of engine difficulty.

INSTALLATION

Satisfactory operation of an engine throughout its service life is dependent, to a great extent, upon its proper installation in the airplane. Careful study of the duties which the engine will be expected to perform and the fundamental principles governing the operating characteristics of the engine should enable the airplane designer to determine definitely the detailed installation requirements so that the engine will operate under all flight and atmospheric conditions with maximum efficiency and durability.

The subject of engine installation and discussions of the many problems involved in providing the proper equipment to insure satisfactory operation should be taken up with the engineers of Pratt & Whitney Aircraft Installation Department, particularly concerning instructive aids and suggestions for the airplane designer on methods of mounting the engine, sizes of fuel lines, sizes of oil lines, method of cowling, etc. For the operator, this information is of secondary importance, in that Pratt & Whitney Aircraft makes an effort to determine the efficiency of the engine installation prior to the delivery of the airplanes. The operator, however, should understand those factors which might impair the efficient operation of the engine. In particular, it should be understood that any change in power rating may require reworking of the installation details.

The following instruments are essential:

1. Tachometer
2. Manifold Pressure Gage
3. Fuel Pressure Gage
4. Oil Pressure Gage
5. Oil Temperature Gage
6. Carburetor Air Temperature Gage
7. Cylinder Head Temperature Gage

Any specific problems relative to the installation of the engine in the airplane should be referred to the Installation Department.

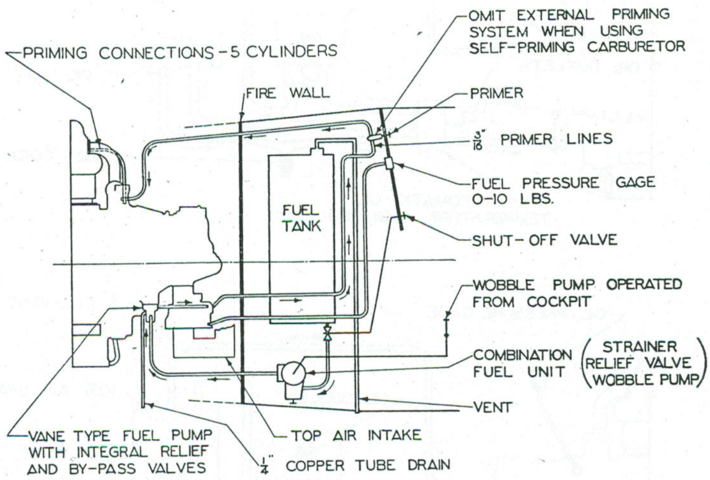


Fig. 7

Schematic Diagram of Typical Fuel System

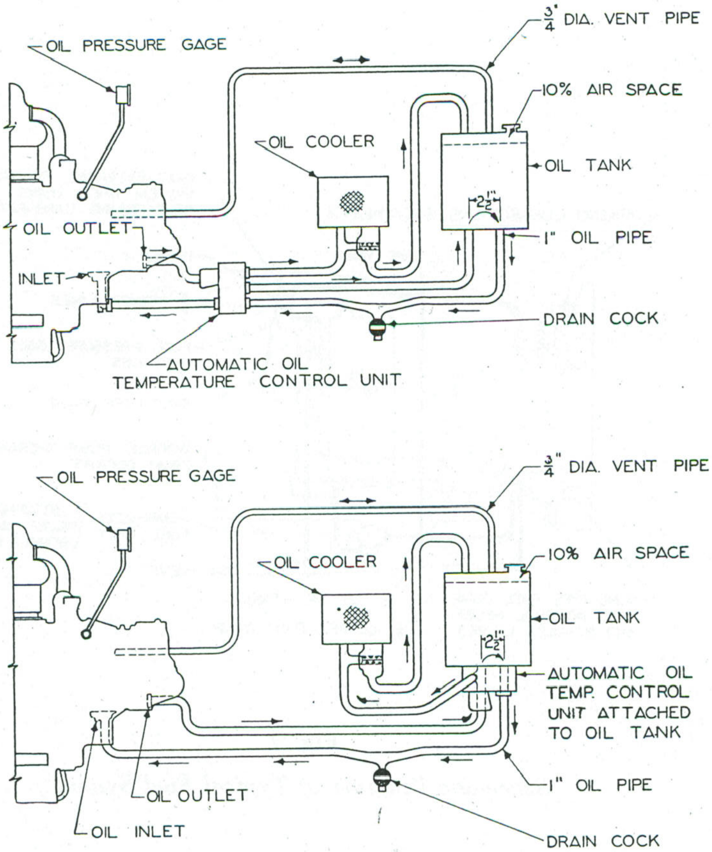


Fig. 8

Schematic Diagram of Typical Oil System

TREATMENT OF NEW ENGINES

Preparation of New Engines for Running—New engines which have been taken out of long time storage must have the oil drained from the cylinders before starting. Some of this oil is heavier than regular engine oil and it is important that the engine stand overnight in a room with a temperature of at least 60°F. (16°C.). The engine should then be placed on an engine stand in a "nose down" position and the front spark plugs, and oil sump plugs removed. The engine crankshaft should then be turned over at least twenty-five times and the oil allowed to drain out of the cylinders for several hours. If the carburetor has been prepared for long time storage, it should be thoroughly flushed, filling it through the fuel inlet opening with gasoline, then rocking it back and forth. The procedure should be repeated as many times as necessary to insure that storage oil has been completely washed out.

The engine should be washed down with white furnace oil, or the equivalent, before installation in the airplane. Care should be exercised to keep the washing fluid away from the magnetos and ignition harness as much as possible. After installation in the plane, the engine should be turned over by hand at least six times before the starter is engaged.

If the engine has been placed in storage while installed in an airplane, or in cases where it is impossible to put the engine in a "nose down" position, remove all spark plugs, oil sump plugs **and the intake pipes at cylinders Nos. 4, 5, 6, and 7,** and drain out any oil which has collected. It is extremely important that no appreciable quantity of preservative compound or oil be permitted to remain in the cylinders or in the intake pipes from where it can be drawn into the cylinders, otherwise buckled connecting rods or other serious damage will result on the first attempt to start the engine. The crankshaft should also be turned over by hand as described above.

The spark plugs should be thoroughly cleaned with gasoline, then bomb-tested at a pressure of 200 lbs. per sq. in. if possible, before attempting to start the engine. The spark plug lead terminal sleeves of the ignition harness should be examined for indications of moisture or damage.

Check magneto breaker points for condition. Make sure they are not oily. Remove any trace of oil or grease from inside the magneto breaker housings with carbon tetrachloride, then dry the housings thoroughly. This is important, as serious burning of the breaker points can result from a minute quantity of oil or grease, or a mixture of cleaning fluid and oil or grease. Do not remove the oil from the cam oiler felt of Scintilla Magnetos. Check synchronization between the two magnetos and, if necessary, make the correction.

Any engine that has been filled with an oil heavier than the standard lubricating oil normally used should be run one hour at 1000 R.P.M. with the regular engine oil, after which the oil should be drained from the engine sumps and oil tank and the tank refilled with fresh oil.

Run-in of Engine After Installation—For starting instructions, refer to paragraphs on "Starting" in the "Operation" section of this Handbook.

Caution: The oil pressure should start rising within thirty seconds after starting.

After starting, run the engine slowly (600 to 800 R.P.M.) for one minute and then at 1000 R.P.M. in order to warm it up gradually. The original run-in should preferably be made with no cowling over the engine accessory compartment. This will permit complete inspection of the installation details and their operation. The main engine cowling should be in place, however, to insure proper cooling of the cylinders. It is desirable that engines run at least thirty minutes, and generally an hour, to make a thorough check for proper engine lubrication system operation.

Advance the throttle momentarily to obtain the manifold pressure for normal rated power. It is preferable to keep the head temperatures under 400°F. (204°C.), but at no time allow the temperature to exceed 450°F. (232°C.). After this run-in the oil strainer should be cleaned to remove any foreign matter that might have come from the tank or pipes of the ship. If any appreciable quantity of foreign matter is found, the oil should be drained. Check all installations and controls to see that everything is satisfactory.

Pratt & Whitney engines are tested for twelve or more hours before leaving the factory. Following the first run-in test, they are disassembled and thoroughly inspected and are then reassembled and put through a final test where they must conform to very rigid requirements. In spite of this extended running that the new engine received prior to flight, it should be borne in mind that it will benefit by careful treatment during its first few hours in service. Prolonged full power operation should be avoided.

Rough Running of a Newly Installed Engine—When a newly installed engine is found to run rough, experience has shown that the causes are usually of a very elementary nature and in the great majority of cases have something to do with the way the engine is installed, or the trouble is due directly to something that has changed during the shipping, handling and installation of the engine. After the final test at the factory—and this test is made with the same spark plugs, magnetos, carburetor and ignition system as shipped with the engine—the engine is washed and prepared for shipment, and it should reach the customer in good running condition. A careful check on those factors which may have changed since the engine was removed from the test stand at the factory will usually clear up the trouble with very little difficulty.

The following causes of rough running are listed in the order in which it has been found that they are responsible for trouble on new installations. However, it should be pointed out that the successful elimination of operating difficulties in aircraft engines depends upon the systematic elimination of the probable causes of the trouble as determined by logical reasoning from the results of observations made of the behavior of the engine, particularly the sound of the exhaust when idling, at medium speeds and at high speeds.

Rough running, failure to run or intermittent running of a newly installed engine is sometimes caused by a ground, partial ground, or a loose connection in the wiring of the plane. Disconnect the magneto ground wires at the magnetos and run the engine. Stop the engine by turning off the fuel supply.

Check the spark plugs. Rough running of a new engine is usually caused by spark plugs fouling on the oil that is placed in the cylinders for shipping. This is particularly true if the engine has been prepared for long time storage, in which case the cylinders are filled with a very heavy oil that is difficult to drain out completely before starting. The engine should be run first on one magneto and then the other to determine if the fouled plugs are all on the front or rear cylinders. If the engine is rough on both magnetos when run on each magneto separately, the fouled plugs are in both the front and rear positions. The cylinders that are missing may sometimes be located by running the engine on one magneto and then noting the cylinder head temperatures or feeling the cylinders or exhaust stacks to determine which are cold or cooler than the rest. In the event that many plugs have fouled at the same time, this plan is not particularly effective. Prolonged running or high output running should not be done on a single magneto.

Check the valve adjustment. Rough running from too large a clearance underneath the valve adjusting screw usually occurs only when one of the valve adjusting screws has become loose and backed off. A visual inspection will determine this condition. Too little valve clearance will cause rough running, particularly at low speeds before the engine has warmed up enough for the expansion of the cylinders to compensate for the condition. Valve clearances should be set according to the instructions under the heading of "Adjust Valve Clearances", on page 83.

If the roughness is particularly noticeable at high speed, it may be caused by a loose propeller hub nut or by the propeller blade adjustment. Propellers that have never been run before or that have been taken off for repairs are sometimes open to suspicion. They should be checked for pitch setting, track and balance. The quickest way to determine if the propeller is the cause of the trouble is to take a propeller that is operating satisfactorily on another engine and try it on the engine that is running rough.

Check the carburetor. Carburetion troubles on new installations are usually caused by dirt in the passages or strainer from the new gasoline tank and piping, or from a lack of pressure or an excessive pressure from an improperly adjusted fuel pump. Dirt in the strainer or a restriction in the fuel pipes will be evidenced by a fluctuating fuel pressure and rough running, particularly at high speeds. Insufficient fuel pressure will cause rough running and cutting out at high engine speeds.

If necessary to change the carburetor idling adjustment to improve the operation of the engine at idling speed, the throttle stop should first be adjusted to give the approximate speed desired (usually between 400 R.P.M. and 500 R.P.M.), and the mixture then adjusted to give the desired operation. In making changes in the mixture adjustment the slack should be turned out of the knurled screw before the clamp screw is loosened; then loosen the clamp screw, turn adjustment as needed, and lock. Open and close throttle and adjust the throttle stop if necessary. The clamp screw should be tightened and the throttle opened and closed between each adjustment of the idle mixture screw. Do not make idle adjustments on a cold engine.

Check the intake system for air leaks. This trouble will be manifested by hard starting and rough running, particularly at low and medium engine speeds. See that the intake pipe packing glands are tight and that the intake pipes have not been damaged in mounting the engine.

Check the ignition wiring, making sure that the spark plug lead terminal sleeves are dry and in good condition and that no part of the ignition cable has been made deficient by water or moisture. The ignition harness may be checked by mounting a temporary harness on the engine. This should seldom prove necessary on a new engine unless it has already been subjected to a great deal of water, as in some seaplane installations.

Investigate the magnetos. If the engine is rough on both magnetos, it is probable that the trouble is elsewhere. If rough on one magneto, it may prove desirable to try a new condenser, coil and breaker assembly, one at a time.

OPERATION

A. STARTING

1. Turn the engine over four or five revolutions by pulling the propeller through by hand. This will help remove any oil or gasoline which might have collected in the lower cylinders while the engine has been idle. (It is advisable to remove the lower spark plugs before turning the engine over if there is any reason to believe the cylinders are loaded. This is especially important where a relatively high position of the exhaust tail pipe will prevent drainage out of the exhaust ports.)
2. In cold weather the oil should be preheated before starting, unless the airplane is equipped with an Oil Dilution System (See Page 54 for information on starting with Oil Dilution System.) In extremely cold weather it may also be necessary to preheat the engine before starting.
3. Propeller control in "Low Pitch" or "High R.P.M." position.
4. Carburetor heat control in "Cold" position (to prevent possible damage to induction system in case of backfire).
5. Fuel supply "On".
6. Priming

   The amount of priming (number of strokes of the priming pump) is dependent upon the length of the priming line, also upon whether the engine is cold, warm or hot. As the length of the priming line varies with different airplane installations, it is necessary through experience to determine the strokes needed to fill the primer line completely before counting the number of strokes necessary to prime the engine.

   It is important that the engine be primed sufficiently but not excessively, with due regard to engine temperature. The number of priming strokes will vary from no prime at all for a hot engine to six or eight, or more, strokes with a very cold engine, having in mind that one stroke of a small sized primer pump will fill about 5 ft.

of primer line. Experience will dictate the exact amount of priming necessary to obtain good starting under various conditions. Excessive priming will load the cylinders with raw gasoline, making it difficult to start the engine. Excessive priming also has a tendency to wash the oil off the cylinder walls and may result in barrel scoring or piston seizure. Rusting of piston rings and cylinder walls will occur if the engine is allowed to stand for a day or more after unsuccessful attempts to start, unless the surfaces are protected by a fresh application of oil. 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.

The instruction book issued by the airplane manufacturer should be consulted for the type of priming system which is incorporated in the airplane involved. Carburetors of current engines have integral primers as described on page 27, and advantage is usually taken of this feature to simplify the priming system through making a separate primer pump and the accompanying extra lines unnecessary.

With the mixture in full rich position, turn on the fuel supply and operate the wobble pump slowly until the fuel pressure registers 3 lbs. on the cockpit gage when the pump is pushed slowly through one stroke. With 3 lbs. pressure the carburetor bowl is entirely filled and a greater pressure may cause flooding of the carburetor and present a fire hazard in case of backfire. In case of carburetors with the integral priming feature, the wobble pump should be very cautiously used to prevent flooding. It is necessary to supply only sufficient fuel pressure to just fill the carburetor bowl.

Where carburetor integral primer is used:

This type of primer utilizes the accelerating pump of the carburetor for priming. To operate, place the mixture control lever in the **full lean or idle cut-off** position. This permits the discharge from the accelerating pump to flow into the priming line. Pump the throttle three or four complete strokes for a **cold** engine (none, or one or two, as required, for a hot or warm engine). The accelerating pump of the carburetor has about three times the capacity of the normal, separate primer pump and the primer line is relatively short, so the number of strokes required is less than with a standard primer pump. After priming, return mixture control lever to **full rich** or **automatic rich** position and refill the carburetor bowl by operating the wobble pump as previously described.

Where separate primer pump is used:

With the mixture control lever in the **full rich** position, prime the engine with the necessary number of strokes. (Refer to page 38). At least six complete strokes are usually necessary with a **cold** engine. Pull the primer plunger back slowly to obtain a full charge and push it rapidly to atomize the fuel. With some fuel systems it is necessary to operate the wobble pump while priming to obtain fuel. After priming, **be sure to shut off the primer valve.**

7. Turn the ignition switch to the "Both On" position.
8. Open the throttle to the equivalent of approximately 600 R.P.M. if direct electric or inertia starter is in use. With a cartridge starter slightly more throttle opening may be desirable in view of the higher initial speed obtained with these starters. It is usually more satisfactory to set the throttle equivalent to about 800 R.P.M., rather than 600 R.P.M.
9. Maintain 4 lbs./sq. in. (.28 kg./cm²) fuel pressure with the wobble pump.
10. Close booster switch (if manually controlled) and engage starter simultaneously. (With starters having integral booster magnetos, the booster automatically operates when the starter is engaged.)
11. After the engine has fired, the throttle **should be manipulated** to get the engine speed up to 500-600 R.P.M. as quickly as possible. In case the

throttle is opened too wide in an effort to obtain this speed, immediately after the engine has fired, care should be taken to close the throttle quickly, as the excessive amount of air admitted to a cold engine by a prematurely opened throttle starves the engine of a proper air fuel mixture and is apt to cause backfires. Once the engine has attained this speed, **the throttle should be left alone. Beware of pumping throttle, because excessive pumping when the engine is cold is the frequent cause of backfire with the accompanying fire hazard.** If the engine is warm, pumping will tend to "load up" and possibly choke the engine.

12. Watch for an indication of oil pressure on the gage. **Caution: If oil pressure does not register on the gage almost immediately, STOP and investigate.** (See "Oil Pressure", page 67.)

13. After the engine has started and is turning at 500-600 R.P.M., move carburetor heat control to "Hot" position.

14. If the engine does not start immediately, do not keep on priming but find out what is wrong. Excessive priming washes the oil from the cylinder walls and is apt to result in the damage described under "Priming". Investigate as follows:

    Check to see if items previously listed have been properly performed.

    Make sure there is ample fuel in carburetor and priming pump.

    Check for leaky primer lines or primer pump packing.

    Check for good spark from starting magneto. This may be done by removing its high tension lead and holding it ¼″ to ⅜″ (6.35 mm. to 9.50 mm.) from some point on the engine or mount while turning the engine with the starter. The spark should jump from ¼″ to ⅜″ (6.35 mm. to 9.50 mm.) without difficulty. Check the insulation on the high tension wire and the ground connection between the starting magneto and the engine.

Check spark plugs if any possibility that gaps are excessively wide or that several plugs are fouled.

It is sometimes desirable to move the idle adjustment a notch or two toward the rich side in extremely cold weather. Care should be exercised not to cause the engine to idle excessively rich, however.

If there is evidence that the engine is overloaded with fuel, it will be necessary to clear the cylinders and the induction system of the excess fuel. This can easily be done by opening the throttle wide and turning the engine **forward** (not backward) about four or five revolutions. Turning the engine backward will return the excess fuel from the cylinders back into the induction system which will hamper starting and can be a fire hazard.

If the starter used is of the inertia type and runs down before the engine starts, the starter jaw will be left in engagement. Before the starter can be rewound, it is necessary to disengage the jaw by pushing in the starter control or by turning the propeller forward a short distance.

B. WARM-UP

Note: It is suggested that the Pilot's Check Chart, samples of which appear on pages 63 and 64, be used in conjunction with the remaining instructions in this section.

1. After approximately one minute, open the throttle to an engine speed of about 1000 R.P.M. (Keep the propeller in "Low Pitch".) Prolonged idling below 800 R.P.M. may result in fouled spark plugs.
2. The mixture control should be in the "full rich" or "automatic rich" position during warm-up.

C. GROUND TEST

1. When the oil-in temperature has risen to about 100°F. or 40°C. the throttle may be opened to approximately 30″ Hg. (760 mm.) absolute manifold pressure with the propeller in "Low Pitch" or "High R.P.M.". Do not attempt to operate above 1000 R.P.M. until the oil-in temperature

has exceeded 100°F. or 40°C. Note the loss of revolutions when switching to one magneto at a time. In switching from both magnetos to one, the normal drop-off is 50 to 75 R.P.M. and does not usually exceed 100 R.P.M. When switching from one magneto to the other, the change in R.P.M. should not be more than 30 or 40. It should be noted that the loss in R.P.M. when operating with one or two magnetos varies with different engine speeds. **This check should be made in as short a time as practicable.**

Continued running on one magneto with manifold pressures as high as 25″ to 30″ Hg. (635 mm. to 760 mm.) absolute, may cause serious detonation.

Check oil pressure, oil temperature, fuel pressure and R.P.M. at 30″ Hg. manifold pressure.

Oil pressure will vary with R.P.M. and temperature and need cause no alarm by falling to as low as 10 lbs./sq. in. (0.68 kg./cm²) with the engine idling and the oil hot. On **initial running after overhaul,** if the oil pressure is not within the specified range, the oil pressure relief valve in the rear section should be adjusted to give the desired pressure. On **subsequent running** of the engine, any appreciable change in oil pressure under the same condition of R.P.M. and oil temperature may indicate trouble within the engine or oil system which should be investigated.

Cooling of the cylinder heads and barrels, and ignition harness is usually insufficient while on the ground for continued running above 1400 R.P.M. Avoid prolonged running at speeds above this. Do not exceed 400°F. (204°C.) head temperature during ground operations.

D. TAXIING

1. The carburetor heat control should be in the "On" position while taxiing, excepting under dry torrid climatic conditions.
2. The propeller should be in "Low" pitch.

FLIGHT

The flight portion of these operating instructions is divided into two parts, each describing the operating technique normally employed in controlling engine power with the two basic carburetor types used. The first covers the Wasp Jr. and Wasp engines using the Stromberg NA-R9B or NA-R9C2 and the NA-Y9H or NA-Y9J carburetors, respectively. The second covers the Hornet engine equipped with the Pratt & Whitney Automatic Power and Mixture Control (Stromberg NA-Y9G or NA-Y9G1 carburetor).

The Wasp Jr. and Wasp group deals with these engines as equipped with propellers of the constant speed or two-position types and discusses the technique of Manual Mixture Control where the NA-R9B and NA-Y9H carburetors (non-automatic) are used. The NA-R9C2 and the NA-Y9J carburetors incorporate the Stromberg automatic mixture control feature. With all these carburetors, power is regulated by throttle opening and by the selection of engine speed with the propeller control.

The Hornet flight operation deals with the engine as equipped with a constant speed propeller. This, in combination with the Automatic Power and Mixture Control carburetor introduces a different technique of power regulation, in that the selection of engine speed with the propeller control primarily determines power output in the two automatic positions of the carburetor.

General smoothness, engine speed, manifold pressure, carburetor air temperature, fuel air ratio, cylinder temperatures, oil temperature, and the oil pressure give the most satisfactory indication of the performance of the power plant. If any one of these appears irregular, the engine should be throttled and, if the cause is not apparent, a landing should be made to investigate and correct the trouble. For specific operating instructions, maximum and minimum limits, refer to page 65. It is recommended that a Pilot's Check Chart be posted in the cockpit for ready reference. See sample Check Chart on pages 63 and 64.

Following are definitions of the engine ratings to which reference is made in this section.

The **Take-Off Rating** is the maximum power to be used for take-off. It is permissible to use this power for **emergency** climb for 1 minute but under ordinary circumstances this maximum should be maintained only long enough to clear obstructions.

The **Military Rating** is the same horsepower as the Normal Take-Off Rating with suitable manifold pressures at varying altitudes, and, for 5 minutes duration, may be used in all attitudes of flight. This is solely a military consideration and is not approved for commercial operations.

The **Normal Maximum Rating**, frequently referred to as Rated Power or Maximum Except Take-Off Power ("Meto Power"), is the maximum power at which an engine may be operated continuously for emergency (such as single engine) or military high performance operation.

WASP JR. AND WASP

E. TAKE-OFF

1. Just before starting the take-off run, recheck oil temperature, oil and fuel pressures and loss of R.P.M. when switching to one magneto at a time, as instructed under "Ground Test" on page 42.
2. It is desirable that cylinder head temperatures be at a minimum of 250°F. (120°C.) before starting take-off, but they should be low enough to insure that the maximum limits are not exceeded during the use of take-off or emergency power.
3. Set propeller control for take-off R.P.M.
4. Turn fuel selector valve on correct tank for take-off. (See plane manufacturer's instructions.)
5. Set mixture control for take-off, i.e., "Automatic Rich" where carburetor has automatic control or "Full Rich" where carburetor has manual mixture control.
6. Set carburetor heat control in "Cold" position excepting under icing conditions.

7. Adjust throttle friction sufficiently to prevent throttle creeping if hand is removed.
8. Open throttle **gradually**, (3-5 seconds desirable), being careful not to exceed limiting manifold pressure.
9. As soon as clear of the ground and obstructions, adjust the power to the normal climb conditions.

F. CLIMB

1. The following procedure is recommended for reducing take-off power to climb power where a constant speed propeller is used: First, bring the manifold pressure down about 2″ Hg., (50.8 mm.) then bring the R.P.M. down approximately 200 R.P.M. If further reduction in power is desired, reduce the manifold pressure 1″ Hg. (25 mm.), then the R.P.M. 100, in successive alternate steps till the desired power is attained for climb.

With a two-position propeller, the climb may be made in either "low" or "high" pitch, unless the climb is to exceed 6,000 or 7,000 feet. The most common practice is to make a gradual climb in "high" pitch. The alternate method is to climb rapidly to cruising altitude in "low" pitch. Cylinder head temperatures should be taken into consideration when deciding which method is the more desirable.

The tactical requirements of the military services may dictate using full power, having less regard for long life of the engine than for the immediate needs under conditions of an emergency. For their purposes, military ratings comparable to take-off power may be used in climb for 5 minutes or rated power for longer periods. Under such conditions of maximum climb performance, it is preferable to maintain "Cold" air to the carburetor. However, under icing conditions it is essential to adjust the carburetor heat to 90° F. (32°C.). See "Carburetor Air Temperature", page 66.

In average service, climbs are made at less than rated power, the power usually varying between 75% rated power and cruising power. For such climbs it is desirable to reduce the engine speed to 1900-2000 R.P.M. Under such reduced power conditions of climb maintain 90°F. carburetor air temperature. (See "Carburetor Air Temperature", page 66.)

It is desirable that cylinder temperatures be kept at somewhat less than the maximum permissible, preferably not more than the maximum permissible for cruising, i.e., 450°F. or 230°C. A material reduction in cylinder and/or oil temperatures can be obtained in climbing at an indicated air speed ten or twenty miles per hour higher than the speed for best climb. A tendency for the oil to overheat can be checked by reducing the engine speed with the propeller control, rather than by throttling alone.

Mixture control should remain in "Automatic Rich" position with carburetors having automatic mixture control. The "Full Rich" position should be maintained up to 5000′ with manual mixture control carburetors. Above 5000′ the mixture should be manually leaned only enough to smooth out the engine, favoring the rich side.

G. CRUISING

1. The maximum permissible cruising horsepower is indicated on the Typical Pilot's Check Charts on pages 63 and 64. These are strictly maximum cruising powers under accepted operating conditions. Average cruising requirements normally warrant reductions of 15% to 30% from maximum cruising power, and still further reductions where long range or endurance is a requisite and where maximum fuel economy is desired. Engine maintenance economy and long periods between engine overhaul are largely a function of using conservative cruising powers.
2. After the airplane has leveled off and while attaining its approximate cruising speed, the engine should be given an opportunity to cool down after the climb, preferably even below the final cruising temperatures, before the carburetor is changed to the "Automatic Lean" position, or, in the case of carburetors without automatic mixture control,

before leaning the mixture manually. This permits the blower and rear sections, as well as the cylinders, to cool down. A well cooled engine will have less tendency toward detonation and overheated pistons when the mixture is leaned, than will an engine where the cylinder temperatures are at the maximum permissible for cruising. It is desirable to maintain cylinder head temperatures below 400°F. or 200°C. in level flight while cruising, and under no circumstances should they be allowed to exceed 450°F. or 230°C.

3. Under most conditions of cruising operation, it is neither necessary nor desirable to use the maximum cruising power available from the engine. Where this is true, maximum engine efficiency and, as a rule, propeller efficiency is attained by operating with **power reduced by lowered engine speed rather than by reduced manifold pressure with a high engine speed.** It is, therefore, recommended, where the engine is equipped with a constant speed propeller, that power be reduced by **keeping the manifold pressure up to the maximum permitted for cruising at critical altitude and reducing the engine speed, thereby the engine power, with the propeller control until the desired lower air speed is obtained.**

This so-called constant B.M.E.P. (brake mean effective pressure) cruising procedure results in maximum fuel economy and is particularly applicable to long-range operation and airline service. The constant B.M.E.P. data, as derived from the power curves can be used to best advantage by coordinating it with the particular airplane characteristics — that is, by plotting true air speed against altitude in terms of R.P.M. and manifold pressure. The flight personnel can then select, from such a performance chart, the optimum combination of engine R.P.M. and manifold pressure for the desired airspeed at the involved altitude. With a two-position propeller, the high pitch setting is of course used for cruising and this method of power control is not possible. Reduction in power must, therefore, be accomplished by retarding the throttle. Refer to the Power Curves and Check Charts on pages 62a, 62b, 63, 64, 64a, and 64b, (or to the proper curve for the engine involved) for manifold pressure and R.P.M. limits, etc. Engine speeds below 1500 R.P.M. may or may not be found satisfactory as in some airplanes undesirable vibrations may be induced at certain engine speeds which should be avoided for continuous operation. The full throttle critical altitudes with low engine speeds are naturally somewhat lower than with high engine speeds. Approximately constant power can be maintained above the full throttle altitude of a low R.P.M. by increasing the engine speed 75 R.P.M. to offset each inch (25 mm.) Hg. loss in manifold pressure with altitude. Conversely, in descending, a gain of 1″ Hg. (25 mm.) in manifold pressure can be approximately cancelled in its effect on engine power by decreasing the engine speed 75 R.P.M. When the lowest usable R.P.M. is reached, it becomes necessary to use the throttle to maintain the manifold pressure below the maximum allowable for cruising or at the desired pressure. Between the full throttle altitude and sea level, the manifold pressure for a constant power (B.M.E.P. or torque) at a constant R.P.M. must be increased gradually due to the effects of back pressure and carburetor air temperature, the approximate rate being ¼″ Hg. per 1000 ft. (20 mm. Hg. per 1000 M.).

More precise control of power can be obtained by reading from the operating curve the exact manifold pressure for the power as corrected for carburetor air temperature. To facilitate reading the engine speed and manifold pressure for desired powers below the full throttle altitudes, special charts can be drawn. The principle benefit of this method of operation comes from the reduced friction and blower horsepower at low engine speed and is usually accompanied by lowered operating temperatures of the cylinders and oil.

4. **Mixture Control:** Take-off and climb mixtures (fuel-air ratios) are necessarily richer than those permissible for the lower horsepowers used for cruising. Carburetors are therefore equipped with either an automatic or a manual mixture control

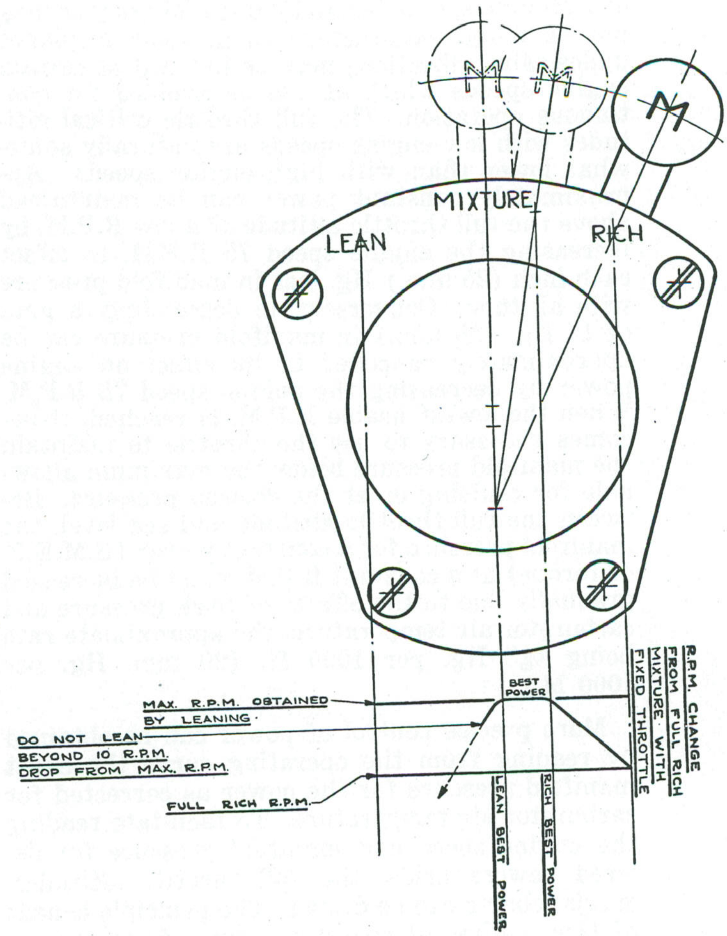


Fig. 9

Diagram of Mixture Control Operation

to provide for leaning the mixture to obtain economical fuel consumption for cruising operation.

a. Where the carburetor incorporates an automatic mixture control the "Automatic Lean" position is used for normal cruising operation.

b. Where the mixture is **manually controlled** and a **constant speed propeller** is in use, an exhaust gas analyzer should be used as a guide when adjusting the mixture control. The analyzer cockpit instrument shows fuel-air ratio vs. manifold pressure figures. The mixture should be leaned only to the manifold pressure figure on the analyzer indicator which corresponds to the manifold pressure showing on the manifold pressure gage. Changes in altitude, and other variables, affect manifold pressure, so the analyzer instrument should be watched and the mixture control adjusted as necessary to maintain the proper fuel-air ratio. The carburetor air temperature should be maintained at 90°F. (32°C.). (See "Carburetor Air Temperature", page 66.)

Note: If there is any reason to believe that the analyzer is not functioning properly, the mixture should be leaned only sufficiently to obtain smooth engine operation, and the cylinder head temperatures should be carefully watched to see that they remain within the desired limit.

c. Where the mixture is **manually controlled** and a **two-position** or **fixed pitch** propeller is in use, the mixture control should be adjusted as follows:

When the throttle has been fixed for the desired cruising R.P.M., adjust the carburetor heat control to maintain 90°F. (32°C.) carburetor air temperature. (See "Carburetor Air Temperature", page 66.)

Rich Best Power Setting is the point at which maximum R.P.M. is first noted when moving the mixture control from the full rich position (or from proper setting to give smooth operation at any altitude) toward the lean position. (Refer to Diagram of Mixture Control Operation, Fig. 9.) This is the extent to which the mixture may be leaned when cruising at 65% **to 75% of normal rated power.** In adjusting the mixture control to this setting, it will be necessary to go slightly beyond the point where maximum R.P.M. is first noted. Be sure to return the control to the point where the maximum was noted, making sure that possible backlash in the control linkage is taken into consideration.

Lean Best Power Setting: Leaning beyond the "Rich Best Power" setting will hold the R.P.M. at a maximum for an appreciable movement of the control, whereupon still further leaning will cause a drop in R.P.M. The point where R.P.M. begins to drop is called "Lean Best Power". This setting may be used for cruising operation at **65% of normal rated power or less.** Do not lean beyond 10 R.P.M. drop from maximum R.P.M. Overheating will result from a too lean mixture.

For operation other than the cruising powers mentioned in the two preceding paragraphs, the mixture control should be in the "full rich" position, or leaned only sufficiently to maintain smooth operation.

Because of changing flying conditions, the mixture control should be reset for each condition of flight by using as an indicator changes in R.P.M. and not by reference to predetermined positions on the mixture control quadrant. With the many variables that enter into an average flight, **the mixture control setting should be checked frequently to make sure that the engine is not running too lean,** especially if there is any change in altitude, carburetor air temperature or throttle.

H. CRUISING DESCENT

1. Under any normal conditions of cross country flight it is general practice to start a descent at a distance from the destination of as much as 100 miles. This distance is determined as a func-

tion of the altitude of the airplane above the destination, the rate of descent desired and the time necessary for the descent, the wind velocity and direction and its effect upon the airplane speed, and the resulting speed of the airplane during the descent. Such a descent should be regarded as a cruising operation. Cruising R.P.M., power, and mixture should be maintained throughout the descent until the point is reached where the final glide or approach for landing is to be made. It is, of course, impossible to maintain cruising power with a two-position propeller without exceeding maximum cruising R.P.M., so the amount of power during cruising descent will be governed by the limiting R.P.M.

2. If mixture is not automatically controlled, the exhaust gas analyzer should be watched and the manual mixture control richened as required.

I. DIVE

The centrifugal or inertia loads on the master rod bearing increase as the square of the R.P.M. These loads, however, are in the opposite direction from the power impulse loads from the pistons. Therefore, high engine speeds with low manifold pressures impose the severest load. Where overspeeding of the engine is unavoidable in dives, it is recommended that the throttle be partially opened to give 15″ to 20″ Hg. (380 mm. to 500 mm.) where practicable. The maximum safe overspeed R.P.M. is 2800 R.P.M. for a duration of 30 seconds. The propeller control should be set for cruising R.P.M. or lower. Since dives are usually accompanied by other maneuvers that may require full power of the engine, the mixture control must be in the "Automatic Rich" position ("Full Rich" without automatic mixture control).

J. GLIDE AND APPROACH FOR LANDING

1. For a relatively long "power-off" glide and in making a landing approach the mixture control lever should be in the "Automatic Rich" or "Full Rich" position. The propeller control should be

set for low cruising R.P.M. until the airplane has slowed down sufficiently to prevent high R.P.M. when the propeller control setting is changed to take-off R.P.M. position. When approaching the landing field, the propeller control should be set for take-off R.P.M. It is suggested that this be done at the time the landing gear and wing flaps are being set for landing.

2. If atmospheric conditions are such that the carburetor might ice, carburetor heat should be used during the glide and approach for landing, as a reduced throttle opening with a rich mixture presents the condition most conducive to icing.

K. STOPPING

If the cylinders are hot due to hard taxiing, permit the engine to idle a short time to allow the cylinder temperatures to cool below 400°F. (205°C.).

To stop the engine move the mixture control to the "Idle Cut-off" or "Full Lean" position. This should be done with the engine turning at any idling speed. When the engine has stopped, turn all ignition switches to "Off".

If "Idle Cut-Off" should not stop the engine, close the throttle, cut the ignition switch and **slowly** open the throttle wide as the engine stops. Have the "Idle Cut-Off" adjusted properly as soon **as possible.**

USE OF OIL DILUTION SYSTEM

The oil dilution system consists of an electrically operated valve which admits fuel, when desired, to the oil inlet line of the engine, usually at the drain cock, reducing the viscosity of the cold oil in the engine and oil system. Unless oil temperatures cannot be maintained in flight above the 40° C. minimum, seasonal changes of oil grade are not necessary. The following procedure is recommended:

Stopping—When a cold weather start is anticipated, permit the engine to cool by stopping or idling until cylinder temperatures fall below 148° C. (300° F.) and oil temperature below 50° C. (120° F.). With the engine running at approximately 800 R.P.M., hold the oil dilution control in the "ON" position for a period varying between one and five minutes. The proper length of time is dependent on the expected temperature and the grade and amount of oil in the system. In all cases dilution should be continued until the engine has stopped after placing the mixture control in "Idle Cut-Off".

Starting—A normal cold engine start should be made. Dilution of the oil with fuel at the time of the previous stop will permit the starter to turn the engine at a higher rate of speed, without the necessity for preheating the oil.

Warm-Up—During the warm-up period, the gasoline will be gradually evaporated as oil temperature increases. If oil in the tank or lines is insufficiently diluted, flow to the engine pump will be restricted by the high viscosity of the oil. In such cases, it may be noted that oil pressure is unsteady or decreases with an increase in R.P.M. The oil dilution system should be used to dilute the incoming oil only if time or extreme temperature conditions do not permit warm-up in the normal manner. Over-dilution can result from use of the valve during warm-up, so that oil pressure must be carefully watched for unusual fluctuation or drop-off during the remainder of warm-up, ground test, and the take-off.

Flight—The dilution valve should not be used in flight. A sudden loss or fluctuation of oil pressure or discharge of oil from the breather during flight may be caused by a leaking dilution valve. Momentarily turning the valve "ON" and "OFF" will assist in correcting the difficulty. Satisfactory operation will be restored after the gasoline has evaporated from the oil. The dilution valve mechanism should be checked after landing.

> **Caution**—The gasoline used to dilute the oil tends to loosen carbon and sludge deposits within the engine, so the oil screen should be removed for inspection an hour or two after the dilution system is first used for the season, and several times thereafter if it appears advisable. Oil pressure should be watched closely as an indication of clogging of the oil screen.

HORNET

(With Pratt & Whitney Automatic Mixture and Power Control)

E. TAKE-OFF

1. Items under "Take-Off" for Wasp Jr. and Wasp (page 45) apply, excepting that mixture control lever should be in "Manual Full Rich" ("Emergency Full Power") position.

F. CLIMB

1. For reducing take-off power to **initial** climb power, follow procedure outlined for Wasp Jr. and Wasp on pages 44 and 45, with the mixture control remaining in the "Manual Full Rich" position.
2. When the initial climb has carried the airplane to a satisfactory altitude, say 500′ to 1000′ above the terrain, the mixture control is shifted as outlined in the paragraphs which follow.
3. For **Maximum** climb, adjust the manifold pressure to 32″ Hg. with the throttle and the engine speed to 2250 R.P.M. with the propeller control. Move the mixture control lever to the "Mid" or "Climb" position, and advance the throttle to the wide open position.

   For military purposes, or single engine or emergency operation, it is permissible to use 2300 R.P.M. and 35″ Hg. manifold pressure from 500′ to 3000′, (34″ Hg. manifold pressure from 3000′ to 7000′) with the mixture control in the **"Manual Full Rich"** position. At 8000′ the R.P.M. should be reduced to 2250 and the mixture control shifted to the "Climb" position.

   Note: Some practice may be necessary in order to accomplish a smooth transition from the "Manual Full Rich" to the "Climb" position and individual pilots will have their own preferred methods. For example, some pilots move the throttle and mixture controls simultaneously, thus avoiding any sharp change in manifold pressure which might be caused when the mixture control is shifted to the climb position. For multi-engine airplanes, it is recommended that the controls be shifted for one engine at a time.

It is desirable to keep the carburetor air temperature at 90°F. (32°C.). It is permissible to use no heat if the maximum climb power is required under conditions of low humidity. However, a close watch of manifold pressure should be kept for any drop which might indicate ice formation, so that carburetor heat may be immediately applied.

4. For **Normal** climb or less, the engine speed is reduced to 2150 R.P.M. or lower with the propeller control. (Refer to Paragraph 3 for method of shifting mixture control from "Manual Full Rich" to "Climb" position). Reductions in power should be made by decreasing R.P.M. with the propeller control, leaving the throttle wide open. It is permissible, however, to reduce power by retarding the throttle if for any reason this is desirable. **Do not climb with the mixture control in the "Cruising" position.**

5. Maintain carburetor air temperature at 90°F. (32°C.)—higher if carburetor icing conditions warrant, but not over 120°F. (49°C.)—for normal climb operation. (See "Carburetor Air Temperature", page 66.)

6. Check manifold pressure gage to ascertain if carburetor automatic unit is maintaining the specified manifold pressure. (Refer to Power Curve or Check Chart) up to critical altitude for the "Climb" position. If automatic unit does not function properly, move mixture control lever to "Manual Full Rich" position and lean manually only enough to obtain smooth operation. Watch cylinder head temperatures closely when leaning manually.

7. It is desirable that cylinder temperatures be kept at somewhat less than the maximum permissible, preferably not more than the maximum for cruising (450°F. or 230°C.). A material reduction in cylinder and/or oil temperatures can be obtained by climbing at an indicated air speed 10 or 20 M.P.H. higher than the speed for best climb.

G. CRUISING

1. Refer to Items 1, 2 and 3 under "Cruising" for Wasp Jr. and Wasp engines, (pages 47 and 48.)
2. Reduce engine speed to at least 1950 R.P.M. with propeller control.
3. Move mixture control lever to "Cruising" position. It is unnecessary to retard the throttle in the change from "Climb" position to "Cruising" position due to the relatively low manifold pressure change involved.
4. Maintain a carburetor air temperature of at least 90°F. (32°C.) but not over 120°F. (49°C.). **This is important.** (Refer to "Carburetor Air Temperature", page 66.)
5. Check manifold pressure gage for proper functioning of carburetor automatic unit, which should maintain a specified manifold pressure (see proper Power Curve or Check Chart) up to the critical altitude for the "Cruising" position. If the automatic unit does not function properly, move the mixture control lever to the "Manual Full Rich" ("Emergency Full Power") position and lean manually only enough to obtain smooth engine operation. The cylinder head temperatures should be carefully watched when leaning manually.
6. Reduction from maximum cruising power should be made, as far as practicable, **by decreasing R.P.M. with the propeller control, leaving the throttle wide open.** If vibration or some other factor should make this method of power reduction below a certain R.P.M. undesirable, the power reduction may be accomplished by reducing manifold pressure with the throttle.

H. CRUISING DESCENT

1. See paragraph under same heading for Wasp Jr. and Wasp.

I. GLIDE AND APPROACH FOR LANDING

1. Mixture control should be in "Manual Full Rich" position; otherwise, instructions for Wasp Jr. and Wasp (page 53) apply.

J. STOPPING

1. See paragraph under same heading for Wasp Jr. and Wasp.

USE OF OPERATING CURVES

The operating curves issued by Pratt & Whitney Aircraft permit quite accurate estimates of engine output under normal engine operating conditions. The correct usage of these curves requires readings from the following instruments:

1. Tachometer (engine revolutions per minute).
2. Manifold Pressure Gage (intake manifold pressure—in. hg.).
3. Altimeter (pressure altitude).
4. Carburetor Intake Air Thermometer (degrees Fahrenheit).

Referring to the Wasp S3H1 curve on page 62a, which will be used for illustrative purposes in this discussion, it will be observed that the chart is divided into two parts, one for sea level conditions and the other for altitude conditions, and shows brake horsepower as a function of manifold pressure R.P.M. and altitude. "Standard Temperatures at Altitude" are shown at the bottom of the Altitude Power Curves.

The power curves alone DO NOT completely prescribe methods of operation. They do provide a means for determining power from instrument observations under flight conditions, regardless of propeller settings. Maximum permissible limits of power output are definitely prescribed by heavy boundary curves and by labeled arrows. The maximum recommended limits of manifold pressure and R.P.M. for cruising are also indicated.

Sea Level Curves—Under standard sea level conditions (29.92″ hg. barometer and 60° Fahrenheit carburetor intake air temperature), power may be read directly for any R.P.M. and manifold pressure within the scope of these curves. The sea level curves are useful in determining power AT OR NEAR SEA LEVEL and they assist in the power determination at altitude.

Referring to the Wasp S3H1 curve on page 62a, the example given is for determining power at 2100 R.P.M. and 33.0″ hg. manifold pressure. If atmospheric pressure is 29.92″ hg. and carburetor air temperature is 60° Fahrenheit, the engine is delivering 510 H.P. (Point A).

Should the same R.P.M. and manifold pressure values be obtained with the carburetor air temperature at 105° Fahrenheit instead of 60° Fahrenheit, the power naturally would be less. This condition could be obtained on a cold day by heating the intake air in the preheating system up to 105° Fahrenheit.

A quick and fairly accurate correction may be made by adding 1% to the H.P. for every 10°F. of temperature deviation below standard temperature and subtracting 1% for every 10°F. above standard temperature. Therefore, a deviation of 45° (105°-60°) above standard would necessitate subtracting 4.5% from 510 H.P., giving 487 H.P.

Had the carburetor air thermometer read 15°F., this would have been (60°-15°) 45° below standard temperature and would necessitate adding 4.5% to 510 H.P., giving 533 H.P.

Altitude Curves—For conditions above sea level, that is, where atmospheric pressure is below 29.92″ hg., power is determined from the altitude power curves. When using the curves in flight, the altimeter zero or barometer setting should be 29.92″ hg. in order to indicate the correct altitude for reference to the power curves. It will be noted that the curves are drawn from "Standard Altitude", that is, where "Standard Temperature" is obtained at each "Pressure Altitude" indicated by the altimeter. The power correction previously mentioned may again be used when carburetor air temperature varies from "Standard Temperature" at any altitude.

Referring to the curve, the R.P.M. lines which extend from sea level (0′ alt.) up to 25,000′ represent full throttle power at "Standard Altitude", with neither ram pressure nor restriction in the carburetor air intake. The short lines crossing the R.P.M. lines represent the manifold pressures necessary to obtain the full throttle power at each altitude.

In the example determination, it will be noted that, with 2100 R.P.M. and 33″ hg. manifold pressure, full throttle power is obtained at 4,000′ altitude and is 540 H.P. (Point E). This is more horsepower than that obtained with the same R.P.M. and manifold pressure at sea level (Point A). If we connect the points of full throttle power obtained at altitude (Point E) and the part throttle power obtained WITH THE SAME R.P.M. AND MANIFOLD PRESSURE at sea level (Point F carried over from Point A), we will have a LINE REPRESENTING THE VARIATION IN POWER WITH CHANGE IN ALTITUDE WHEN MAINTAINING CONSTANT R.P.M. AND CONSTANT MANIFOLD PRESSURE.

Ram pressure at the carburetor, obtained as a result of facing the carburetor air intake scoop into the slip stream so as to gain the supercharging effect equivalent to the velocity pressure of the air stream, raises the altitude at which "full throttle manifold pressure" may be obtained. Thus, sufficient ram pressure might be obtained in flight in order to permit the sample engine to develop 2100 R.P.M. and 33″ hg. manifold pressure at 4500′ instead of only 4000′ (Point E for no ram). Then the power would be 543 H.P. (Point X) and is obtained, as shown on the curve, by following the line of constant R.P.M. and constant manifold pressure for 2100 R.P.M. and 33″ hg. up to the altitude at which these values are obtained in actual flight, which in this case is 4500′.

Part throttle power at 2500′ for standard conditions is shown to be 530 H.P. (Point G). Should the preheater raise the carburetor air temperature to 90°F., this would be 40° higher than standard temperature at 2500′, (lower curve shows standard temperature at 2500′ to be approximately 50° Fahrenheit). Then, the correct power for 2100 R.P.M. and 33″ hg. manifold pressure would be obtained by finding the deviation from standard temperature at 2500′ (90°-50°) 40°F. and then subtracting 4% from 530 H.P. and finding the power to be 509 H.P.

As shown by the examples, ACCURATE DETERMINATION OF POWER AT ALTITUDES IS OBTAINED BY CONNECTING THE FULL THROTTLE ALTITUDE POINT AND THE PART THROTTLE

SEA LEVEL POINT (as projected across from the sea level curves to zero altitude on the altitude power curves) FOR THE SAME R.P.M. AND MANIFOLD PRESSURE. Then follow up the altitude line indicated by the altimeter to the point where it intersects the constant R.P.M. manifold pressure line and find the H.P. for standard temperature. Correction for variance in carburetor air temperature is made in the manner described previously.

Following are two more examples which illustrate how part throttle power at altitude is determined:

1. With a combination of 1850 R.P.M. and 27″ hg. manifold pressure at an altitude of 5000 feet, the horsepower is determined on the sample curve as follows:

Find Point L by following the 1850 R.P.M. line of the altitude curve to the 27″ manifold pressure line.

Project Point L^1 (H.P. represented by 1850 R.P.M. and 27″ hg. at S.L.) across to the altitude curve at zero altitude (Point L^2).

Follow a straight line, connecting Points L and L^2, to the vertical line representing 5000′ altitude (Point L^3).

By projecting Point L^3 across to the space for horsepower figures between the altitude and sea level curves, it will be noted that the horsepower reading is 362.

If the carburetor air temperature is other than standard for altitude of 5000 feet, correction is made as previously described.

2. For determining the horsepower resulting from 1600 R.P.M. and 25″ hg. manifold pressure at an altitude of 6000 feet, find M, M^1, M^2, and M^3 in the order described in Example 1, but using the 1600 R.P.M., 25″ Hg. manifold pressure and 6000′ altitude lines on the sample curve. It will be noted that the resultant horsepower reading is 280, with no correction for any variance in carburetor air temperature.

Note: On the Hornet S1E3-G power curve on page 64a, horsepowers for climb and cruise operation with the Pratt & Whitney Automatic Mixture and Power Control may be read directly from the curves, obviating necessity for following the foregoing procedure.

TYPICAL PILOT'S CHECK CHART

Pratt & Whitney Wasp Jr. or Wasp — Aviation Grade 91

Operating Condition	Engine RPM or Prop. Control Position	Manifold Pressure (Max. "Hg.)	Mixture Control Position	Carb. Air Temp. (°F.)	Oil Inlet Temp. (°F.)	Cyl. Head Temp. (Max. °F.)	Oil Pressure (lbs./in.²)
Start	500–600 (1 minute)		Auto. Rich	Full Cold			Press. must show in less than 30 sec.
Warm-up	1000		"	Full Hot			(50 minimum)
Ground Test	Low Pitch	30	"	90°	100 (minimum)	400	70–90
Take-off	2300	36.5	"	Full Cold	"	550	"
Military Rating (5 minutes)	2300	35.5	"	" (or heat as required)	140–185	550 (1½ minutes)	"
Normal Max. Rating (Rated Power)	2200	33	"	"	"	500	"
Climb, Desired	2000	30	"	90	140–167	450	"
Cruising, Max.	2000	28	Auto. Lean	"	"	(400 or less desired)	"
Cruising, Desired	1900 or less	26.5 or less	"	"	"	"	" (50 minimum)
Approach for Landing	Take-off	As required	Auto. Rich	Full Cold (or heat as required)	"	"	"
Stopping	400–500		Idle Cut-off (Full lean)	Full Cold		"	10 (minimum idling)

NOTE: Desired Fuel Pressure 4-6 lbs./in.²

TYPICAL PILOT'S CHECK CHART

Pratt & Whitney Hornet (with Pratt & Whitney Automatic Mixture and Power Control) — Aviation Grade 91

Operating Condition	Engine RPM or Prop. Control Setting	Manifold Pressure (Max. "Hg.)	Mixture Control Position	Carb. Air Temp. (°F.)	Oil Inlet Temp. (°F.)	Cyl. Head Temp. (Max. °F.)	Oil Pressure (lbs./in.²)
Start	500–600 (1 minute)		Manual Full Rich	Full Cold			Press. must show in less than 30 sec.
Warm-up	1000		"	Full Hot			(50 minimum)
Ground Test	Low Pitch	30	"	90	100 (minimum)	400	70–90
Take-off	2500	39.5	"	Full Cold	"	550	"
Continuous Emergency	2300	34.0	"	Heat as required	140–185	500	"
Normal Max. Rating (Rated Power)	2250	32.5	"	"	"	500	"
Climb, Desired	2000 or less	29.5 or less	Climb	90	140–167	450	"
Cruising, Max.	1950	27	Cruise	90	"	(400 or less desired)	"
Cruising, Desired	1850 or less	26 or less	Cruise	90	"	"	(50 minimum)
Approach for Landing	Take-off	As required	Manual Full Rich	Full Cold (or heat as required)	"	"	"
Stopping	400–500		Idle Cut-off (Full lean)	Full Cold		"	10 (minimum idling)

NOTE: Desired Fuel Pressure 4-6 lbs./in.²

Operating Limits

Minimum Oil Inlet Temperature for Take-Off	104°F. or 40°C.
Desired Oil Inlet Temperature	140-167°F. or 60-75°C.
Maximum Oil Inlet Temperature	185°F. or 85°C.
Maximum Cylinder Temperature —1 to 1½ min. climb	Head 550°F. or 288°C. Base 335°F. or 168°C.
Maximum Cylinder Temperature —continuous cruising	Head 450°F. or 232°C. Base 300°F. or 149°C.
Desired Cylinder Temperature —continuous cruising	Head 400°F. or 204°C. or less. Base 200-250°F. or 93°-121°C.
Minimum Oil Pressure (at idling speeds)	10 lbs. or 0.7 kg/cm²
Minimum Oil Pressure (at cruising speeds)	50 lbs. or 3.5 kg/cm²
Desired Oil Pressure	70 to 90 lbs. or 4.9 to 6.3 kg/cm²
Minimum Fuel Pressure (400 R.P.M. or less)	2 lbs. per sq. in or .14 kg/cm²
Minimum Fuel Pressure (all speeds above 1200 R.P.M.)	4 lbs. per sq. in or .28 kg/cm²
Desired Fuel Pressure	5 lbs. per sq. in. or .35 kg/cm²
Maximum Fuel Pressure	6 lbs. per sq. in. or .42 kg/cm² (5 lbs. per sq. in. or .35 kg/cm² for automatic mixture control carburetors)
Desired Carburetor Air Intake Temperature	90°F. or 32°C.

Oil pressures refer to measurements taken on the **left hand side** of the rear section at the boss provided for this purpose immediately under the left hand synchronizer drive pad.

Pressures should not be measured at the similar connections on the right hand side.

The above fuel pressures will care for ramming carburetor pressures equivalent to 200 M.P.H. (322 KM/HR). For engines with ramming pressures up to the equivalent of 300 M.P.H. (483 KM/HR) the minimum fuel pressure for all speeds above 1200 R.P.M. should be 5 lbs. per sq. in. (.35 Kg/cm²). It should be noted that these fuel pressures are based on measurements taken at the fitting provided for this purpose on the carburetor and do not apply when measurements are taken somewhere in the line or relief valve housing.

CARBURETOR AIR TEMPERATURE

It is recommended that the temperature of the air below the carburetor be maintained at 90°F. (32°C.) for average cruise and climb conditions as a protection against ice formation and to aid mixture distribution. A higher temperature (100°F. or more) is often necessary under severe icing conditions. It requires much more heat to melt ice already formed in a carburetor than to prevent its formation.

For the NA-Y9G and NA-Y9G1 carburetors used on Hornet engines in conjunction with the Pratt & Whitney Automatic Mixture and Power control, it is imperative that a carburetor air scoop temperature of at least 90°F. (32°C.) be maintained for cruising operation. The carburetor setting for the automatic cruising position is based on this carburetor air temperature and any deviation will result in a change in mixture strength through changing the density of the air entering the carburetor. Temperatures below 90°F. (32°C.) will cause leaner mixtures, therefore should be avoided. Higher temperatures may be necessary under severe carburetor icing conditions. It is advisable also to keep the carburetor air temperature at 90°F. (32°C.) with the mixture control in "Mid" or "Climb" position.

Normally, it is unnecessary to use carburetor heat during take-off, although it is possible, under atmospheric conditions most conducive to icing, for the carburetor to ice dangerously on take-off. It is well always to have the carburetor heat control in the "Hot" position while taxiing preliminary to take-off.

In some airplane installations a temperature gage is connected above the carburetor, rather than in the air scoop. In such instances the temperature should be kept above freezing (32°F. or 0°C.), at least. The usual difference between temperatures below and above the carburetor while cruising will vary from 35°F. to 50°F., depending upon the engine or blower speed, the vaporizing characteristics of the fuel and atmospheric conditions.

The location of the temperature gage should be taken into consideration in making carburetor air temperature corrections when determining horsepower from the power curves. An accurate temperature correction cannot be made when using the temperature above the carburetor, and in such cases it is necessary to add the estimated difference between temperatures above and below the carburetor (say 35°F.) using the result for purposes of temperature correction, as described under "Use of Operating Curves" on page 59.

OIL PRESSURE

Oil pressure should register immediately after starting engine.

If there is no indication of oil pressure after 30 seconds, STOP, check the oil supply and especially the oil suction pipe and oil inlet connections. A very small leak in the oil suction line will prevent the oil pump from working properly. Do not continue running the engine unless oil pressure is obtained. The normal operating pressure is 70 to 90 lbs. (4.9 to 6.3 $Kg./cm^2$).

In checking for an air leak the oil line from the tank to pump should be examined, especially the tightness of connections. If hose connections are used, be sure that at least an inch overlaps both the pipe and its connection in order to have sufficient area for the hose clamp. In checking the oil corrections, care must be taken to see that the oil inlet thermometer connection provides a tight joint.

Clogging of the pressure strainer with foreign matter or carbon will sometimes cause a loss of pressure, as will also a particle lodged on the pressure relief valve seat.

An adjustable relief valve is provided on the right side of the rear section. This valve may be adjusted to give the desired pressure on a particular installation but once adjusted, should not be readjusted to care for variations in oil pressure. If low pressure is found, investigate the cause and do not attempt to correct by a new adjustment of the relief valve. See that oil pressure gage is connected to the proper place on engine which is on the left hand side under the gun synchronizer pad. If after checking all connections the pressure is still low, it may be due to accumulated wear in the engine. This possibility, however, is very unlikely and should be investigated only after all other causes have been considered.

LUBRICATING OIL

The modern, high performance aviation engine has introduced lubricating problems which are the subject for continuous investigation. Extensive research, close cooperation between the engine and the oil companies and service trials have to a great extent eliminated many of the unknown factors surrounding the problem. However, due to the special problems that are inherent with various types of engines and the complex chemical structure of lubricating oils with the resulting effect on the lubricating and stability properties of the oil, it is impossible to enter into any comprehensive discussion of the subject in this Handbook. For similar reasons, it is not possible to lay down all inclusive and enduring specifications of what is considered a satisfactory lubricant. The following general properties have been found to be common in all oils that have proved suitable in service:

	Temperate	*Torrid*
Flash Point	475 minimum	500 minimum
Viscosity (210°F. Saybolt Univ.)	100 plus or minus 5 sec.	120 plus or minus 5 sec.
Viscosity (100°F. Saybolt Univ.)	Not over 12.5 times viscosity at 210°F.	Not over 14.5 times viscosity at 210°F.
Viscosity Index (Dean & Davis)	95 minimum	95 minimum
Pour Test	10°F. maximum	10°F. maximum
Carbon Residue	1.00% maximum	1.25% maximum
Neutralization No. — New Oil	.10 maximum	.10 maximum
Emulsion Test	60 min. maximum time to settle out using distilled water at 180°F.	60 min. maximum time to settle out using distilled water at 180°F.

We wish to emphasize that the above properties are only of a general nature and that a given oil meeting these requirements is not necessarily satisfactory for use in Pratt & Whitney engines.

A new operator should communicate directly with the Service Department of Pratt & Whitney Aircraft for approval on the oil which is to be used, before operating Pratt & Whitney engines. It is urgently recommended that the engines be operated with an oil approved by Pratt & Whitney Aircraft.

The number of flying hours between oil changes is a variable factor, depending upon the type of engine service and the amount of oil carried in the oil tank. It has been found that in installations which carry relatively large amounts of oil and are operated, for the most part, at cruising horsepower, the oil changes may be made at intervals up to 100 flying hours. In high performance aircraft, particularly of the single engine type wherein the engine is operated at or near its full horsepower for protracted periods of time and wherein the capacity of the oil tank is necessarily limited, it has been found necessary to change the oil every 50 hours of flying time. In installations and types of service in between these two extremes, the hours between oil changes may be regulated in accordance with the type of service and installation in which the engine is operated.

Great care should be exercised in the handling of lubricating oil to prevent dust and dirt from collecting in it as this will act as an abrasive in the engine. The oil storage should be kept covered at all times and oil funnels and measures cleaned each time before using. When filling the tank after it has been drained, turn the propeller over several times by hand, or with the starter, in order that the piping and the oil pump will be thoroughly primed. Every precaution should be taken to see that the oil is kept entirely free from water. Very small amounts of water in the oil will cause violent foaming and a sudden discharge of oil from the breathers and the oil tank vent.

As a result of service experience, it has been found that, where the oil inlet temperature can be maintained between 140°-167°F. (60°-75°C.), it is desirable to use an oil of 95-105 viscosity, even in warm weather. Generally speaking, the use of the lighter oil results in better lubrication for the parts subject to wear and tends to reduce the amount of carbon deposits.

FUEL

One of the most essential considerations in the operation of an engine is the use of suitable fuel, the importance of which cannot be stressed too highly. Unsuitable fuels will not only cause overheating, but the resultant detonation will probably bring on serious damage to pistons, cylinders and other parts of the engine. The reliability of the engine and freedom from mechanical difficulty is dependent on using the proper grade of fuel for a given engine type.

Space does not permit a complete discussion of the many specifications that control our definition of a suitable fuel. For practical purposes, however, the anti-knock quality, which is expressed in Fuel Grade Designations is of primary importance. The Fuel Anti-Knock requirements are dependent on the model and rating of the engine being operated. Service experience has repeatedly shown that it is false economy to make any compromise on the quality of fuel used in high performance engines. The increase of the cost of maintenance as well as the sacrifice of the reliability of the engine operation far outweigh the small savings in the cost of fuel.

The anti-knock value of gasolines obtained from different crudes varies considerably as do their susceptibility to tetraethyl lead, and the lead content of different fuels does not necessarily qualify their octane rating.

Another important consideration in the procurement of suitable fuels is its volatility, and it is recommended that the fuel meet the Pratt & Whitney fuel specification for the particular model of engine as listed on the engine specification sheet and that no departure from this specification be made without first consulting the Service Department.

Under no circumstances should an engine be flown on a fuel whose anti-knock value is unknown. The use of a fuel of higher anti-knock than required for a given engine is preferred in case the particular fuel desired is not obtainable.

When gasoline is being poured into the tank of the airplane, extreme care should be exercised that it is kept free from foreign matter and water. There are several devices in use today for properly straining fuel and removing water and their use is advocated.

Minimum Fuel Grade Designations

Engine Model	Fuel Designations
Wasp Jr. T1B	91 Grade
Wasp Jr. SB, SB2, SB3	91 "
Wasp S1H1	91 "
Wasp S2H1	91 "
Wasp S3H1	91 "
Wasp S1H1-G	91 "
Wasp S2H1-G	91 "
Wasp S3H1-G	91 "
Hornet S1E-G, S1E2-G, S1E3-G	91 "

MAINTENANCE

To insure realizing the maximum service and efficiency from an engine, it is necessary that it be given proper care. The maximum number of hours which an engine should be operated between overhauls depends primarily upon the nature and severity of the operating conditions. General recommendations on the number of flight hours between overhauls, to serve as a starting point for maintenance procedure, are applicable only to operators who are beginning to operate new equipment with which they have had no experience. From then on, the time between overhauls is governed by the individual operator's experience. The safe procedure with new equipment is to start with a conservative time limit, such as 400 hours, then gradually approach longer periods, (preferably in increments of 15%), based on the satisfactory condition of the engine at overhaul and the service record of dependability. When an operator is considering an extension of time between overhaul periods, it is recommended that the Pratt & Whitney Aircraft Service Department be consulted. The overhauling operation should be done by a shop having personnel experienced in the overhauling of Pratt & Whitney engines and equipped with the proper facilities and tools.

An Overhaul Manual, which describes the proper procedure to be followed in overhauling the Wasp Jr. B, Wasp H1 and Hornet E Series engines, is published by the Manufacturer. When having an engine overhauled, it is essential to have the carburetor, magnetos and fuel pump overhauled at the same time.

Top overhauling—that is, the overhauling of the valve mechanism, pistons and rings—is not recommended except in case of emergency. Under normal operating conditions, where engines are overhauled at regular intervals and periodically checked and inspected in accordance with current instructions, top overhauling is an unnecessary procedure. Under unusual circumstances, when top overhauling might be considered essential, it is usually more practical and satisfactory to completely disassemble the engine in an overhaul shop to make certain that other parts of the engine have not also suffered.

If the engine is operated and maintained as described in this Handbook, trouble should not develop between overhauls, and the time spent in caring for the engine will be repaid by freedom from motor difficulties and excessive maintenance expense.

Tool Kit—A light weight tool kit, suitable for carrying in an airplane, is furnished with each Pratt & Whitney engine. The tools are in sealed canvas carrying roll with a list designating the tools contained and their uses. The tools in the kit are emergency tools required for making minor adjustments to the engine, such as removing valve mechanism, adjusting valve clearances, tightening the various external nuts, screws and bolts, removing and disassembling the spark plugs, and all operations required for periodic checks of the engine. Any additional tools which may be desired will be found in the Parts Catalog.

Periodic Inspection—The engine should be checked before each flight and at regular intervals. The following definite checks are recommended:

Before Each Flight—

1. Check Fuel and Oil levels.

2. Test ignition by running momentarily on each magneto with the propeller in the low pitch position. (The drop should not be over 100 R.P.M. at the cruising R.P.M. and manifold pressure).

3. See that the desired oil and fuel pressures show on gages.

4. See that engine will turn up its usual revolutions per minute. The revolutions per minute should be correlated with the manifold pressure with the propeller in full low pitch position.

5. Oil inlet temperature should be at least 104°F. (40°C.) before take-off, preferably 140°F. (60°C.).

6. Check the propeller to see that it is functioning properly.

It is also recommended that engines be run up just prior to take-off and the magnetos again checked, together with oil inlet temperature. This insures against the engine's having possibly loaded up, or the oil cooled down, in case the engine has been allowed to stand or idle slowly for any length of time after the above checks were made. It is further desirable to see that cylinder head temperatures have reached at least 250°F. (121°C.) before the take-off is started.

Preliminary Check—It is recommended that a new engine, or an engine which has just undergone overhaul, be given a thorough check 15 to 30 hours after installation in the airplane. This should be in accordance with Periodic Check Form, page 75. The purpose of this preliminary check is to inspect thoroughly and make any necessary adjustments after the engine has "shaken down".

50-75 Hour Check—Following the preliminary check, the engine should be checked at regular intervals. The maximum period between these regular checks will depend largely upon the operating conditions. For the average case however, it is recommended that checks be made at 60 to 75 hour intervals in accordance with the Periodic Inspection Form shown on the following page. Military engines, which are frequently subjected to severe usage, are apt to require attention more often than at 60-hour intervals and it may prove desirable to make complete checks at 40 to 50 hour periods, or oftener. Under very conservative and uniform operation, either military or commercial, it is possible to extend checking periods considerably beyond 75 hours.

PERIODIC INSPECTION FORM
50 to 75 Hour Check

Work Order No............................

Name of Operator.................................. Airplane...............

Engine No................ Total Time............ Time S.O..........

Work should be done in order listed.
Special work to be indicated in colored pencil.

1. Disconnect battery and ground plane.
2. Clean oil Pressure Strainer (Engine).
3. Drain Main Oil Sump.
4. Change Oil.*
5. Clean out rocker boxes.†
6. Grease rocker arm fittings.†
7. Fill rocker boxes with grease.†
8. Clean and adjust spark plugs.*
9. Adjust Valve Clearances.*
10. Inspect ignition harness —Ground and booster connections.
11. Inspect thermocouple connections.
12. Check nuts and screws for tightness and safe-tying.
13. Check intake pipe packing nuts.*
14. Check push rod cover tube packing nuts.
15. Check engine controls:
    Throttle
    Mixture
    Heater
    Propeller
    Oil Radiator Shutter (if used).
16. Check oil lines and brackets.
17. Inspect fuel system—clean strainers.
18. Check carburetor braces.
19. Check engine mounting bolts and fittings.
20. Check exhaust system and supporting brackets.
21. Check carburetor air scoop and heater valve.
22. Inspect propeller and control.
23. Check accessories.
24. Check fire extinguisher.
25. Check cylinder baffles and engine cowling.
26. Wash down engine.
27. Run up engine on ground.
    R.P.M. (both mags.) ....
    R.P.M. (right mag.) ....
    R.P.M. (left mag.) ....
    Idle R.P.M. ....
    Idle Oil Pressure ....
    Max. Oil Pressure ....
    R.P.M. ....
    Max. Fuel Pressure ....
    Min. Fuel Pressure ....

†For grease lubricated engines only.
*See comments under detailed instructions which follow:

Remarks ....

....

....

Signed ....

Dated..

1. **Disconnect Battery and Ground Plane**—To prevent possible fire due to accidental shorting of some electrical circuit, or from static electricity, the airplane's battery should be disconnected and the airplane positively grounded.

2. **Clean Oil Pressure Strainer**—The pressure strainer, located at the lower central part of the rear section, should be cleaned at each regular check and should be cleaned oftener if excessive carbon deposit indicates the desirability. Particular care should be exercised in removing the strainer to see that the upper oil seal ring does not remain in the oil system. It is also very important to see that the oil screen cover gasket is in good condition before reinstalling the screen and cover, and it is even good practice to install a new gasket each time the oil screen cover is removed.

Caution: Make sure that the rubber oil seal is correctly positioned between the **check valve assembly** and the **screen** body when strainer is reinstalled.

3. **Drain Main Oil Sump**—Upon removing the sump plug, examine its cavity for signs of metal particles or other foreign matter. Normally, very little sediment collects in this plug, but it is the lowest point of the engine oil system and any foreign particles usually deposit there. If metal chips are found, they are a possible indication of trouble within the engine and further investigation should be made. If the chips are numerous, it is advisable to remove the sump screen and examine for more, and the source should be determined, if possible. In a new installation, the oiling system is not always entirely cleaned of metal particles and, in such cases, there is not necessarily cause for alarm when particles appear in the sump plug. If nothing wrong can be found after foreign matter is discovered in the sump plug, it is advisable to check the plug again after the engine has been given a ground test.

4. **Change Oil**—The oil does not necessarily have to be changed at each check and it is frequently satisfactory to change it only at every other check, where the appearance of the oil and freedom from sludge and carbon indicate the feasibility. The type of operation has considerable bearing on the frequency of oil

changes. When the oil is drained, be sure to drain the sump and clean the oil pressure strainer.

Use only an oil which is approved by Pratt & Whitney Aircraft. (See page 68.)

5. **Clean Out Rocker Boxes (Grease Lubricated Engines Only)**—Remove all old grease and any foreign matter which may have collected in the rocker boxes.

6. **Grease Rocker Arm Fitting (Grease Lubricated Engines Only)**—When greasing the rockers, it is advisable to turn the crankshaft so that the piston is at the top of the compression stroke of the cylinder being greased. This allows grease to reach the ball end of the push rod and the adjusting screw since neither is under pressure. At the same time the fittings on the exhaust rocker boxes should be greased. The top five cylinders require half again as much grease as the lower cylinders due to the tendency of the lubricant to drain down the push rod cover tubes. Normally inlet rocker boxes require half as much grease as the exhaust rocker boxes.

In order to obtain the best results, the grease gun should be used after every 5 hours of flight. If conditions permit, it is advisable to use the gun after every flight.

The extent of wear to the valve mechanism is dependent on the frequency and thoroughness of lubrication.

7. **Fill Rocker Boxes with Grease (Grease Lubricated Engines Only)**—The proper method of taking care of grease lubricated rocker boxes depends on the service conditions. In hot climates it is feasible to use a rather heavy non-fluid oil in the rocker boxes with good result. The space around the valve springs and rocker arms can be filled with this material so that rusting of the springs is prevented and lubrication is provided for the valve stem and guide. It will soon be learned by experience how much lubricant to apply each time the gun is used in order to maintain the proper supply in each rocker box. In cooler climates, it is not usually advisable to use as stiff a lubricant as the above nor to keep as much of the lubricant in the rocker boxes. In extremely cold climates a heavy engine oil is recommended.

The most suitable lubricants for the valve mechanism are heavy mineral oils or non-fluid mineral oils of 2000 to 3000 seconds. Such lubricants as No-Oxide-E, No-Oxide EEE, Stanavo Rocker Arm Grease No. 2, Texaco Star Grease No. 3, Texaco Marfak No. 2, Richlube, Shell No. 3, Shell No. 4, Kendall Aircraft No. 11, Mobile Grease No. 2, Pennzite No. 42 Rocker Box Grease, Atlantic Rocker Box Grease, Penna. Lubricating Co. No. 5834, Sun Rocker Arm Brg. Grease, Deep Rock Rocker Box Grease, Thurmar Grease, Amalie A-200 lubricant or some lubricant of equal consistency have been found satisfactory under some conditions of operation. It will be necessary for the operator to determine by experience what lubricants best meet his operating conditions.

Note: On some Wasp Jrs., a **manually operated pressure lubricated system** has been incorporated using engine oil for the lubrication of the rocker boxes. At the first running-in of an engine incorporating this system, it is advisable (when the oil temperature reaches 100°F.) to open the control valve for approximately one-half minute, or until white smoke starts to come from the exhaust stacks.

During the flight operation, it is desirable to open the valve for 10 seconds every hour or preferably 5 seconds every half hour.

Caution: Never exceed one hour without opening valve.

8. **Clean and Adjust Spark Plugs**—It is very seldom necessary and definitely undesirable to completely disassemble spark plugs at every periodic inspection. Under normal conditions, such as schedule operation where control is rigidly maintained, the following service procedure is recommended:

Spark plugs should be installed in the engine as received, and operated until the tips of the center electrodes have been reduced to approximately the manufacturer's specified minimum diameter or the ground electrodes to the minimum thickness, being removed only for inspection at the prescribed periods and serviced as outlined in this section. Before installing the plugs, a light coat of mica lubricant should be applied to the threads, and before screwing the plug into the cylinder, inspect the spark plug bushing threads to make sure they are absolutely clean. Use fully annealed solid copper gaskets that are in good condition. Do not use old gaskets which have become hard, distorted, or burred from previous service. Care should be exercised in preventing excessive force being used when tightening the plugs in the cylinder. The pressure exerted should not exceed 450 inch pounds (approximately 37 foot pounds) when cold.

Spark plugs which are removed from the engines at the prescribed inspection periods can usually be serviced by the following maintenance procedure without being disassembled.

Lightly brush the threads and end of the shell using a soft wire brush. Do not use excessive pressure as it will tend to round off the electrodes.

Inspect shell threads for nicks and burrs. Chase with 18 mm. die when necessary.

Inspect top barrel threads for nicks and burrs. Chase with 9/16″-27 or 5/8″-24 die when necessary.

Thoroughly rinse the electrode end of the oily plugs in clean, unleaded gasoline. Do not hold the plugs immersed in the gasoline and if they are not coated with dirt or oil film, this operation may be eliminated. The blackened appearance at the end of the plug in the absence of heavy oil or lead deposit is not detrimental to its operation. This is acquired after a few minutes of operation in the engine. Permit the plugs to dry thoroughly after rinsing.

Clean the inside of the upper shielded barrel. For this operation, use a small piece of soft cloth wound on a wooden stick dipped in clean, unleaded gasoline.

If time permits, it is desirable to bake all plugs in an oven at 300°F. to 350°F. (149°C-180°C.) for a period of two hours or more, to remove possible moisture.

Set the gaps to the recommended .012″ clearance, using a flat narrow width thickness leaf gage.

Check the electrode gaps, using a wire feeler gage.

Bomb test all spark plugs set at .012″ gap, at 200 lbs./sq. in. For this purpose use CO_2. Air may be used where an adequate and dependable supply of dry, high pressure air is available.

This procedure is to be repeated at each period until the limiting factors outlined previously are reached, at which time those makes of spark plugs which can have the center electrodes retipped or new shells to replace the ground electrodes installed, should be returned to the manufacturer. Otherwise the plugs should be discarded as unserviceable.

In the event that the conditions of operation are such that spark plugs require further reconditioning by the operator, the following procedure should be followed:

Disassembly—Spark plugs should be disassembled, using snug-fitting socket wrenches. Open end wrenches should never be used as they are liable to slip and cause damage.

If the threads securing the core and shell together have a tendency to bind during the disassembling procedure, do not attempt to force the threads. Place the plugs in a rack, electrode end up, and pour a very small quantity of penetrating oil in the firing chamber. Place the plugs in a heat regulated oven with a temperature maintained to between 150°F.-200°F. (65°C.-93°C.) for at least twenty-four hours. This procedure will facilitate the disassembly in most cases. If difficulty is still experienced, it may become necessary to scrap the parts.

Shell Assembly—Where large quantities of shells are being serviced and the facilities are available, removal of carbon and lead deposits is best accomplished by placing the shells in a heated salt bath, or a similar preparation which is recommended by the manufacturer. In small quantities, they may be soaked in clean, unleaded gasoline to remove the oil and carbon. Hard carbon and lead deposits may be removed with a knife or round wire brush. A small wad of steel wool wound on a drill and used in a lathe or drill press chuck is also effective in cleaning the inside of the shell. Care should be taken to prevent damage to the internal threads, the core gasket seat, and electrodes.

Rust may be removed by dipping in a 10% solution of sulphuric acid at 120°F. (49°C.) for a few minutes and then rinsing in cold running water. After drying, coat the shells with a light oil, or suitable rust inhibitor.

All shells should be inspected for damaged hexagons, condition of the electrodes and burred threads. Damaged threads should be cleaned up with a tap or die, or in some cases with a file.

When the shell electrodes are burnt away in excess of the manufacturer's limit and can no longer be properly adjusted, they should be discarded and new shells used. On some makes, new electrodes may be inserted, as long as the shell is in otherwise good condition.

Core Assembly—Check the core assembly for defects. If the 9/16″-27 or 5/8″-24 elbow attaching threads at the shielded end of the plug are crossed or badly damaged, the core should be scrapped inasmuch as there would not be positive assurance that the elbow would be secured firmly in place. Small nicks or burrs can be cleaned up by running a die over the threads, or with a toolmaker's file.

Check the mica insulation in the upper barrel for defects, such as deep scratches or gouging. Minor scratches or gouging may develop trouble later on. A definite crack in the insulation should be cause for rejection. Remove all traces of dirt, oil, etc. from within the shield barrel. A small round wooden stick, or dowel, with several layers of clean cloth wrapped around it and dipped in clean, unleaded gasoline proves effective for cleaning the inside of the barrel.

Examine the core threads for nicks, pitting, forms of corrosion, or mutilation. Small nicks or pits can usually be stoned out or removed with a fine toolmaker's file. Threads which are badly scuffed during disassembly are cause for rejection. Corrosion, if not too severe, may be tolerated. Check the amount of metal left on the center electrode shoulder in accordance with the manufacturer's instructions, and if worn in excess of the manufacturer's limit, the core should be scrapped.

To remove the lead deposits which have accumulated on the mica core nose, it is recommended that the core be inserted in a motor driven cleaning socket and revolved at a speed of approximately 1750 R.P.M. Sockets for the various plugs should be obtained from the respective spark plug manufacturers. Preferably grade No. 180 Aloxite cloth should be used for this process. However, No. 00 sandpaper will also serve the purpose. Lead deposits are not of uniform hardness or equally distributed; hence it is possible that some sections on the core nose may offer greater resistance to removal than other sections. For this reason, the operator is cautioned not to exert too much pressure on the cloth in the early stages of cleaning. Following the removal of the carbon, lead deposit, etc., polish the mica using No. 300 Aloxite cloth or No. 000 Crocus cloth in order to obtain a smooth finish. The operator is cautioned not to remove any more mica insulation than is absolutely necessary to obtain a clean and well-polished core nose. Never use emery or carborundum cloth or paper, steel wool, file or sand, since particles from these materials might effect the plugs in the event that they become imbedded in the mica insulation. Sandblasting is too harsh on mica insulation and would wear away the insulation at a rapid rate.

Care should be taken during the core nose cleaning operation to prevent unnecessary wear of the center electrode tips.

If there is sufficient metal left upon the center electrode tip, it can be rounded up by inserting the core in the chuck of a motor-driven lathe and turning down the tip. Only enough material to obtain a smooth finish should be removed. The tip should be rechecked for contour after this operation.

On certain types of plugs, it is possible to retip the center electrodes when worn to an extent that they exceed the manufacturer's limits. In this respect, the manufacturer should be consulted.

Examine the clean mica core nose surfaces for pits, burned areas, or unusual wear. Evidence of any one of these defects should be cause for rejection. Check the diameter of the core nose, using the gage provided by the manufacturer. If the mica diameter adjacent to the core tip passes through the narrow part of the opening in the gage, the insulation has worn away beyond the safe point and is cause for rejection.

Assembly—Using mica lubricant sparingly, on the lower threads, assemble the core into the shell of the plug. Normal tightening is sufficient. Overtightening will only distort the core and perhaps damage it. The manufacturer of the particular spark plug should be consulted for the torque limit which generally is never in excess of 350 in. lbs.

Bomb Test—After assembly, the spark plugs should be tested in a pressure tester or bomb test at 200 lbs./sq. in of CO_2. Air may be used providing special precautions are taken to exclude any moisture.

All new or reconditioned spark plugs should fire regularly across the .012″ gap at 200 lbs./in.^{2} pressure. The duration of the test should be approximately fifteen seconds. If any plugs fail to fire consistently at this pressure, there may be a possibility of moisture having collected on the core nose or in the shield chamber. Place such plugs in a heat regulated oven and bake them for approximately two hours at 250°F. to 350°F. (121°C. to 177°C.). Retest them after they have cooled sufficiently for handling. If they still fail to fire consistently after the operator has assured himself that the test equipment is operating satisfactorily, and that the flash-over is not occuring within the shield chamber, the plug is short-circuited and should be rejected.

Practice is required to determine when a plug fires regularly in a bomb. With some types of plugs, the spark "hunts" from one electrode point to another, firing across the point having the least resistance at the instant. To an inexperienced operator this hunting might appear to be a "miss".

To avoid the effects of moisture, spark plugs should always be stored in a dry place. This is particularly important during the winter periods or damp weather. A cabinet, or a box, heated with one or more 100 watt electric light bulbs provides a suitable storage place.

9. **Adjust Valve Clearances**

Note: It has been demonstrated in service that it is usually quite satisfactory to operate Wasp H1 and Hornet E engines, as well as Wasp Jr. engines with fully automatic valve gear lubrication, for the entire period between overhauls without adjusting the valve clearances or inspecting the valve operating mechanism. The valve clearances of grease lubricated engines should be checked as frequently as indicated desirable through the experience of the individual operator. Checks should be made at 50-hour periods at the start, then the periods may be extended if the condition of the valve operating mechanism justifies it. With frequent and careful greasing, a good lubricant and normal operating conditions, the valve clearance check periods can be extended considerably beyond 50 hours. Where the valve action is lubricated by oil, but not by a fully automatic system, it is usually necessary to check valve clearances at least twice during a 500 to 600-hour run.

When adjusting valves, make sure that the engine is thoroughly cool. Both the exhaust and intake valves are adjusted to a cold clearance of .010″ between the valve stem and the valve adjusting screw. After removing the rocker box covers and at least one of the spark plugs from each cylinder, turn the engine crankshaft in a counterclockwise direction until the No. 1 piston is at the top dead center of the compression stroke. Insert a .010″ feeler gage between the valve stem and the ball end of the adjusting screw, then, loosen the valve adjusting screw lock nut and adjust the screw until the feeler indicates the proper clearance has been obtained. Retighten the adjusting screw lock nut being careful not to turn the screw. The lock nut should be tightened snugly with the Wrench PWA-1075 furnished in the engine tool kit, however, an excessive pressure should not be exerted as such will preload the adjusting screw and thus create a potential failure of the part. **Do not strike the wrench with any object while locking the nut.** The clearance of the valve should be rechecked after the nut has been tightened.

When the valves of cylinder No. 1 have been adjusted, check the valves of the remaining cylinders in the same sequence as the firing order (1-3-5-7-9-2-4-6-8) and in the same manner as that outlined for No. 1 cylinder. It is important that the piston of each cylinder be at the top dead center of the compression stroke when the valves of that cylinder are checked.

The following applies to Wasp H1 and Hornet E engines only:

After all the valves have been adjusted, the crankshaft should be rotated two complete revolutions and the clearances rechecked. Any clearances which have decreased to less than .010″ should be readjusted; any clearances which may have increased should be disregarded.

When the rocker box covers are reinstalled upon completion of the valve check, the condition of the gaskets should be noted and any which may be in poor condition should be replaced. It is important to have these gaskets in good condition, else serious oil leakage may result. If rocker box covers have become distorted, they may be refaced by lapping them on a surface plate with a coarse lapping compound. The rocker box cover nuts should be reasonably tight, but not tight enough to distort the covers. A torque of 75-85 inch-pounds is recommended for tightening these nuts.

10. **Inspect Ignition Harness-Ground and Booster Connections**—Examine the ignition harness for loose connections and for chafing of the radio shielding. Check the spark plug lead cable ends and terminal sleeves for burning or other damage. Make sure that the terminal sleeves are wiped dry and are not scratched or cracked before connecting them to the spark plugs. Care should be exercised to prevent damage to the terminal sleeves while disconnecting or connecting them at the spark plug. The sleeves should not be touched with the fingers after they have been wiped dry as oil, acid, dirt, etc. will tend to cause flash-over and eventual failure of the sleeve. The repeated installation of dirty sleeves in a spark plug is apt to result in contamination of the mica insulation on the inside of the plug barrel and eventually cause faulty operation.

Make sure that all magneto ground connections are secure and that there are no loose terminals. The ground wires should be checked back to the ignition switch for tightness of connections. Booster wire cable and connections should be examined.

11. **Inspect Thermocouple Connections**—Examine thermocouple leads and connections for breakage and tightness.

12. **Check Nuts and Screws for Tightness and Safetying**—Go over engine carefully and check for loose nuts or palnuts and broken safety wire. Look for oil leaks as such are likely to indicate loose connections, packings or nuts.

13. **Check Intake Pipe Packing Nuts**—Inspect for evidence of leakage or chafing at the intake pipe packing nuts. Unless clear gasoline is used, intake pipe

leaks are usually apparent due to a slight deposit of dye around leaking or chafed portion. Intake pipe packing nuts and flanges should be snug but not excessively tight. Excessive tightening will tend to neck the pipes and disturb the packing by unnecessary turning of the packing nuts.

14. **Check Push Rod Cover Tube Packing Nuts**—The instructions for checking intake pipe packing nuts also apply to push rod cover tube packing nuts.

15. **Check Engine Controls**—All engine controls should operate freely without lost motion and should be properly safetied. The movement of one control should in no way cause motion of any other control. The positions and travels of the controls should be checked at the engine and in the cockpit to insure that they are registering properly in the cockpit; this is particularly important in the case of the carburetor mixture control. Oil the clevis joints and other bearing parts where desirable.

16. **Check Oil Lines and Brackets**—All hose clamps and connections in the oil lines should be checked for leakage and tightness. Insure that there is some adjustment left in the clamps after they have been securely tightened. When there is no more adjustment left in the hose clamps, the entire connection should be renewed. Check supporting brackets for cracks and tightness.

17. **Inspect Fuel System—Clean Strainers**—Any traps in the system should be cleaned, and one pint of gasoline drained from the sump of each fuel tank in the airplane. This is for the purpose of removing sediment or water that may have accumulated in the lowest point or points of the lines or tanks. Clean the carburetor strainer.

In checking fuel lines for leaks, it is good practice to build up pressure with the hand pump. Inspect for any abrasions or interference with other members of the installation. Check support brackets and clamps for chafing, looseness or wear. The dye in leaded gasoline will usually give evidence of any fuel leaks.

18. **Check Carburetor Braces** (If provided)—See that the carburetor braces are not cracked, and are tight and properly fastened.

19. **Check Engine Mounting Bolts and Fittings**—Check for any indication of looseness at the engine mounting bolts. When the bolts are tightened, a torque of 400 inch-pounds should be applied.

20. **Check Exhaust System and Supporting Brackets**—Examine the exhaust system for cracks and excessive burning. Check to see that the slip joints are free. Check all connections for tightness and check supporting brackets for rigidity and tightness. If cockpit or cabin heat is furnished by an exhaust manifold type of heater, make sure that heater tubes have not burned through, or become damaged or loose and that there is no possibility of exhaust gases becoming mixed with the heated air. Inspect for blown gaskets at exhaust ports of cylinder head.

21. **Check Carburetor Air Scoop and Heater Valve**—See that the air scoop is tight and that the valve for regulating the temperature of the air in the scoop is in good condition and can be properly controlled from the cockpit. See that exhaust gases are not leaking into the carburetor hot air system.

22. **Inspect Propeller and Control**—It is improbable that the propeller will have to be removed for servicing between overhauls. If this becomes necessary, however, refer to the instructions issued by the propeller manufacturer. See that the blades are free from sharp nicks which might result in cracks. Check the propeller governor, if provided, for oil leaks and see that the control from the cockpit is free and does not have excessive backlash.

23. **Check Accessories**—Make any desirable checks on the vacuum pump, hydraulic pump or other accessories, as recommended by the respective manufacturer.

24. **Check Fire Extinguisher** (If provided)—Check fire extinguisher lines and control and note any instructions which the manufacturer has recommended for maintenance of the unit.

25. **Check Cylinder Baffles and Engine Cowling**—See that cylinder baffles and attaching brackets are free from cracks and are mounted securely. Make sure that the brackets have not worn into the cylinder barrels. Check engine cowling for cracks or other damage and make necessary repairs. See that all cowling is securely fastened.

26. **Wash Down Engine**—Washing down the engine may be done at the operator's discretion. It is, of course, desirable to keep the engine clean to facilitate inspection, as well as for the sake of appearance. White furnace oil, or the equivalent, is suitable for this purpose and may be sprayed on the engine, but great care should be exercised to prevent the cleaning fluid from being forced into the ignition harness.

27. **Run Up of Engine on Ground**—See Operations Chapter, page 42, for the proper procedure and precautions for ground running of the engine.

MAGNETOS

The magnetos seldom need attention between overhauls. Under normal conditions, the wear or burning of the contact breaker points is balanced by the wear on the cam follower; therefore, the spark timing remains at approximately its original setting. A faulty condenser or deposits of oil or grease on the breaker points will cause excessive burning of the points; lack of lubrication on the cam will result in excessive wear of the cam follower. If the wear at one of these locations exceeds the wear at the other, a change of spark timing will result. An appreciable change of spark timing will be indicated by an excessive drop in R.P.M. or fluctuation of engine speed, when the engine is checked on each magneto singly. When such an indication occurs, **after the spark plugs and ignition harness leads and connections have been examined,** the magneto breaker points should be inspected and the timing checked.

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

Reconditioning Contact Breaker Points—Unless the breaker points are oily, dirty or badly pitted, do not disturb them. If it becomes necessary to remove and clean the points, remove the breaker assembly, then disassemble the contact points. Clean the contact points with gasoline or any cleaning fluid; remove high

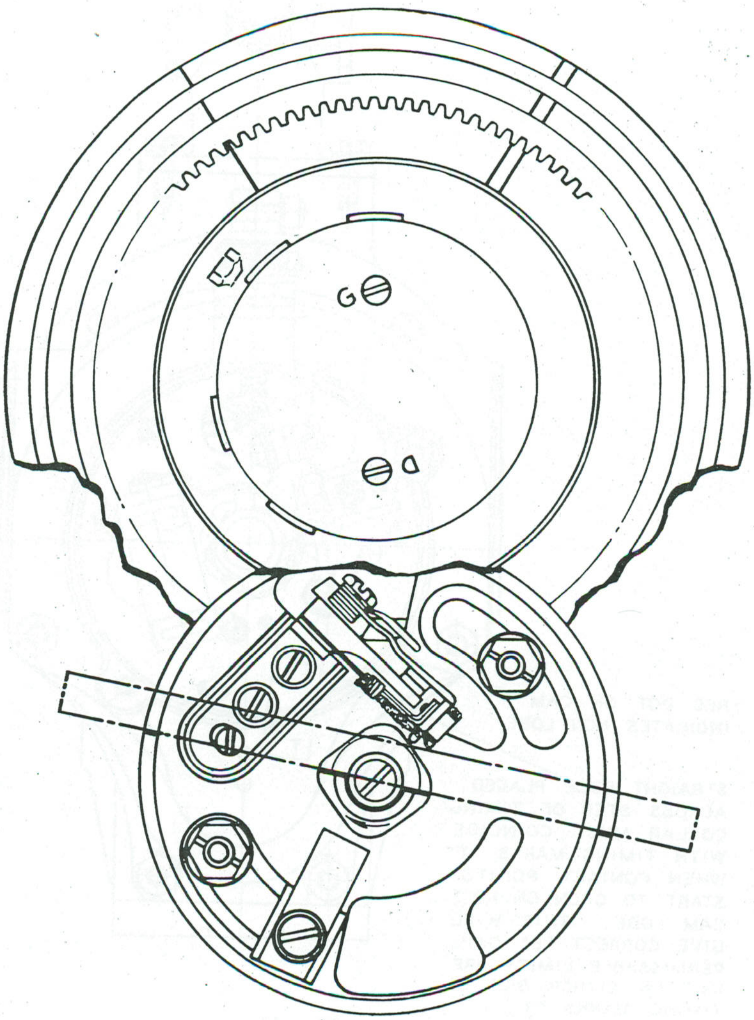


Fig. 10

Rear View of Scintilla SB9R Magneto Showing Timing Marks

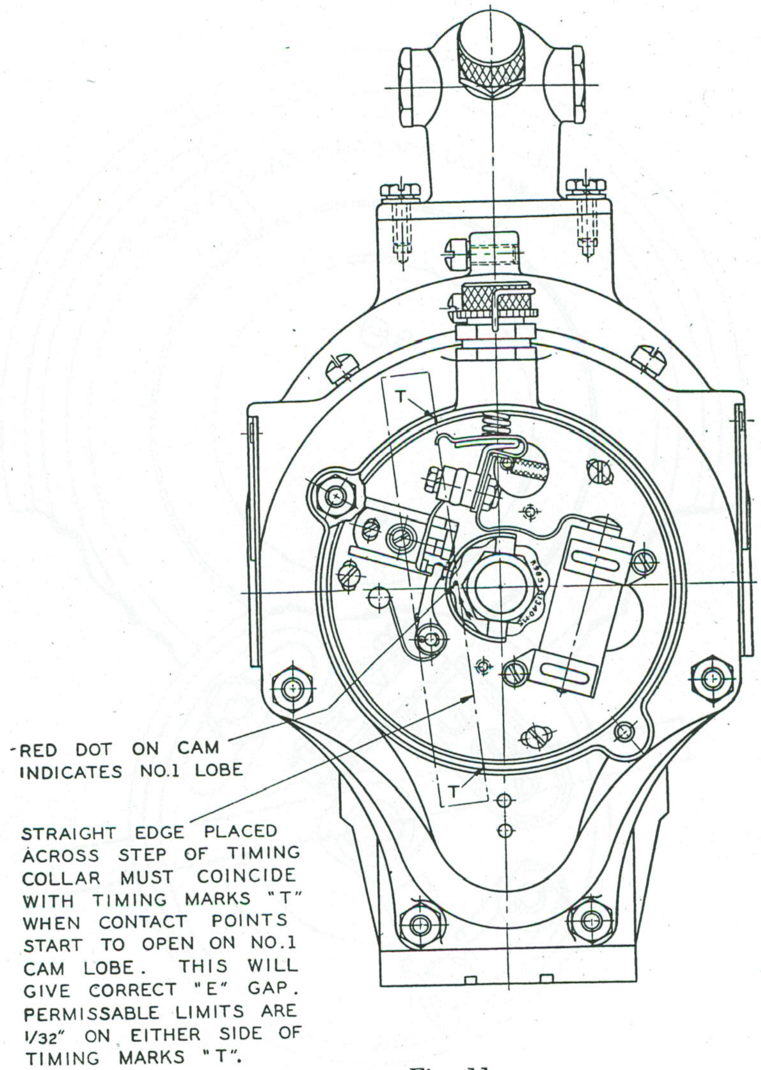


Fig. 11

Rear View of American Bosch SB9RU-3 Magneto Showing Timing Marks spots with an oil stone or with No. 400 to 600 "Wet-or-Dry" paper. (Do not use emery cloth.) Reinstall and adjust as described in the following paragraphs.

Adjusting Contact Breaker Points and Checking Magneto Timing—In considering the matter of timing, there are two timing operations. First, the magneto is timed to its own marks by adjusting the contact points. Second, the magnetos are synchronized on the engine by setting the magnetos so that the contact points break simultaneously on the timing marks.

Scintilla Magnetos—The contact points must always be adjusted to open at the proper position of the cam in relation to the timing marks at the breaker end of the magneto and not for any fixed clearance between the contact points. If the points are breaking at this position, the clearance between the points will automatically be cared for. The method of adjustment is as follows:

Turn the propeller shaft until the timing mark on the distributor finger is in alignment with the timing mark on the distributor housing and a scale or straight edge placed on the flat step on the breaker cam is in alignment with the two marks on the breaker housing. (See Figure 10.) In this position the breaker contacts should be just opening to fire cylinder No. 1.

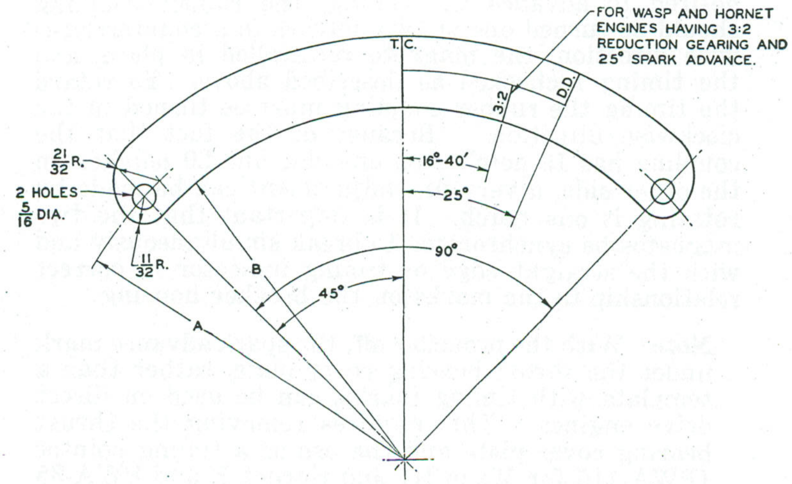
If the straight edge, which has been placed on the flat step of the breaker cam, is more than 1/8″ out of alignment with the markings on the breaker housing the contact points should be adjusted so that they open when the straight edge is in alignment with the marks. To make this adjustment, hold the cam in a position to open the contacts, as indicated by the straight edge; loosen the two locking screws in the plate which holds the breaker in place, and adjust the opening of the breaker contacts with the eccentric adjusting screw. After the adjustment has been made, tighten the two locking screws.

American Bosch Magnetos — The contact points should always be adjusted so that they are about to open when a straight edge placed across the cam step lines up with the registering marks 'T' on the breaker housing and when the cam follower is on No. 1 cam lobe (indicated by a red dot). The contact points are initially set at .009″ to .010″ when they are fully open and under normal conditions should never have to be reset, between overhauls, solely to correct gap clearance. The method of adjusting the contact points for the proper opening position is as follows: (See Fig. 11.)

Turn the propeller shaft until the straight edge placed across the cam step lines up with the registering marks 'T' on the rim of the breaker housing. Loosen the adjustable contact locking screw and shift the contact bracket by turning the eccentric screw until the contact points are in such a position that the slightest movement of the propeller in a counterclockwise direction will open the points.

Checking Timing and Synchronization of Scintilla and American Bosch Magnetos—After completing the foregoing procedures for each make of magneto, connect a timing light across the points (or insert a .0015″ feeler strip between the points). Turn the propeller shaft about 90° in a clockwise direction, then back in the counterclockwise direction until the timing light just goes out (or the feeler strip is just released). This should occur when the straight edge against the cam step falls in line with the marks on the breaker housing.

To check the timing of the magnetos to the engine, turn the propeller shaft in the counterclockwise direction until No. 1 piston is at the exact top center of its firing stroke. Attach a template made up in accordance with Figure 12 to the nose section or reduction gear housing of the engine at the two top holes which are provided for attaching cowling brackets. Improvise a timing pointer by fastening a stiff piece of wire securely to the propeller shaft, or propeller hub, and line up its end with the top center mark on the template. Then turn the propeller shaft about 90° in the clockwise direction, after which it should be turned back gradually in the counterclockwise direction, by jarring the propeller blade with the hand, until a timing light connected across the points (or the tension on .0015″ feeler strip between the points) indicates that the breaker points of the magnetos have just started to open. The points should be just starting to open as the timing pointer reaches the proper spark advance mark on the template.



MODEL	A	B
WASP JR.	$4\frac{1}{4}$	$3\frac{29}{32}$
WASP H1	$4\frac{7}{16}$	$4\frac{3}{32}$
WASP H1G	$4\frac{1}{2}$	$4\frac{5}{32}$
HORNET EG	$4\frac{25}{32}$	$4\frac{7}{16}$
HORNET E2G	$4\frac{25}{32}$	$4\frac{7}{16}$
HORNET E3G	$5\frac{1}{8}$	$4\frac{25}{32}$

Fig. 12

Timing Template

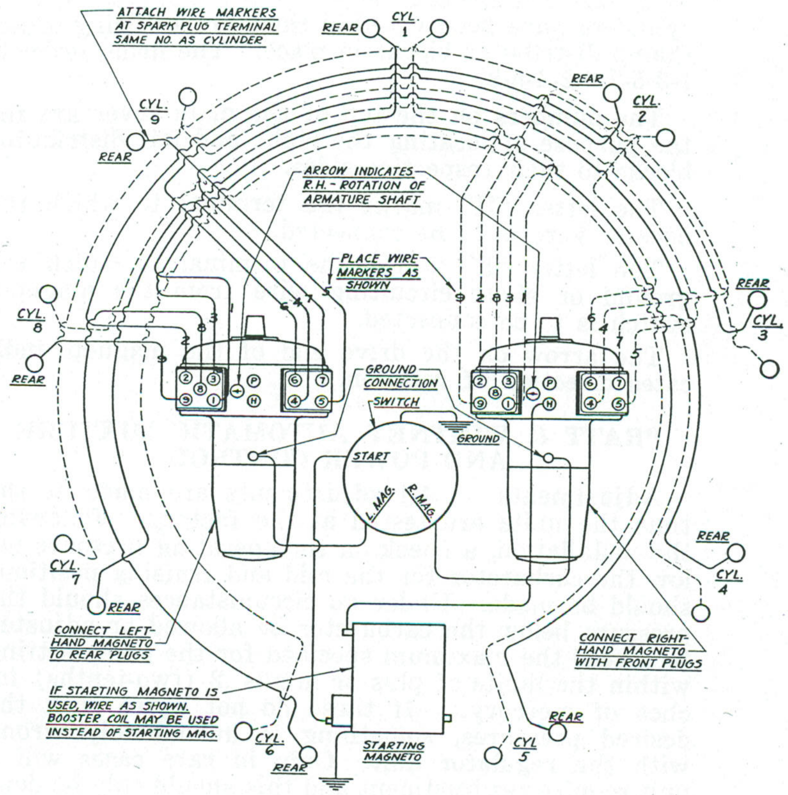
If the timing of one or both magnetos to the engine is incorrect, it will be necessary to remove the cap screws which attach the incorrectly timed magneto to its mounting pad and move the magneto away sufficiently to turn the rubber drive coupling. If it is desired to advance the timing, the rubber coupling should be turned one or two notches in a counterclockwise direction, the magneto reinstalled in place, and the timing rechecked as described above. To retard the timing the rubber coupling must be turned in the 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 straight edge or timing indicator in correct relationship to the marks on the breaker housing.

Note: With the propeller off, the spark advance mark under the thrust bearing cover plate, rather than a template with timing marks, can be used on direct drive engines. This requires removing the thrust bearing cover plate and the use of a timing pointer (PWA-115 for Wasp H1 and Hornet E and PWA-85 for Wasp Jr.). On geared engines, the timing mark is stamped in the bearing support plate under the reduction gear housing, making it necessary to remove the housing and reduction gear assembly to use this mark for timing purposes. The general procedure for checking timing with the reduction gearing removed is the same as previously described when using a template with the propeller installed except that Timing Pointer PWA-535 is attached to the reduction gear driving gear, and the spark advance mark on the bearing support plate, or anchor plate, is used for reference.

WIRING

The numbers on the distributor blocks show the serial firing order of the magneto, not the firing order of the engine.

The wiring diagram is shown in Fig. 13. Wires lead from the magneto so that No. 1 on the distributor blocks connects to No. 1 or the first cylinder in the firing order of the engine, while No. 2 on the distributor



VIEW LOOKING AT MAGNETO END
FIRING ORDER—1-3-5-7-9-2-4-6-8

Fig. 13

Wiring Diagram

blocks connects to the second cylinder in the firing order of the engine, which is No. 3. No. 3 on the distributor blocks connects to the third cylinder in the firing order of the engine, which is No. 5, etc., until all cylinders have been wired in their proper firing order. Clamp distributor blocks in place. The firing order is 1-3-5-7-9-2-4-6-8.

The numbers on the top of the main cover are for the purpose of locating the right and left distributor blocks to their respective sides.

The letter "H" marks the terminal to which the booster wire is to be connected.

The letter "P" marks the terminal to which the ground or short circuiting wire from the magneto switch is to be connected.

The arrow on the drive end of the magneto indicates direction of rotation.

PRATT & WHITNEY AUTOMATIC MIXTURE AND POWER CONTROL

Adjustments — All adjustments are made at the time the units are tested at the factory. Following the installation, a check on the operating pressure below the carburetor for the mid and cruising positions should be made. Under no circumstances should the pressure below the carburetor be allowed or adjusted to exceed the maximum specified for the given setting within the limits of plus or minus .2 (two-tenths) inches of mercury. If these do not agree with the desired pressures, something is undoubtedly wrong with the regulator unit. Only in rare cases will a unit require readjustment and this should only be done by specially trained personnel.

To check the automatic mixture control unit while installed on the engine, the following procedure should be carried out:

1. Connect a calibrated manifold pressure gage to the fitting on the carburetor provided for this purpose. This fitting is located on the accelerating pump side of the carburetor near the parting section and automatic mixture regulator flange.
2. Put selector valve in position that requires checking or adjustment. Rev up engine until

gage reaches a point where there is no change in pressure for an increase in throttle opening. This will be the pressure to which the automatic unit is regulating. Adjust carburetor inlet temperature to 90°F. and be careful not to allow the cylinder temperature to exceed 400°F. (205°C.).

3. Perform adjustments as outlined in Chapter XVII of Overhaul Manual.
4. Check air control valves when selector valve is in the emergency position, to be sure they open **fully.**

Note: Carburetor Air Pressure is the pressure below the carburetor which is independent of R.P.M. above approximately 1200 R.P.M.

Manifold Pressure is the pressure in the induction system which varies with the R.P.M. of the engine.

The carburetor is of the fixed jet type, the proper jet sizes having been determined and tested in each carburetor. Under no circumstances should these be changed without first consulting the factory.

ADJUSTMENT OF PRATT & WHITNEY AUTOMATIC VALVE LUBRICATOR

For Wasp Jr. engines having the **Pratt & Whitney Automatic Valve Lubricator** the amount of oil supplied to the rocker mechanism may be adjusted as follows:

Located on the head of the automatic metering pump is a scale for the adjustment of oil flow to the rocker mechanism. When first installing this pump on an engine it has been found that the mark on the sliding plate should be set as a point somewhere between one (1) and one and three-quarters (1¾) on the scale. However, this may not be a permanent setting, but may be used during the first engine test after the installation of the unit. As a precaution, it is well to remove the rocker box covers after about ten (10) minutes of running to determine if sufficient oil is being furnished to the rocker mechanism in each cylinder. If an over-supply is being furnished, which is likely to cause slight smoking from the exhaust, it may be overcome by setting the pointer at a lower position on the scale. If there is not enough oil found in the rocker boxes, that is if the springs, washers and rockers are not moist with oil, adjustment should be made toward the higher end of the scale.

Other than the adjustment of this unit at the time of installation which is described above, no further attention is required between overhaul periods.

CYLINDER REMOVAL

Whereas top-overhauling of an engine is not recommended (see page 72), it may become necessary to remove a cylinder for inspection or other purposes. The following paragraphs contain the necessary instructions for performance of this work. When other than original cylinders or piston assemblies are to be installed, the Overhaul Manual should be referred to regarding the lapping of piston rings.

Removing Cylinder From the Engine

1. Remove a sufficient number of cowling sections to make the cylinder readily accessible.

2. Remove all front spark plug lead elbows from the spark plugs and remove the front spark plugs. Remove the rear spark plug elbow and the rear spark plug from the cylinder to be removed.

3. Turn the propeller shaft until the piston of the cylinder to be removed is on top dead center of the compression stroke. Unscrew the nuts which fasten the exhaust stack or piping to the cylinder exhaust port and remove the pipe. This procedure may be modified to accommodate the particular installation.

4. Remove the pressure baffles from both sides of the cylinder. These baffles are held in place by a butterfly clamp which is positioned between a pair of cylinder barrel fins. On engines employing cylinder head baffles, the inter-cylinder baffles are also secured to these either with bolts or with spring latches.

5. Loosen the push rod cover gland nuts, using either PWA-439 or PWA-550 Wrench. Loosen and remove the rocker box covers. On early engines the covers are held in place by a spring clamp which is released by movement of the eccentric lever forming part of the clamp. On later engines the covers are held in place with three fiber lock nuts which may be removed with PWA-658 Wrench, (or a 7/16″ socket wrench).

6. Depress the valves, using PWA-455 Depressor and remove the push rods and cover tubes.

7. Remove all primer lines, lubricator oil pipes (if used), etc. which are fastened to the intake pipe and remove the pipe. Loosen the packing nut on the blower end of the pipe with PWA-237, Wrench for Wasp Jr. engines or PWA-144 for Wasp and Hornet engines. Remove the two nuts and the cap screw which attach the flange at the cylinder port.

Caution: The intake pipe is constructed of thin gage aluminum which is easily dented or damaged if not handled carefully.

8. Loosen clamps or wrap locks which secure the hose connections of the inter-cylinder oil pipes and slip the hose connections to one side. If the No. 1 cylinder is being removed on engines having an automatic valve lubricator, this procedure will also apply to the hose connection which joins the oil pipe at No. 1 cylinder to the oil supply pipe from the lubricator unit.

9. Remove the cylinder hold-down nuts, using PWA-186 Wrench and pull the cylinder from the engine.

Caution: If the master rod cylinder is to be removed, arrange to hold the master rod in the center of the crankcase opening so it cannot turn to either side upon removal of the cylinder. This may be done by rigidly blocking the master rod. If the master rod is permitted to move sidewise, the scraper rings on some of the other pistons will come out of the cylinders and seriously damage the piston and skirt of these cylinders.

10. Remove the piston pin and piston from the connecting rod. If difficulty is experienced in pushing out the piston pin, the head of the piston should be slightly heated and then the pin lightly tapped out, using PWA-12 Drift. When using the drift to remove a piston pin, the connecting rod in which the pin is fitted should be supported to relieve the strain.

11. Block the openings in the crankcase and blower section to prevent the entrance of foreign material.

Note: If several cylinders are to be removed, the master rod cylinder should be removed last and installed first. The master rod cylinder is No. 7 in Hornet engines and No. 5 in Wasp and Wasp Jr. engines.

Cylinder Disassembly

1. Place the cylinder over a wooden block having the same contour as the dome of the head to hold the valves in place while removing the locks and springs.

2. Remove the cylinder head baffle, if present.

3. Compress the valve springs with PWA-459 Compressor and remove the split locks from the valve stems. Then remove the upper valve spring washers, valve springs and lower washers.

4. Remove the safety circlets from the valve stems.

Caution: Use a blunt-ended flat piece of dural to prevent mutilating the circlet and lock grooves.

5. Remove the cylinder from the wooden form and remove the valves from the guides, being careful not to allow them to fall and strike the cylinder wall.

*6. Unscrew the nuts from the ends of the rocker shafts and drive out the rocker shafts using a suitable drift; then remove the rocker arms.

Note: On Wasp Jr. engines the valve lubricator oil pipes fasten directly to the ends of the rocker shafts. To remove the rocker shafts, loosen and remove the oil pipes and drive out the shaft with a suitable drift.

*7. Remove the rocker arm bearings from the rocker arm. Double row rocker bearings may be removed with an arbor press and PWA-614 Drift and Base or its equivalent. On early engines which use two single row bearings in each rocker arm, remove each bearing separately with PWA-281 Extractor.

Cylinder Assembly

1. Align the oil holes in the rocker bearings with the oil passages in the rocker arm and press the bearings into the rocker arms, using an arbor press. On engines using the two single row bearings in each rocker arm, the steel spacer must be inserted between the the bearings. The maximum difference in thickness between this spacer and the flange in the rocker arm must not exceed .002″.

*These operations may also be performed without removing the cylinder from the engine.

2. Rotate the inner race of the rocker bearings so that the filling notches (if present) are 180° apart, then install the rocker arms in the cylinder and install the rocker shafts. Drive the shafts into position with a suitable drift.

3. Install the necessary gaskets, oil seals and steel washers and secure the shafts in place with the nuts or oil fittings. The proper procedure for tightening rocker shaft nuts is to tighten snugly (approx. 35 in.-lbs.) and then turn to the next cotter pin hole.

4. Oil the valve stems and insert the valves into their guides while the cylinder is in a horizontal position.

5. Holding the valves in place with the forefingers around the stems, place the cylinder over the wooden form used for disassembly.

6. Install the safety circlets on the valve stems; then install lower valve spring washers, valve springs and upper washers.

7. Compress the valve springs with PWA-459 Compressor and install split locks.

8. Reinstall the cylinder head baffle (if provided).

Installing Cylinder on the Engine

1. Fit the piston pin through the piston and bushing of the connecting rod or master rod; then coat the cylinder walls, piston and rings with a generous amount of oil.

2. Place the rubber oil seal on the cylinder skirt, then lock the ring clamp over the piston and rings and slide the cylinder over the piston and into place on its mounting pad. Use PWA-249 Ring Clamp for Wasp Jr. engines, PWA-13 Ring Clamp for Wasp engines and PWA-49 Ring Clamp for Hornet engines.

3. Install and tighten the cylinder hold-down nuts. If possible, a torque indicating handle and PWA-2006 Cylinder Wrench should be used to tighten the nuts to a torque of 300 in.-lbs. However, PWA-186 Cylinder Wrench may be used if a torque handle is not available.

Caution: When using PWA-186 Wrench, do not tighten the nuts excessively as the studs may be stretched or broken.

4. On engines having the automatic lubricator or full pressure lubrication of the valve mechanism, slip the hose connections in place on the inter-cylinder oil pipes and secure with clamps or wrap locks.

5. Fit the packing nut and rubber packing over the blower end of the intake pipe; then place the pipe in position and screw the packing nut loosely into the blower section. Install the copper gasket at the cylinder port opening and tighten the flange in place evenly; then tighten the packing nut.

Caution: Do not tighten the packing nut excessively as this will neck down the blower end of the intake pipe.

6. Depress the valves and install push rods and covers. Each push rod is marked with its position and should be installed according to the markings. The marked end is the inner end. The push rod covers are installed with the flanged end toward the center of the engine. When tightening the gland nuts, the inner nut should be tightened first.

7. Adjust the valve clearances to .010″, then install the rocker box gaskets and covers and fasten in place.

8. Install all spark plugs previously removed and connect the spark plug lead elbows to the spark plugs. Reinstall all primer lines, oil pipes, etc. which were previously removed.

9. Install the inter-cylinder baffles and secure them in place.

10. Reinstall the exhaust piping and replace the cowling sections.

Note: The preceding installation instructions are based on the assumption that the connecting rod assembly has not been moved since the cylinder was removed and that the connecting rod is on the top dead center of the compression stroke of the cylinder being installed.

Ground Run-In of Engine After Replacement of Pistons, Rings or Cylinders — If the operator finds it necessary to replace a piston and ring assembly or a cylinder, the engine should be run-in as follows, with both the engine cowl ring and the inter-cylinder baffles removed.

4 Hours at 1000-1100 R.P.M.

1 Hour at 1200 R.P.M.

1 Hour at 1300 R.P.M.

1 Hour at 1400 R.P.M.

1 Hour at high R.P.M. in short bursts providing 400°F. cylinder head temperature is not exceeded.

Note: It is desirable that the propeller control be set to allow the engine to turn the same number of R.P.M. on the ground as it does in the air at cruising speeds.

SUDDEN STOPPAGE OF ENGINES

Sudden stoppage of an engine due to the propeller striking some object can result in damage to the blower gear train. If an engine has been stopped suddenly from such cause, it should be disassembled for careful inspection and magnafluxing of the blower drive parts, where there is any suspicion that these parts may have suffered damage.

The propeller shaft should, of course, be checked for trueness and the propeller reduction gearing for possible damage in such instances.