Warner Engine Handbook
SS-50 and SS-50A Engines
145 HP

Warner Engine Handbook

Models
Super Scarab SS-50
and
Super Scarab SS-50A

Transcribed from a copy of the original manual printed First Edition, August 1945.

The Warner Aircraft Corporation
Detroit, Michigan

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Table of Contents

Warner Engine Handbook:

Introduction

This Handbook covers complete and detailed instructions for the operation, service, and maintenance of Warner Super Scarab Series 50 and Super Scarab Series 50A (145 HP) engines. Included also are a complete Parts Interchangeability List, Table of Limits, Service Tools List, and Station Overhaul Tools List.

The instructions cover the complete line of Warner 145 HP engines, include the older type engines with three (3) ring pistons, and flat cylinder base gaskets as well as the current type engines with reinforced four (4) ring pistons, "O" ring cylinder base packings, improved type cylinder hold-down studs, and other minor engineering improvements. For conversion of older type engines to the improved "O" ring cylinder base packings and cylinder hold-down studs refer to Warner Service Letter No. A-17.

Additional instructions on any specific installation or service problem will be furnished by our Service department upon request should information herein contained prove inadequate.

July 1945, The Warner Aircraft Corporation, Detroit Michigan.

This version of the handbook has been modified to include photos and description of parts and assembly from an example of a current type Warner 145 HP engine, Serial Number SS693E. All text additions to this manual are in blue itallics; added pictures can be distinguished from originals because they are in color.

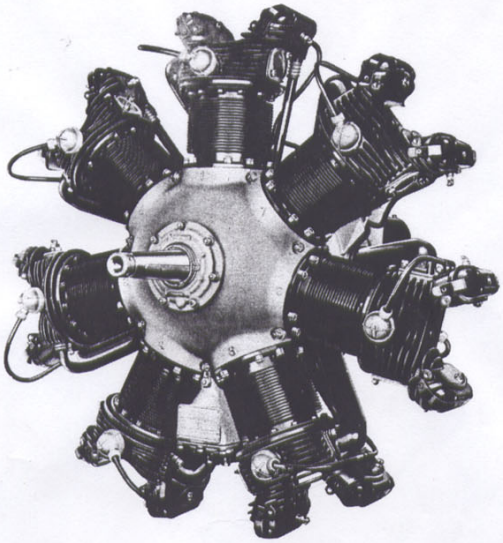


Fig. 1

3/4 Left Front View
of Warner Super
Scarab Series 50
Engine

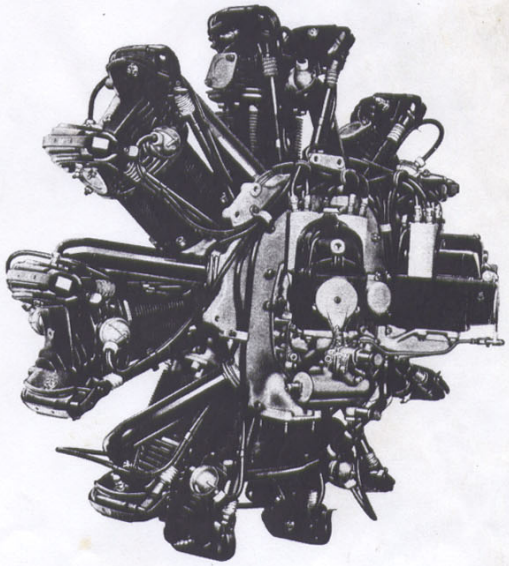


Fig. 2

3/4 Left Rear View
of Warner Super
Scarab Series 50
Engine

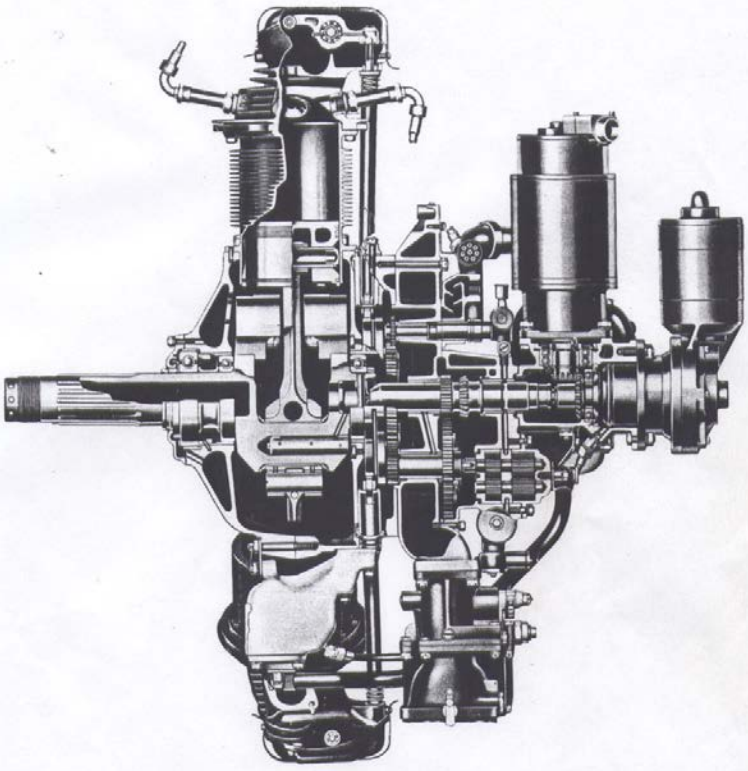


Fig. 3

Left Side Cutaway
View of Warner
Super Scarab
Series 50A Engine

Warner Engine Handbook:

Section I - General Specifications

1. General Specifications

The following Warner Aircraft Corporation drawings, power curves, and specifications form a part of this:

Curve 24-A	Installation drawing No. 7716
Curve 23-A	Installation drawing No. 8100
Curve 38	Assembly drawing No. 7700
	Assembly drawing No. 11300

2. Type

This specification covers the design and construction of the Warner Aircraft Models SS50 and SS50A, direct drive, seven-cylinder, radial type, air-cooled engine.

3. Detail Requirements

1. **Rating**. This engine is rated at 145 h.p. at 2050 rpm at sea level, (take-off rating 145 hp at 2050 rpm), using 73 octane fuel. When fixed propeller is used, this engine is rated at 145 h.p. at 2050 rpm, at sea level, using 73 octane fuel. Engine Type Certificate No. 104 has been assigned to this engine by the Civil Aeronautics Authority.
2. **Maximum Cruising Power Ratings**. The maximum permissible cruising power rating of this engine, when using a fixed propeller is 109 h.p. at 1865 rpm.
3. **Weight**. The average dry weight of the standard engine is:
    a. SS50, 306 lbs.
    b. SS50A, 307 lbs.
4. **Bore and Stroke**. This engine has a bore of 4-5/8" and a stroke of 4-1/4".

5. **Compression Ratio**. This engine has a compression ratio of 5.55:1 and has a piston displacement of 499.8 cubic inches.

6. **Crankshaft Rotation**. The crankshaft rotation, viewed from the anti-propeller end of the engine, is clockwise.

7. **Center of Gravity Position**. The center of gravity of this engine, with accessories drives installed, is:

   a. SS50 - 4-1/2" forward of rear face of mounting bosses.

   b. SS50A - 4.63" forward of rear face of mounting bosses.

8. **Mounting**. A mounting bolt circle, 17 inches in diameter, provides for the use of ten 5/16" diameter mounting bolts for mounting this engine.

9. **Overall Diameter and Length**. The overall diameter of this engine is 36-9/16". The overall length of this engine is:

   a. SS50 - 29 inches

   b. SS50A - 29-3/4 inches

10. **Magneto**. The shielded engine is equipped with Scintilla Type VMN7D dual magnetos. The direction of rotation of the magneto drive, viewed from the anti-propeller end of the engine is counter-clockwise. The firing order is 1,3,5,7,2,4,6.

11. **Spark Plugs**.

   a. SS50 - Champion C-26 spark plugs are furnished with unshielded ignition. Champion C-26-S spark plugs are used with shielded ignition.

   b. SS50A - Champion C-26 spark plugs are furnished with unshielded ignition. Champion C-26-S spark plugs are used with shielded ignition.

12. **Fuel Metering**.

   a. SS50 - This engine is equipped with a Stromberg NAR-5A carburetor which may be adapted for use with a fuel pump or a gravity fuel system.

   b. SS50A - This engine is equipped with a Stromberg NAR-5A or a Holley Model 419 carburetor which may be adapted for use with a fuel pump or a gravity fuel system.

13. **Fuel**. The use of 73 octane fuel, conforming to Army Navy Specification No. AN-VV-F-761 is recommended for this engine. The desired float needle valve pressure for gravity fuel system is 1-1/2 pounds per square inch, and the desired pressure for fuel pump system is 3 pounds per square inch.

14. **Fuel Inlet Connection**. The carburetor is provided with a 3/8 Briggs Standard Pipe Tapped hole for installation of a fuel inlet connection.

15. **Fuel Pump**. A fuel pump drive conforming to Installation Drawing No. 7716 is available as special equipment. The direction of rotation of the fuel pump drive, is counter-clockwise.

16. **Fuel Consumption**. The attached guaranteed minimum specific fuel consumption curve No. 38 shows the minimum specific fuel consumption is .525 lbs/hp/hr at cruising conditions.

17. **Priming System**. A 1/8" Briggs Standard Tapped Hole is provided in the induction housing adjacent to No. 1 cylinder intake port to permit the installation of a priming line.

18. **Oil**. See Table of Recommend oils.

19. **Oil Consumption**. At rated power and speed the maximum oil consumption is .025 lbs/hp/hr. At cruising power and speed the maximum oil consumption is 0.020 lbs/hp/hr.

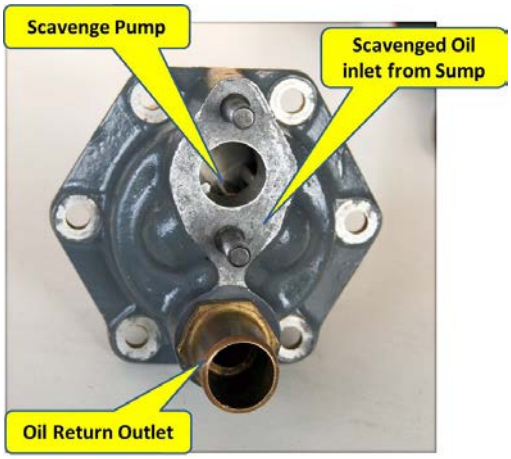
20. **Oil Inlet and Outlet Connections**. 3/4" O.D. hose nipple inlet and outlet connections are provided in the oil pump for the installation of oil inlet and outlet connections.

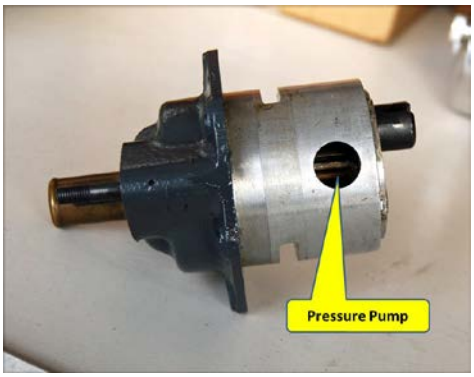
21. **Oil Pressure Gage Connection**. A 1/8 NPT tapped hole is provided in the oil pump housing for the installation of an oil pressure gage connection.

22. **Oil Tank Vent Connection**. A 1/4" Briggs standard tapped hole is provided in the rear of the induction housing cover between the generator mounting pad and the right magneto for the installation of an oil tank vent connection.

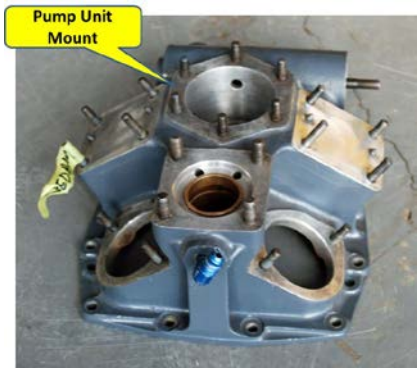
23. **Oil Pump**. An oil pump, consisting of one pressure pump and a scavenging pump built into one complete unit, is mounted below the starter mounting flange.

The scavenge pump is twice the volume of the pressure pump. Intake for the pressure pump from the oil tank is mounted on the engine induction housing below the accessory case. Both pumps are gear type pumps.





The pump attaches to the accessory case as indicated below.



24. Alemite fittings are installed on rocker arm shafts for the

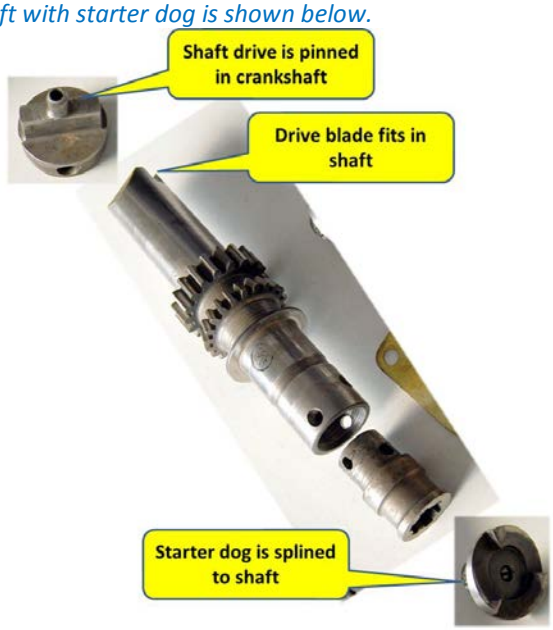
lubrication of the rocker arm bearings.

25. **Manifold Pressure**. A 1/8 NPT tapped hole for manifold pressure gage is provided in the carburetor mounting flange of the induction housing.

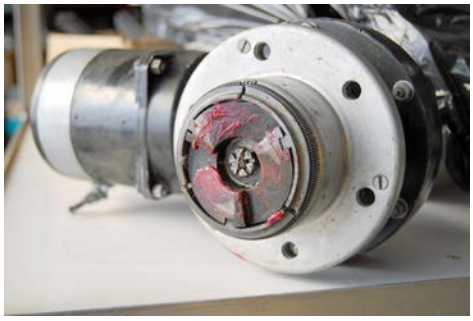
26. **Radio Shielding**. Radio shielded ignition harness may be furnished with this engine as special equipment.

27. Booster Coil. A terminal is provided on each right magneto block for the booster coil or booster magneto cable connection.
There is no booster coil on this engine.

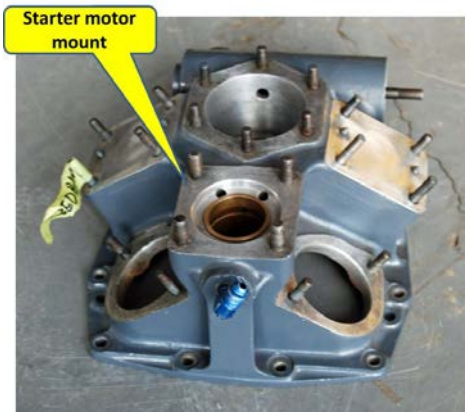
28. Starter. A starter drive is furnished with this engine. The direction of rotation of the starter drive, looking at drive, is clockwise. The starter dog incorporates three jaws.
The starter shaft with starter dog is shown below.



The starter with dogs forward is shown below.



The starter mounts on the accessory cover in the location shown below



29. **Tachometer**. A tachometer drive is provided. The direction of rotation, looking into drives, is counter-clockwise.

30. **Generator**. A generator drive is available as special equipment. The direction of rotation of the generator drive, looking at drive is counter-clockwise.
There is no generator on this engine.

31. **Thermocouple**. Thermocouples may be installed as special equipment, by the aircraft manufacturer.
There is a thermocouple installed as a washer under the Number one cylinder rear plug.

32. **Intercylinder, Head, and Oil Sump Air Baffles**. Intercylinder, cylinder head and oil sump air baffles are furnished with this engine as special equipment.
This engine has no air baffles.

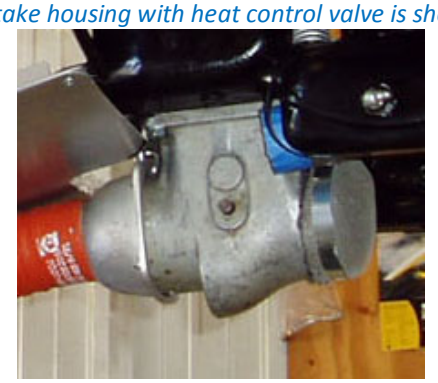
33. **Exhaust Collector**. Two studs, 1/4" x 28 thread, are provided on the exhaust flange of each cylinder head for installation of an

exhaust collector. Exhaust collector flanges and gaskets are provided for installation of the exhaust collector.

This engine has a ring exhaust collector as shown below.

34. **Carburetor Air Intake Housing**. The use of a carburetor heat control valve is recommended for this engine in order to obtain maximum performance. Provision is made for the installation of a carburetor heat control valve in accordance with Installation drawing No. 7716.

The carburetor air intake housing with heat control valve is shown below.



Heat is supplied from the exhaust collector muff as shown below.

35. **Venturi Diameter**. The diameter of the Stromberg carburetor venturi is 1-7/8 inches.
36. **Propeller Shaft End**. This engine provides a No. SAE #1 tapered propeller shaft end for the SS50. The SS50A provides a No. SAE #20 splined propeller shaft end.
    This engine has a tapered propeller shaft end.
37. **Accessory Drives - Ratios**. The gear ratio of each accessory drive to the crankshaft is as follows:

    - Fuel Pump Mounting Pad and Drive:

    Direction of Rotation: Counter-clockwise
    Speed (in multiples of crankshaft speed) .4

    - Starter Mounting

    Direction of Rotation: Clockwise
    Speed (in multiples of crankshaft speed) 1.0

    - Generator Mounting Pad and Drive

    Direction of Rotation: Counter-clockwise
    Speed (in multiples of crankshaft speed) 1.5:1

    - Tachometer Drive

    Direction of Rotation: Counter-clockwise
    Speed .5:1

38. **Installation**. The installation of this engine shall be subject to the approval of the engine manufacturer. The manufacturer's warranty is contingent upon approval of the engine installation.

4. Inspection and Test

All engine parts and assemblies used in the construction of the engine are thoroughly inspected for conformity to specifications and drawings. Upon completion of assembly, the engine is tested for

approximately nine hours before leaving the factory. Following the first run-in (initial), the engine is disassembled and thoroughly inspected. After re-assembly, the engine is given a final test in order to calibrate the fuel and oil consumption.

The following values, as determined by flight testing, shall not be exceeded under any condition:

Oil Pressure: Minimum Idling - 40 pounds per square inch

Normal 50 to 90 pounds per square inch.

Maximum Permissible Oil Inlet Temperatures: The maximum permissible oil inlet temperature is 200 degrees F.

Cylinder Temperatures: Maximum permissible cylinder head temperature measure at rear spark plug gasket is 525 degrees F. Maximum permissible cylinder base temperature measured at the lee side of the cylinder barrel is 300 degrees F.

Magneto Temperature: Maximum permissible magneto temperature is 150 degrees F.

Carburetor Air Intake: Carburetor cold air intake shall be approved by the engine manufacturer for distribution. Provision shall be made for the use of hot air to the carburetor. When using hot air, a temperature rise of carburetor air of 120 degrees F., above outside air or cold air is desirable.

Note: The above limitations shall not be exceeded during ground operations.

Table I

APPROVED OILS FOR ALL WARNER ENGINES

The fact that an oil is not included in this list, does not necessarily indicate that it is unsuitable. Any aviation oil of the proper grade, which is approved by the Army or Navy in accordance with their latest apecifications, is suitable. Our Service Department should be consulted in regard to oils not on this list or not approved by the Army or Navy.

Trade Name of Oil	HEAVY SUMMER OILS Air Temp. 90°F. & Up			SUMMER OILS Air Temp. 40°F. to 90°F.			WINTER OILS Air Temp. 40°F. & Lower		
	Grade	Viscosity @ 210°F.	Pour Point Deg.F.	Grade	Viscosity @ 210°F.	Pour Point Deg.F.	Grade	Viscosity @ 210°F.	Pour Point Deg. F.
DOMESTIC									*Note
Aero Mobiloil	Green Band	120	10	Red Band	100	0	Grey Band	80	0
Aeroshell	120	120	10	100	100	10	80	80	0
Alemite Aero				H.	105/110	10			
Conoco Aero	No. 4	125	0/5	No. 2	95	0/5	No. 2	95	0/5
Conoco Aero Germoil	H.	125	0/5	M.	95	0/5	M.	95	0/5
Esso Aviation	No. 120	120	10	No. 100	100	0	No. 80	80	0
Kendall	"J"	120	0	"G"	100	0	"F"	85/87	0
Pennzoil	Aircraft XX	120	10	Aircraft X	105	10	H.	89	5
Quaker State	H. Aero	120/125	0/-5	Aero	100/105	0/-5	#80 Aero	80	0/-5
Redline Aero	E.H.	110	20	H.	85	10	M.	71	10
Richfield Penns. Aviation	Grade 120	122	10	Grade 98	98	10	Grade 77	78/80	0
Sinclair Opaline	Aircraft	120/122	10	E.H.	98/100	5			
Sinclair Pennsylvania	Aircraft	120/122	10	E.H.	99/101	5	Aircraft H.	78/80	0
Stanavo Aviation	No. 120	120	10	No. 100	100	5	No. 80	80	0
Texaco Airplane	No. 120	115/125	15	No. 100	94/102	10	No. 80	74/80	0
Tiolene Aircraft	E.H. No.120	119/124	15/20	S.H. No.100	95/100	15/20	H. No. 80	73/77	20/25
Valvoline	E.H. No. 60	122	30	H. No. 50	95	30	H.M. No.40	78	10
Wolf's Head Special Aircraft	Grade 8-120	120	15	Grade 8-100	100	15	Grade 8-80	80	15
FOREIGN									
Aeroshell	120	120	10	100	100	10	80	80	0
Intava Aviation	Green Band	120	10	Red Band	100	0	Gray Band	80	0
Valvoline	E.H. No.60	122	30	H. No.50	95	30	H.M. No.40	78	10

Abbreviations: E.H. - Extra Heavy; S.H. - Special Heavy; H. - Heavy; H.M. - Heavy Medium; M. - Medium
* For operation in extremely low temperatures, oils with low pour points should be used.

In selecting the proper grade of oil for the engine, it should be kept in mind that in the heavy summer oils and summer oils, the pour point is immaterial.

The heavy summer oils should be used only where the temperature is above 90°F., or for general summer use when more than normal work is expected from the engine. For racing purposes, where the engine is run above its rated maximum speed, they should be used exclusively.

In selecting an oil for winter use, it should be kept in mind that, the lower the air temperature, the lower pour point oil should be used.

LIST OF RECOMMENDED ROCKER ARM LUBRICANTS	Conoco Rockarlube	Gulf Precision Grease	Kendall Aircraft	Lubri-zol	Marathon Rocker Arm Grease	Mobilgrease	Pennzoil	Phillips Rocker Arm Lubricant	Pure Oil Aircraft Rocker Arm Grease	Richlube Combat Rocker Arm	Shell Rocker Arm	Stanavo Rocker Arm Grease	Texaco Marfak	
Summer Grade	9060	B-B	73	045	512	3	2	Yes	Yes	Heavy	15A	2	2	
Winter Grade			11	45			1-1/2					1	1	

Table II

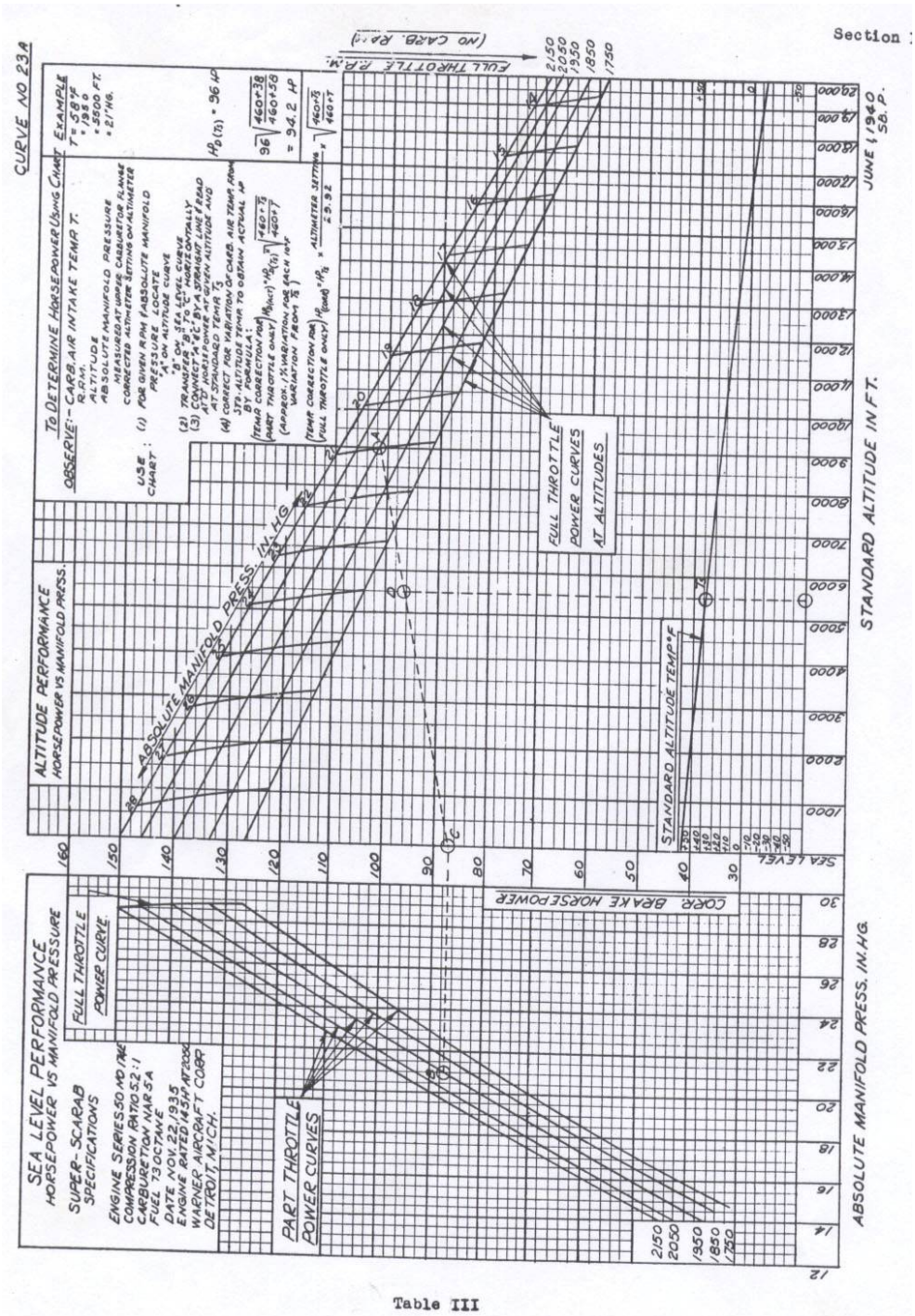

CURVE NO 23A
SEA LEVEL PERFORMANCE
HORSEPOWER VS MANIFOLD PRESSURE
SUPER-SCARAB
SPECIFICATIONS
ENGINE SERIES 50 NO. ONE
COMPRESSION RATIO 5.2:1
CARBURETION NARSA
FUEL 73 OCTANE
DATE NOV. 22, 1935
ENGINE RATED 145 HP AT 2200
WARNER AIRCRAFT CORP
DETROIT, MICH.
PART THROTTLE
POWER CURVES
FULL THROTTLE
POWER CURVE
ALTITUDE PERFORMANCE
HORSEPOWER VS MANIFOLD PRESS.
ABSOLUTE MANIFOLD PRESS. IN. HG.
FULL THROTTLE
POWER CURVES
AT ALTITUDES
STANDARD ALTITUDE TEMP °F
CORR. BRAKE HORSEPOWER
SEA LEVEL
STANDARD ALTITUDE IN FT.
FULL THROTTLE R.P.M.
(No CARB. RAM)
2150
2050
1950
1850
1750
To DETERMINE HORSEPOWER USING CHART
OBSERVE:- CARB. AIR INTAKE TEMP T.
R.P.M.
ALTITUDE
ABSOLUTE MANIFOLD PRESSURE
MEASURED AT WIDE OPEN THROTTLE FLANGE
CORRECTED ALTIMETER SETTING ON ALTIMETER
USE CHART: (1) FOR GIVEN R.P.M. & ABSOLUTE MANIFOLD PRESS. READ HP
'A' ON ALTITUDE CURVE
'B' ON SEA LEVEL CURVE
(2) TRANSFER 'B' TO SEA LEVEL CURVE HORIZONTALLY
(3) CONNECT 'A' & 'C' BY A STRAIGHT LINE & READ CORRECTED HORSEPOWER AT GIVEN ALTITUDE AND AT STANDARD TEMP. Ts
(4) CORRECT FOR VARIATION OF CARB. AIR TEMP. FROM STD. ALTITUDE TEMP TO OBTAIN ACTUAL HP
BY FORMULA:
(TEMP. CORRECTION FOR PART THROTTLE CHART) (HP(act)) = (HP(Ts)) √(460+Ts)/(460+T)
(APPROX. 1% VARIATION FOR EACH 10° VARIATION FROM Ts)
(TEMP CORRECTION FOR FULL THROTTLE CHART) (HP(std)) = (HP(Ts)) x ALTITUDE SETTING = 29.92 √(460+Ts)/(460+T)
EXAMPLE
T = 58°F
= 1950
= 5500 FT.
= 21"HG.
HP(Ts) = 96 HP
96 √(460+38)/(460+58) = 94.2 HP
Section
JUNE 1, 1940
58. P.

Table III

CURVE NO. 24A

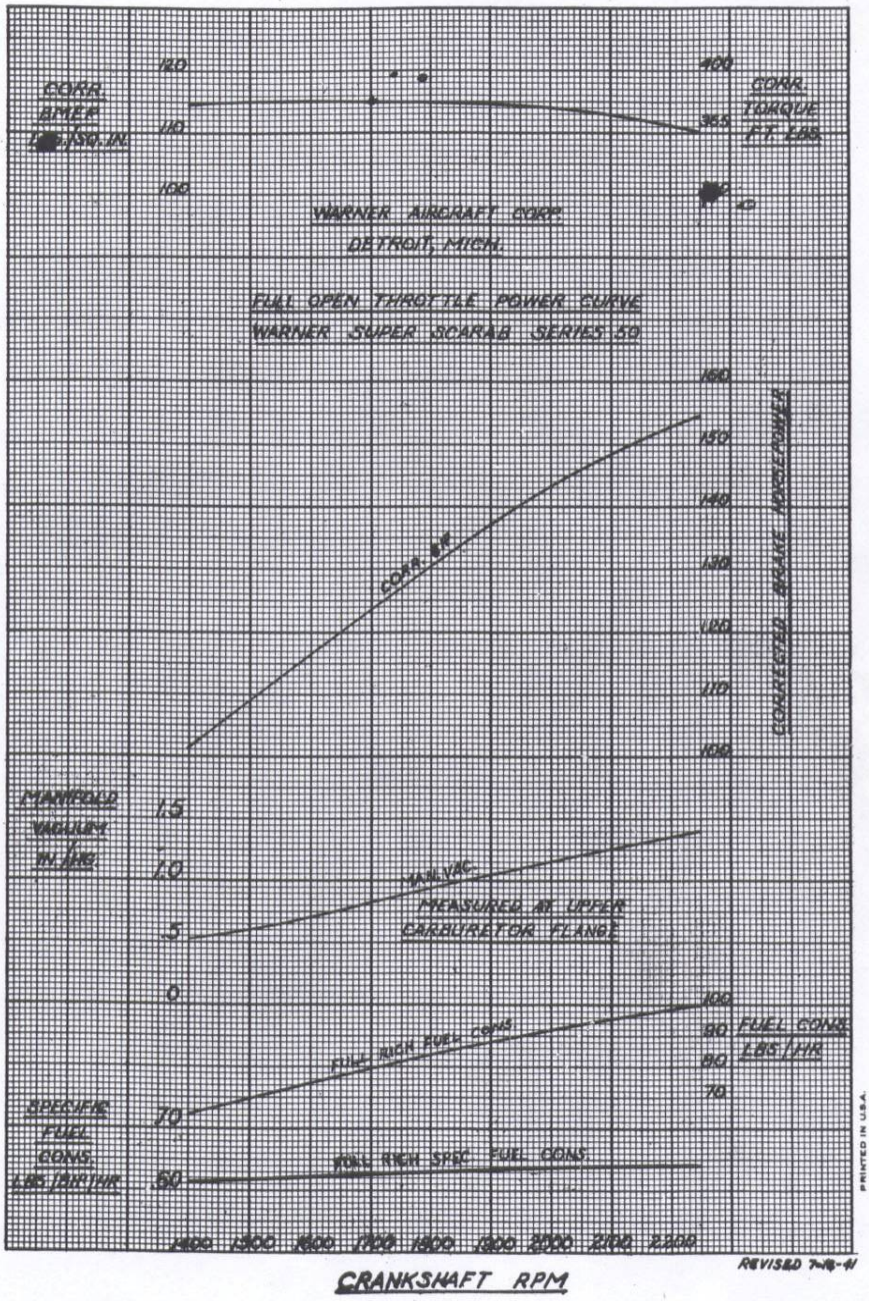


Table IV

Table II - List of Recommended Rocker Arm Lubricants

Brand	Summer Grade	Winter Grade
Conoco Rockerlube	9060	9060
Gulf Precision Grease	B-B	B-B
Kendall Aircraft	73	11
Lubri-zol	045	45
Marathon Rocker Arm Grease	512	512
Moboil-grease	3	3
Pennzoil	2	1-1/2
Phillips Rocker Arm Lubricant	Yes	Yes
Pure Oil Aircraft Rocker Arm Grease	Yes	Yes
Richlube Combat Rocker Arm	Heavy	Heavy
Shell Rocker Arm	15A	15A
Stanavo	2	1
Texaco Marfak	2	1

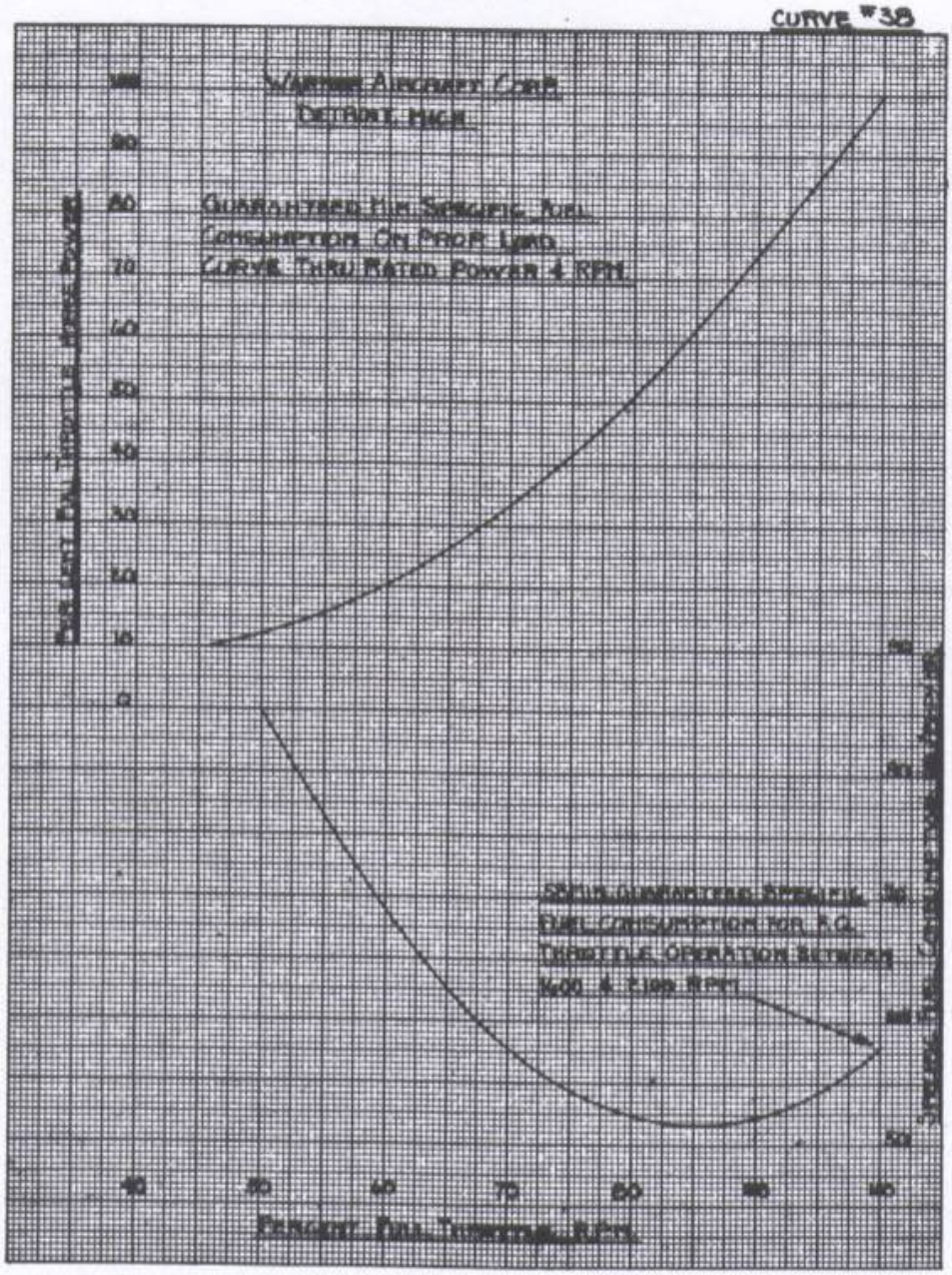

CURVE #38
Guaranteed Min. Specific Fuel Consumption On Prop. Limit Curve Thru Rated Power & RPM.

Table VI

Table V - Fuel Consumption Data

Correct Fuel Consumption In Gal/Hour In Level Flight For Super-Scarab Engine (145 H.P.)														
Wide Open Throttle RPM	Wide Open Throttle Fuel Consumption	Part Throttle Fuel Consumption When Cruising At The Following RPM												
		1700	1750	1800	1850	1900	1950	2000	2050	2100	2150	2200	2250	2300
2000	15.2	8.1	8.8	9.5	10.4	11.6	13.0							
2050	15.5	7.7	8.4	9.0	9.8	10.7	11.8	13.4						
2100	16.0	7.6	8.0	8.7	9.4	10.1	11.0	12.2	13.6					
2150	16.3	7.4	7.8	8.3	8.9	9.7	10.4	11.3	12.5	14.2				
2200	16.5	7.2	7.7	8.1	8.6	9.2	9.9	10.7	11.6	12.8	14.2			
2250	16.8		7.4	7.9	8.3	8.8	9.5	10.1	10.9	11.9	13.0	14.5		
2300	17.0		7.3	7.7	8.1	8.5	9.0	9.6	10.4	11.2	12.1	13.0	14.7	
2350	17.1			7.4	7.8	8.2	8.7	9.2	9.8	10.5	11.3	12.2	13.3	14.9

Example: An engine turning 2150 RPM wide open in level flight should consume 16.3 gallons at wide open throttle and 8.9 gallons minimum when cruising at 1850 RPM.

The above are minimum consumptions. Richer settings are entirely satisfactory.

Warner Engine Handbook:

Section II - General Description

1. General

The engine is a static, seven cylinder, radial, air-cooled four cycle engine with a piston displacement of 499 cubic inches. The cylinder bore is 4.625 inches and the stroke is 4.250 inches.

2. Cylinders

a. Construction and General Features

1. The cylinders are built up by shrinking cast aluminum alloy heads on forged chrome-molybdenum steel barrels.

The heads are secured to the barrel by means of staked nuts and should under no circumstances be removed except by Warner Aircraft at the factory. A copper washer is installed between the cylinder head and barrel.

2. Each cylinder head is provided with one inlet and one exhaust valve. The inlet valve seats on an aluminum bronze valve seat insert. The exhaust valve seat is Austenetic steel. Both of these valve seat inserts are shrunk into the head.

b. Principal Details of Parts

1. Cylinder Head. The exhaust port boss faces toward the side of the cylinder head and is provided with two studs for securing the exhaust stacks.

The intake port boss is on the opposite side of the cylinder head. A gasket is used between the intake pipe flange and cylinder head.

Comment [DL1]: This might be reversed with the one above.

The valve guides and valve seat inserts are shrunk into the head. (See picture above.) Bronze spark plug inserts are screwed and pinned in the front and rear of each cylinder head. (See picture below.)

The two integrally cast rocker boxes are each provided with a rivet on each end to hold the quick-adjustable spring fastener on the rocker box cover in place.

2. Cylinder Barrel. The cylinder with integral cooling fins, bolting flange, and flange to secure the head is machined from an alloy steel forging.

3. Valves. The valves are inclined to the center line of the cylinder at an angle of 32 degrees, permitting an hemispherical combustion chamber. The exhaust valves (on right below) are austenetic steel which permits the use of ethylized fuels.

The intake valves (on left above) are made of low tungsten steel.

The valves have solid stems. The valves face the air stream for better cooling of the valve seats. The valves have a face angle of 45 degrees.

4. Valve Seat Inserts. The intake valve seat insert is machined from extruded aluminum bronze alloy. The exhaust valve seat insert is made of austenetic steel. Both valve seat inserts are faced at an angle of 45 degrees. (See picture below.)

3. Valve Operating Mechanism

a. Construction and General Features

1. The cam, cam drive gear, and cam follower guides are located in the rear section of the crankcase. (Picture is of rear of rear half of crankcase.)

2. The push rods and push rod tubes are located behind the cylinders.

3. Push rods, rocker arm bearings, rocker arms, and valve springs are totally enclosed.

Comment [DL2]: Need picture of push rod, rocker arm, bearing, and springs along side enclosure tubes

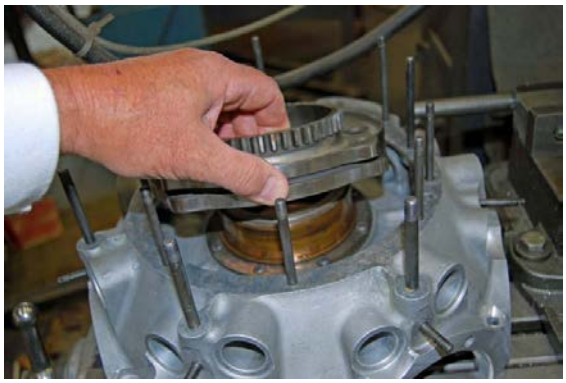


4. The push rods and cam followers (shown below) are lubricated automatically by oil spray from the crankcase. The rocker arm bearings and push rod sockets are lubricated by means of alemite fittings on the end of the rocker arm shaft.

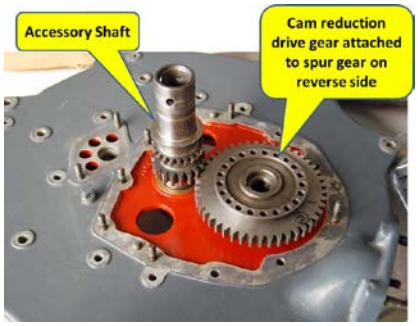
b. Principal Details of Parts

1. The operation of the valves is accomplished through a cam ring which is located in the crankcase rear section, and consists of a hardened alloy steel ring with two sets of four cam lobes each on its outside diameter.

The cam rotates at 1/8 crankshaft speed and in the same direction as the crankshaft. The cam is supported on a floating type bronze bushing which serves as a bearing surface between the cam ring and the outer surface of the rear main ball bearing cage.



The driving gear is integral with the cam ring, and is driven from the auxiliary shaft by means of a simple spur gear train through an idler shaft.



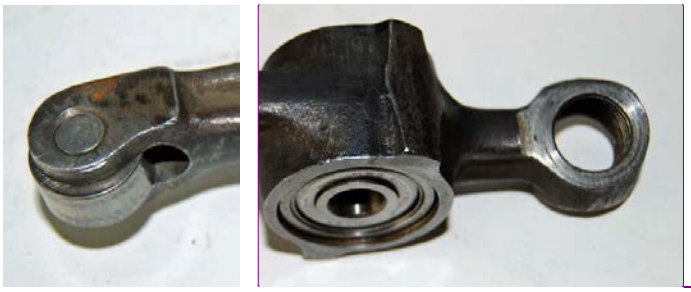
2. Cam followers take their bearing in aluminum cam follower guides which are chill cast in permanent mold. The cam follower guides are supported in reamed bosses throughout their entire length, positively preventing all side motion.

The cam followers make contact with the cam by means of rollers, and have at the opposite end a spherical socket for the push rod.

3. The push rods are made from steel tubing with hardened and polished ball ends pressed on each end. The upper ball end fits into an adjustable socket in the rear of the rocker arm.

4. The rocker arms are supported by replaceable ball bearings.

The rocker arms are made from alloy steel forgings. The adjustable rocker arm socket is located on the push rod end of the rocker arm while the roller which contacts the valve stem is located on the other end.



Comment [DL3]: Need picture with push rod socket installed

5. Both intake and exhaust valves employ an inner and an outer valve spring. The springs have dampener coils which face the seat and both springs are wound in the same direction in order to induce rotation to equalize the wear.

Comment [DL4]: Need pictures of these springs in place

4. Crankshaft

a. Construction and General Features

1. The single throw crankshaft is made in one piece from an alloy steel drop forging, carefully heat-treated for the highest physical properties, and finish-machined all over to close tolerances.

The crankpin is ground and lapped to exact dimensions. Counterweights are straddle-mounted to the crank cheeks and bolted to them by steel bolts set in reamed holes, thus providing utmost safety in absorbing torque reactions and centrifugal force.

2. The crankshaft is bored throughout for lightness and oil passages.

3. The rear end of the crankshaft is connected with the accessory drive shaft by means of a tongued coupling.

This accessory drive shaft drives the magnetos, the oil pump, and the cam gear; and it also has splines on the end as provision for installing a starter and generator combination drive assembly.

b. Principal Details of Parts

1. The crankshaft is supported in the crankcase by three ball bearings.

There are two main ball bearings and one thrust ball bearing. The front main ball bearing is directly forward of the front crank cheek

while the rear main ball bearing is directly behind the rear crank cheek.

The thrust bearing is forward of the front main bearing and is separated from it by a bearing spacer.

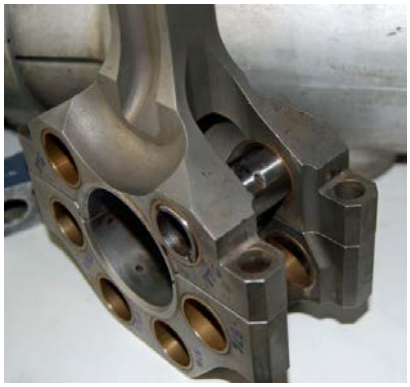
2. The front main and rear main bearings are chamfered on the inner races to clear the generous fillets on the crankshaft.

5. Connecting Rods

a. Construction and General Features

1. The master and link rods are machined all over from alloy steel forgings, heat-treated for high strength.

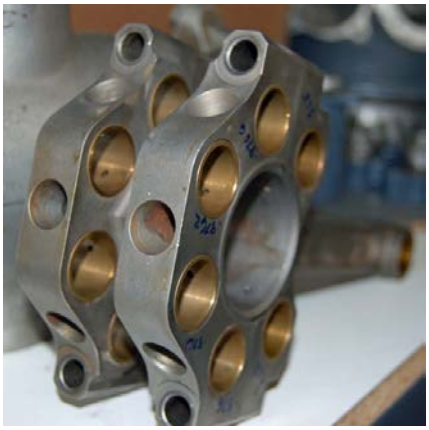
- The connecting rod assembly consists of one master rod and six link rods which are assembled to the master rod by means of wrist pins locked to the link rods and take their bearing in bronze bushings, which are pressed into the master rod after drilling to provide full force feed lubrication.



Bronze bushings are also pressed into the piston end of all rods for the floating type of piston pins.

b. Principal Details of Parts

1. The master rod is of a split type, four bolt design, with a replaceable cadmium silver steel-backed bearing shell at the crankpin end.



2. The wrist pins are made of alloy steel with a very hard ground surface on the outside diameter. A flat is machined at the mid-point of the wrist pin to provide a recess for the bolt in the link rod which secures the wrist pin.

6. Pistons and Piston Pins

a. Construction and General Features

1. The pistons are made from heat-treated aluminum castings, and are so designed as to combine lightness with greatest strength.

2. The piston pins are made from heat-treated alloy steel with a very hard surface. They are ground smooth inside and the external surface is lapped to secure a smooth finish.

b. Principal Details of Parts

1. The earlier engines were equipped with three-ring pistons employing two compression rings and one combination oil control ring. All of the rings are located above the piston pin bore. Later engines are equipped with four-ring pistons employing two compression rings and two oil control rings. The two compression and one oil control ring are located above the piston pin bore while the other oil control ring is located below the piston pin bore on the skirt. [See piston photo above.]

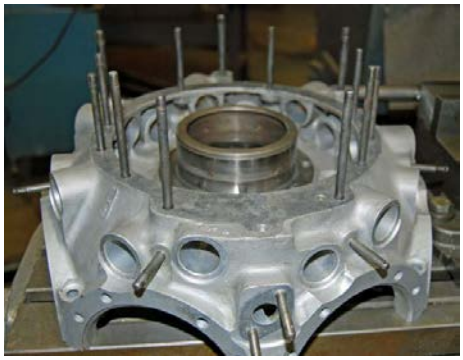
2. Aluminum alloy plugs are pressed in each end of the floating type piston pin in order to prevent scoring or scuffing of the cylinder walls.

7. Crankcase

a. Construction and General Features

1. The crankcase is made up of two heavily ribbed halves which are machined from heat-treated aluminum alloy castings.



The front and rear halves are joined together on one locating stud [see picture above] and six bolts

and machined as an assembly and neither the front nor the rear section can be replaced separately for this reason. This type construction facilitates the assembling of the crankshaft and connecting rod assembly as a unit.

b. Principal Details of Parts

1. Each section carries one main bearing. The front section, in addition, supports the thrust bearing.

Comment [DL5]: Get picture of where bearing go in crankcase

The crankcase houses the crankshaft,

Comment [DL6]: Get picture of crankshaft in pusical order to put in crank shaft.

the cam ring,

the front part of the accessory drive shaft,

Comment [DL7]: Need photo here; not sure what this is referring to

the front and rear main bearing sleeves, and the thrust bearing sleeve [see pictures above]. The cam follower guides are held in reamed bosses in the rear section of the crankcase by means of forked crabs.

Comment [DL8]: Also need picture of "forked crabs"

2. When specified for use with a pusher propeller, a push type thrust bearing sleeve may be installed in the crankcase as special equipment when the engine is being assembled at the factory.

3. The cylinders are secured to the crankcase by 5/16" studs

Comment [DL9]: Need picture of new stud per AD

which are driven into the cylinder mounting pads on the crankcase.

8. Induction System

a. Construction and General Features

1. The induction housing is machined from a heat-treated aluminum alloy casting. [Front shown]

Comment [DL10]: Need picture of front of induction housing

2. The induction housing consists of a correctly proportioned annular passage in the aluminum casting which also serves to support the engine in the airplane.

3. The induction housing contains bronze bushings for the geared drive shafts which are lubricated through tubes integrally cast in the housing. [Rear shown.}

b. Principal Details of Parts

1. The carburetor is attached to the lower part of the annular ring of the induction housing,

and separate intake pipes lead to each cylinder.

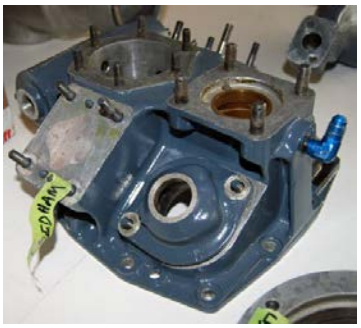
Comment [DL11]: Need picture of carburetor mount

2. The induction housing is so designed as to bring the carburetor and carburetor heat control valve within the overall diameter.

9. Gearcase and Oil Screen Assembly

a. Construction and General Features

1. The gearcase is machined from a heat-treated aluminum casting.



2. The gearcase is attached to the induction housing rear by means of studs.

b. Principal Details of Parts

1. The oil pump is mounted in an accurately machined recess in the gearcase.

2. The magnetos are mounted on brackets attached to the gearcase. [See flats on photo below.]

3. The construction is so arranged as to allow the mounting of a starter between the two magnetos. [See large hole between magneto mount flats in above photo.]

4. The oil screen and by-pass valve assemblies are mounted in a machined recess in the lower part of the gearcase housing.

Comment [DL12]: This should be the same as the recess for the oil pump, right?

10. Lubrication System

a. Construction and General Features

1. The oil sump housing is machined from a heat-treated sand cast aluminum casting.

2. The oil tube elbows are cast bronze.

Comment [DL13]: Need photo of these

3. The oil pump housing assembly is composed of three parts which are machined from heat-treated aluminum castings.

Comment [DL14]: Need photos of oil pump housing and oil pump parts

b. Principal Details of Parts

1. The oil pump fits into an accurately machined recess in the gear case at the rear of the engine. The pump is arranged in tandem with one drive shaft operating both the pressure pump and scavenger pump.

Comment [DL15]: Get photo of this area

2. The oil is drawn from the oil tank by the pressure pump and from there it is forced through and oil screen mounted in the gear case to the accessories drive shaft

and thence to the crankshaft.

It passes through drilled passages to the crankpin bearing and from there it is forced into each wrist pin bearing.

The oil which is forced out of these bearings lubricates the remainder of the engine by splash and then collects in the oil sump which is located at the bottom of the crankcase. [Photo shows sump attach point at bottom of rear crankcase half.]

The oil is returned from there through the oil tubes, to the oil tank by means of the scavenger pump.

3. Lubricate the rocker arm shafts using an approved rocker arm lubricant (see Table II for a list of approved rocker arm lubricants).

Comment [DL16]: Need photo of zirc fittings on rocker arms

Care should be exercised not to use an excessive amount of lubricant as the excess grease will accumulate in the rocker arm housing and will flow into the valve guide where it may eventually harden and freeze the valve.

11. Ignition System

a. Two Scintilla magnetos are furnished.

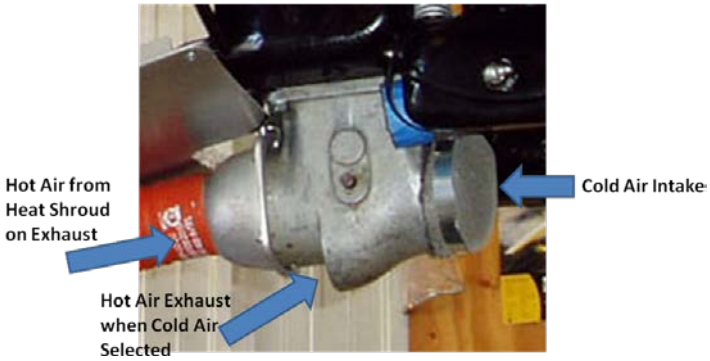
b. Unshielded or radio shielded ignition is optional on the engine.

c. An impulse coupling can be installed on one magneto when a hand cranking starter is to be used.

d. A control rod connects the advance and retard levers on the two magnetos.

12. Carburetor Heat Control Valve

A carburetor air heat control valve attached to the bottom of the carburetor is used to control the temperature of the incoming air. The picture is of the air collector under the carburetor. The air intake is on the left. Hot air from the exhaust muff is piped into the air intake port on the right. The gap at the bottom dumps hot air when carburetor heat is not selected.



13. Accessories

Accessories may be furnished as optional equipment at additional cost.

a. Starter Equipment

The following starters are available for use on all Super Scarab engines.

1. Air Injection Starters. The special compressor unit for these starters attaches directly to the engine on the mounting provided for the starter adapter. All later cylinder heads are equipped with a boss for installing the injection valves but **these bosses are drilled and tapped** only if specially requested by the airplane manufacturer when ordering the engine.

2. Starters are available for all Super Scarab engines. If using a starter, without generator, a special starter adapter and jaw assembly is required. If, in addition to the starter, a generator is used, a special

generator and starter adapter manufactured by Warner Aircraft Corporation is required to complete the assembly. This drive is braced by means of a bracket mounted under the oil pump.

14. Testing of Engine in Plant Before Shipment

a. Each aircraft engine is subjected to a regular preliminary test and a final test. The engine must develop full rated horsepower with a test club propeller before it is shipped from the factory.

b. The tests are conducted with the engine mounted on a rigid test stand. A two-bladed wood test club which allows the engine to turn approximately at the rated speed of 2050 R.P.M. at full open throttle is installed on the engine for test. No torque determinations are made during the preliminary or final tests.

Warner Engine Handbook:

Section III - Unpacking, Storage Preparation and Re-Packing Procedures

1. General

a. The models SS50 and SS50A engines will be packed, unpacked and prepared for storage in accordance with the instructions given in this section.

b. Engines which are to be shipped or stored will be packed in cases furnished by the Warner Aircraft Corporation.

c. All Warner Engines for domestic shipment will be prepared in accordance with instructions under "temporary storage" in Preparation of Engines for Storage part of this section.

d. All export engines and only those domestic engines specifically designated by purchaser as intended for long storage will be prepared for "Extended Storage" at additional charges as outlined in Preparation of Engines for Storage Section.

2. Unpacking

The engine is shipped in a substantial crate with the crankshaft in the vertical position. The upper part of the crate is merely a cover, held in place with wood screws through the angle-irons at the four corners of the case. The box, after the cover is removed, should be laid on the side next to the carburetor. **Care must be taken to see that the crate does not tip over when this position.** The Scarab and Super Scarab Engines can then be fastened to a hoist by means of the engine lifting eyes, which will be found at the rear ends of the two upper crankcase bolts, using Tool No. FA-58. Where this tool is not available, use a wooden spacer or a piece of steel tubing approximately 18 inches long to hold the ropes or cables apart, which lead from the lifting eyes to the hoist. After the hoist has been secured to the engine, the four nuts holding the engine shipping plate to the crate should be removed, and the engine and plate removed from the crate together. The shipping plate should then be removed from the engine by removing the attaching bolts. Spark plugs should not be installed until later, as covered in paragraph 3-c.

3. Recommended Procedure For the Preparation Of Engines for Storage and Service After Storage

Since the use of leaded aviation fuels is becoming more and more predominant, it is imperative that engines be protected against the corrosion effects of such fuels, during inoperative periods. The degree of such protection depends upon the duration of the inoperative period. From the Civil Aeronautics Administration Safety Regulation Releases No. 148 and 180, the following procedures are given:

a. Overnight Storage

Idle the engine for at least 5 minutes before stopping it, to draw oil up to the combustion chamber.

b. Temporary Storage of Up To One Week

Inject or spray into each cylinder through a spark plug opening, fresh lubricating oil or a mixture of lubricating oil and corrosion preventive compound (one part of corrosion preventive compound to three parts of engine lubricating oil) and turn the engine through several complete revolutions by hand, thus coating all surfaces in the combustion chamber. Corrosion preventive compounds may be obtained commercially both as a concentrate and mixed with lubricating oil.

c. Temporary Storage One To Eight Weeks

When the engine is to be kept in a flyable condition but is to remain idle for this period of time, corrosion prevention should be carried out, due to variable atmospheric conditions. When it is impracticable to operate the engine at least once a week, observance of the following procedures should provide adequate protection under normal conditions. If the aircraft is stored near salt water or in a tropical area, or under other unfavorable conditions, it may be necessary to prepare the engine for dehydration in accordance with the procedures listed in paragraph 3-e. (Dead Storage)

1. If not previously accomplished, the lubrication system should be serviced with a corrosion preventive mixture such as one part of compound and three parts of engine lubricating oil. The engine should be run on regular 73 octane fuel for at least 15 minutes or until the oil reaches operating temperatures. This operation should not be conducted in a sandy or dusty area. It is not necessary to drain the compound-lubricating oil mixture from the oil tank.

2. Spray the exhaust valves with compound-lubricating oil mixture through the spark plug openings with each exhaust valve successively open.

3. Spray each cylinder bore through the spark plug openings with the piston at the bottom of the stroke in order to cover as much of the interior surface of the cylinder as possible. Each cylinder should then be **resprayed** through the spark plug openings without further turning of the crankshaft.

d. Returning Engines To Service After Temporary Storage

After engines have been in temporary storage from one to eight weeks, before returning the engine to service, the instructions given in paragraph 4, Section IV, pertaining to Ground Test Prior to Flight should be carried out.

e. When the Engine Is To Be Placed In Extended Or Dead Storage

When the engine is not to be operated for an extended period of time, eight weeks or over, the following procedure should be conducted:

1. EXHAUST PORTS. The exhaust manifolds should be removed from the engine and each exhaust port sprayed with sufficient quantity of compound-lubricating oil mixture to thoroughly coat the exhaust valves. The shipping baffles should be installed on all exhaust ports with one Hydrol gasket which has been dipped in the compound-lubricating oil mixture, next to the exhaust port. The baffles should be installed with the sanded side next to the Hydrol gasket and secured with 1/4" lock washers and nuts which should be finger tight plus 1/4 turn with a wrench. Care must be exercised in tightening the nuts to prevent warping the baffle.

2. THRUST BEARING. The thrust bearing cover should be removed and the thrust bearing thoroughly coated with the compound-lubricating oil mixture, and the thrust cover reinstalled and tightened.

3. CARBURETOR. The carburetor should be removed and emptied of all residual gasoline. It should then be filled with Grade 1065 lubricating oil which must be worked into the passages by operating the throttle and by rotating the carburetor in all directions. The oil is then emptied from the carburetor bowl and the carburetor reinstalled on the engine. Then install two 1/4 lb. bags of Silica Gel in the carburetor air horn

and attach the heater valve substituting cover and gasket with cap screws to form an airtight seal. Plug the fuel inlet.

4. OIL INLET AND OUTLET NIPPLES. The oil inlet and outlet nipples are covered withnon-hygroscop1c tape to form an airtight seal.

5. BREATHER AND TACHOMETER DRIVE. The breather and tachometer drive openings are sealed with non-hygroscop1c tape to seal out the air.

6. CYLINDER BORES. The procedure given in paragraph 3-c (3) should be carried out.

Caution
Do not rotate the crankshaft following this procedure. If, by accident, the shaft is rotated, the cylinders must be resprayed according to the foregoing procedure, to ensure adequate un-broken coverage or corrosion preventive mixture on all surfaces.

7. SPARK PLUG OPENINGS. 14 AMS AS-7 spark plug substituting dehydrator plugs are installed in the spark plug openings and tightened to a torque or 300-360 lbs. after the seals have been removed from the dehydrator plugs. Do not remove these seals until ready to install in the engine. The dehydrator plugs should be inspected weekly and changed as soon as their color indicates unsafe storage conditions.

8. PROPELLER SHAFT. The exposed surface or the crankshaft should be thoroughly coated with corrosion preventive mixture. If the crankshaft is a tapered one, it should be wrapped with greaseproof paper and taped with the non-hygroscopic tape. If the shaft if splined, the greaseproof paper should be used and the shipping tube installed over the paper. Install the crankshaft end plastic shipping cap.

9. ROCKER BOXES. The rocker box covers should be removed and the valves, valve stems, guides and rocker arms coated with the compound-lubricating oil mixture. Replace and tighten the covers.

10. MAGNETOS. Seal the magneto vents with non-hygroscopic tape. Coat the cam and all other distributor breaker mechanism parts, **except the points**, with petrolatum. Seal all joints where moisture might enter with a coating of melted wax compound.

11. OTHER EXPOSED SURFACES. The exposed unpainted surfaces of ferrous metal parts of the engine accessories such as pumps, starters,

manifolds, etc., should be thoroughly coated with corrosion preventive compound.

12. ENGINE COVERS. All engines installed in aircraft should be covered with engine covers furnished with the airplane and securely fastened.

f. To Prepare Engine For Service After Extended Or Dead Storage

In addition to the instructions given in Section IV, the following should be carried out:

1. Remove dehydrator plugs from spark plug openings, silica gel bags from carburetor, cover plates from carburetor and exhaust ports, tape, plugs etc., which have been installed to close the various openings.

2. Reinstall the exhaust collector rings.

3. Connect fuel and oil lines, controls etc.

4. Clean the propeller shaft and re- mount the propeller.

5. Remove the carburetor and flush out with gasoline. Then re-install and safety.

6. Clean any oil accumulation from the breaker points in the magnetos. Remove any trace of oil or grease from the inside of the magneto breaker housings with acetone, then dry the housing thoroughly. Do not remove the oil from the cam oiler felt or the magneto.

7. Clean inspect and install (if previously removed) all accessories such as starters, pumps etc.

8. Clean and adjust the spark plugs and install in the engine.

9. Pre-oil the engine before starting to completely fill all lubricating passages and the oil inlet line by means of an external pump or without the aid of such pump as follows:

a. Fill the oil tank.

b. Remove the oil inlet line connection at the oil pump and drain one quart or more of oil to insure that no air remains in the line.

c. Reinstall the oil inlet line to the pump.

d. Remove the oil pressure relief valve.

e. With the ignition switch off, turn the crankshaft by hand or starter until sufficient oil is expelled through the oil holes to indicate that no air remains in the oil pump. Reinstall the valve. The engine should be operated as soon as possible after pre-oiling.

4. Materials Needed For Corrosion Prevention

a. Anti-corrosion compound-lubricating oil mixture, consisting of three parts lubricating SAE 60 oil and one part compound.

b. AMS AS-7 Plug - shipping - engine cylinder dehydrator - spark plug substituting (14 required).

c. AMS 342O Dehydrator - silica gel - 1/4 Ib. bags (2 required)

d. *Tube - shipping - SAE #20 spline - crankshaft protector (1 required)

e. AMS 3542 paper - Grade A - wrapping for crankshaft.

f. *Cap - shipping - SAE #20 spline - crankshaft end protector (1 required)

g. *Cover- carburetor heat control valve substituting (1 required)

h. *Gasket - carburetor heat control valve substituting cover (1 required)

i. ANS 3810 Non-Hygroscopic tape for sealing engine openings and tapered crankshaft wrapping.

j. *Baffles - exhaust port shipping - Tenite #2 (7 required)

k. *Hydrol gaskets - exhaust port flange (7 required)

NOTE

1. Most of the above articles can be obtained at the local airports. However, all of these items are obtainable at the Warner Aircraft Corporation.

2. * indicates that these items can be furnished by the Warner Aircraft Corporation only.

3. A corrosion preventive compound which when mixed with 3 parts of engine lubricating oil affords protection of internal engine parts under dehydration and does not require de-preservation. For contact preservation of all exposed ferrous surfaces where permanent

protection is required and on parts suited to de-preservation methods, it should be used as originally prepared without mixing with oil.

Warner Engine Handbook: Installation

Section IV - Installation of Engine In Airplane

1. General

a. Engine Mount

1. Before the engine is mounted in the airplane, great care must be taken to inspect the bosses on the mounting ring for flatness. They must be flat within .003 inches if the engine is bolted up solidly, whereas a maximum variation of .015 inches is permissible if wood veneer or suitable auto brake linking, approximately 1/8" thick, is used between engine and the mount.

2. Rubber mounts of proper design and manufacture, which allow no fore and aft motion at each mounting bolt and only a very limited flexibility to absorb the torque impulses in the radial direction may be considered satisfactory. Rubber motor mounts with excessive radial flexibility or giving any appreciable fore and aft motion must not be used as excessive stresses will be imposed on all engine parts from inertia and gyroscopic loads.

3. In installations where rubber bushings are provided at each mounting bolt to eliminate telegraphing of vibration to fuselage structure, great care must be taken at the periodic inspection that these bolts have not become loose. These bushings are provided to eliminate the telegraphing or noises rather than to allow appreciable movement of the engine. All bolts must be equal in tension and as tight as possible without placing undue strain on the bolts.

4. If in doubt as to the mounting, we suggest you communicate with us and we shall be glad to forward service instructions.

5. Regular 5/6" Aircraft bolts must be used for the installation of the engine to the airplane.

b. Fuel Supply

1. The fuel line should be made of 3/8" O.D. tubing. All fuel lines should be made of seamless copper tubing which has been heated and quenched after bending.

2. A fuel strainer must be installed in the fuel line.

3. A 1/4" or 3/8" Briggs Standard pipe tap was used on early carburetors but the carburetors which are now installed on these engines will have a 1/2" Briggs standard pipe tap at the fuel inlet.

4. A 1/8" Briggs standard pipe tap is provided on the upper side of the top mounting lug for the installation of a primer.

c. Lubrication System

1. Oil Tank

(a) The oil tank should have a total capacity of approximately six gallons. In service it should be filled with five gallons of oil which allows an air space of approximately 20% of the capacity which is sufficient for the expansion of the oil. The oil tank should be located near the engine so that its lowest point is slightly above the oil pump when this airplane is standing on the ground.

(b) The oil lines between the engine and the tank should be 3/4" O.D. seamless copper tubing which has been annealed and quenched after bending to remove all stresses.

(c) A 5/8-18 tapped hole should be provided in the oil tank wall close to the bottom, or in the oil line from the tank to the engine for the oil thermometer. When placed in the oil line, the thermometer well should be made to Air Corps drawing S31B1096 as shown in volume 1 of "Handbook of Instructions for Airplane Designers". The oil thermometers used should have a range of 0 to 200 F. (or 18° to 93°C.)

(d) The drain plug in the oil tank and the oil outlet from the tank must be placed at the lowest point of the tank.

(e) The filler cap should be about 2 inches in diameter and provided with a vent.

(f) When the airplane is stunted frequently, a 3/8" O.D. vent tube should lead from the top of the tank to the 1/4" pipe tapped hole provided for this in the rear wall of the induction housing.

2. Oil Pressure Gauge and Fittings

(a) The oil pressure gauge connection fits into a 1/8" Briggs standard pipe tapped hole on the top of the gearcase.

(b) The oil pressure gauge line is made from 1/4" O.D. copper tubing.

Note
During cold weather, the engine oil in the oil gauge line may become so viscous that it would cause the oil pressure gauge to work sluggishly. Normal operation may be secured by disconnecting the line, blowing it out with air, refilling with petroleum base hydraulic brake fluid, and then reconnecting the line. Ordinarily, this treatment will suffice for a period of 60 to 90 days, after which time it can be repeated.

(c) An elbow fitting must be used at the gearcase in order to clear the tachometer shaft. All engines equipped with a generator drive adapter installed at the factory are furnished with this elbow and a right angle tachometer drive in place, as they must be installed before the generator drive adapter is mounted to the engine.

(d) The oil pressure gauge should have a range from 0 to 150 pounds per square inch.

d. Ignition System

1. Both battery and magneto ignition are available on the Super Scarab and Scarab engines.

2. Care must be taken to install the proper switch for the different ignition systems used. A switch closing the circuit is required for cutting off magneto ignition by means of grounding, whereas a switch opening the circuit is required for cutting off battery ignition.

e. Cowling

1. Two 5/16-24 tapped holes are provided on the front side of each rocker arm housing, for attaching the cowling to the engine.

2. If an additional attaching point is desired, and no air starter is used, the air starter boss on the cylinder head can be furnished taped 5/16-24 upon special request, and a bracket may be used.

Caution
At no time should the cowling rest upon the springs of the rocker arm housing cover.

3. On all installations equipped with N.A.C.A. cowlings, a cylinder head temperature indicator must be installed to take a reading at the rear spark plug for test purposes.

4. When cylinder head temperature indicators and thermo-couples are installed, care must be taken that the thermo-couple under the spark plug is fitted tightly against the bronze spark plug insert. There must be no distortion of the thermo-couple gasket which will allow possible leakage.

5. An Army-Navy type thermo-couple gasket should be used and the tab should be placed in the recess provided at No. 1 cylinder rear spark plug boss. If the recess is not provided one should be carefully chiseled for the tab to lay flat to prevent distortion of the gasket and possible leakage. Leakage at this point will cause erroneous readings.

f. Exhaust Manifolds

1. Exhaust manifolds should be so designed that there will be no more than eight inches of water back pressure.

2. Exhaust manifolds should have flexible joints between the exhaust ring and exhaust pipes leading from the exhaust ports into the collector ring.

g. Propeller Mounting

1. The propeller should be designed and set to allow the engine to turn up at least the rated speed in full throttle level flight. The advantages of the proper propeller installation are: best all-around performance of the plane, best fuel economy, and the minimum amount of stress upon the engine.

2. Quite often a very pronounced roughness will be experienced even with new propellers, due to a static or dynamic unbalance or due to differences in the shape of the two blades. It will be found that roughness will be most pronounced at certain speeds due to the fact that at these speeds there is a synchronization between the impulses and the natural period of the structure. All engines are very carefully and uniformly balanced before passing inspection in the factory, and if roughness is experienced in the airplane it is advisable to determine the origin of the roughness and to change propellers before trying to remedy it by making adjustments on the engine.

3. Another source of roughness may be due to a loose fit between the propeller hub and the crankshaft.

4. For proper operation, a propeller should track within 1/16" at the tip, and when an adjustable propeller is used, the adjustment between the two blades must be alike within 1/4°. All surfaces and edges of the propeller blades must be smooth and any pitting should be smoothed

down with a fine file and emery cloth, and finished with crocus cloth. The propeller must be rebalanced if an appreciable amount of material has been removed. In this connection, it is well to remember that removing only 1/4 ounce from the tip of one blade of a 7-1/2' propeller results in an unbalanced radial force of 84 pounds at 2050 R.P.M.

2. Installation of Engine In Airplane

a. General

1. Since the installation and removal of Super Scarab engines varies in different airplane models, the following outline may serve as a general guide for the typical job.

2. At least two men are required for this operation, and procedure will follow the steps indicated below, with variations permitted when the particular installation so requires.

3. Improper use of the engine hoisting equipment may result in serious damage to the engine. The hoisting equipment must be attached to the engine lifting eyes only. The equipment must not be used for lifting an airplane or the engine when it is attached to the engine mount.

b. Attaching Engine To the Airplane Mounting Ring

1. Attach lifting sling to the engine lifting eyes, take weight of engine on hoist, and remove bolts holding engine to assembly stand.

2. Raise the engine to the level of the airplane mounting ring.

3. Carefully guide the rear section of the engine through the mounting ring being careful to avoid striking any part or the engine or its projecting parts.

4. Install, tighten, and safety main engine mounting bolts. Remove engine sling and hoist.

Caution
Do not install mounting bolts without a flat steel washer between the bolt heads and the aluminum induction housing mounting bosses. Draw up evenly on all bolts to assure proper alignment of the engine and mounting ring.

c. Connecting Controls and Installing Accessories

1. Connect battery ground wires.

2. Connect oil pressure gauge lines to oil pressure gauge connection on gearcase housing.

3. Attach tachometer cable to tachometer drive.

4. Connect oil tank overflow to the induction housing.

5. Connect both magneto ground wires.

6. Install thermometer bulb in the oil inlet line.

7. Install generator and starter, if provided, making all electrical connections necessary.

8. Connect the control rod to the advance-retard lever on the rear of the magnetos, and test for full action in both directions when operated from pilot's cockpit.

9. Connect mixture and throttle controls to carburetor and test the controls to ascertain minimum and maximum operation of control levers when operated from the pilot's cockpit.

10. Install gasoline supply line to the carburetor.

11. Connect the carburetor air scoop, and the heat control valve to carburetor control, if the airplane is so equipped.

12. Connect "Oil in" and "Oil out" lines to oil pump.

13. Install exhaust stacks or exhaust collector ring.

14. Carefully inspect all installation connections and their safetying. Any loose electrical wires, tachometer cables, or lines of any kind must be securely taped down to prevent chafing or breaking during service.

15. Install necessary cowling.

d. Installing Propeller

1. General

(a) Before installing a propeller or hub, all parts will be examined for defects and damage, and checked for proper fitting.

(b) All raised portions of nicks, burrs, galls, scores, etc. on joining surfaces will be carefully dressed off and thoroughly cleaned before the propeller or hub is assembled on the crankshaft. All external surfaces, except the thread portion of the hub of the hub retaining nut, the rear cone, and the rear cone seat (which is to be installed dry) will be

coated with clean engine oil to provide lubrication and prevent corrosion.

2. Installation On Splined Shaft

(a) In the order given, assemble the rear cone spacer (if used), rear cone, propeller hub, front cone, and propeller hub retaining nut on the crankshaft.

(b) Screw in retaining nut.

(c) Install snap ring.

(d) Secure the retaining nut by installing and securing the clevis pin. A washer will be placed under the cotter pin on all propeller hub nuts having elongated locking pin holes.

3. Installation On Tapered Crankshaft

(a) Dress off all raised portions of nicks, galls, scores, etc. on the tapered surfaces, and thoroughly clean the shaft and hub.

(b) Cover the crankshaft taper with a thin coat of Prussian blue. Press hub on crankshaft as tightly as possible without turning it. Then rotate hub about 45 degrees. Remove the hub and examine its tapered surfaces as well as that on the crankshaft. If the parts have the required bearing contact and clearance, the bearing surface at the large end of the hub taper will be evenly coated with a thin film of blue transferred from the crankshaft and the small end will have little or none. Furthermore, the blue on the crankshaft will be light on the hub bearing section at the large end and dark on the small end section where the clearance is required. After completing the check, thoroughly remove the blue from all parts.

(c) If improper fit is indicated, the taper may be trued up by lapping.

(d) When the parts are properly fitted, cleaned, and lubricated, installation is accomplished as follows: Press the hub onto the crankshaft end by hand and, in the order given, screw in and firmly tighten the retaining nut and lock nuts. Use the proper wrenches with no additional leverage. Secure the lock nut with the lock ring.

(e) Before starting engine, all oil, moisture, or fuel accumulated should be drawn from the cylinders as outlined in the section on storage of engines.

Caution
Specific operating instructions and preflight instructions outlined in other sections of this publication must be

complied with before engine is placed in service.

3. Removing Engine from Airplane

a. The removal of the engine approximately reverses the procedure outlined in the preceding paragraphs. As the removal of the engines may vary slightly in different airplanes, the following guide may serve as a general guide for the typical job. This operation requires two men, and whenever possible should be accomplished indoors where a suitable hoist, parts bench, and other necessary facilities are available.

b. Removal of Propeller

1. Removal from Splined Crankshafts

(a) Remove the clevis pin securing the propeller hub retaining nut.

(b) Unscrew the propeller hub retaining nut. This should draw off the propeller hub.

(c) If the above fails, then additional force must be used. First remove the snap ring, nut and cone. Then thoroughly clean the threaded portions of the nut and shaft. Lubricate the cone, nut, and shaft with clean engine oil, reassemble and apply sufficient force to loosen the hub from the rear cone. Unscrew the propeller hub retaining nut.

2. Removal from Tapered Crankshaft

(a) Remove the safe tying lock wire or cotter pin.

(b) Remove, clean, and thoroughly lubricate the threads of the lock nut and retaining nut.

(c) Thoroughly lubricate the threads of the-hub and crankshaft.

(d) Reinstall and tighten both nuts. Then back out the lock nut one turn and back out the retaining nut until it seats lightly against the lock nut.

(e) Place the proper wrenches on each nut and holding the outer nut stationary turn out the inner nut until the hub loosens from the crankshaft.

(f) After the hub is loosened the nuts and remaining parts can be removed.

(g) If the above method fails to loosen the nub, then additional force must be used. Tap the end of the nut with a soft hammer while force is

applied on the nut by the wrench. Two or three applications should loosen the nut after which it may be removed.

Caution
Under no circumstances should a flame or any kind be used to heat the propeller hub in an attempt to expand it.

c. Remove cowling as required to permit the disconnecting of all engine attaching controls, lines, and mounting bolts.

d. Drain the oil out of the bottom of the tank by disconnecting the "oil in" connection at the oil sump.

e. Remove exhaust stacks or exhaust collector ring.

f. Removing Accessories and Disconnecting Accessories

(1) Disconnect "oil out" lines to oil pump.

(2) Take off the carburetor air scoop, and the heat control valve to the carburetor control, if the airplane is so equipped.

(3) Disconnect gasoline line from carburetor.

(4) Detach mixture and throttle controls from the carburetor.

(5) Disconnect the control rod from the advance-retard lever on the rear of the magnetos.

(6) Remove generator and starter if installed.

(7) Remove thermometer bulb from the oil inlet line.

(8) Disconnect ground wires from both magnetos.

(9) Remove oil tank overflow line.

(10) Detach tachometer cable from tachometer drive.

(11) Disconnect oil pressure gauge line.

g. Removing Engine

(1) From overhead hoist, attach engine sling to engine lifting eyes that are located on the rear half of the crankcase between the No. 1 and No. 7 cylinders on the left and the No. 1 and No. 2 cylinders on the right. Operate the hoist until the weight of the engine is removed from the airplane but does not lift the airplane.

(2) Remove the engine mounting bolts, leaving the two bolts at the rear or number one cylinder until last.

(3) Slowly separate engine from engine mount, carefully guiding rear or engine past the mounting ring. Lower the engine and attach it to assembly stand with at least four 5/16 inch bolts.

4. Ground Test Prior To Flight

After installation of engine in airplane has been completed and checked, the following steps are necessary for preparing the engine for flight tests:

a. PREPARATION. Remove rocker arm housing covers, and front spark plug substituting plastic plugs. Remove oil screen, wash thoroughly and replace.

b. CLEANING. Thoroughly clean the corrosion preventive compound from the rocker arm housings by spraying the valve stems, springs and housing with mineral spirits. Blow off excess spirits with compressed air and spray valves, valve stems carefully with SAE 40 or 50 lubricating oil, and grease rocker arms while turning the engine crankshaft to work the oil into the valve guides and to inspect for valve sticking. Replace the rocker arm housing covers and install the spark plugs, using thread lubricant.

c. LUBRICATING OIL. Fill the oil tank with proper lubricating oil, the grade of which will be governed by seasonal conditions.

d. TESTING. Start the engine observing that proper oil pressure is maintained. Warm the engine gradually and run at 1000 to 1200 RPM for 15 minutes. A full throttle magneto check should then be conducted to determine proper functioning of the engine. Any malfunctioning of the engine during this test may be caused by spark plug fouling due to the residual corrosion compound in the cylinders. Remove and clean the spark plugs and re-run the magneto check. The amount of corrosion compound in the engine is very small and it will not be necessary to change the oil in the tank at the conclusion of the ground test. It will be necessary to change the oil only at regular oil change periods.

e. INSPECTION. Before the flight test is conducted, inspect the installation very thoroughly to ascertain that no leaks exist in the fuel and oil systems, and that the installation has been properly conducted. Install all cowling and conduct the flight test.

Warner Engine Handbook: Starting and Normal Operation

Section V - Starting and Normal Operation

1. General

Consult the airplane or engine specifications for fuel and oil grades and requirements, limitations of crankshaft speeds, power, temperatures, pressures, and other operating conditions. Do not exceed these limitations.

2. Pre-Flight Inspection

a. Inspection prior to starting engine for first time after installation

1. Check the magneto ground wires to make sure that they are properly connected to the magnetos and engine crankcase or airplane fuselage. See that all connecting wires are in good condition. Inspect the connections and insulation carefully.

2. Check all bolts and nuts on the engine and mounting ring to see that they are tightened properly and securely locked.

3. Check the propeller and hub for tightness and proper safetying.

4. Check for proper connection of the oil pressure gauge, tachometer, cable thermometers and thermocouples, if provided.

5. Check the priming system, if installed, to see that it is in proper working condition.

6. Check throttle and mixture controls for full travel and proper connection.

7. Try gas cocks. Check all fuel and oil lines for tight connections and freedom from constrictions.

b. Before each flight, check the following:

1. Fill the oil tank to the proper level with the recommended grade of oil.

2. Fill the gasoline tanks with the specified grade or gasoline.

3. Operate the throttle and mixture controls to see that they function normally over their entire range.

c. Immediately before starting, make certain that the ignition system switch is in the "off" position, pull the propeller through by hand for at least three complete revolutions. If the propeller turns harder than it should, remove the spark plugs on the bottom cylinders and check to see if liquid is present. If liquid is found, continue working up the engine pulling plugs until dry cylinders are found.

Warning
The rods may be bent or broken if the engine is started with excessive oil or fuel in the cylinders. It is therefore urgently recommended that all operators take steps to have engines pulled through three complete revolutions by hand before they are started.

3. Starting the Engine

Caution
If the engine has been in storage and is being started for the first time then the procedure given in the section on stored engines must be followed.

a. Hand Starting

(1) Place spark in the fully advanced position. When starting a hot engine the spark should be retarded slightly to avoid kick back.

(2) Place the ignition switch in the "off" position.

(3) Turn the gasoline shut-off valve to the "on" position.

(4) Open and close the throttle rapidly several times. This will place a charge of gasoline into the induction housing by means of the accelerator pump within the carburetor.

(5) Turn the propeller several times with the throttle fully closed.

(6) Place the ignition switch on "contact" and throw the propeller quickly through compression. If the engine does not start, consult the section on "Engine Troubles".

b. Starting With Electric Starter

(1) Use the same sequence as in 3a except retard the spark approximately two thirds.

(2) Allow the engine to gain momentum before turning the ignition switch on. This will prevent possible kick-back against the starter.

4. Cold Weather Starting

In extremely cold weather, unless the airplane is equipped with an oil dilution system, the oil should be preheated.

5. Warm-Up

a. Aircraft engines will always be warmed up on the ground until proper lubrication and engine operation for the take-off and flight are assured.

b. After the engine is started, do not allow it to run at a speed greater than 800 R.P.M. until the oil thermometer indicates a rise in temperature. The thermometer will indicate a different temperature according to the type cowling installed as well as the manner in which the thermometer is installed. The proper running temperature should be determined by experience on the various installations.

c. When free flowing oils are used, safe operation of the engine under take-off conditions and cruising may be obtained when the oil temperature indicator hand begins to show a rise in temperature.

d. If the oil gauge does not show pressure within one-half minute the engine should be shut down and the cause of the trouble located.

e. Short bursts of speeds not to exceed maximum permissible ground R.P.M. and not to be maintained for periods in excess of 20 to 30 seconds may be used during warm-up period to check instruments and controls on the ground after the oil temperature gauge shows a definite increase indicating the circulation of the oil and also the oil pressure is two thirds of the minimum full power oil pressure. Maximum permissible ground R.P.M. will be that specified for "Minimum Cruising" in the specific operating instructions.

f. The magnetos may be checked by switching to one magneto at a time and checking for a loss in R.P.M. Normal loss in R.P.M. while running on one magneto should not exceed 1OO R.P.M. It is important to switch back to "both" after testing one magneto to make sure that the engine has picked up the lost R.P.M. before testing the other magneto.

g. Adjust the carburetor air heat to the hot position if atmospheric conditions are conducive to ice formation.

6. Taxiing

a. Hot Weather

1. The mixture control must be in the full-rich position.

2. The carburetor air heat must be in the coldest position.

b. Cold Weather

When engine and oil temperatures are subnormal prolonged ground operation is permitted, provided normal engine temperatures are maintained and the engine speed is increased periodically to scavenge the cylinders of accumulated exhaust gases and oil.

7. Take-Off and Climb

a. The mixture control must be in the full-rich position.

b. The spark control should be in the full-advance position.

c. Do not start the take-off with cylinder head temperature above 203 F. or below 104 F.

d. Manifold pressures must be reduced on take-off and climb to prevent detonation and resultant engine failure when abnormally high temperatures exist.

e. Always set carburetor air heat in the cold position during take-off unless severe atmospheric ice is present, such as ice or snow. Before changing the carburetor air heat, richen mixture, if not already rich.

f. Take-off will be accomplished at full-throttle.

8. Flight

a. When flying, the spark control should always be in the full advanced position.

b. After take-off, the throttle control should be set at the desired Cruise R.P.M.

c. It is not recommended that the mixture control be used below an elevation of 5,000 feet, and at such time as it is used, it should be used to give the best running condition of the engine, rather than in an

attempt to save gasoline. An excessively lean mixture will cause overheating of the cylinders.

d. The R.P.M., oil temperature And the oil pressure give the most satisfactory indication of the engine's performance. If any of these appear irregular, the engine should be throttled and if the cause cannot be eliminated, a landing should be made to investigate and remove the trouble.

9. Landing

a. General. Landing operation includes the operation of the engine preparatory to landing and after landing.

b. Before landing, the mixture control should always be placed in the full rich position to prevent the stalling of the engine, due to an exceptionally lean condition on reaching the lower altitudes.

c. From cruising condition, slowly close throttle to 1,000 R.P.M.

d. If the airplane must execute a prolonged glide to reach the ground, keep turning the engine under partial throttle so as to retard rapid cooling of the engine.

e. Periodic low R.P.M. bursts of the engine will insure clean cylinders and a warm engine ready for instantaneous emergency application of power.

10. Stopping The Engine

a. The correct method of stopping the engines will reduce time in stopping, reduce backfire, and also prevent overheating of tightly baffled engines.

b. Set mixture control at full rich.

c. Set the throttle for normal idling of 400 to 600 R.P.M. and let the engine run with nose cowls fully opened until the engine has cooled appreciably below cruising temperature.

d. After obtaining the proper temperature, the R.P.M. should be increased to 1,000 to 1,100 R.P.M. for one-half minute in order to permit scavenging of the crankcase oil.

e. Cut the ignition switch. As the propeller slows down and with the ignition switch off, slowly move the throttle to the full open position.

f. Allow the throttle to remain in its open position after stopping the engine, as this lessens the likelihood of accidental starting while the engine is hot.

11. Mixture Control Operation

a. Definitions of Settings Applicable To Manual Control

(1) "**Full-Rich**" is the setting of the mixture control lever in the position giving maximum fuel flow.

(2) "**Best Power**" or "**Maximum Power**" is the setting of the mixture control level which, with a given fixed throttle setting, results in the maximum engine R.P.M. at the leanest fuel flow; i.e., further leaning to the mixture would cause a decrease in engine R.P.M.

(3) "**Rich Best Power**" is the setting of the mixture control lever which, with a given fixed throttle setting, results in the maximum engine R.P.M. at the richest fuel flow.

(4) "**Smooth Operation**" is obtained by setting the mixture control lever for "Best Power" and then enriching the mixture until the engine speed drops 20 to 30 R.P.M.

(5) "**Maximum Economy**" is obtained by adjusting for "Best Power" and then leaning the mixture to obtain a decrease in engine speed of 40 to 50 R.P.M.

b. The mixture control should never be used without a full understanding of its effect on the engine and a knowledge of the general conditions under which the engine is operating.

c. It is possible to ruin an engine in a few minutes by improper use of the mixture control, as too lean a mixture will rapidly overheat the engine.

d. When using the mixture control, the cylinder temperatures must be carefully checked to prevent overheating.

e. The mixture control is set at a "full rich" position for take-off and landing.

f. Above 5000 feet the mixture control is adjusted for smooth operation.

12. Carburetor Air Heat Control

a. The function of the carburetor air heat is to prevent or eliminate the formation of ice in the induction system. The formation of ice restricts the carburetor air flow and results in loss of power.

b. Induction system icing consists of one or both of the following: Atmospheric ice is ice formed from water already in the atmosphere as ice, snow or liquid water, while fuel evaporation ice is that formed from moisture vapor present in the air and is due to the cooling effect of the fuel evaporating in the air after it is introduced into the air stream at the carburetor.

c. Formation of Ice in Induction System

(1) Normally, the formation of ice may be indicated by either a gradual loss of R.P.M. or a reduction in manifold pressure, or perhaps a combination of the two, without changing the throttle setting or the altitude of flight. Under most conditions the formation of ice is relatively slow, and the pilot may be able to maintain constant R.P.M. by slowly and continuously advancing the throttle.

(2) In extreme cases, the formation of ice may be so rapid and the loss or power so abrupt that the prompt use of the carburetor air heat is necessary to prevent total loss of power.

d. Operation under Icing Conditions

(1) GENERAL Use full carburetor air heat under icing conditions with precipitation near the freezing point to insure ice elimination. Then maintain a temperature between 86° and 95° F. measured with a carburetor air mixture thermometer.

Caution
If these temperatures cannot be maintained, place control in full "cold" position.

Note
It will be necessary to readjust the mixture control whenever the carburetor air heat control setting is changed.

(2) STARTING Carburetor air heaters will always be in full "cold" position to eliminate heater valve damage due to backfire.

(3) GROUND RUNNING. Ordinarily the carburetor heat will be in the "cold" position. However, during icing conditions the instructions in (1)

above will followed during extended ground operation and just before take-off.

(4) TAKE-OFF Carburetor air heat will not be used during take-off. Under icing conditions, carburetor air heat will be used immediately before take-off, to insure that all ice is removed from the induction system. Immediately after take-off when power is reduced, carburetor heat will be adjusted to maintain the temperatures in (1) when icing conditions are indicated.

(5) CRUISING When cruising under severe icing conditions, at least 75 per cent engine power will be used and the mixture control will be set on the rich side of best power. At the same time it is advisable to seek a more favorable altitude where precipitation can be avoided and where the temperature is farther from the freezing range.

(6) LANDING Carburetor heat control will be in the "hot" position when in a long glide before landing. but will be in the "cold" position immediately prior to the landing approach so as to have full power available.

13. Run Out On Unleaded Fuel

a. If engine is to be shut down over 48 hours, it should be operated at 40 to 50 per cent of normal rated R.P.M. for 15 minutes on the propeller load with 73 octane unleaded fuel. This is necessary to avoid corrosion caused by tetra-ethyl lead.

b. Before shutting off engine, run it between 700 and 800 R.P.M. long enough to permit the cylinders to come to a maximum temperature of 250 F. Then turn the ignition switch to the "off" position.

Warner Engine Handbook: Engine Troubles and Service Repair

Section VI - Engine Troubles and Service Repair

1. Failure of Engine to Start

a. Inadequate Fuel Supply

1. See that gasoline supply is "on".

2. Check to see that the gasoline in the tank is high enough to flow to the carburetor.

3. Make sure that the carburetor float is not stuck and that there is a definite flow of gasoline to the carburetor.

Note
In no case will the carburetor be disassembled to determine these conditions.

4. Check fuel lines and tank for possibility of vapor lock.

5. Check fuel lines to see if flow is restricted by obstructions such as dirty strainers or water in lines.

b. Engine Under-Primed or Over-Primed

1. The correct amount of priming necessary for each engine must be determined by trial.

2. It engine is under-primed, check functioning of primer system and "load" the engine more by turning the propeller in the direction of rotation with the switch "off" and throttle "closed".

3. Over-priming and a resultant flooded condition is more often experienced during warm or hot weather.

4. Over-priming is easily identified, especially it the engine seems to fire on one or two cylinders with a fizzling exhaust report and emission of black smoke accompanied by a weak "kick" of the propeller with the engine finally dying.

5. If over-prim1ng is indicated, turn the main gasoline supply valve "off"; turn the magneto switch "off"; open the throttle wide and turn the propeller opposite direction of rotation ten to fifteen revolutions. This should "unload" engine and a new attempt can be made to start.

c. Mixture Control and Throttle Operation

See section on Starting and Normal Operation.

d. Defective Ignition

1. Examine ignition wires for shorts or leaks caused by faulty insulation.

2. Make sure that the ignition switch is turned on, is not defective, or that the ground wire insulation is not damaged so as to permit a contact with the metal of the airplane somewhere between the switch and magneto ground terminals.

3. Check magneto points for proper gap clearance, a possible pitted condition, or evidence that the condenser has burned out. Refer to the section on Limits for Proper Gap.

4. Ascertain that the magnetos are in good working condition and in correct time. Refer to section on timing of the engine for this information.

5. Check all spark plugs for correct gap setting and see that they are not fouled by oil or carbon. A visual examination may reveal the cause of failure.

(a) If the plug is clean but the metal snows signs of overheating then the cylinder has been running too hot, which indicates pre-ignition, detonation or poor cooling.

(b) If the plug is clean but wet with fuel or oil, no conclusions should be formed since this may occur during the moment of stopping only.

(c) Caked carbon is evidence of the beginning of excessive oil consumption or misfiring or non-firing of the plug.

(d) A thin deposit of fine black carbon may be sufficient to short circuit a plug which otherwise looks quite free from deposits.

e. Valve Action

1. Check valve stems to be sure that they are not gummed up with carbon making the valve stick open.

2. See that all valve springs are in good order and that their assembly to the valve stem is in good order.

3. Check to ascertain the free and good working order of all rocker arm assemblies, especially evidence of a rocker arm striking the side of a rocker box causing a delayed action.

4. Check for worn or bent pushrods.

5. Check for correct valve clearance.

f. Cold Oil

Turn propeller over by hand to break the drag created by cold oil. If engine is excessively stiff, it may be necessary to drain and heat the oil.

g. Hot Engine

A hot engine is exceedingly easy to over-prime, and it must be appreciated that frequently it will start without an additional prime over that left in the cylinders when the engine was shut down. If the engine is hot and seems to refuse to start for that reason, turn main gasoline supply off; open throttle, turn ignition switch off, and allow engine to stand for ten or fifteen minutes and cool. Do not operate engine at any time without all cowling and baffles installed. After engine has cooled, proceed as directed for over-primed engine.

h. Air Leaks In Induction System

Examine intake pipes for leaks at all induction system connections. Air leaks sometimes cause a sharp high-pitched whistling noise that is particularly audible at or near idling speeds when the intake manifold vacuum is at its highest.

i. Carburetor Flooding

Caution
Because of the fire hazard involved, the engine should not be started if the carburetor leaks excessively.

1. If there is a slight leakage, it may be due to sticking of the float. A light tap on the carburetor housing with the hand w111 usually remedy this condition.

2. In no case will the carburetor be disassembled to correct any leakage. Replace the carburetor instead or remove it and repair it. Refer to the carburetor manual.

2. Low Oil Pressure

a. Determine whether main oil tank contains a sufficient quantity or lubricating oil.

b. Carefully inspect main oil line from tank to input side or duplex oil pressure pump to ascertain if there are any leaks causing the pump to starve for oil.

c. During cold weather the oil may become congealed in the suction line from the oil tank, preventing the oil from reaching the pump.

d. Excessive temperatures reduce the viscosity or the oil, which then offers less resistance when forced through the oil passages and thus tends to make the pressure drop.

e. Foaming is a frequent cause of fluctuating oil pressure and loss of oil pressure. The presence of some air in the scavenge oil is normal. If the oil is foaming, it should be drained from the oil tank and replaced with fresh oil. Water or metal soaps in the oil will cause excessive foaming.

f. Inspect oil pressure relief valve to ascertain whether the ball is seating well, and that the control spring is functioning properly.

g. Ascertain whether oil pump is actually turning so that excessive wear of gears or housing or failure of drive or drive shaft has not occurred. Consult directions in overhaul section of handbook for repair of pump.

h. Remove oil pressure screen and observe if it is partly clogged or contains an excessive deposit of metal particles. If metal particles of appreciable size and quantity are found, the cause should be determined and the engine cleaned out and repaired if necessary before further operation.

3. Low Power

a. Remove front set of spark plugs and test compression of each cylinder. If no gauge is available, cylinder compression can be determined with a reasonable degree of accuracy by placing the thumb over the spark plug hole and swinging the propeller by hand so as to

bring the piston up on compression stroke. At top of compression stroke, suddenly remove thumb from spark plug hole so as to rapidly release compression and a rather loud, snappy report of escaping air should be heard. If the propeller is rotated twice and the number of uniform compression strokes equals the number of cylinders, lack of or uneven compression could, in most cases, be eliminated as the cause of the trouble. A little practice will produce fairly accurate results. Blown or sticking valves, or excessive loss of compression past pistons can easily be heard by listening to the individual cylinder being tested.

b. Check all valves. Any valve having appreciable increased clearance will indicate cam ring, push rod, or rocker arm trouble. It is impossible for the engine to jump valve timing.

c. Ascertain whether engine lubricating oil is correct grade or not.

d. Check ignition system operation, especially for cylinders periodically "cutting out" due to failure of spark plugs, ignition wiring, or sticking of magneto points. Be sure magneto is functioning in accordance with instructions set forth in the manufacturer's handbook. Ascertain that magneto breaker point has minimum clearance behind the arm when points themselves have their required clearance. Ascertain whether magnetos are in full advance. If necessary, check ignition timing in accordance with instructions in Section XI of this handbook.

e. Make sure that pilot's throttle lever has full operation and is completely opening the butterfly in the carburetor.

f. Check carburetor for proper setting. See Carburetor Manufacturer's handbook of instructions.

g. See that an unrestricted flow of gasoline of the proper grade is available at the carburetor.

h. Ascertain that carburetor air heater, if provided, is being operated properly and that there is no evidence of ice in the induction system.

i. Check for air leaks in the induction system.

j. Check propeller for weight and setting.

4. Rough Running

a. Check the propeller for balance, track, and correct installation on the propeller shaft.

b. Remove and check spark plugs.

c. Check magneto operation. Ascertain whether insulation of ignition cables is failing at high engine speeds.

d. Check valve operation, especially evidence of sticking or any lag in valve operating mechanism. Check valve clearance.

e. Check engine mounting bolts for looseness.

f. Check engine mount for cracked or broken members.

g. In extreme cases, check possibility of magneto ground wire swinging and periodically grounding, or having damaged insulation at the points where they are taped down.

h. If airplane has been nosed over, check for bent crankshaft.

i. See that propeller hub nut is tight.

j. Check air intake temperature to intake sure that it is not too hot.

k. Check for ice formation in the induction system.

l. Make sure that the engine operating temperature is not too low.

m. Check carburetor for proper mixture setting.

5. High Oil Temperature

a. Check quantity and quality of supply of oil in main oil tank. Oil may be too light or excessively diluted.

b. Check functioning of oil cooler and by-pass valves if airplane is so equipped.

c. Check compression as described in paragraph 3.a. in this section. Excessive discharge of oil or oil fumes at crankcase breather would indicate piston blow-by with excessive pressure, due probably to worn out piston rings.

d. Check to see that crankcase vent system is functioning properly.

e. Check scavenger pump for proper operation.

f. Check oil screen strainer for deposits indicating any evidence of failure in the master rod bearing.

g. Check air flow around oil reservoir tank.

6. High Cylinder Head Temperature

a. Check ignition timing. Engine time may be too late.

b. A lean mixture in any or all cylinders could cause high temperatures. This could result from improper setting of carburetor or air leaks in induction system.

c. Test for pre-ignition or detonation.

d. Check inter-cylinder baffling, being sure of its proper installation.

Caution
Inter-cylinder baffling should be tight against the O.D. of cylinder fins.

7. Carburetor

a. Idle adjustment, located on the front side of carburetor, is set for smoothest idle on final acceptance run of engine at the factory. As the engine loosens up during service the adjustment should be regulated as the needs require, to keep the engine idling smoothly.

b. Any further maintenance, service or adjustment will be accomplished in accordance with carburetor manufacturer's instructions.

8. Magneto

All adjustments or service of magnetos will be accomplished in accordance with the instructions published by the magneto manufacturer.

Warner Engine Handbook: Service Inspection and Maintenance

Section VII - Service Inspection and Maintenance

1. General

a. The work outlined in this section consists of periodic inspection, cleaning, servicing, lubricating, adjusting, and such maintenance work as is associated with the routine inspection system. For pre-flight inspection refer to Section on Starting and Normal Operation.

b. The necessary tools for this work may be found listed immediately preceding Section VIII of this publication.

c. Tightening nuts is one function of periodic inspection. Failures of nuts, bolts, and studs have been traced to excessive force in tightening. Therefore proper torque values should be used on all threaded parts. See torque limits in Table of Limits Section XIII of this manual.

2. Inspection and Maintenance

a. Daily

1. Inspect for evidence of engine throwing oil.

2. Inspect all oil plugs and drain cocks for proper safetying.

3. Inspect carburetor and fuel line connections.

b. 25-Hour

Note
We recommend the following inspection routine be performed at least every 25 hours. Such regular inspection will give the most satisfactory engine performance and disclose defects otherwise likely to cause engine trouble. An engine that has been properly cared for will give much more satisfactory service, the time between overhauls will be lengthened and the total life of the engine will be

considerably increased.

1. Check all mounting bolts, especially when rubber bushings are used.

2. Inspect all oil lines for: leaks, particularly at connections; security of anchorage; wear, due to chafing or vibration; dents or cracks.

3. Check all external nuts and bolts for tightness, immediately replacing cotter pins and lock wires when they have been removed for any purpose.

Caution

The bolts or nuts holding the intake pipes to the cylinders should not be tightened excessively as this will deform the flanges and cause leaks.

4. Check throttle, mixture and spark controls, making sure that the full movement of the controls in the cockpit corresponds to the full movement of the controls at the engine. Adjustments may be necessary where wires and springs are used to make control connections.

5. Check the ground wire and switch wire connections when the magnetos are used, at the engine and at the switch. It is very important that these connections be tight and that there are no breaks in the wires. This is to prevent accidental starting of the engine should the propeller be turned while the airplane is standing on the ground with the ignition switch on "off".

6. Check all high tension wires, to be certain that the insulation is not being chafed anywhere by sharp edges.

7. Spark Plugs

(a) Examine all spark plugs for tightness in the cylinder, for cracks in the core and for leakage between the core and the shell.

(b) Do not attempt to disassemble any spark plugs or set up gaps, as these gaps should be repaired by an authorized service station when the gap reaches .028, which will usually take 300 hours or more of flying. Improperly assembled spark plugs are likely to overheat and to cause serious damage to the engine.

(c) If a spark plug does not screw freely into the head, there either may be a burr on the thread of the plug, or the thread in the cylinder may be closed slightly, requiring cleaning of the thread with a spark plug tap.

(d) Check spark plug terminals.

8. Oil magnetos with 5 to 8 drops or good grade oil at the drive end, and slightly less at the rear end.

9. Remove rocker arm housing covers and wipe out rocker box. Inspect valve gear in regard to springs, spring washers, security or retaining split cone keys, rocker arms, etc. The rocker arms and rollers must move freely, and the rollers should be lubricated with a few drops of light oil. 0il exhaust valves with light oil.

10. Grease rocker arm shafts with a grease of good quality and high melting point. Ball bearing rocker arm lubricants, which have been round satisfactory by the Warner Aircraft Corporation, are listed in Section I, Table II of this book.

Caution
Grease containing graphite, asbestos, or other filler must never be used, as serious damage to the ball bearings in the rocker arms will result from use of such lubricants.

11. During inspection it will be well to remove the push rods and lubricate the ball ends thoroughly with rocker arm grease. Inspect push rods for wear and straightness.

12. Drain oil by opening the pet cock or plug at the bottom of the oil tank. The tank and engine should be flushed with clean light oil if grit is found in the old oil.

13. Remove and clean all removable oil screens. Clean sumps also.

14. Fill oil tank as specified on filler cap of oil tank after drain plug has been replaced and has been secured with a lock wire.

15. Check tappet clearances, which should be .010" to .012" for the intake and exhaust valves when the engine is cold. Proceed as follows:

(a) Turn the propeller forward until the Intake valve on cylinder No. 1 closes, then turn propeller an additional 120 degrees (1/3 of full turn) which brings the piston to the top center.

(b) Insert the feelers between the valve stem and the rocker arm roller for measuring. Make adjustments if the clearance is found to be below .010" or above .012".

(c) When cylinder No. 1 has been adjusted, turn the propeller forward 120 degrees beyond the closing of intake valve on cylinder No.2. Then check clearance of this cylinder.

(d) Continue this until all tappets are checked and adjusted.

16. Inspect carburetor and fuel line connections for fuel leakage, paying particular attention to drain plugs, passage plugs, and parting surface between body castings. Inspect all safety wiring on carburetor.

17. Remove float chamber drain plug and remove fuel strainer plug and strainer, and clean. Flush out water and sediment by allowing fuel to flow through strainer and drain plug openings.

18. Grease the rocker arms using the approved rocker arm lubricant.

Caution
Use only enough grease to fill the chamber in the rocker arm as an excessive accumulation of grease in the rocker boxes may lead to valve failure.

c. 50 Hour

1. Magneto

(a) Remove magneto breaker cover and check clearances between contact points when held wide open by the cam. The clearance should be .010" to .014", the most satisfactory .012".

(b) Put 20 to 30 drops of lubricating oil into the oil cup on the magneto front plate, and 5 to 8 drops into the oil cup on the magneto coil cover. Avoid over oiling.

(c) Examine the felt wick at the bottom of magneto breaker clip to make sure it is moist with oil. If oil appears on the surface of the felt when squeezed with the fingers, no additional lubricant is needed. If it is dry, moisten it with lubricating oil.

2. Inspect all ignition wiring for security of attachment.

3. See that inter-cylinder baffling is properly fastened and does not rub cylinder fins.

4. Inspect cylinders for damaged or broken fins.

5. Inspect induction system for security of attachment, leaking gaskets, broken studs, and leaks in the pipes.

6. Check carburetor heater (if installed) and air scoop for security.

7. Inspect thrust bearing nut and tighten if necessary.

8. Inspect cylinders for general condition.

9. Check compression an all cylinders by removing one spark plug from each cylinder except the cylinder to be tested. Swing the propeller by hand. The compression of the cylinder being tested can be judged by the amount of resistance offered. All cylinders should be checked in a similar manner, and all should "feel" the same. Check in the firing order which is 1-3-5-7- 2-4-6. All cylinders will come up on compression once in every two revolutions and an equal distance apart.

d. 100 Hour

1. Replace all sparks with new or reconditioned plugs of approved type. Inspect all spark plugs for gap clearance.

2. Carburetor

(a) Inspect parting surfaces between body castings for leakage and check all nuts and bolts on carburetor for tightness.

(b) Strainer assemblies, strainer plugs, or plugs marked "drain" should be replaced if found in bad condition.

3. Required Tools List

Tool Kit for Models SS50 and SS50A Engines

Part No.	Part Name	No. Req.
FA-23	Gage - Feeler (Bonney FA-23)	1
FA-26	Pliers - 6" Combination (Bonney B6)	1
FA-27	Screwdriver - 12" (Bonney W06)	1
FA-28	Tool Container - Canvas	1
FA-30	Tool - Valve Supporting	1
FA-33-A	Wrench - Cylinder Base Nut (with Handle) (Bonney X-1241)	1
FA-34	Wrench - Magneto Breaker Setting (Furn. with magneto - Scintilla 4-490)	2
FA-35 **	Wrench - Propeller Nut (Bonney 810 C)	1
FA-36-2	Wrench - Socket with 7/16" Socket and Handle (Bonney Socket T14, Handle 7750 and Cross Handle T32)	1
FA-37	Wrench - 3/8" and 7/16" Open Ends (Bonney 1723)	1
FA-39	Wrench - 5/8" and 3/4" Open Ends (Bonney 1729 or Cornwell #EW 28)	1
FA-40	Wrench - 15/16" and 1" Open Ends (Bonney 408B)	1
FA-90 **	Wrench - Propeller Nut Inner (Bonney 809 S)	1

FA-91 **	Wrench - Propeller Nut Outer (Bonney 7889)	1
FA-105-A	Tool - Valve Grinding	1
FA-111	Gun - Alemite - Hydraulic - (#6556)	1
FA-164	Tool - Valve Spring Depressing	1
FA-167	Wrench - Spark Plug 11/16" or	1
FA-259	Wrench - Socket 7/8" (Bonney LD28)	1
FA-171	Wrench - 1/2" and 9/16" Box Socket (Bonney 2805L)	1
FA-11238	Wrench - 3/8-24 Cylinder Hold Down Palnut	1

Note **: FA-35 is furnished for use with No. 7226 nut for Hamilton metal propeller or OX type wood propeller hub.

FA-90 and FA-91 are furnished for use with standard steel propellers. The customer must specify which type of propeller is to be used so that the proper wrench may be furnished.

Warner Engine Handbook: Top Overhaul

Section VIII - Top Overhaul

1. Top Overhaul

a. General

(1) By top overhaul is meant the lapping of valves and the making of necessary repairs of those parts on the crankcase which are accessible without disassembling the crankcase. It includes the removal of cylinders, pistons, piston rings and valve gear for replacement or service.

(2) The need for a top overhaul is usually indicated by not being able to get the required engine speed with full open throttle while the airplane is on the ground. It is also indicated by excessive oil consumption.

Note
Winds, and extremes in humidity, temperature or barometer, due to atmospheric conditions or altitudes will cause variations in propeller speed. Loses or gains in propeller R.P.M.'s can be partially accounted for by taking into consideration such temperature, barometer or humidity extremes. It is therefore advisable to have mean ground temperature and operating conditions when checking top overhaul need by means of propeller R.P.M. at full throttle. It must be particularly kept in mind that observed R.P.M. is considerably lower at low humidities.

(3) Before testing the ground R.P.M. with full open throttle when determining the need of a top overhaul, the following checks must be made:

(a) Mixture control is in full rich position.

(b) Throttle level is fully open and level has full and free travel.

(c) Spark is fully advanced.

(d) All cylinders are firing properly.

(e) Tappet clearances are .008" to .012".

(f) Magneto breaker gap is .010" to .014".

(g) Spark plug gaps are .015" to .020".

(h) Magneto attaching nuts must be tight. Loose nuts may allow the magneto to move thereby altering timing. Magneto coupling bolts must be tight.

(i) Be sure that the fuel flow to the carburetor is not obstructed. Clean strainers in fuel system.

(j) Check the compression of each cylinder on the engine after it has cooled down. If the compression is satisfactory, a top overhaul is not indicated and either the ignition or fuel system is at fault.

(4) If an engine ahs been properly taken care of, a top overhaul should not be necessary before 200 to 250 hours of flying time, and in some cases, more, has elapsed.

b. Cleaning And Preliminary Operation

(1) General

(a) A top overhaul can readily be made with dismounting the engine from the plane. Only those tools in the tool kit furnished with each engine need be used for this work.

(b) Be sure the ignition switch is turned "off" so that the engine will not be started accidentally while it is being repaired.

(c) Drain the oil tank.

(2) Cleaning

(a) Remove propeller, cowling, and exhaust stacks or ring. Disconnect or remove the battery so that there will be no danger of sparks igniting inflammable substances.

(b) Place airplane in a well ventilated spot where the fire hazard will be minimum.

(c) Clean engine with suitable cleaning compound.

Caution
On account of the fire hazard, do not attempt to wash the engine before it has thoroughly cooled.

(d) Allow the cleaning compound to vaporize for the exterior of the engine.

(3) Operations Preliminary To Disassembly

(a) Place airplane in a protected dust free location which has good lighting.

(b) It will be necessary to climb around the engine installation so suitable scaffolding and padded ladders would be of great assistance.

(c) The work bench should be located in a clean place with plenty of light.

c. Disassembly of Parts From The Engine

1. General

(a) New gaskets should be installed.

Note
If new gaskets are not available, be careful in removing the old ones, and immediately place them between two wooden covers to prevent their drying and cracking.

(b) Have plenty of clean lintless cloth on hand. Never use waste ravelings to wipe parts of an engine because they tear loose and may cause damage later on.

(c) All tools should be listed and each must be accounted for upon completion of the job.

(d) As parts are removed, they should be placed upon the bench in an orderly manner and marked or tagged so that they will be returned to the proper places during reassembly.

(2) Disconnect all ignition cables from the spark plugs.

Note
In order to facilitate reassembling, it is advisable to tag and mark each cable as it is taken off the cylinder.

(3) Remove all spark plugs.

(4) Remove rocker arm housing covers.

(5) Remove all intake pipes by unscrewing the two nuts with which each is attached to the cylinder.

(6) Removing Cylinders

(a) On engines which use palnuts to lock the cylinder hold down nuts in place, care should be taken in removing them. Be sure that these

palnuts are removed with a wrench, and are never forced off by turning the cylinder hold down nuts.

(b) The cylinders are detached by unscrewing the cylinder hold down nuts with the cylinder base nut wrench. The two rear nuts (those between the cylinder and the induction housing) are the most difficult to reach and should be removed first. The six nuts remaining may then be removed.

(c) Remove cylinders, pistons, push rods, and push rod tubes in the order of rotation, leaving the cylinder containing the master rod piston (cylinder No. 1) until last.

Caution
In performing this operation, great care must be taken that the rods or pistons do not drop against the crankcase and become marred or dented.

(d) As each cylinder is taken off, push out the piston pin immediately and remove the piston. If it is necessary to drive the piston pin out of the piston, a soft drift should be used, and the piston supported in such a manner that no dr1ving thrust is taken by the connecting rod.

(e) Never allow the piston or rod assembly to slap against the sides of the crankcase or mounting studs after the cylinder has been removed from the crankcase or while the crankshaft is being rotated.

(f) Secure seven pieces of rubber hose whose I.D. is large enough to encompass the entire section of the connecting and link rods and long enough to extend from the piston to the wrist pin. Cut these pieces along one side and install them over the connecting and link rods immediately after each cylinder has been removed.

(g) All parts so dismantled from the engine should be laid on a clean bench in the order in which they are removed.

(h) While overhauling the cylinders, cover the crankcase openings with clean pieces of cloth for protection against dust and dirt.

(7) Remove the oil screen and inspect for metal chips, dirt, etc. If metal is present, a thorough search for the source must be carried out, and steps taken to correct the trouble.

d. Inspection

(1) Inspect the crankshaft and connecting rod assemblies for abnormal wear, safe tying of retaining members, etc., through cylinder base holes in crankcase.

(2) Inspect cowling panels, fasteners, etc. for defects. Repair if necessary.

(3) Inspect propeller for nicks, burrs, fit, etc.

(4) Inspect exhaust ring or stacks for cracks, leakage at joints, condition of gaskets, etc.

(5) Remove carburetor from engine and service check in accordance with carburetor manufacturer's instructions.

(6) Completely service check the magnetos in accordance with the magneto manufacturer's instructions.

(7) Replace all spark plugs with new or reconditioned plugs. Carefully inspect the entire ignition harness for serviceable condition.

(8) Inspect all cylinder hold down studs. Remove all cylinder hold down studs that are loose, broken, or have damaged threads. Replace with the proper oversized studs.

(9) Check entire engine and ascertain that all nuts are tight in accordance with torque values set forth in the table of limits. See that all safetying is complete and tight.

(10) Inspect, tighten, and safety all engine mounting bolts.

e. Servicing the Cylinder Assemblies

(1) Rocker Arms

(a) On all engines, it is not necessary, nor is it desirable to remove the rocker arms in order to grind the valves and they should be taken apart only when some part is damaged or indicates wear.

(b) If a rocker arm roller is stuck or shows signs of wear or excessive clearance, it should be replaced. A new roller can be fitted into a rocker arm by an authorized service station equipped with proper facilities.

(2) Grinding And Replacing Valves

(a) Determine which valves are leaking and need lapping by pouring gasoline into the valve ports. Valves which leak must be lapped or replaced.

(b) Removing Valves

1. Place the cylinder over a block of wood which should be 4-1/8 inches in diameter, 9 inches high, and rounded at its upper end to fit,

approximately, the cylinder dome. It is best to have the block attached to a wooden base, so that it stands upright on the work bench. This block serves to hold the valves closed while the springs are being removed.

Note
The valve supporting tool in the engine tool kit may be used for the same purpose; but the wood block will prove the more convenient when the cylinder has been removed from the engine.

2. Remove the rocker arms and shafts in order to install the valve depressing tool. Depress the valve springs with the valve spring depressing tool. Remove the split cone, the valve washers, and the springs. Care must be taken to keep the valve washers and valve retainers separate as different units are used.

3. To avoid damaging the valve guide when removing the valve, inspect the end of the valve for burrs. If any are found, they must be removed.

(c) Reconditioning and Valve Grinding

1. After both valves have been removed, scrape off all carbon from the cylinder dome and from the valves, being careful not to mar or scratch the valve seats and the valve stems.

Note
A simple and handy fixture for holding the cylinder while grinding the valves or cutting the valve seats as described under "Complete Overhaul" , is a 6" x 12" steel plate 1/8" thick, with a 4-7/8" hole near one end of the plate. Such plates may be purchased from the Warner Aircraft Corporation. The cylinder should be attached to these plates with two 5/16" diameter bolts holding the cylinder flange to the plate. The other end of the plate should be held in a vise.

2. To grind the valves, spread a small amount of valve grinding compound around the seat of the valve, insert the valve in the guide and grind with the valve grinding tool from the engine tool kit. Repeat the operation until a good seat is obtained.

3. Wash the valves and the cylinder carefully with gasoline so that no trace of the grinding compounds remains.

4. Inspect valves with magnifying glass for cracks.

(d) Reinstalling Valves

1. Put the valves in place, being careful not to interchange those of different cylinders. The cylinder number is etched on the valve stem below the groove.

2. Put the cylinder over the wooden block tool used for disassembling.

3. Snap the circlets, where used, into their grooves from the side, and assemble the lower valve spring washer, the springs, and the upper washer to the head.

4. Depress the valve springs with the valve spring depressing tool. Insert the two halves of the split retainer, being careful that the proper type retainers and upper washer are used. Be sure that the two retainer halves used on each valve, if numbered, bear the same number.

5. After the valves have been assembled, they must be tested with gasoline for tightness, and if they still leak, the valve grinding must be repeated until they are tight.

(3) Cylinders and Heads

(a) Check cylinder bores for out-of-round, taper, scores, cracks, etc.

(b) Check cooling fins for cracks, etc.

(c) Carefully check the fit of the spark plugs in the cylinders. Carbon in the threads or the effect of frequent heating and cooling may cause the plugs to become tight. If such is the case, retap with a special tap which can be procured from the Warner Aircraft Corporation.

(4) Pistons, Piston Pins, and Rings

(a) Cleaning and Servicing Pistons

1. Remove all the rings from the piston by spreading the ends apart until each ring can be pulled out of its groove over the top of the piston.

2. Scrape the carbon from the top surface of the piston and then polish by rubbing it on a piece of kerosene soaked crocus cloth, spread on a flat plate.

3. Remove all carbon from the ring grooves.

4. Inspect the piston for cracks and scores.

5. If there are any sharp edges or scratches on the pistons or in the cylinder wall surfaces, they should be carefully removed by stoning with a fine grade oil stone which has been dipped in kerosene.

6. When a defective piston is replaced, the new piston must be selected so that its weight does not differ more than 1/4 ounce from the others. When ordering pistons for replacement, please state the engine number. Records are kept of the weights of the pistons originally furnished in the engine. Therefore, pistons of the proper weight can be shipped when the engine serial number is furnished.

(b) Servicing Rings

1. Remove all carbon from rings and make sure that they are not damaged.

2. If the engine is equipped with expander type oil rings, it is highly recommended that new expanders be installed at the top overhaul in all cases; rings and shims showing no scratches or other signs of wear may be reinstalled. The use of new expanders greatly facilitates the reseating of the ring. Best results may be derived from the top overhaul if a new complete expander type ring assembly is installed.

3. Test tension of rings. Refer to the table of limits.

(c) Piston Pins

1. If plugs are loose install new ones.

2. Magnaflux pin to check for cracks and possible failure.

3. Check for fit in piston and connecting rod bushing.

(5) Installing Piston Rings

(a) Be sure that all parts are absolutely clean and in good condition.

(b) The ring gaps must be staggered so they do not line up causing blow-by with excessive oil consumption.

Figure 4. Checking Piston Ring Side Clearance in Piston.

(6) Assembling Rings To Four Ring Pistons

(a) The rings furnished by the Warner Aircraft Corporation are fitted and inspected in regard to the proper gap width. See Table of Limits for this width.

(b) The fourth (bottom or oil control) ring must be placed on the piston in such a manner that on pistons No. 1, No. 2, No. 3, and No. 4, the ring gap is on the exhaust side of the cylinder. In other words, when looking at the top of the piston with the number on the piston toward the observer, the ring gap should be to the right and at right angles to the piston pin. On pistons No. 5, No. 6, and No. 7 the arrange is reversed. The ring gap should be on the intake side (to the left when looking at the top of the piston when facing the numbering).

(c) The rings must have the side clearance and gap specified in the Table of Limits (see Figures 4 and 5).

(d) All rings must be installed to obtain approximately 90 degree spacing between the four gaps of the rings on each piston.

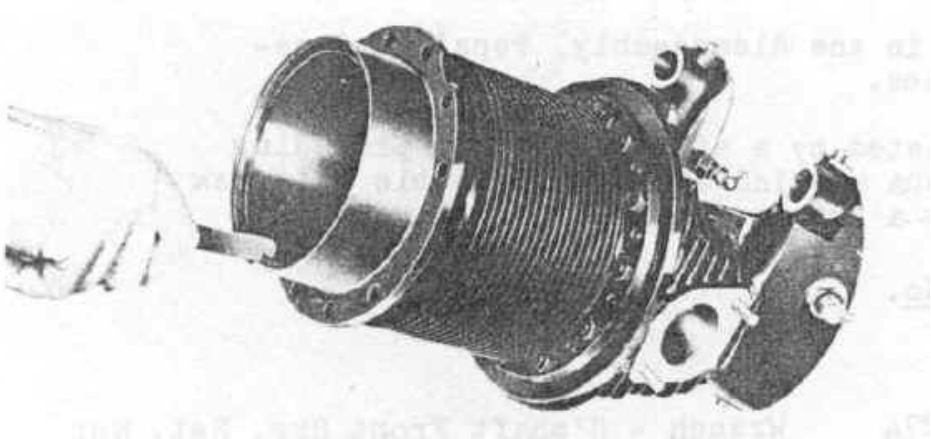


Fig.5 Checking Piston Ring Gap (Closed) in Cylinder Barrel

(7) Assembling of Pistons to Cylinders

(a) It will be found advisable, if new rings are assembled to the piston, that because of the tight fit of the rings, the piston be put in the cylinder while it is on the bench.

(b) Oil the piston generously.

(c) Use a piston ring clamp to hold the rings in place. Great care must be taken when putting the piston ring clamp on the piston that the rings actually slide into the grooves while the clamp is slowly tightened. To help the rings slide into the grooves, the clamps should be lightly tapped with a block of wood or the end of a screwdriver.

(d) Holding the numbered end toward the propeller end, the piston should be pushed in to such a depth that all the rings are in the cylinder, but not so deep as to cover the piston pin hole. The piston pin can then be pushed in while assembling the unit to the engine.

(8) Assembling of Cylinders and Pistons To Engine

(a) Install new cylinder base "0" ring packings on cylinder skirts or new cylinder base gaskets on the cylinder mounting pad on older type engines.

(b) Turn the crankshaft to a position in which the connecting rod of No. 1 cylinder extends the maximum distance outside the cylinder flange and the cam followers are in the lowest position.

(c) Holding the cylinder assembly, line-up the piston pin hole in the piston with the bushing in the rod and with the number on the edge of the piston facing the propeller. Insert the piston pin.

(d) Push the cylinder on to the piston so that it is even with the bottom of the piston skirt. When installing cylinder, squeeze the fourth ring, if provided, with the fingers.

(e) Slip a steel washer between the new packing and the shoulder on the inner end of the push rod tube.

(f) On the outer (longer) end, assemble the spring, the washer, and the packing, in the order given. In the event the spring may have taken a set, two packings may be installed to increase the spring tension. This is only possible on the push rod tubes which do not contact the packed cam follower guides.

(g) Dip both ball end of each push rod into the rocker arm grease then place the push rods into the tubes with marked end toward the rocker arms. The rods are marked alphabetically, starting with "A" for the exhaust side of the cylinder No. 1 and follow around the engine clockwise order, as viewed from the rear.

(h) Holding a push rod tube assembly in each hand, push the cylinder into place on the crankcase with the body, at the same time guiding the push rod tubes into place.

Note
The long end of the push rod tube with the spring, washer, and packing is inserted into the head of the cylinder.

(i) Install and tighten cylinder hold-down nuts using cylinder base nut wrench. Tighten nuts with desired torque as outlined in the Table of Limits.

Caution
Do not exceed torque limits.

(j) When palnuts are used, they should be tightened only 1/4 turn after coming in contact with the cylinder hold-down nuts.

(k) After cylinder No. 1 has been assembled to the crankcase, all other cylinders should be assembled in numerical order in the same way.

(l) On the intake pipe install, in the order named, the spring, gland, and new packing.

(m) Install new gaskets on the intake flange of the cylinder.

(n) Insert the end of the intake pipe into the induction housing opening, and push the flanged end into place over the studs.

(o) Install a plain washer, lockwasher, and nut on the inside stud of the intake pipe flange and an ignition wire clip, lockwasher, and nut on the outside stud. (Ignition cable clip is not used when Breeze shielding is installed).

OVERHAUL TOOL LIST

The following is a list of overhaul tools used in the disassembly, repair and reassembly of the Models SS50 and SS50A Aircraft Engines.

The tools required for the Model SS50 are indicated by a single asterisk preceding the tool No. Those tools required for the Model SS50A are indicated by a double asterisk and those tools used for both models are preceded by a triple asterisk.

Tool No.	Nomenclature	Tool No.	Nomenclature
CRANKSHAFT			
*** FA-213-1	C'shaft Brg. Puller Assy.	** FA-274	Wrench - C'shaft Front Brg. Ret. Nut
*** FA-197-B	Disc	* FA-274-1	Wrench - C'shaft Front Brg. Ret. Nut
*** FA-213-A	Puller	* FA-274	Wrench
*** FA-213-B	Spacer	* FA-183-C	Adapter
** FA-182	Turning Bar Assembly		
CRANKCASE			
*** FA-45-1	C'case Reaming Base Assy.	* FA-16	Timing Disc Assembly
*** FA-45-A	Base	* FA-16-M	Disc and Hub
*** FA-45-C	Plate	* FA-16-L	Pointer
** FA-16-2	Timing Disc Assembly	* FA-16-H	Wrench
** FA-16-1	Disc and Hub		
** FA-16-L	Pointer		
CYLINDER HEAD AND BARREL ASSEMBLY			
*** FA-257-2	Valve Seat Grinder Assembly	*** FA-52-C	Drift - Valve Guide Assy. (Exhaust)
*** FA-257	Valve Seat Grinder	*** FA-57-1	Fixture - Cylinder Overhaul Att.
*** FA-257-P	Pilot - Valve Seat Grinder	*** FA-122	Tool - Valve Guide Taper Reaming
*** FA-257-Q	Wheel - Finishing		
*** FA-257-R	Wheel - Roughing		
INDUCTION HOUSING AND COVER			
*** FA-47	Drift - Cam & Mag. Dr. Shaft Bushing Stand	*** FA-59-A	Reaming Fixture - Idler and Tach. Shaft Bushings
*** FA-49	Drift - Idler Shaft Bushing	*** FA-59-E	Fixture Assembly
*** FA-51	Drift - Tach. Drive Shaft Bushing	*** FA-59-G	Fixture
*** FA-315	Reamer - C'shaft Ext. Shaft Bushing	*** FA-59-D	Bushing
** FA-55-A	Reaming Fixture - Cam and Mag. Drive Shaft Bushing	*** FA-59-K	Bushing
		*** FA-59-H	Pilot
		*** FA-59-F	Plug - Locating
		*** FA-59-C	Reamer - .5005 ∱ .0005 - .0000
		*** FA-59-D	Reamer - 1.0005 ∱ .0005 - .0000
		*** FA-85	Spotface Tool - Cam and Magneto Drive Shaft & Idler Shaft Bushings
CONNECTING RODS AND PISTONS			
*** FA-60-1	Piston Ring Lapping and Checking Fixture	*** FA-63	Wrench - Wrist Pin Locating
*** FA-60-A-1	Holder - Checking	*** FA-56-H	Bushing
*** FA-60-C-1	Holder - Lapping		
*** FA-60-B-1	Plate - Checking		
OIL PUMP AND ACCESSORIES			
*** FA-268	Puller - Magneto Coupling	*** FA-99	Wrench - Oil Screen Bushing
*** FA-232	Wrench - Generator Pinion Bearing Retaining Nut		

(p) Tighten the intake pipe flange nuts to the required torque.

Note
The ignition cable clips must be in a position with the open end facing out.

(q) Set all valve tappets.

(r) Install spark plugs and attach ignition wires.

(s) Take off crankshaft turning bar.

(t) Connect battery.

(u) Install exhaust stacks or collector ring.

(v) Install cowling.

(w) Install propeller.

(x) Fill fuel and oil tanks after replacing drain plugs.

(y) Inspect according to instructions in Section VII.

(z) Start and run in accordance with instructions in Section XI.

Warner Engine Handbook: Dismantling and Disassembly

Section IX - Dismantling and Disassembly

1. General

a. The procedure outlined in this section covers dismantling of the engine into its major component parts, or subassemblies, and cleaning of these items.

b. For complete disassembling and reconditioning of the engine a number of special tools are necessary.

c. As parts or sub-assemblies are removed from the engine, they should be placed on a portable rack preparatory to being cleaned. Small boxes, tins or other receptacles should be provided in which bolts nuts, washers and other small parts can be placed as they are removed.

d. As each part or sub-assembly is removed from the engine, it should be inspected carefully before cleaning to note any unusual conditions such as sludge deposits or the collection of metallic chips. Samples of the sludge or chips, if present, should be retained for later analysis. In addition, during the various stages of dismantling, close observation must be made of all parts or components for signs of scoring or burning due to undue friction, as it often happens that many valuable indications of defects can be obtained when the oil or the loosened surface of metal is present to indicate them, rather than after all parts have been washed and laid out for examination. The sub-assemblies should be checked for the freedom of movement of all gears, shafts or bearings. After the preliminary inspection all components and sub-assemblies should be thoroughly cleaned.

e. The threads on the front end of the crankshaft should, whenever possible, be covered with a suitable thread protecting cap.

2. Dismantling Engine Into Sub-Assemblies

a. Installation on Assembly Stand

(1) After the engine has been removed from the packing box or airplane (refer to Section III), it should be attached to the Engine Assembly Stand (Tool No. FA-21) with at least four 5/16" bolts.

(2) Lock the tilting mounting plate in a vertical position. Lower the engine onto the stand allowing the carburetor side of the rear section to pass through the open portion of the mounting plate. A lifting hoist with a minimum capacity of 1/2 ton should be used. Secure the engine to the mounting plate with bolts inserted from the rear side of the plate through the engine mounting lugs on the induction housing. Install a plain washer between each mount bolt nut and the front face of the mating engine mount lug to prevent the nut from damaging the front face of the lug.

(3) Before proceeding to dismantle the engine into its various sub-assemblies it is advisable to wash the exterior of the engine thoroughly with unleaded gasoline, cleaning spirits, or cleaning compounds.

Note
Precautions must be observed in order to minimize fire hazards. Under no circumstances should leaded (ethyl) gasoline be used for cleaning, because of its poisonous properties.

b. Removal of Ignition Wires

(1) Disconnect the ignition wires from the spark plugs. Be sure the lock is released before pulling terminal.

(2) If cylinder air deflectors are installed, remove ignition wires from cylinder head baffles, by removing grommets and pulling wires and terminals through the baffles.

(3) Disconnect and remove ignition cable clips, brackets and tube from engine.

(4) Disconnect and remove magneto blocks (with ignition cables attached) from the magnetos, exercising care not to allow the magneto blocks to strike the engine and be damaged while they are being removed.

c. Spark Plugs

(1) Remove the spark plugs.

d. Removing Cylinder Head and Inter-Cylinder Air Deflectors

(1) Before removing the inter-cylinder and cylinder head air-deflectors, mark or stamp in some suitable manner. These markings will be used to identify and determine the re-installation positions of the air deflectors after the engine is overhauled.

(2) Disconnect air deflectors from cylinders and cylinder heads.

e. Draining Oil Sumps

(1) Remove the two nuts that hold the flanged tube to the bottom of the oil sump.

(2) Loosen hose clamps on hose that connects flanged tube.

(3) Move the flanged tube away from the mounting face on the sump. This will allow the oil to drain from the sumps.

f. Removal of Accessories

(1) Magnetos

(a) Remove clevis pin and locknut from the eye on the end of each magneto lever.

(b) Remove magneto control rod assembly.

(c) Install a turning bar, FA-182, or Timing Disc, FA-16-2, on the crankshaft.

(d) Turn crankshaft until one of the two screws on the front side of a magneto coupling is on top.

(e) Remove screw.

(f) Repeat procedures (d) and (e) for removing the remaining screws on the couplings.

(g) Remove the magneto retaining bolts and washers.

(h) Remove magnetos.

Caution
Unless magneto brackets are damaged and must be replaced, they must never be loosened or removed as the magneto face of the bracket is machined on a holding fixture to ensure proper alignment of magneto coupling

drive and magneto shaft.

g. Removal of Gearcase and Attaching Parts

(1) Starter

(a) Remove nuts and washers which hold the starter to the adapter, and carefully remove starter.

(b) Remove nuts and washers which hold the-adapter to its mounting flange and remove adapter.

(c) To remove the starter jaw assembly, loosen the set screw in center of shaft. This screw tightens an eccentric washer which locks behind the mating splines of the starter clutch. The starter jaw can be withdrawn when the set screw is loosened sufficiently to allow the washer to center in the opening below the splines.

(2) Magneto Drives

Remove retaining nuts, lockwashers and drives, tapping drive with fiber or rubber mallet if necessary.

(3) Remove oil sump tube from oil pump by loosening hose clamp if pump is equipped with fuel pump drive, or remove nuts and lockwashers from flanged tube on pump if there is no fuel pump drive on pump.

(4) Unscrew and remove oil inlet fitting bolt, and fitting directly underneath oil pressure regulating valve.

(5) Remove oil pump retaining nuts and lockwashers.

Note
Do not attempt to remove oil pump at this stage.

(6) Remove gearcase retaining nuts and lockwashers and pull off gearcase.

Note
Do not pullout crankshaft extension shaft at this stage.

(7) Drive out oil pump tram gearcase by tapping on the slotted drive shaft with a fiber or rubber mallet.

h. Removal of Breather Elbow and Tachometer Drive Housing

(1) Remove the two nuts and lockwashers from breather elbow and pull off breather elbow.

Note
(a) Tachometer drive housing is fastened permanently to breather elbow and is not to be removed. (b) Do not attempt to pullout tachometer drive shaft from induction housing as it is retained with a pinned gear on the opposite end of the shaft.

i. Removing Idler Gear

(1) While crankshaft extension shaft is still in place remove the three idler shaft gear retaining screws.

(2) Remove gear from idler shaft flange

(3) Pull out crankshaft extension.

j. Removing Oil Sump

(1) Turn engine in flat position with crankshaft pointing up.

(2) Remove screw from front of oil sump at supporting link.

(3) Remove the two nuts and lockwashers at rear of oil sump.

(4) Pull sump off studs.

k. Removal of Cylinders and Pistons

(1) Remove all rocker box covers which are retained by spring clips.

(2) Remove all of the intake pipe eta1ning nuts and lockwashers.

(3) Remove intake p1pes, spr1ngs, glands and pack1ngs.

(4) Using special cylinder base palnut wrench, No. FA-11238, remove the palnuts from the cylinder hold-down studs. See Figure 6.

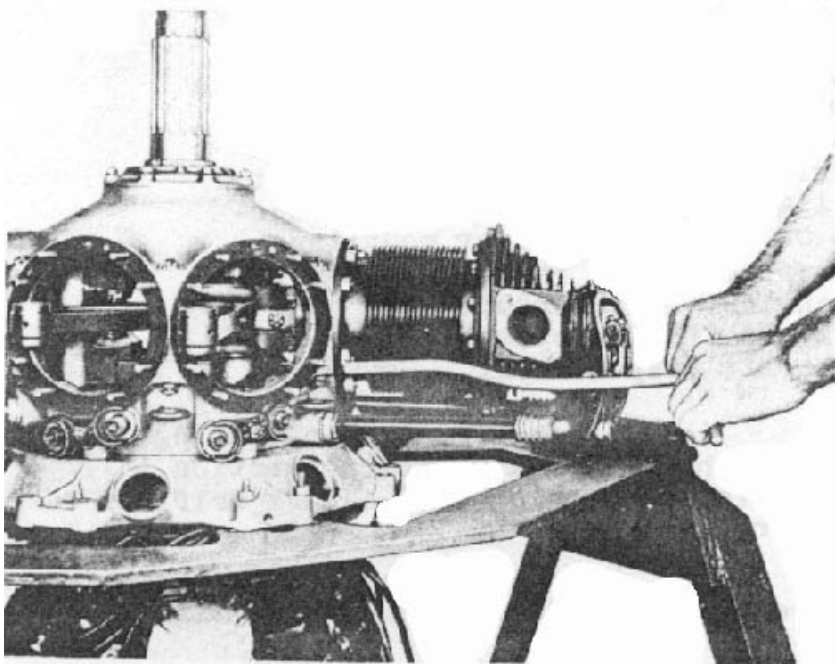


Figure 6 - Removing Cylinder Base Hold Down Nuts and Palnuts

(5) In removing the cylinders, the No.1, or Master rod cylinder, is the last one to be removed.

(6) Before removing the cylinder from the crankcase, bring the piston in that cylinder to the top of its stroke. This can be done by rotating the crankshaft until the piston can be observed through the spark plug hole to be at the top of its stroke.

(7) Turn the crankshaft until the No.2 piston is at the top of its stroke.

(8) Remove cylinder hold-down nuts with cylinder base nut wrench No. FA-33-A, see figure 6. Jiggle cylinder loose and remove push rod tubes and push rod.

Note
(a) The push rod tubes must be held as the cylinder is being worked loose as they will fallout if cylinder is withdrawn too far. (b) When pulling cylinders off, be careful to support the piston so that the piston does not rock against the rod and damage the piston skirt. The piston pin should be prevented

from falling out, which may happen in the case of a worn pin, because piston pin and piston would fall on the floor and be damaged.

(9) Turn the crankshaft until No. 3 piston is at the top of its stroke, remove cylinder hold-down nuts and pull off the cylinder as instructed above.

(10) Continue on around the engine, going through the same steps as above until No. 1, the master rod cylinder, is removed last.

(11) After removal the cylinders should be set down on wood or some other soft surface in order not to distort or burr the ends of the barrels.

(12) Pistons are removed by first pushing out the piston pins.

Note

If difficulty is experienced in pushing out any piston pin, the pin can be driven out of the piston by using a soft drift, at the same time being careful to support the piston in such a manner that no driving thrust is taken by the connecting rod.

l. Removal of Carburetor Air Heat Control Valve and Carburetor

(1) Carburetor Air Heat Control Valve

(a) Loosen and remove the screws and washers that attach the carburetor air heat control value to the carburetor.

(b) Remove the carburetor air heat control valve.

(2) Carburetor

(a) If safety wired, break and remove all safety wire on studs that secure carburetor to induction housing.

(b) Loosen and remove retaining nuts and washers that secure carburetor to induction housing.

(c) Remove carburetor.

m. Removal of Thrust Nut, Thrust Cover, Oil Slinger, Crankcase Front Section and Bearing Spacer

Note

In case the engine is received for overhaul with rear

propeller hub cone on the crankshaft, the cone is removed by inserting a screw driver blade in the slot and twisting screw driver to expand cone, then remove cone from crankshaft.

(1) Thrust Nut

(a) Using crankshaft turning bar No. FA-182 to hold crankshaft, loosen thrust nut with wrench FA-183-1. See figure 7 for method of removal.

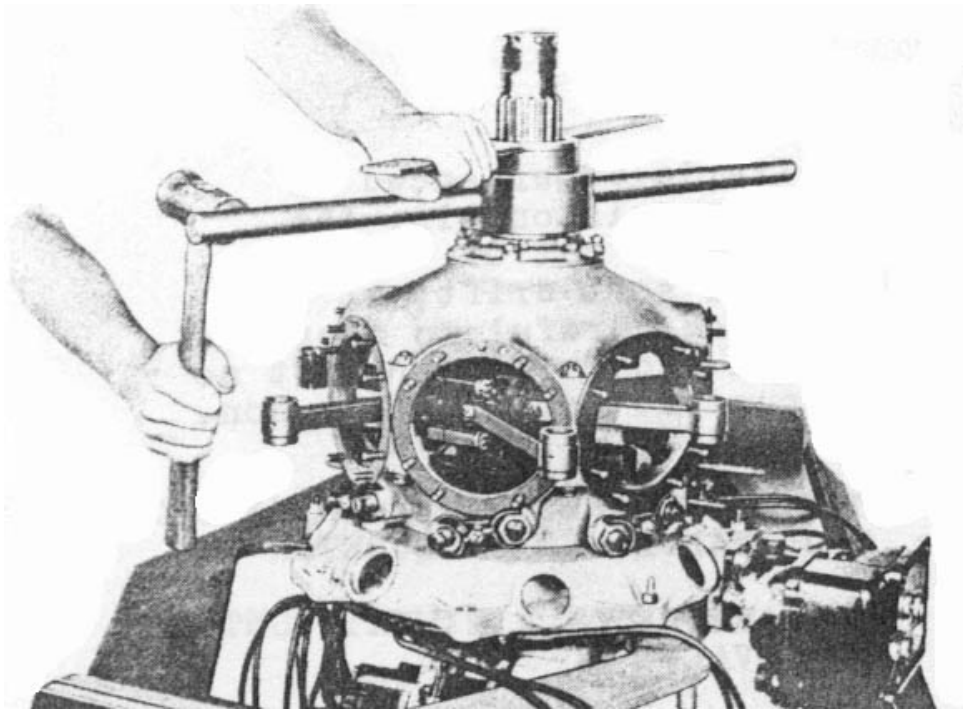


Figure 7 Removing Crankshaft Thrust Nut

(b) Remove thrust nut.

(2) Thrust Cover And Oil Slingers

(a) Remove the thrust cover retaining nuts and washers.

(b) Remove thrust cover and oil slinger.

(3) Crankcase Front Section and Bearing Spacer

(a) Remove cotter pins and retaining nuts and washers from the six crankcase bolts and bottom stud.

(b) Drive back the six crankcase bolts, that are between cylinders but do not try to drive back the protruding end of stud between cylinders

No. 4 and 5. This stud will act as a guide when the crankcase front section is being pulled from the crankshaft.

(c) Attach puller No. FA-197-A to the thrust cover studs with retaining nuts. Install spacer FA-197-B on the end of the crankshaft to provide a bearing seat for puller screw. See Figure 8.

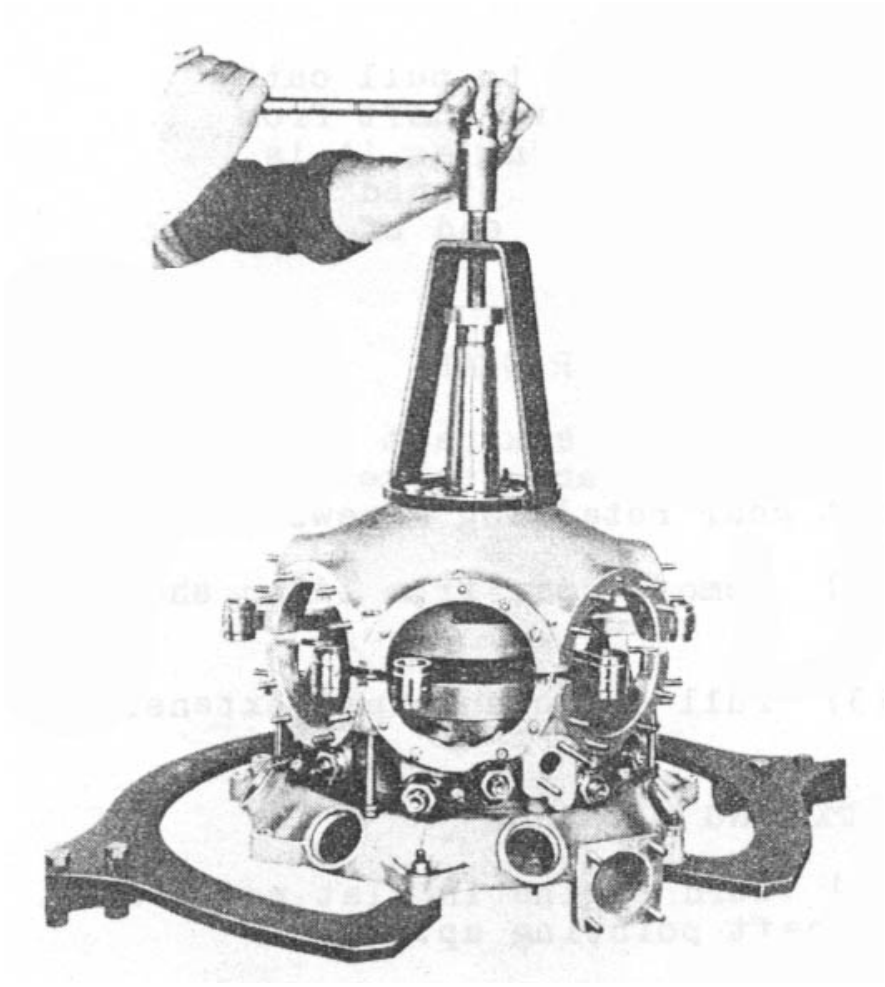


Figure 8 - Removing Crankcase Front Section

(d) Turn puller screw until crankcase front section is free of guiding stud and bolts. Remove crankcase front section

Note
While pulling crankcase front section care should be exercised that it comes up straight and does not bind on the

guiding stud. If binding should be experienced, with a raw-hide mallet tap lightly the crankcase front section on the thrust cover mounting pad surface which faces the front of the engine. This should free the crankcase front section from binding and permit easy removal.

(e) If the front main bearing comes off with the crankcase front section it can be removed by tapping with a soft drift on the outer race only.

(f) Remove bearing spacer if it has not been pulled off the crankshaft with the crankcase front section.

(g) If the front main bearing remains on the crankshaft place the bearing puller No. FA-213-A, with the horseshoe shaped base straddling the front cheek and resting against the outer race of the bearing. See Figure 9.

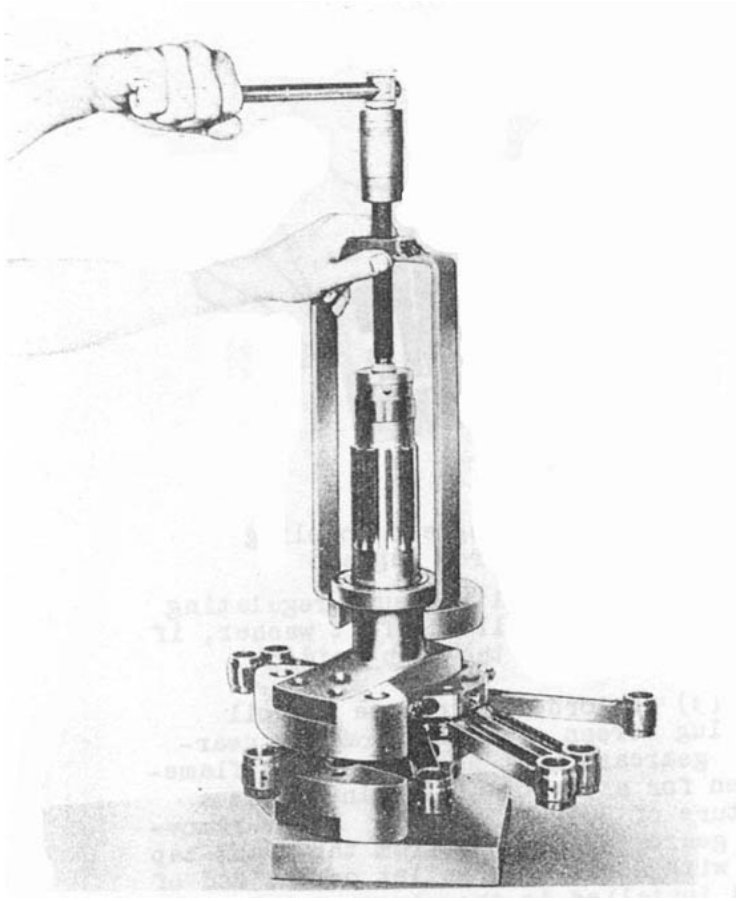


Figure 9 - Removing Crankshaft Front Main Bearing

(h) Place disc No. FA-197-B on the front end of the crankshaft to act as a bearing seat for the puller screw.

(i) Holding crankshaft in place turn screw and lightly tap bearing with a rawhide hammer until front main bearing can be removed from crankshaft

n. Removal Of Crankshaft and Master Rod Assembly From Crankcase Rear Section

Note
Crankshaft and Master Rod Assembly are removed from the crankcase rear section as a unit. See figure 10.

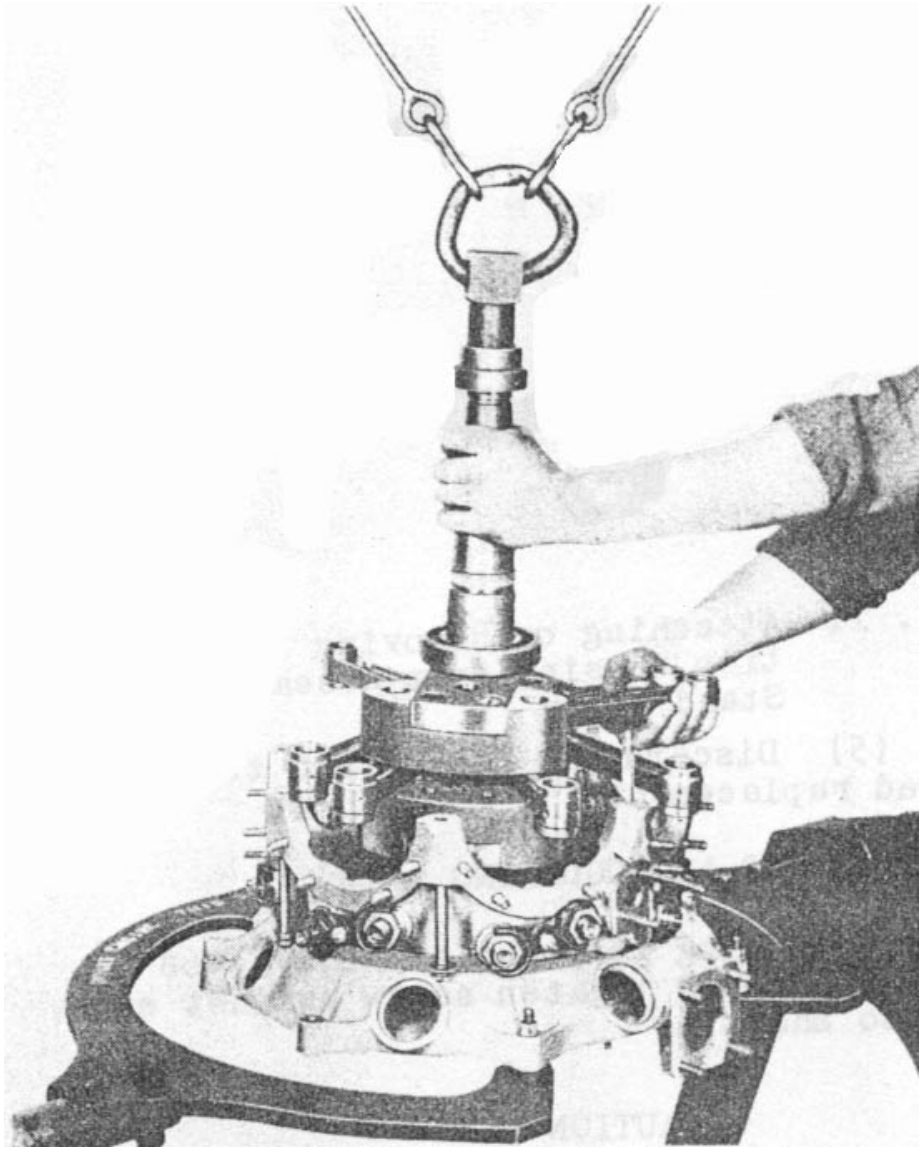


Figure 10 - Removing Crankshaft And Connecting Rod Assembly From Crankshaft Rear Section

(1) Screw on propeller hub nut down as far as possible on crankshaft.

(2) Attach a suitable hook or sling to the propeller hub nut and by means of a chain or power hoist and pull crankshaft assembly straight up.

(3) If propeller hub nut is not installed on crankshaft use a No.20 SAE propeller hub nut.

o. Removal Of Crankcase Rear Section From Induction Housing

(1) Rotate engine assembly plate so that crankcase rear section and induction housing are in a horizontal or "flight" position. Lock the plate in this position.

(2) Remove the cotter pins and retaining nuts and washers from the studs that attach the crankcase rear section to the induction housing. These retaining nuts and washers are located on the rear face of the induction housing.

(3) Tap the ends of the studs with a soft mallet. This will aid in separating the crankcase rear section from the induction housing.

(4) Remove the crankcase rear section from the induction housing.

p. Removal Of Induction Housing From Assembly Stand

(1) Loosen and remove all nuts and washers from bolts that attach induction housing to assembly stand plate. See Figure 11.

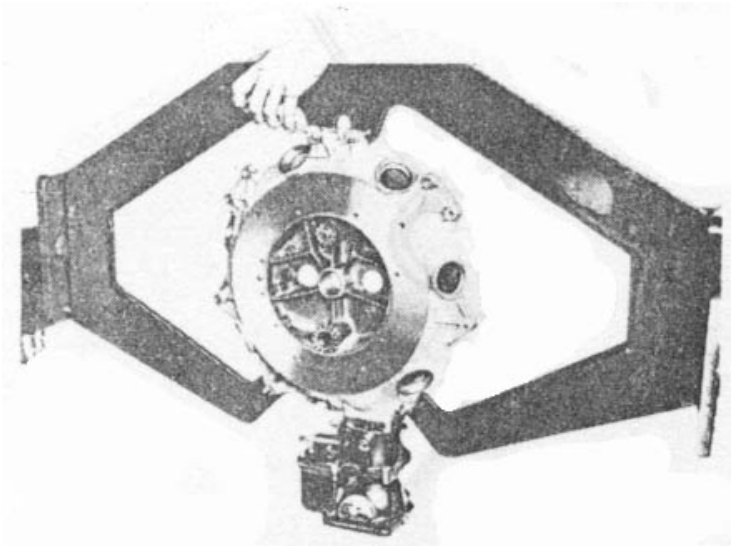


Figure 11 - Attaching Or Removing Induction Housing From Assembly Plate Stand

(2) Remove Induction housing from assembly stand plate.

3. Disassembly of Sub-Assemblies

a. Ignition Cables, Terminals, And Magneto Distributor Blocks

(1) Disconnect all cables from the magneto distributor blocks to which they are attached by means of a screw.

(2) Replace and secure the magneto distributor blocks on their magnetos.

(3) Remove all ignition cables from the ignition cable tubes.

(4) Remove rubber rings and all attaching clips from ignition cables.

(5) Discard all cables and terminals that need replacement.

b. Magneto and Coupling

(1) Using gear puller No. FA-268 as shown in figure 12 tighten screw against end of magneto shaft.

Caution
Leave magneto coupling retaining nut partially screwed on the end of magneto shaft when pulling magneto coupling. This precaution prevents the end of the shaft from being damaged when the gear puller screw is tightened against it.

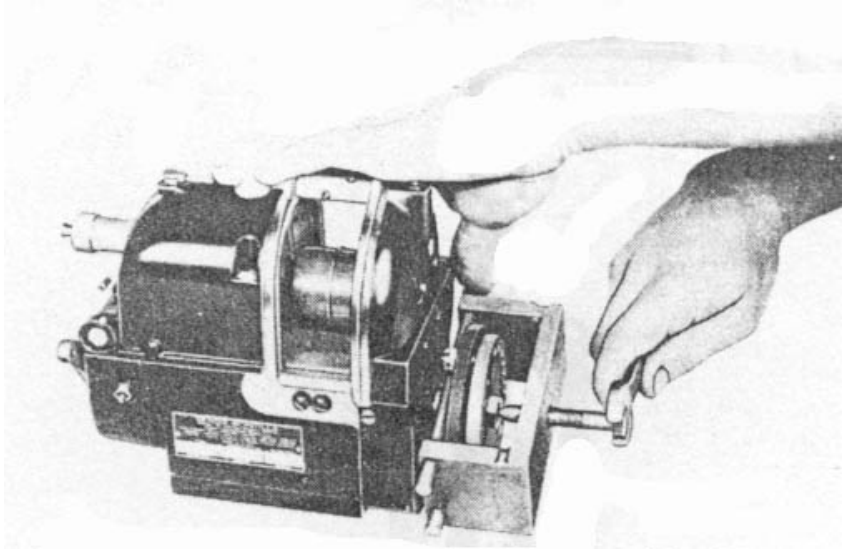


Figure 12 - Removing Magneto Coupling Assembly From Magneto.

(2) Tap end of gear puller screw lightly with a hammer, at the same time increasing the tension on the screw until coupling breaks loose of the taper seat on magneto shaft.

(3) Remove nut and coupling.

(4) Remove 4 castle nuts from magneto coupling and disassemble the component parts. The studs on the ring are riveted and cannot be removed.

c. Magneto Drive

(1) Remove cotter pin, nut and washer from the end of the drive shaft.

(2) Remove gear and Woodruff key from shaft.

(3) Push the drive shaft out of the magneto drive housing.

(4) Push out bearing, spacer and oil slinger using a drift if necessary.

Note
In this operation the drift is pushing directly against the oil slinger. Care must be exercised so as not to damage the slinger by hammering excessively on the drift.

d. Gearcase

(1) Remove acorn nut, oil screen plug and oil screen from gearcase on left side.

(2) Remove oil pressure regulating valve plug, spring, ball and flat washer, if any, from gearcase on the right side.

(3) In order to remove the oil screen plug screen assembly from the gearcase the gearcase must be heated in a flameless oven for a period of 30 minutes at a temperature of 300° Fahrenheit. After removing the gearcase assembly from the oven, tap lightly with a raw hide mallet on the end of the stud installed in the plug assembly.

(4) With wrench FA-99 unscrew pressure regulating valve bushing.

Note
Do not remove or loosen magneto brackets unless they need replacing.

e. Oil Pump

(1) Remove inlet and outlet connections.

(2) Remove four pump body retaining screws from the front of oil pump.

(3) Secure the pump in a vise by clamping the vise jaws on the slotted end of the pump drive shaft across the slot.

(4) Remove the rear pump body.

(5) Remove fuel pump drive shaft and disassemble the two rings, scavenger idle gear and Woodruff key from shaft.

(6) Remove ring from oil pump drive shaft.

(7) Remove scavenger pump drive gear and woodruff key from pump drive shaft.

(8) Remove oil pump spacer.

(9) Remove pressure pump idler gear.

Caution
Do not drive oil pump drive shaft out of pressure pump housing until pressure pump drive gear and Woodruff key are removed from drive shaft as the pressure pump housing would be damaged by the key.

(10) Remove pressure pump drive gear and Woodruff key from pressure pump drive shaft

(11) Remove pressure pump drive shaft from housing.

(12) Using tool No. FA-245, remove oil pump drive shaft oil seal from oil pump rear body.

(a) Install plate No. FA-245-A with smaller pilot against oil seal.

(b) Secure plate with two nuts to fuel pump mounting face.

(c) Drill four holes into the seal through the inner four pilot holes in plate No. FA-245-A using a #40 (.098 dia.) drill. Drill holes into seal not more than 1/8" deep.

Caution
Do not drill through outer four holes of the plate. This would damage the pump housing.

(d) Install four #6 x 5/8 long Round Head Self-Tapping, screws through the plate and into the seal.

(e) Install pulling bracket No. FA-245-B over the two remaining studs on mounting face.

(f) Install washer and pulling screw through pulling bracket No. FA-245-B into plate No. FA-245-A.

(g) Remove the two retaining nuts from the plate.

Caution
Do not try to remove seal with plate secured to studs because the studs would be pulled and pump housing damaged.

(f) Remove seal by turning screw.

Note
After removing seal do not discard the self tapping screws as they are a part of Tool No. FA-245.

f. Oil Sump

(1) Remove nuts and lockwashers from bottom of sump.

(2) Remove oil sump bottom cover, screen and gaskets.

g. Cylinders

Caution
Under no circumstances should the nuts be removed at the joint between the cylinder barrel and cylinder head and these two items separated, because this is a permanent joint. It either the head or the barrel should be damaged or worn beyond repair a new head and barrel assembly should be installed.

(1) Remove cotter pins, nuts and washers from rocker arm shafts.

(2) Remove rocker-arm shafts.

(3) Remove lubrication fittings from shafts.

(4) Remove rocker arms and washers.

(a) Using a 1/4" diameter soft drift, drive out rocker arm bearing. Insert drift through one side of the rocker arm and tap against inner

race of bearing on other side of the rocker arm. The bearing should be driven out uniformly by tapping all around the bearing inner race.

(b) Remove bearing spacer.

(c) Using a soft drift tap out second bearing from rocker arm.

(5) Do not remove the rocker arm roller.

(6) Removing valves, springs, washers and retainers:

(a) Place cylinder on valve spring assembling stand No. FA-188 and use Valve Spring Depressing Tool No. FA-104 from tool kit.

(b) Turn cylinder over and remove valves.

Note
When turning cylinder over hold both valves in the guides in order to prevent them from sliding out and hitting against the cylinder walls.

(7) Remove exhaust flange shipping baffles if any have been installed on the cylinders.

h. Pistons and Pins

Note
After the rings are removed from the piston they should be mounted on card and adequately marked in proper assembly order so that the inspection department can use them for reference during piston inspection.

(1) Do not remove piston pin plugs from pin unless they are loose and require replacement.

Note
The piston pin plugs are a press fit in the bore of the pin.

(2) Using piston ring spreader No. FA-67, remove the rings from piston.

i. Carburetor Heat Control Valves

Unless damaged it is unnecessary to disassemble the carburetor heat control valve.

j. Thrust Cover

Do not attempt to remove the thrust ring from the thrust cover. Ring is permanently attached to cover and cannot be removed without damage to cover.

k. Crankcase Front Section

(1) Remove thrust bearing from crankcase front section by tapping on outer race of bearing with a soft drift.

Caution
Do not remove the bronze bearing sleeve because it is shrunk and pinned to the crankcase front section.

l. Crankshaft And Master Rod Assembly

(1) Place the crankshaft in a vise with copper covered jaws, as shown in Figure 13. Clamp vise jaws securely against front crankshaft cheeks.

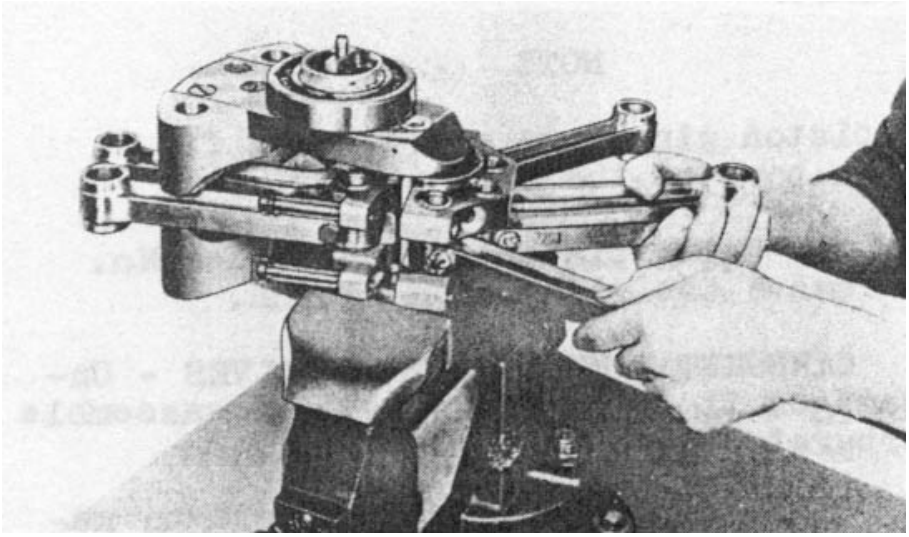


Figure 13 - Method of Clamping Crankshaft Assembly in Bench Vise For Disassembly.

(2) Remove cotter pin and retaining nut from one master rod bolt.

(3) Remove bolt from master rod and replace nut on master rod bolt, to avoid necessity of selecting nuts at assembly.

(4) Continue with other three bolts as above until they are all removed from master rod.

(5) Remove the two master rod sections from the crankshaft.

(6) Remove long 1/8" diameter cotter pin from rear cheek of crankshaft.

(7) Reset crankshaft in vise and clamp rear cheek securely as shown in Figure 14.

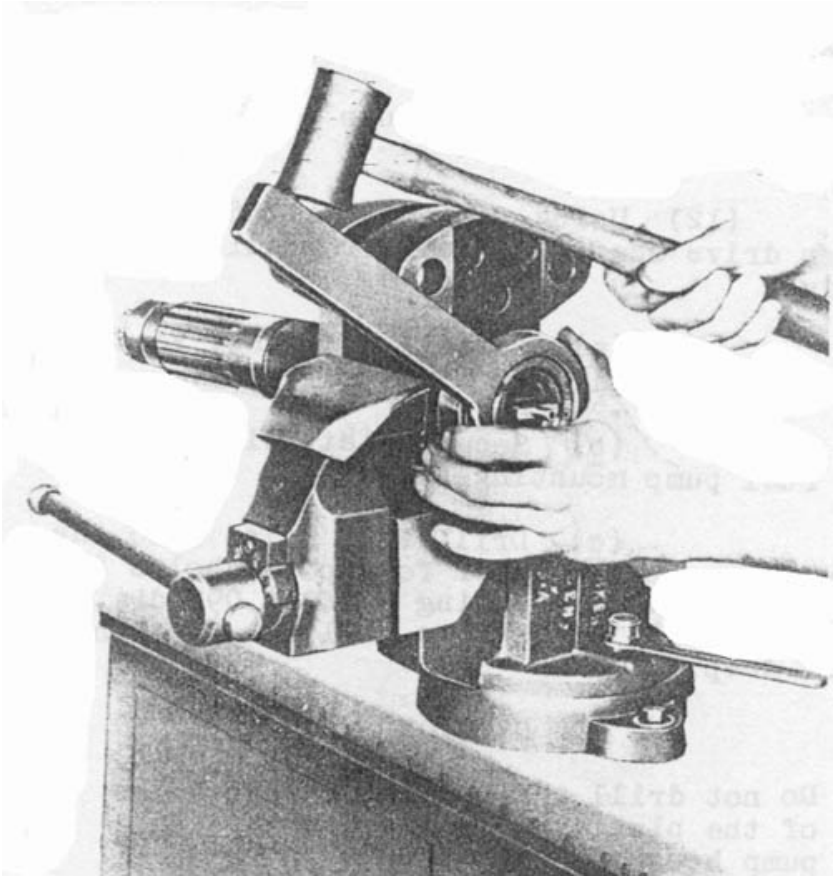


Figure 14 - Method of Clamping Crankshaft In Bench Vise for Removal of Rear Main Bearing Retaining Nut.

(8) Remove rear bearing retaining nut lock ring.

(9) Using wrench No. FA-71-1 and a hammer, remove rear bearing retaining nut as shown in Figure 14.

(10) Reset crankshaft in vise.

(11) Place horseshoe shaped base of tool No. FA-213-A to straddle rear cheek of crankshaft and rest against the inner race of rear main bearing.

(12) Place long spacer No. FA-213-B on the rear end of the crankshaft to act as a bearing seat for puller screw.

(13) Use same procedure to remove rear main bearing as was used with this tool to pull front main bearing. See figure 15.

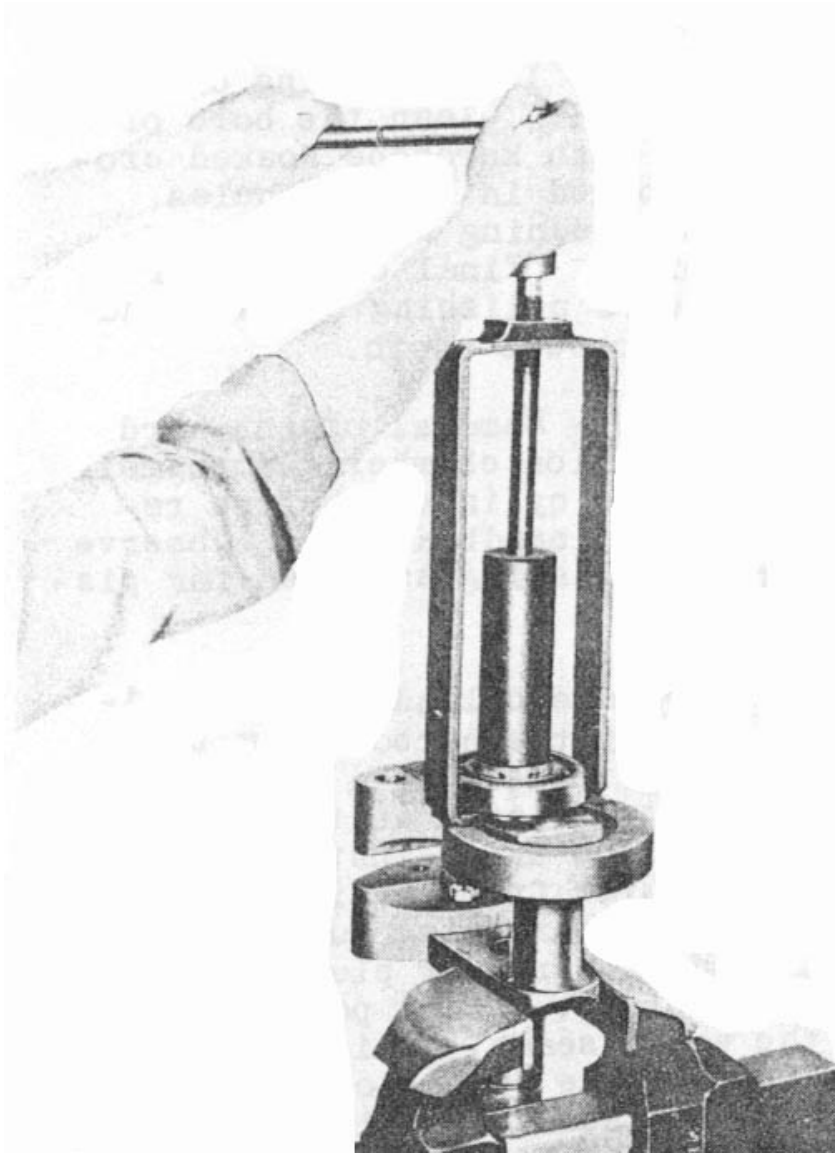


Figure 15 - Method of Removing Rear Main Bearing From Crankshaft.

(14) Reset crankshaft in vise as shown in Figure 12 and drive coupling pin out, using a soft drift.

(15) Remove coupling.

(16) Using Tool No. FA-194 remove crankpin plug. See Figure 16.

Note
Do not remove the plug that is located in the rear bore of the journal because it is permanently installed.

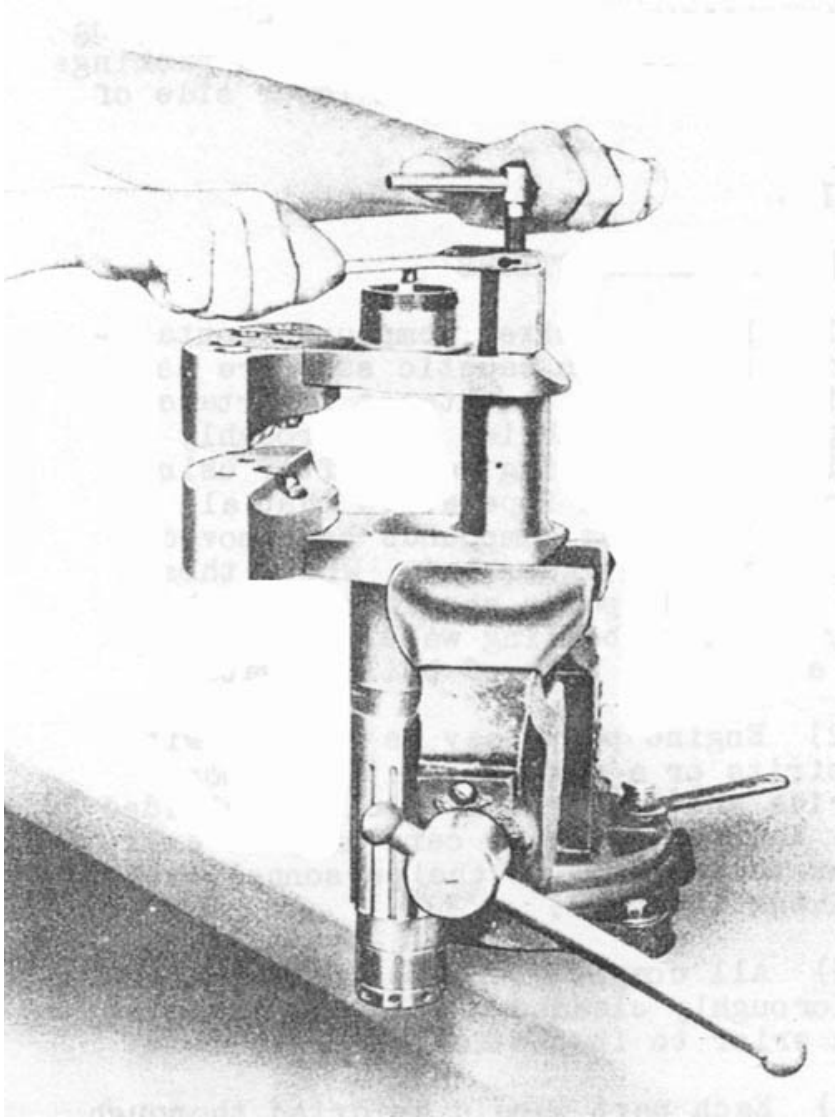


Figure 16 - Method of Removing Crankshaft Crankpin Plug From Crankshaft.

m. Master Rod and Link Rods

(1) Remove bearing shells from the master rod by tapping them lightly with a soft mallet if necessary.

(2) Remove nuts and bolts from all link rods.

(3) Prior to driving out the wrist pins place a small steel wedge between the inner surface or the master rod and the bottom surface of the flanges of the link rod "I" section. This precaution will eliminate any possibility of the bushings being moved and loosened when the wrist pin is being driven out. This precaution is important as any movement of the wrist pin bushing will partially close the oil supply hole from the master rod bearing, as well as causing excessive side clearance in the link rod.

(4) With wedge in place drive out wrist pin.

(5) Using same procedure as outlined above remove all remaining link rods.

n. Crankcase Rear Section

(1) Remove cam ring retaining snap ring. This can be done by pressing with a screw driver against the tongue of the snap ring, which protrudes into the rear main bearing sleeve. With another screw driver disengage snap ring from groove.

(2) Remove cam ring and bushing from rear main bearing sleeve.

Note
The cam followers guides are stamped with letters from "A" to "N" on the cam follower bosses to correspond with the stamped letters on the cam follower guides. This is done to facilitate the reinstallation of the cam follower guides into the positions from which they were removed at disassembly.

(3) Remove cotter pins and retaining nuts from the crab studs.

(4) Remove crabs.

Note
Do not remove rear main bearing sleeve which is bolted to the crankcase rear section.

(5) Remove cam follower guides with cam followers.

o. Induction Housing

(1) Remove primer connection if one has been installed on the engine.

(2) Removing cam drive idler shaft.

(a) Remove the bolt and nut from the hub of the gear flange.

(b) Pullout oil pump drive coupling

(c) Remove gear flange using puller FA-191. A disc or flanged plug must be placed over the end of the shaft for the puller screw to push against. The diameter of the disc or flange on the plug must be smaller than the hole in the flange.

(d) Remove the Woodruff key from the idler shaft.

(e) Pullout idler shaft from the front side of the induction housing.

(3) Removing Tachometer Drive Shaft

(a) Pry end of spring from hole in shaft and pull off spring, washer and packing.

(b) Close the slotted end of the tapered retaining pin in hub of gear.

(c) Pull gear off shaft.

(d) Pull shaft out from rear side of induction housing.

p. Cam Follower Guide

Remove the packing nuts, plain washers, spring washers and packings from the six guides removed from lower side of the crankcase.

4. Cleaning

a. General Instructions

(1) If water mixed compounds containing any form of soap or caustic soda are used for cleaning, it is of the utmost importance that all parts or assemblies be thoroughly cleaned with clear boiling water after using such compounds. It is imperative that all traces of the cleaning compounds be removed before the parts are assembled. Where these compounds are used, parts should be scrubbed thoroughly in clear boiling water and then rinsed in a separate bath of boiling water.

(2) Engine parts may be cleaned with mineral spirits or a mixture of 50% carbon tetrachloride and 50% benzol or clear unleaded gasoline. However, extreme care must be exercised to prevent injury to the personnel when handling these mixtures.

(3) All component parts of the engine must be thoroughly cleaned of all oil, grease, and carbon prior to inspection.

(4) Each part should be dried thoroughly with compressed air and placed on the rack. If the parts are to remain on the racks for any length of time they should be sprayed or slushed with engine oil or suitable slushing compound to prevent corrosion.

b. Cleaning Procedure

(1) General - After the external surfaces of the parts are cleaned, a special effort should be made to insure that all internal passages of the engine are thoroughly cleaned and blown out with compressed air. Particular attention should be paid to the oil passages of the crankshaft, induction housing, oil pump and oil sumps.

(2) Pistons - Scrape carbon from all ring grooves using every precaution not to cut or damage the lands. Hard carbon may be removed from the top and bottom of the piston head by careful scraping or by sandblasting with #120 sand propelled by not over 30 pounds air pressure. If sandblasting is used it should only be done after the piston pin holes have been plugged and the O.D. of the piston covered from the bottom of the skirt to the top of the head. The glazed surfaces present on the piston skirt will not be removed, except score marks will be removed by light stoning or kerosene soaked crocus cloth. Clean the bore of the piston pin holes with kerosene soaked crocus cloth. Carbon lodged in the oil holes should be removed by cleaning with an undersized drill if required. Final cleaning of the pistons may require polishing of the head with kerosene soaked crocus cloth.

(3) Cylinders - Removal of the hard carbon from the combustion chamber and enamel from the outside of the cylinders before repainting may be done by sandblasting. Observe instructions for sandblasting as given for piston heads.

(a) Prepare cylinders for sandblasting or scraping of the carbon from the combustion chamber by installing a suitable cylinder wall protector sleeve in the cylinder. If sandblasting is to be used, install rubber plugs in the valve guide from the inside. The threaded holes in the spark plug bushings should be protected with rubber plugs or with dummy or discarded plugs. It is permissible to sandblast the valve seats. This is often desirable, as it cuts the carbon or glaze that is apt to form on the seats, particularly the exhaust, and facilitates reconditioning.

Caution
When sandblasting is used to remove carbon, great card should be exercised not to make "pock marks" that may cause damage to the part being sandblasted.

(4) Valves - Any hard carbon remaining on the heads of the valves after removal from the cleaning solution may be removed with a fine wire brush.

(5) Master Rod Bearings - To clean the master rod bearing wipe the bearing with a clean cloth saturated with unleaded gasoline or carbon tetrachloride. Do not attempt to clean used bearings by any other means such as polishing, burnishing or subjecting them to the action of any cleaning solution other than unleaded gasoline or carbon tetrachloride.

Warner Engine Handbook: Inspection, Repair, and Assembly

Section X - Inspection, Repair and Assembly

1. General

a. This section contains complete instructions for the inspection, repair and assembly of the sub-assemblies and then the major component parts. Descriptions are given by sub-assemblies in the proper order to facilitate assembly to their major assemblies for component parts, which in turn are assembled in proper order to the engine.

b. Special precautions should be exercised during final assembly to observe any indication of loose studs. That is noticeable only when pressure of an applied nut is brought to bear on the stud. Equal precautions should be taken to prevent dirt or any foreign material from falling into the engine during assembly operations.

2. Inspection

a. All fits, clearances, etc. will be held to limits as set forth in the Table of Limits.

b. Where out-of-round, taper or wear exceeds replacement limits, a new part, or permissible reworking will be accomplished to Warner oversize or undersize standards.

c. Where some particular fit clearance of an assembly cannot be determined without the size of its mating mounting or attaching unit, the size value required will be exchanged between the inspection or assembly departments involved.

d. The following inspection procedure will be generally applicable to all detail parts and assemblies, and will be performed in conjunction with such inspection as may be specified in this section for certain parts.

(1) STUDS - Examine all studs for tightness in their respective locations and for possible damage to external threads.

(2) BUSHINGS

(a) Examine all bushings for looseness with their respective parts.

(b) Examine condition of bores for scoring, pitting, galling and any other unusual wear.

(3) PAINT - Examine condition of paint on all painted surfaces and repaint if necessary.

(4) FORGINGS AND CASTINGS

(a) Examine for nicks, cracks and other possible damage.

(b) Examine all tapped holes for thread damage.

(c) Examine all flange faces for smoothness and remove remnants of old gaskets.

(5) STEEL PARTS - Steel parts which are subject to stress except anti-friction bearings, studs, exhaust valves, standard nuts and washers, should be subjected to magnetic inspection.

(6) GEARS AND SHAFTS

(a) Gears will be examined for uneven tooth bearing, cracks or other damage due to wear.

(b) Shafts will be examined for cracks, scoring and straightness.

(7) ANTI-FRICTION BEARINGS - Ball bearings will be inspected and lubricated.

(8) VALVES - Exhaust valves will be subjected to etching test.

(9) Backlash will be measured with the mating gear teeth clean and dry.

3. Repair Procedures

a. Whenever drilling or reaming holes, break all sharp edges remaining around the holes and smooth away all burrs with a fine stone or crocus cloth.

b. Never use emery cloth for cleaning and polishing engine parts nor for any other purpose unless particularly specified in this handbook. The use of emery cloth may leave abrasive particles in the engine as well as scratches which may develop into cracks and ultimate failure of part and engine.

c. The incorrect marking of parts or the marking of parts in certain areas may produce surface cracks which can progress into complete failure of the parts. Marks placed on certain areas or parts by the factory are located at definite points where experience has indicated it will be safe to place them. Other parts are identified through the use of special etching fluid. This fluid may be used to saturate an ordinary ink stamping pad and is used with a rubber stamp. After part is etched, the surface should be cleaned and well oiled with engine oil to prevent corrosion.

d. To obtain alignment of an oil hole in a bushing with the mating hole in the mating part, draw a pencil or crayon line lengthwise on the outside of the bushing through the center of the oil hole and square with the face of the bushing. Mark the edge of the hole which is to receive the bushing. Install the bushing on its press-in plug. Align the two marks and press in the bushing.

e. Remove all nicks, scratches or undesirable marks from all parts prior to assembling. These instructions apply especially to all mating bearing surfaces, and to any other place where nicks, scratches and marks might serve as a starting point for structural failure.

f. STUDS

(1) Any loose, broken, or damaged stud, or any stud that has been turned until it does not have the proper height above its flange, will be removed and an oversize stud will be installed. All the original studs have a .005" oversize pitch diameter at the screwed-in end to obtain a tight fit in the aluminum part.

(a) If a stud needs replacement it must be replaced by one with a larger pitch diameter. These oversize P.D. studs are identified by - .005 added to their part number. Example: S-506 - .005 stud has a 3/8-24 thread with a .005" larger pitch diameter (.010" over basic thread) than the standard stud which is listed as S-506.

(b) These oversize studs should be used only when the thread in the aluminum is not damaged.

(2) If, by excessive tightening, the thread in the aluminum part is stripped, the hole should be drilled and tapped out to a 1/16" larger size and a stud with a 1/16" larger thread at the screwed-in end shall be used.

The studs with 1/16" larger screwed-in end than the original studs are identified by "- .062" added to their part number.

Example: S-506 - .062 stud has a 7/16-20 thread with a .005" larger pitch diameter (.005" over basic thread P.D.) on the screwed-in end as compared with the S-506 stud, which has a 3/8-24 thread with a .005" larger pitch diameter (.005" over basic thread P.D.)

(3) When installing an oversize stud into the 3/8-24 tapped hole the minor diameter of the hole should be cleaned up with an 11/32 drill or reamer in a tee-handled tap wrench and the chips then cleaned out with a standard pitch diameter 3/8-24 tap. If the 3/8-24 thread is stripped or damaged, it shall be necessary to use a - .062 stud with a 7/16-20 thread by drilling out the old thread and tapping with a ground tap having a pitch diameter of .4081-.4101. Engines already having - .062 studs installed should have the minor diameter cleaned up with a 25/64 drill or reamer and have chips removed with a standard 7/16-20 tap. (See Warner Aircraft Corporation Service Letter No. A-17 for the replacement of No. S-506 cylinder hold down stud and nut N-511 with S-911 stud and N-910 nut.)

(4) The pitch diameter of the tapped holes for the studs should be from basic to .002" over.

(5) The following tap drill sizes must be used:

- For 5/16-24 thread use 17/64 drill
- For 3/8-24 thread use 21/64 drill
- For 7/16-20 thread use 3/8 drill

(g) Valves found warped beyond possible reconditioning will be discarded.

(h) New piston rings will be installed at every overhaul.

4. Assembly Precautions

a. The successful operation of the engine is entirely dependent upon the attention given to every detail in the inspection and assembly. It should be born in mind by the inspector and mechanic that the slightest neglect on their part may result in the failure of the engine.

Caution
Cotter pins, safety wire, all gaskets, oil seals, lock washers, ignition cables, and rubber hoses should never be used a second time. Other safety features which have been bent or worn should be replaced with new parts.

b. Great care should be taken to prevent dirt, dust and cotter pins, nuts, washers and other small particles from falling into the engine during assembly. Such foreign material can damage the gears and the bearings.

c. Before assembly, all parts should be carefully cleaned. The use of compressed air for this purpose is recommended.

d. Completely finish each step in the process of assembly as the work progresses. Do not leave a nut loose or uncottered with the intention of coming back to it later unless other specified.

e. Do not slack off a nut to line up castellation with the cotterpin hole in the bolt or stud. If it cannot be tightened without exceeding the permissible torque value, use a new nut.

f. Use cotterpins that fit tightly in their bolt or stud holes. Always install the head or loop end of the cotterpin to fit the castellation of the nut and not across or outside the castellation. Bend one leg of the cotterpin up and back over the bolt or stud tip and the other down against the nut, except when installing cotterpins on link rod bolts. See assembly of link rod to master rod for method of installing link rod bolt cotterpin.

g. When using safety wire select a size which will fit the hole fairly tightly. Twist the wire uniformly with pliers and obtain tight loops at each end. The wire should be sufficiently tight to eliminate vibration which would cause breakage of the wire from wear.

h. In places where there is possibility of oil seeping out from between machines surfaces, the surfaces may be coated with a gasket paste before assembly. Install new gaskets under cylinder flanges, new seals on intake pipe seats, and new oil pump packing and seal.

i. The oil pump will not begin to deliver the regular supply of oil until the engine has turned over several revolutions. For this reason is is necessary to coat all surfaces normally lubricated by oil from the pump, with a good supply of engine oil when the parts are being assembled. All parts which are a drive or push fit should likewise be coated with oil to facilitate their assembly in the engine. In order to avoid chafing or scoring of crankshaft when ball bearings are pressed in place, colloidal or micrographite should be used between the inner race of bearing and the shaft. The shaft should be wiped clean with a dray cloth and a quantity of micrographite applied to the surface of the shaft and to the shoulder against which the inner race rests before

pressing on bearing. After the bearing is in place, the excess graphite should be removed.

Note
In the assembling procedures following, it will be assumed that the above recommendations and precautions, with those which may have specified at repair and assembly, have been applied.

5. Ignition Harness Assembly

a. REPAIR - Replace all ignition cables. Replace clips, brackets, tube or terminals if they requirement replacement. (See Table VIII below)

Table VIII - Table of Cable Lengths In Inches

	Total Length		Position Installed in Mag. Block	
Cylinder No	Front Plugs	Rear Plugs	Front Plugs	Rear Plugs
1	32-3/4	29	1L	1R
2	35-3/4	25-1/2	5L	5R
3	44-1/2	32	2L	2R
4	48-3/4	37	6L	6R
5	44-1/4	44	3L	3R
6	39-1/4	37-3/4	7L	7R
7	32	30-1/2	4L	4R

Used terminals may be removed from the used ignition cables by heating the soldering iron between crimped wires and terminal guide and then pulling the terminals off the cable ends.

b. ASSEMBLY - Right magneto fires rear plugs and left magneto the front plugs.

(1) Trim the insulation off the end of the ignition cable 1/4" and install spark plug terminals. Solder the wire to the spark plug terminal. Do not use any more solder than is necessary to firmly fasten wire to terminal.

(2) For the purpose of identification the cables at the magneto block ends may be numbered by placing markers over the cables. The cables should be installed at final assembly in accordance with the table shown above. The engine firing order is 1, 3, 5, 7, 2, 4, 6. The lead from No. 1 cylinder spark plug must be inserted in the No. 1 hole

in the magneto distributor block and leads 3, 5, 7, 2, 4, and 6 must be inserted in the magneto distributor block holes 2, 3, 4, 5, 6, and 7 respectively.

6. Spark Plugs

See paragraph on accessories in section IV of this handbook.

7. Magneto Control Rod

a. After cleaning, assemble all parts of magneto control rod.

8. Magneto Coupling

a. INSPECTION

(1) Check the holes in the magneto coupling flange. If they have worn elongated the flange should be discarded.

b. ASSEMBLY

Note
Old rubber discs should never be used. Always replace with new ones.

(1) Assemble the rubber disc to the magneto coupling with the heads of the flat head screws against the rubber disc.

(2) Assembly the adjusting ring to the rubber disc.

9. Magneto

See paragraph on accessories in Section IV of this handbook.

a. INSPECTION - Before placing coupling assembly on tapered shaft of magneto, check the height of the Woodruff key above the tapered surface of the shaft. This height must not be such that when the coupling is assembled to the shaft it would ride on the top of the key instead of on the taper of the shaft. A minimum clearance of .003" is desired between the top surface of the key and the bottom of the key slot in the coupling.

b. REPAIR - Remove all burrs and clean the tapered bearing surface of shaft and key with crocus cloth.

c. ASSEMBLY

(1) Install coupling assembly.

(2) Install washer and nut and secure nut with cotter pin. Take care that cotter pin is bent in such manner that there will be no interference between cotter pin and magneto rive coupling.

10. Magneto Drives

a. INSPECTION

(1) Check diameter of bearings in housing and on shaft (see table of limits)

(2) Check all ball bearings for wear.

(3) Check gear teeth and shaft for wear, nicks, scoring and scratching.

(4) Check to see if oil slinger has been bent in the disassembling of the drive.

(5) Check housings for cracks.

b. REPAIR

(1) Remove any nicks, burrs, or scratches from gear teeth by light stoning.

(2) Clean shafts with crocus cloth and kerosene.

c. ASSEMBLY

(1) Assemble in order, the housing, oil slinger, one bearing spacer, and second bearing. Make sure that the slinger spacer and bearing are pressed tightly into place in the housing against the shoulder of the housing.

(2) Install cotter key on shaft.

11. Gearcase Oil Pressure Regulating Valve and Screen

a. INSPECTION

(1) Oil Pressure Regulating Valve and Screen

(a) Inspect valve seat in bushing for wear. Replace if seat is more than 3/64" wide. If engine had indicated low oil pressure, the bushing should be discarded regardless of the appearance.

(b) Check screen assembly for breaks in the screen.

(2) Gearcase

(a) Inspect the gearcase for condition of all finished surfaces and for cracks.

(b) Check all studs for stretching and thread damage.

(c) Check bushing diameter (See table of limits).

b. REPAIR

(1) Gearcase

(a) Make necessary stud replacements.

(b) Remove all nicks, burrs or score marks and clean all finished surfaces with crocus cloth and kerosene.

(c) If bushing needs replacing lay the gearcase down on flat surface. Push the bushing out using drift FA-47-B with end opposite the flange inserted in the bushing.

(d) Pull out the bushing retaining pin if it remains with the gearcase.

(e) To install new bushing, lay the gearcase down on a 2 x 4 on edge against the starter mounting flange between the studs. Make sure gearcase is not resting on magneto brackets. Press in new bushing. Use the same drift, FA-47-B, with the flanged end of the drift inserted in bushing. Be certain that holes in bushing line up with oil passages in gearcase housing.

(f) Using a #31 (.120) drill drill a hole in the flange of the bushing 11/32 deep. Make sure this new hole is not in the same location as the old one. Countersink hole.

(g) Drive in new retaining pin. End of pin must be 1/32 below face of bushing.

(h) Stake retaining pin.

Note
For the reaming and spotfacing of this bushing see the section on the repair of the induction housing. This bushing is line reamed with the bushing in the induction housing and spotfaced afterwards.

c. ASSEMBLY

(1) Install the pressure regulator valve bushing. Bushing must be screwed in tightly to prevent oil leakage.

(2) Install oil screens, gasket, plug and acorn nut. Lockwire nut.

12. Oil Pump

a. INSPECTION

(1) Check all clearances with Table of Limits.

(2) Inspect for burrs on gears and inside walls of pump housing.

b. REPAIR

(1) Check inside surface of pumps and if scored or nicked remove nicks and scoring with crocus sloth and kerosene.

(2) Clean the finished surfaces of housings with crocus cloth and kerosene. Make necessary stud replacements.

(3) Stone the teeth of the gears to remove nicks and burrs.

(4) Remove all burrs, clean the bearing surface of the shafts and examine the keyways and keys. Usually it will be necessary to hand-fit replacement keys.

(5) Remove all burrs or score marks from gear spacers.

c. ASSEMBLY

Note
The oil pump front section, the pump housings plate and the oil pump rear section are all stamped. When the pump is assembled these stamped numbers must be in line and identical. Do not interchange pump housings or plates from one pump to another.

(1) Hold pump drive shaft in a vise by the slotted end.

(2) Install front section of oil pump over drive shaft.

(3) Install Woodruff key into pump drive shaft in the pressure pump gear key slot.

(4) Install driven gear into the place opposite the keyed driving gear.

(5) Install pump plate over drive shaft and against the pump front section exercising caution that the stamped numbers on the outside of

the pump front section and plate are in line; also, that the recess in the drive shaft hole of the plate is facing toward the rear of the pump; that is, toward the fuel pump drive mounting flange.

(6) install Woodruff key into drive shaft in the scavenger pump gear key slot.

(7) Install scavenger gear on drive shaft.

(8) Install small retaining ring in recess on drive shaft.

(9) Driven shaft and Scavenger Gear Assembly

(a) Install Woodruff key in driven shaft.

(b) Install scavenger gear on driven shaft.

(c) Install retaining rings in recesses on each side of scavenger gear in shaft.

(10) Install driven shaft assembly into the pump with the fuel pump drive end facing toward the rear of the pump.

(11) Install rear section over pump shafts.

(12) Remove pump from vise and install four pump housing screws. Before tightening screws in place, check to see that there is no binding when drive shaft is rotated by hand.

(13) Install new fuel pump drive shaft seal by inserting seal pilot No. FA-179 into end of fuel pump drive shaft and then pressing seal into recess in fuel pump drive mounting pad over pilot and shaft.

Caution
Lip of seal when seal is installed must face towards front of pump, that is, away from fuel pump drive mounting pad.

(14) Remove seal pilot

(15) Install fuel pump drive substituting cover gasket and substituting cover.

(16) Secure cover in place with washers, lock washers and retaining nuts.

13. Assembly of Oil Pump to Gearcase

a. Place cover on a flat surface.

b. Install pump packing ring (which has been coated on front and back sides with "Permatite" or equivalent gasket paste) in the bottom of oil pump well.

c. Install pump gasket in proper position over the studs on the flange of the oil pump mounting pad on the gearcase.

d. Install pump into oil pump well.

e. Secure pump to gearcase with washers, lock washers, and retaining nuts.

14. Oil Sump

a. REPAIR

(1) Clean the finished surfaces of the sump with crocus cloth and kerosene.

b. ASSEMBLY

(1) Install gaskets and screen over studs on bottom of oil sump.

Note
Make certain that one gasket is on each side of the screen.

(2) Install oil sump bottom cover.

(3) Assemble plain washers, lockwashers and nuts.

15. Cylinder Assembly

a. CYLINDER

(1) Inspection

(a) Check cylinder bore for wear, corrosion, pit marks and out of round.

(b) Check studs for tightness, straightness and damage of threads.

(c) Check finished surfaces and flanges for burrs, nicks, chafing or gall marks.

(d) Check cylinder heads for cracks and for broken, corroded or bent finds.

(e) Check cylinder barrel for dents, bent skirt or damaged fins.

(f) Check intake and exhaust valve guides for looseness in the heads, cracks, galling, scuffings or wear of valve stem bores.

(2) Repair

(a) Cylinder Barrel Grinding

Note
The cylinder head and barrel are not serviced or repaired separately. Under no circumstances should the nuts be removed at the joint between the cylinder barrel and cylinder head and these two items separated because this is a "permanent" joint.

(1) If after inspection it seems advisable to rind the cylinder barrel oversize, the barrel should be ground and honed to .012" oversize without removing the head from the barrel. (Refer to table of limits for nominal piston clearances in barrel).

Note
It is recommended that all cylinders in one engine be ground to the same oversize dimension in order to eliminate the possibility of an oversize piston being installed in a standard size bore or vice versa.

(2) The barrel diameter is choked where the head is shrunk onto the barrel. When regrinding, the barrel should be ground straight.

(3) It is sometimes possible to re-barrel cylinder assemblies in which the heads are in good condition. For this operation it is necessary that the cylinder assemblies be returned to the manufacturer.

(4) Local wear such as ring steps, or slight scores or scratches may be removed by honing, providing the clearances specified in table of limits are not exceeded.

(b) Make whatever stud replacements are necessary.

(c) Repair fins on head by profiling. If fins are broken to root of fin the cylinder and head assembly should be replaced.

(d) Clean all finished surfaces with crocus cloth and kerosene.

(e) Valve Seat Inserts

Note
If new valve guides are to be installed in head the valve seat inserts must be ground after the new valve guides are installed.

(1) The valve seat inserts should be ground whenever they are pitted, burned or not concentric with valve guides.

(2) Use valve seat grinding Tool No. FA-257-1 or other suitable grinding tool and grind inserts to desired finish. The least amount of material should be removed from the valve seats.

(3) If, after "truing up", the 45° seat is wider than 1/8" it should be reduced to 1/8" with 15° and 75° grinding wheels.

(f) Valve Guides

(1) If after inspection it is not necessary to replace valve guides, clean the bores with crocus cloth and kerosene.

(2) If, after inspection, it is necessary to remove valve guides proceed as follows:

a. Before removing valve guides with Tool No. FA-199 remove all burrs from the O.D. of the protruding end of guides.

b. Heat the cylinder head to approximately 400°F (205°C).

c. Install puller screw (part number FA-199-B) into intake guide from inside of cylinder.

Note
Asbestos gloves should be used for this operation.

d. Install yoke (part number FA-199-A) over screw with large dia. and resting against bottom of rocker box.

e. Install the AN325-6 nut onto the screw and with a wrench tighten the nut.

f. After tension is established in the screw, tap against the yoke with a hammer. This will loosen the valve guide and allow its removal.

g. To remove exhaust valve guide proceed as outlined above for intake guide.

(3) After the valve guides have been removed all the head to cool to room temperature. Check the diameter of the bore in the cylinder head and the outside diameter of the valve guide to be used as replacement. Refer to table of limits for correct shrink fit. If the bore in the cylinder head has not been damaged, a standard valve guide may be installed. If the bore has been damaged, it will be necessary to ream the bore oversize and install oversize valve guides. Oversize guides are available in .003" and .010" oversize O.D.

(4) To install valve guides use following procedure:

Note
Valve guides when installed must be cold.

a. Heat the cylinder head to a temperature of approximately 350°F (177°C).

b. Using intake valve guide assembling drift FA-52-A, install intake guide.

c. Using exhaust valve guide assembling drift, FA-52-C, install exhaust guide.

Note
It is important that each guide be driven in until the shoulder on the guide rests solidly against its seat in the cylinder head and held there until set.

d. After guides are tight remove the installing tools and allow cylinder to cool to room temperature. Ream the valve guide to proper size. Clean the bore with crocus cloth.

e. Reface the valve seat inserts after installing new valve guides.

b. VALVES, SPRINGS, WASHERS AND RETAINERS

(1) Inspection

(a) Valves

1. Check valves for wear, warping, cracks, scuffing and scratches.

2. Since the exhaust valve is made of austenetic steel, it cannot be magnetically inspected. Inspect valve with magnifying glass.

3. Any valve found to be badly warped should be discarded.

4. Inspect the retainer grooves for nicks, wear or damage, and the stem tips for cracks and excessive wear.

(b) Valve Springs

1. Inspect springs for breakage and cracks.

2. Subject the springs to a tension test in a spring tester. Reject any spring which does not come within the limits specified in table of limits.

(c) Washers - Inspect retaining washers for wear.

(d) Retainers - Inspect retainers for wear, cracks or burrs. Keep intake retainers in pairs.

(2) Repair

(a) Valve

1. Stone light scores and remove all burrs from the valve retainer recess.

2. If valve face is pitted or slightly warped, reface it in a standard valve facing machine. Angle of both intake and exhaust valve faces are 45°. Remove no more metal than is absolutely necessary to true up face.

3. If, after refacing, the thickness of the valve head is less than 3/64" at the extreme diameter at any point on the periphery the valve should be checked by the etching method as following to determine if the stellite seat has been ground off:

a. Clean the surface of the valve so that it is free and clean of oil or grease.

b. Make an etching solution the same day by mixing two parts by volume of 10% Chromic acid and one part of Hydrochloric acid. The 10% chromic acid stock solution is made by dissolving 100 grams of chromic acid ($Cr\ O_3$) in one liter (1000 C.C.) of water.

c. The face of the valve is immersed in the etching solution at room temperature for fifteen seconds, then washed and dried.

d. Any area in which the stellite has been ground through will be darkened.

Note
Serviceable valves are not damaged by etching and may be used without further grinding.

4. Remove scores, scratches or pit marks from valve stems and tips by polishing.

5. Polish head with crocus cloth and kerosene to remove all scratches.

6. After refacing the valves must be lapped with their mating valve seat.

7. Apply a light coat of 3M oil missed lapping compound, or equivalent, on the seating face of valve to be lapped, and insert the valve in its respective guide.

Note
It is important that each guide be driven in until the shoulder on the guide rests solidly against its seat in the cylinder head and held there until set.

8. Oscillate the valve back and forth with a twisting motion using tool No. FA-105-A from the tool kit, attached to valve stem. This process should be continued until there is a good bearing surface and full contact around valve seat and valve face.

9. After the lapping operation, the valves and cylinders should be cleaned thoroughly to remove all traces of grinding compound.

(b) Washers and Retainers - Stone nicks and burrs from valve spring washers and from the retainers.

(c) Rocker Arms, Rocker Arm Bearings, Shafts, Socket Lock Nuts, and Sockets

1. Inspection

a. Rocker Arms and Bearings

1. Check the condition of the rocker arm threads at the socket end.

2. Check oil hole for being clean.

3. Inspect the outer diameter of the rollers for chipping, nicks, or flat spots.

b. Rocker Arm Shafts, Socket Lock Nuts, and Sockets

1. Check the rocker arm shafts for nicks, cracks, wear and damaged threads. Check the oil holes for cleanness.

2. Check the sockets for condition of the threads, cracks and socket depth wear.

3. Check the lock nuts for wear, nicks and burrs.

2. Repair

a. Rocker Arms

1. If roller, bushing or pin requires replacement use tool No. FA-204 to remove pin, also, for swedging ends of pin after roller and bushing are replaced.

2. Place rocker arm with one end of the roller pin over hole of the drilled anvil on Tool No. FA-204.

3. Drive pin out with a small punch.

4. Remove roller and bushing.

5. Check fork for burrs and nicks. Clean with crocus cloth.

6. Install roller, bushing and new pin.

7. Place rocker arm on Tool No. FA-204 with one en of pin resting in depression of recessed anvil.

8. Peen over end of pin.

9. Place rocker arm with peened-over end of pin on the solid anvil.

10. Peen other end of pin.

11. The fork in the arm will not be closed up by riveting as the roller hub is slightly wider than the roller.

b. Rocker Arm Shafts, Sockets and Socket Lock Nuts

1. Remove any nicks or burrs on the rocker arm shafts.

2. Remove all burrs or nicks from the screw driver slot of socket. Clean the threads if necessary. Remove all sharp edges and clean the oil hole after polishing.

3. Remove burrs or nicks from socket nuts.

3. Assembly

a. To install new rocker arm bearings, smooth the bearing recesses in the rocker arm with crocus cloth and unleaded gasoline. Do not ream recesses.

b. If bearing to be replaced was loose in rocker arm use oversize outside diameter bearings.

c. To assemble bearings to rocker arm use Tool No. FA-195 and proceed as follows:

1. Place rocker arm over pin with one of the bearing recesses resting against the base.

2. Install bearing on the rocker arm recess with the sealed end facing away from rocker arm.

3. With drift No. FA-195-B, drive bearing into rocker arm recess.

4. Reverse rocker arm on assembling stand with driven-in bearing against base.

5. Place small spacer over pin and slide down against driven-in bearing. Do not omit the spacer from assembly.

6. Place other bearing over pin against rocker arm.

Caution
Both bearings must have their sealed ends on the outside when installed in the rocker arm recesses.

7. Drive second bearing into its recess.

8. After bearings are installed in rocker arm, check bearings for freedom of movement.

d. Install sockets and socket lock nuts into rocker arm and secure lock nut only finger tight.

c. ASSEMBLING OF CYLINDER

(1) Place valves into their respective guides.

Caution
Do not interchange valves from different cylinders.

(2) Place cylinder with valves on valve assembly stand No. FA-188.

(3) Install lower spring washers with the recess as the bottom side of the washer resting against the exhaust valve guide shoulder.

(4) Install inner and outer valve springs on exhaust valve. Make certain that the dampener coils of the springs are against lower spring washers.

(5) Install upper spring washer.

(6) Using Spring Depression Tool No. FA-104 from the tool kit, depress springs and install into the exhaust valve retainer recess the narrow exhaust valve retainers.

(7) Remove spring depressing tool.

(8) Install intake valve parts in like procedure as was done in assembling the exhaust valve parts.

Note
Care should be exercised not to interchange the exhaust and intake upper washers and valve retainers. These parts are not interchangeable.

Caution
After the valves have been assembled check the valve retainers to see that they are properly seated.

(9) Test valves for tightness as outlined below:

(a) Lay the cylinder on a bench with first the exhaust and then the intake ports facing upwards.

(b) In order to be acceptable the valves must not leak any gasoline for 1 minute.

(c) Fill each port with gasoline.

(d) Remove gasoline.

(e) If valve seating does not pass the above test the valves should be re-lapped and tested as outlined above until acceptable valve seating is obtained.

(10) Before installing the rocker arms into their respective housings place a rocker arm washer against each bearing in the rocker arm (2 per arm).

(11) Place rocker arm and washer into their proper positions and line up the group with the rocker arm shaft bores in the housings by using rocker arm shaft pilot No. FA-186.

Note
The rocker arm shafts must be installed so that the heads face out except the intake of No. 4 cylinder and the exhaust of No. 5; that is, when cylinders are installed the heads of the shafts will be facing between the cylinders except the two at the oil sump which face away from the sump. This installation allows clearance for the lubrication gun on rocker arm shaft fittings.

(12) Install all the rocker arms into their boxes as outlined above.

(13) Install rocker arm washers and nuts and tighten to torque as specified in table of limits.

(14) Install rocker arm shaft cotter pins.

(15) Install all of the rocker arm sockets and locknuts with the socket screwed back, so that the socket can be screwed in to the required clearance when setting the tappets.

Note
Do not tighten the locknut.

16. Push Rod Tubes and Intake Pipes

a. INSPECTION

(1) Check push rod tubes for cracks, burrs, dents and straightness.

(2) Check intake pipe for cracks and corrosion.

(3) Inspect the intake pipe finished surfaces for cracks, nicks and condition of finish. Check the painted surfaces for general condition.

b. REPAIR

(1) Straighten push rod tubes if not excessively bent.

(2) Remove push rod tube dents on a suitable mandrel.

(3) Remove any nicks or burrs from push rod with a fine file or crocus cloth.

(4) Remove all nicks, burrs and scratches from finished surfaces of intake pipe with crocus cloth.

(5) Repaint intake pipes and push rod tube as required.

17. Piston and Piston Pins

a. INSPECTION

(1) Check pistons for possible cracks, burned spots, scoring wear and general condition of all finished surfaces.

(2) Inspect piston pins for scoring, cracks and loose plugs.

b. REPAIR

(1) New rings should be installed at each overhaul.

(2) Replace old pistons which do not check within limits specified in the table of limits with new pistons.

(3) Polish all finished surfaces and piston pin bores with crocus cloth and kerosene.

(4) Clean piston pins with crocus cloth and kerosene.

(5) Check piston pins for loose plugs.

Note
Piston pin plugs are press fitted into the piston pin hole.

c. ASSEMBLY

(1) When installing new rings at overhaul it is important that the side and end clearances be within the limits specified in the table of limits.

(2) Check piston ring side clearance.

(3) Check ring gap with Tool No. FA-60-1 as follows:

(a) Place ring in checking fixture No. FA-60-A-1. Hold ring in checking fixture with plate No. FA-60-B-1 and check ring gap with feeler gage.

(4) Use lapping holder No. FA-60-C-1 to lap any ring that does not have the desired clearance.

(5) Assemble rings in grooves. They must be installed in the grooves for which they were lapped. The two top rings must be assembled with marking "TOP" on the rings, toward the head of the piston. The two bottom rings are tapered and must be installed with the tapered side, that is the small diameter, toward the head of the piston.

Caution
Care must be exercised not to expand the piston rings any more than necessary where installing them into the piston ring grooves.

(6) Replace loose piston pin plugs.

d. OVERSIZE PISTONS AND RINGS

(1) Where is was necessary to grind the barrel oversize, it is important that the same desired clearance be maintained between the piston and barrel as with standard size pistons.

(2) Pistons and rings are available in .012" and .024" oversize.

18. Push Rods and Rocker Arm Housing Covers

a. INSPECTION

(1) Check the rocker arm housing covers for cracks, galling of the parting surfaces and condition of the painted surfaces.

(2) Check the push rod ball ends for cracks, formation of projections due to wear, and looseness in the tube. Check the tubes for cracks. Do not attempt to remove the ball ends.

b. REPAIR

(1) Push rods which are bent must be discarded. Check for straightness with "V" blocks and dial indicator. Check the ball ends for tightness and the tubes for cracks after straightening.

(2) Clean the ball ends of the push rods with crocus cloth and kerosene.

(3) Rocker Box Covers

(a) Remove old gasket.

(b) Scrape out old sealing compound.

(c) Spread Permatex or equivalent sealing compound lightly on gasket.

(d) Set evenly in cover.

(e) Immediate install on rocker box until sealing compound is set.

Note
Care must be taken not to shift gasket when installing.

(f) Repaint covers as required.

19. Thrust Cover and Thrust Nut

a. INSPECTION

(1) Check thrust cover for cracks. Check finished surfaces for scratches, burrs and nicks.

(2) Check thrust cover ring in thrust cover for wear, gall marks and cracks.

(3) Examine thrust nut for marred or damaged threads. Check for cracks and damage to wrench slots.

b. REPAIR

(1) Remove scratches, burrs and nicks from finished surfaces of thrust cover.

(2) If steel thrust ring is badly galled or grooved, the thrust cover assembly should be discarded as the ring cannot be removed without damage to cover.

20. Crankcase Front Section

Note
The crankcase front section and crankcase rear section are machined together as a unit and cannot be replaced separately.

a. INSPECTION

(1) Check the crankcase front section for cracks; any part of the case in which it is doubtful whether or not it is cracked should be inspected with a magnifying glass and, if necessary, etched. The case should be most carefully inspected around the stud and bolt holes, and thrust bearing location, and at the parting surfaces. Under no circumstances should a case that is cracked be used. A cracked case cannot be welded. Check the finished surfaces for scratches or nicks and high spots around the studs.

(2) Check all studs for tightness, stretch and condition of thread.

(3) Inspect the front bearing sleeve, (which is shrunk and pinned to the crankcase front section) for tightness, cracks, scoring and wear.

b. REPAIR

(1) Clean the finished surfaces of the crankcase front section. Make whatever stud replacements are necessary.

(2) The crankcase bearing sleeve is not repairable at overhaul. If proper limits between sleeve and standard or oversize O.D. bearings cannot be obtained due to excessive wear of the sleeve the crankcase must be returned to the manufacturer where sleeve replacement and proper line boring can be made.

Note
It is not necessary to replace bearing sleeve if the limits between sleeve and oversize bearings conform to limits established for standard outside diameter bearing and sleeve (Refer to Table of Limits).

21. Crankshaft and Coupling

a. INSPECTION

(1) Crankshaft for straightness.

(a) Place shaft in two "V" blocks which will support the shaft on the main bearing journals next to the crank cheeks. Due to the difference in diameter between the front and rear ball bearing surfaces, it is necessary to shim up the rear "V" block .2058", which will bring the crankshaft in parallel with the surface plate.

(2) Rest the blocks on a surface plate in a manner which will allow the shaft to be rotated without touching the surface plate.

(a) While turning the shaft, an indicator must show not more than a total reading of .004" at the front end of the crankshaft.

(b) Inspect the crankpin for being parallel with the main journals. This must be done in two positions, with crankpin located at the top and then with crankpin located at the right angle to first position. In either position, the indicator must not show more than .002" variation between the two ends of the crankpin.

(3) Crankshaft Coupling and Pin

Note
If a new coupling is to be installed a new pin must also be used.

(a) Check fit of coupling in crankshaft. Any coupling which is .002" or more loose on the diameter should be replaced as it would cause an excessive leak in the oil pressure system.

(b) Check fit of pin through crankshaft and coupling. The pin must have a light push fit in the hole. Do not use any pin having clearance in excess of a push fit.

(4) Examine the interior of the hollow crankpin for trapped sludge.

(5) Inspect crankshaft magnetically.

Caution
Do not magnetize ball bearing.

(6) Inspect crankpin fillets and bearing journal fillet for cracks.

(7) Check all threads on crankshaft and extension shaft.

(8) Inspect splines for burrs, nicks and wear.

(9) Check bearing journals for galling, scuffing and scoring.

(10) Check the oil passages.

(11) Inspect rear main bearing retaining nut for galling, nicks and damaged threads.

b. REPAIR

Note
The spline blocking screw should never be removed from shaft except when it is obviously damaged and needs replacement.

(1) Crankshaft must be replaced if the following conditions are present:

(a) Bent shaft.

(b) Damaged splines or threads.

(c) Severe scoring and galling.

(d) Any fatigue cracks.

(e) Damaged coupling pin holes.

(2) Crankshaft Coupling and Pin

(a) If coupling is replaced, fit to the crankshaft with .001 looseness. Hone if necessary.

(b) If a new pin is used it must have a light push fit in hole. Hone if necessary. A coupling furnished for service has the hole reamed to size and no other reaming is necessary.

(3) Polish the crankpin with crocus cloth and kerosene. Slight scratches, nicks or burrs may be removed using a fine round stone. Use a rocking motion when stoning to avoid flat spots. Lightly stone the crankpin fillets to remove scratches or light burrs.

(4) Stone any nicks or burrs from the splines.

(5) Any areas there slightly galled or scuffed should be smoothed with crocus cloth and kerosene.

(6) Remove any burrs from the rear main bearing journal bore.

(7) Remove any roughness or galling from the crankpin plug by light stoning or cleaning with crocus cloth and kerosene.

(8) If, after inspection, it is determined that the crankpin is worn beyond limits established in table of limits it should be ground to

1.867" plus or minus .0005. Crankshaft with ground crankpins should be tagged so that .008" undersize master rod bearing shells will be installed at assembly of shaft and master rod.

(9) If, after inspection, it is determined that the crankpin is only slightly worn beyond the limits established in the table of limits the crankpin should be cleaned up with crocus cloth and kerosene and tagged so that .002" undersize bearing shells can be fitted to the shaft at assembly of shaft and master rod.

c. ASSEMBLY

(1) Check spline blocking screw. If this item has been removed install new screw in place.

Note
The spline blocking screw is located in place on the centerline of the crankshaft and No. 1 cylinder when No. 1 cylinder piston is at top dead center.

(2) Clamp crankshaft in vise on the rear cheek as shown in Figure 16.

Note
Vise must have copper covered jaws and shielded arm.

(3) Install crankpin plug in crankpin bore. Care should be exercised that the oil holes in the plug and in the crankpin are in line.

Note
The crankpin has three oil holes drilled in such a manner, that two holes are on the left side and the third on the right side when the crankshaft is viewed from the rear and the counterweights face downward.

Note
Do not install the crankpin plug in such a manner that the open side of the plug would face away from the counterweights when the plug is installed in the crankpin, because the oil holes in the plug and crankpin would not be in line and consequently the master rod would not receive any lubrication, which would result in damage to the engine.

(4) Install crankpin plug cotter pin.

(5) Install crankshaft coupling.

(6) Install coupling pin.

(7) With crankshaft clamped in vise coat rear main bearing journal with colloidal or micrographite and start rear main bearing on its journal in such a manner that the chamfered end of the inner race faces the rear crank cheek.

(8) Using a suitable hollow bearing driver approximately 16" long and having an inside diameter of 2-1/2", drive bearing onto journal until the face of the inner race is well seated against the journal shoulder.

Caution
When installing bearings, drive on inner race only.

(9) Install rear main bearing retaining nut using wrench No. FA-71-1 as shown in Figure 14. Check to see that nut is tight against bearing.

(10) Observe and mark the hole that is in line on the retaining nut and rear main bearing thread. Into this hole will be installed the tongue of the rear main bearing nut lock ring.

Note
The rear main bearing nut lock ring should not be installed on nut until after crankshaft and crankcase front section assembly is completed.

22. Cam and Magneto Drive Shaft

a. INSPECTION

(1) Check shaft and starter clutch assembly for nicks, scratches, burrs and cracks.

(2) Inspect pins through starter clutch for looseness. This can be evidenced by observing the edges of the peening on the pins which show sharp edges not solid against the shaft when loose. If the pins are loose to any extent, they must be replaced

b. REPAIR

(1) If starter clutch pins are to be replaced, drive out old pins with a drift.

(2) Install new pins and peen over.

(3) File pins flush with shaft.

(4) Use care in filing and do not file the diameter of the shaft just ahead of the front pin as this will damage the bearing surface.

23. Master Rod and Link Rods

a. INSPECTION

Important
The master rod piston pin bushing and all the wrist pin bushings and the crankpin bearing bore must be parallel within .004" in 6 inches and be in the same plane within .004" in 6 inches. Also, all the link rods must have the piston pin bushings and the wrist pin bores parallel within .004" in 6 inches and be in the same plane within .004" in 6 inches.

(1) Link Rod Inspection

(a) Check the link rods for cracks, nicks, burrs and condition of piston pin bushing.

(b) Check piston pin bushings for clearance with piston pin in accordance to table of limits.

(c) If it is determined that the piston pin bushings need replacement tag or label the rods with the necessary information.

(d) Check the wrist pin bore and wrist pin clearances in accordance to the table of limits.

(e) If wrist pins are loose or push fit in the link rods the wrist pins must be replaced with oversize wrist pins. Wrist pins are available in .0005, .001, .0015 and .004 oversize.

(f) When standard wrist pins are replaced with oversize wrist pins it may be necessary to ream the wrist pin bushings in the master rod to the new oversize clearances, which will be in accordance to limits in table of limits. If it is established that the wrist pin bushings in the master rod must be reamed, the link rods and their master rod must be tagged or labeled with the information that oversize wrist pins are to be used and that the wrist pin bushings in the master rod are to be reamed to have proper clearance with the oversize wrist pins.

(g) Check link rods for straightness before rebushing.

(2) Master Rod Inspection

(a) Check the master rod for cracks, nicks, burrs, and condition of bushings.

(b) Check all the bushings for clearances as specified in table of limits.

(c) Check the condition of the crankpin bearing bore in the master rod for burrs and nicks.

(d) Check the distance between the front and rear wrist pin bushings installed in the master rod which must be .875" minus .000" plus .002".

(e) Check all oil holes to determine if any wrist pin bushings may have become loose and rotated thus blocking the oil passage.

(3) Link Rod Bolts, Master Rod Bolts, Wrist Pins and Crankpin Bearing Shells Inspection

(a) Check all bolts for nicks, burrs, scratches, galling, condition of threads and cracks.

(b) Check wrist pins for cracks, nicks, burrs, wear and clearances in link rods and bushings in the master rods.

(c) Check the crankpin bearing shells for size using inside micrometers or other suitable instruments. Take readings at several locations while bearing shells are clamped in the master rod. Check for end clearances.

(d) Check bearing shells for scoring, wear, nicks, scratches, and burrs.

(e) Check oil holes in bearing shells for being clean.

b. REPAIR

(1) Link Rods

(a) To not attempt to straighten a bent rod no matter how slight the bend. Bent rods should be discarded.

(b) Nicks, burrs and slight scratches should be removed with crocus cloth and kerosene.

(c) Clean wrist pin bore in link rod with crocus cloth and kerosene.

(d) Replace loose, worn or cracked piston pin bushings. Piston pin bushings are available with .002 oversize O.D. and .009 undersize I.D.

(e) If a piston pin bushing must be replaced use the following procedure:

(1) Place the link rod piston pin boss into recess on stand No. FA-50-B.

(2) Install the 59/64" dia. x 7/8" long end of the drift No. FA-50-A into the bushing and press out bushing with an arbor press.

(3) Clean piston pin bushing bore in link rod boss of any score marks.

(4) Place new bushing on the 59/64" dia. x 1-3/8" long end of the drift No. FA-50-A and press into place in link rod.

(5) Using a 1/8" drill, drill two holes into the new bushing, through the oil holes in the top of the piston pin boss.

(f) After a new piston pin bushing is installed it must be reamed to size on Reaming Fixture No. FA-56-D-1 with a No. FA-56-F piston pin bushing reamer.

(1) Place the rod in reaming fixture with the numbered side facing outward and with the wrist pin bore on the pilot near the center guide pin. Do not tighten nut until after rod is aligned.

(2) With adjustable anvil lowered away from the piston pin boss, remove burrs from oil holes and install reamer No. FA-56-F into bushing so that approximately 7/8" of the flutes on the reamer are in the bushing.

Caution
The floating block in which the adjustable anvil is located must be free enough so that when the reamer is installed in the piston pin bushing it will center itself without binding against the bushing.

(3) Tighten the nut and retaining washer on the pilot, against the wrist pin boss of the link rod.

(4) Adjust the anvil by screwing it up against the end of the piston pin boss just so that it will provide a support for that end of the rod while the bushing is being reamed.

Caution
Do not adjust the anvil against the rod so that it will spring the rod even a slight amount, because this would cause misalignment of the piston pin bushing and the wrist pin bore after the bushing has been reamed.

(5) Using cutting oil and feeding the reamer very slowly through the bushing, ream the piston pin bushing to size and check for alignment as outlined under "Inspection".

(2) Master Rod

(a) Remove nicks, burrs and slight scratches by light stoning.

(b) Remove burrs from crankpin bearing bore in master rod with crocus cloth and kerosene.

(c) Use only carbon tetrachloride to clean bushings.

(d) The bushings in the master rod are replaced only when they are loose, damaged or worn.

(e) When it is determined oversize wrist pins are to be used with link rods and if the wrist pin bushings are in good condition it is not necessary to replace the wrist pin bushings. They should be reamed oversize if necessary.

(f) When wrist pin bushings are to be reamed to an oversize inside diameter it is important that the guide pin be used to locate the master rod in reaming fixture No. FA-56-D-1 for proper alignment. Use applicable oversize reamers.

(g) Replacing Piston Pin Bushing

(1) Place the master rod piston pin boss into recess on stand FA-50-B.

(2) Install the 59/64" dia. x 7/8" long end of the drift No. FA-50-A into bushing and press out bushing with an arbor press.

(3) Clean the piston pin bushing bore of any score marks.

(4) Place new bushing on the 59/64" diameter x 1-3/8" long end of the drift No. FA-50-A and press into place in master rod.

(5) Using a 1/8" drill, drill two holes into the new bushing through the oil holes in the top of the piston pin bore.

(h) Replacing Wrist Pin Bushings

Note
Use Tool No FA-54 to remove and install wrist pin bushings in the master rod using the following procedure:

(1) Assemble master rod to mating cap.

(2) Place master rod on stand No. FA-54-A in arbor press.

(3) Using drift No. FA-54-B press out bushings from one side and then turn rod over and press out bushing from other side. Bushings are pressed into and removed from the link rod space between wrist pin bushing bosses of the master rod.

(4) Clean wrist pin bushing bores in master rod with crocus cloth and kerosene before installing new bushings.

(5) Check clearances between the wrist pin bushing outside diameters and the wrist pin bushing bores in the master rod in accordance with table of limits.

Note
Sometimes it is necessary to replace a wrist pin bushing that may have become loose in the master rod and enlarged the wrist pin bushing bore in the rod.

(6) When loose bushings are being replaced, oversize wrist pin bushings should be used. Wrist pin bushings are available with .002 oversize O.D. and .005 undersize I.D.

(7) Place master rod on stand No. FA-54-A in an arbor press.

Note
When new wrist pin bushings are pressed into the master rod, the space for the link rod boss between the two bushings must be maintained at .875" minus .000 plus .002" This is accomplished by the use of locating block No. FA-54-C which has one end ground to .875" plus .001 minus .000 think and the other end ground .891" plus .001" thick.

(8) Place the thicker end of the locating block into the space between the wrist pin bosses and press the new bushing into its boss until it bottoms against the locating block. Drift No. FA-54-B should be used to press in the bushing. Proceed in the same manner until all the bushings are pressed in on one side of the master rod.

(9) Turn the rod over and place the narrower end of the locating block into the space between the wrist pin bushings in such a manner than when the second bushings are pressed in they will bottom against the locating block, thereby establishing the desired .875 plus .002" minus .000 dimension.

(10) Press in the second group of bushings using drift No. FA-54-B. Make certain that the master rod is well seated on the stand when the bushings are being pressed in because if the master rod is not well seated, the first group of bushings will be pushed out where bottoming the second group of bushings.

(11) After the bushings are in place, separate the master rod and its cap and drill 12 oil holes into the new bushings using a 1/8" drill and

drilling through the oil holes that are located in the crankpin bearing bore of the master rod and cap.

Caution
Drill through only one side of each new bushing.

(i) Reaming Piston Pin Bushing and Wrist Pin Bushings

(1) Remove the link rod wrist pin bore "pilot" from the reaming fixture No. FA-56-D-1 by unscrewing pilot nut on the back of the fixture and then tap out the pilot.

(2) Place master rod into fixture on the center guide pin.

Note
The bearing shells are not used when the master rod is placed on the center guide pin.

(3) With the adjustable anvil lowered away from the piston pin boss start the piston pin bushing reamer No. FA-56-F about 1/8" into the bushing. This procedure will align the master rod in the fixture.

(4) Loosen the piston pin reamer slightly and then place the circular top plate over the three guide pins and tighten securely against the master rod with the slotted washer and the nut.

(5) With the piston pin reamer No. FA-56-F still in place, adjust the anvil by screwing it up against the end of the piston pin boss just so that it will provide a support for that end of the rod while the bushing is being reamed.

Caution
Do not adjust the anvil against the piston pin boss so that it will spring the rod even a slight amount because this would cause misalignment of all the bushings with each other and the crankpin bearing bore after the bushings have been reamed.

(6) Using cutting oil and feeding the reamer very slowly through the bushing, ream the piston pin bushing to size.

(7) Remove the reamer from the bushing and insert in its place the alignment pin.

(8) Read under paragraph 23 a. Inspection 1 d-e-f and before reaming wrist pin bushings determine what size wrist pins are going to be assembled to the master rod and link rods and then ream bushings

accordingly, using reamer bushing No. FA-56-J and reamer collar No. FA-56-K and the desired reamer. See below for reamer to be used:

Condition of Bushing	Wrist Pin to be used with Link Rod	Use Reamer Number
Slightly worn	.0005" oversize	FA-56-E-3
Slightly worn	.0015" oversize	FA-56-E-1
New	standard	FA-56-E

(9) After the size of the reamer is determined proceed to ream the wrist pin bushings.

(10) After all the bushings are reamed, remove the rod from the fixture and remove any burrs that may have resulted from the reaming operation.

(11) Check rod for alignment as outlined in paragraph on Inspection (See 23-a).

(3) Link Rod Bolts, Master Rod Bolts, Wrist Pins and Crankpin Bearing Shells Repair

(a) Bearing shells are not repairable if they are worn, scratched, galled, scored or cracked. Replace with new bearing shells after determining the size required by measuring the crankpin on which they will be assembled. Bearing shell assemblies are available in .002 and .008 undersizes.

(b) If bearing shells are usable they may be lightly scraped to remove slight scratches, or scoring. Do not clean bearing shells with any abrasive material.

(c) Clean wrist pins, master rod bolts and link rod bolts with crocus cloth and kerosene.

(d) Replace any link rod bolts and master rod bolts that are scored, cracked or have damaged threads.

c. ASSEMBLY OF MASTER ROD AND LINK RODS

Note
When assembling the link rods and the wrist pins to the master rod, make certain that the stamped numbers on the link rods, the stamped numbers on the master rod and the slotted ends of the wrist pins are on the same side of the master rod assembly.

(1) Assemble master rod and cap with the four master rod bolts and their retaining nuts. Tighten nuts on finger tight.

(2) Place master rod with the numbered side up in an arbor press and install a link rod between its corresponding wrist pin bushings.

(3) Install a small steel wedge between the lower surface of the link rod and the steel boss around the lower wrist pin bushing. Do not put the wedge on the lower bushing because this bushing would be pushed out when the wrist pin is being installed into the link rod.

(4) Carefully press or tap the wrist pin through the wrist pin bushing and the smaller end of the link rod after "lining up" this notched in the wrist pin with the link rod bolt holes in such a manner that the link rod bolts can be easily installed into the link rods.

(5) Proceed to install the rest of the link rods and wrist pins as outlined above, at the same time being careful that the small wedge is used under each link rod when its wrist pin is being installed.

(6) If after the wrist pins are installed, the notch in the wrist pins does not properly "line up" with the link rod bolt holes use wrench No. FA-63 to turn the wrist pins the required amount so that the link rod bolts can be easily installed.

(7) Install link rod bolts, tighten retaining nuts and secure cotter pins as outlined below:

(a) Install all link rod bolts with the threaded end toward cylinder No. 1 and their cotter pin holes at 45° to the link rod.

(b) Install and tighten nuts snugly with a wrench in order to draw the head of the bolts against the link rods.

(c) Loosen the retaining nuts and then re-tighten only finger tight.

(d) Observe and note the positions of the cotter pin hole in the link rod bolt and the first and second castellations to the left of the hole.

(e) Tighten the nut from approximately 3/8 of a castellation (22-1/2 degrees) to a maximum of 1-1/4 castellation (75°).

Note
This method of tightening has been found more satisfactory than using a torque wrench which is influenced by the amount of lubrication and fit between the nut and bolt.

(f) Install cotter pin. Be sure to bend both legs of the cotter pin as indicated because if one of the legs were bent over the bolt end an adjacent link rod may strike it.

24. Assembly of Master Rod and Link Rods to Crankshaft

a. Secure crankshaft in a vise by clamping on the front crank cheek with copper covered jaws.

Note
It is important that copper shields be used on the jaws and the arm of the vise so as not to burr or scratch the crankshaft when it is being assembled with other parts of the engine.

b. Lightly tap into place the upper and lower master rod bearing shells in their respective halves of the master rod. The bearing shell with the offsets in the center assembles to the upper half of the master rod and the bearing shell without the offsets assembles to the master rod cap. Check the alignment of the oil holes after the shells are installed in the master rod.

c. Assemble the master rod to the crankpin so that the numbered side of the master rod and link rods faces the splined end of the crankshaft.

d. Before installing the master rod bolts measure their length with a micrometer. The dimensions will aid in determining the amount of tightening of the nuts necessary to obtain the right stretch when the bolts are secured to the master rod.

e. Install the master rod bolts and nuts to the rod and tighten all nuts with a small wrench to take up all slack. Then loosen one nut at a time and draw up to remove all clearance only. Check the positions of the holes in the bolts and the slots in the nuts. These should be in line. If the hole and slot do not line up, remove the nut and install it on another bolt. Proceed in this selection until all nuts and master rod bolts are matched.

f. Next, tighten all four nuts, evenly, one castellation in order to obtain a stretch on the bolts of .003" minimum to .006" maximum. This stretch can be measured over the entire bolt with a micrometer.

g. Install and secure cotterpins to the master rod bolt retaining nuts.

h. Remove crankshaft and master rod assembly from vise.

25. Crankcase Rear Section, Cam Followers, Cam Follower Guides, Cam Ring and Cam Follower Guide Crabs

a. INSPECTION

(1) Crankcase Rear Section

Note
The crankcase front section and crankcase rear section are machined together as a unit and cannot be replaced separately.

(a) Check the crankcase rear section for cracks. Any part of the case in which it is doubtful whether or not it is cracked should be inspected with a magnifying glass and, if necessary, etched. The case should be most carefully inspected around the stud and bolt holes and at the rear main bearing sleeve location and at the parting surface. Under no circumstances should a case that is cracked be used. A cracked case cannot be welded.

(b) Check the finished surfaces for scratches, nicks and high spots around the studs.

(c) Check all studs for tightness, straightness, stretch and condition of thread.

(d) Check all clearances between cam follower guides and their bosses. The cam follower guides should have a light push fit into their respective bosses. (Refer to table of limits).

(e) Check clearances of cam ring and its bushing on the rear main bearing sleeve. (Refer to table of limits).

(f) Check the rear main bearing and the rear main bearing sleeve for clearances as established in the table of limits.

(g) Check rear main bearing sleeve for galling, scoring and cracks.

Note
The rear main bearing sleeve must not be removed from the crankcase rear section because it is shrunk in place and then line reamed with the front main bearing and thrust bearing sleeves.

(2) Cam Ring

(a) Inspect the cam ring for wear, nicks, scratches, cracks and scoring.

(b) Check condition of teeth on cam ring gear.

(3) Cam Follower Guides, Cam Followers, Crabs and Crankcase Bolts

(a) Check cam follower guides for wear, nicks, burrs, scratches and cracks.

(b) Check cam follower guides for clearances as established in the table of limits with the crankcase rear section bosses and with the cam followers.

(c) Check cam followers for clearances as established in the table of limits.

(d) Check cam follower rollers for wear, cracks and scoring.

(e) Check cam followers for scratches, nicks, burrs, cracks and for condition of push rod socket.

(f) Check crabs for nicks, burrs and cracks.

(g) Check crankcase bolts for nicks, cracks, scoring and condition of threads.

b. REPAIR

(1) Crankcase Rear Section

(a) Clean all finished surfaces of the crankcase rear section. Make necessary stud replacements.

(b) If oversize cam follower guides are to be installed in crankcase rear section, it may be necessary to ream cam follower guide bosses to the desired bore.

(c) Remove any nicks, burrs and scoring from rear main bearing sleeve by light stoning.

(d) If the rear main bearing sleeve is worn or cracked and needs replacement it will be necessary to send the entire crankcase to the manufacturer for replacement of bearing sleeves and proper line reaming.

Note
Oversize rear main bearings are available for slightly worn rear main bearing sleeves in .002 and .0035 oversize.

(2) Cam Ring

(a) Clean all surfaces and gear teeth by lightly stoning nicks, burrs, slight scratches and scoring.

(b) Worn cam ring should be replaced.

(c) Remove nicks, burrs, scratches or scoring from cam ring bushing by light scraping or stoning. Do not use crocus cloth or emery cloth.

(d) Remove any nicks, burrs and scoring from cam ring bushing retainer by stoning.

(3) Cam Follower Guides, Cam Followers, Crabs, and Crankcase Bolts

(a) Clean all finished surfaces of the cam follower guides with crocus cloth and kerosene.

(b) Replace worn cam follower guides.

(c) Replace worn cam followers, rollers, sleeves or pins. Drive out old pin and replace new roller, sleeve and pin. Peen over ends of new pin so that the ends are within a 39/64" maximum diameter.

(d) Remove nicks, burrs, scoring and scratches from usable cam followers with crocus cloth and kerosene or light stoning.

(e) Remove nicks, burrs and galling from cam follower guide crabs with crocus cloth and kerosene or light stoning.

(f) Remove nicks, burrs and scoring from crankcase bolts using crocus cloth and kerosene.

Note
When cam follower guides are replaced with new guides the new guides should be stamped with the same letter as appears on the guide being replaced.

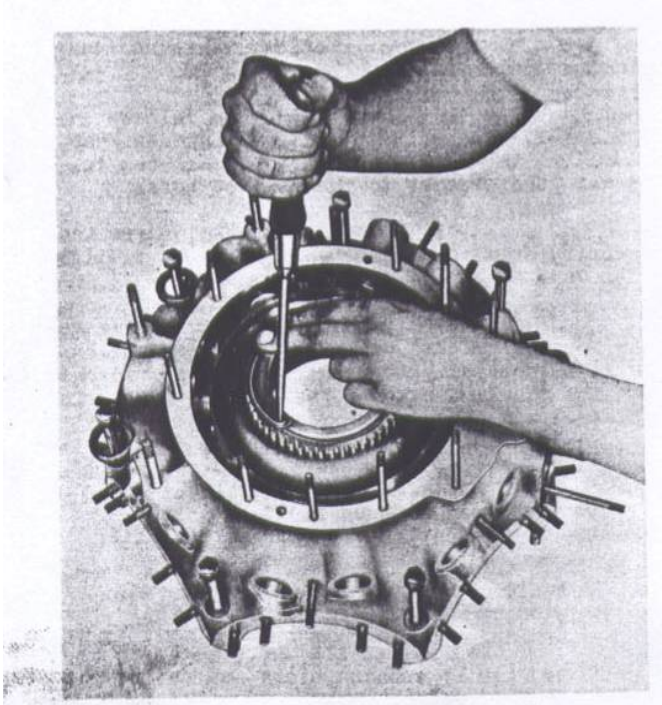


Fig. 17. Method of Installing Cam Ring Retainer

c. ASSEMBLY OF CRANKCASE REAR SECTION

Note
See Figure 17 before assembling crankcase rear section.

(1) Place crankcase rear section on a flat, smooth surface so that the rear of the crankcase rear section is facing upward.

(2) Install the cam ring bushing into the cam ring from the cam lobe end.

(3) Install cam ring and bushing on the rear main bearing sleeve in such a manner that the gear end of the cam ring will be to the rear and cam lobes will be to the front when cam ring is in place.

(4) Install cam ring retainer, making certain that it is well seated in the groove and slot in the rear bearing sleeve.

(5) Install the cam followers in the cam follower guides. In each of the six guides for the lower part of the crankcase install the spring washer, flat washer, two new packing and packing nut, proceeding as follows:

(a) Install in order the spring washer, flat washer, one packing and packing nut.

(b) Tighten the nut lightly to set the first packing.

(c) Remove the packing nut and install the second packing.

(d) Reinstall the packing nut, tighten lightly to set the packing, then tighten approximately one sixth of a turn until a flat on the hex of the nut is parallel to the flat on the guide.

Caution
Do not tighten excessively as this may cause cracking of the guide.

(6) Before installing the cam follower guides check the stamped letters on the guides and the stamped letters on the crankcase to make certain that the cam follower guides are assembled in their corresponding bosses.

(7) Install gasket on each guide in addition to a small sealing ring in each of the two bottom guides.

(8) Install cam follower guides with cam followers and gaskets into their correspondingly stamped bosses. After cam follower guides are installed make certain that the machined seats for the forked crabs are in such position that the forked crabs can be easily installed.

(9) Install cam follower guide crabs with the forked ends squarely seated on the milled shoulders of the guides. Secure crabs in place with retaining nuts tightened with the proper torque (see table of limits) and install cotterpins. (See Figure 18 for position of crabs).

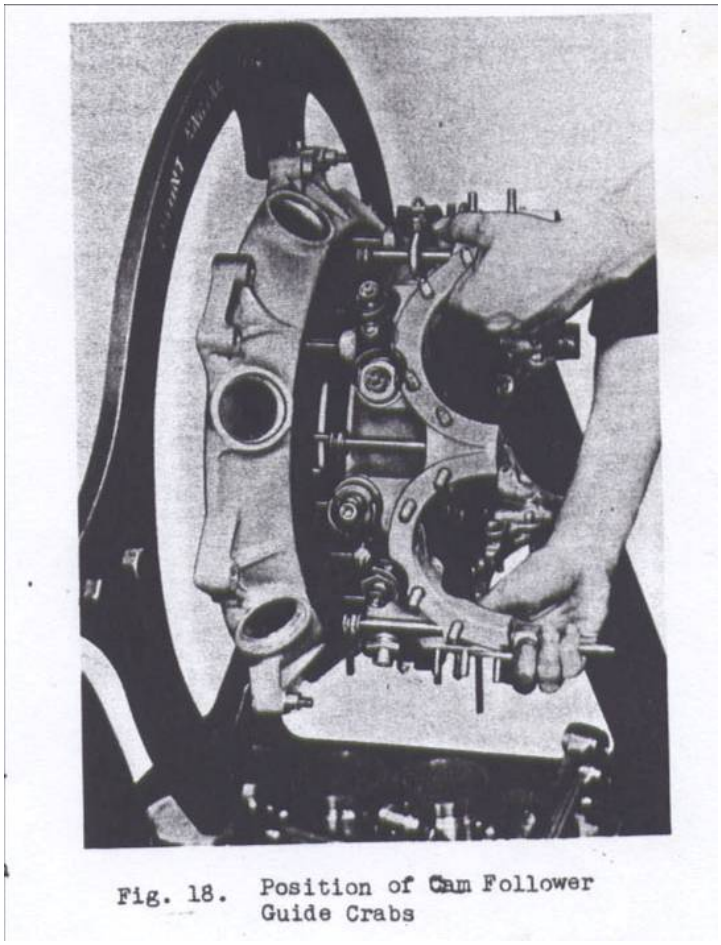


Fig. 18. Position of Cam Follower Guide Crabs

(10) Install crankcase bolts, with flat washers under their heads, into their bosses in the crankcase rear section. Do not tap the bolts completely through, only up to the front parting surface.

Caution
It is important that the crankcase bolts are installed at this stage of re-assembly. If they should be omitted and the crankcase rear section were assembled and secured to the induction housing, it would be impossible to install the crankcase bolts into the crankcase rear section, because the front surface of the induction housing would be too near the bolt holes in the crankcase rear section and thus not allow enough space for bolt installation.

(11) Install induction housing to crankcase gasket to the rear face of the crankcase rear section, being very careful that the gasket is not damaged when being pushed over the studs.

26. Induction Housing, Cam Drive Idler Shaft and Tachometer Drive Shaft

a. INSPECTION

(1) Induction Housing

(a) Inspect the housing for cracks. Any part of the housing in which it is doubtful whether or not it is cracked should be inspected with a magnifying glass, and, if necessary, etched. The housing should be carefully inspected around the stud and engine mounting holes at the different bushing bosses, flanges and parting surfaces. Under no circumstances should a housing that is cracked be used.

(b) Check the finished surfaces for scratches, burrs, nicks, galling and high spots around the studs.

(c) Check all studs for tightness, straightness, stretch and condition of thread.

(d) Check all oil passages for being clean and clear.

(e) Check all bushings for scoring, scratches, burrs and wear.

(2) Cam Drive Idler Shaft and Tachometer Drive Shaft

(a) Check gears and shafts for wear, nicks, scoring and cracks.

(b) Check all clearances and fits with table of limits.

(c) Check cork plug in tachometer drive shaft for looseness and deterioration.

(d) If gear hub has become loose on cam drive idler shaft, hub, gear and retaining bolt should be discarded. Hub and shaft cannot be replaced separately as the retaining bolt hole is reamed at assembly.

b. REPAIR

Note
All the bushings in the induction housing except the cam and magneto drive bushings are located for reaming from the shaft bushing and the two dowel pins in the gearcase mounting flange. The cam and magneto drive shaft bushing

is located for "line-reaming" from the main bearing sleeve in the crankcase.

(1) Induction Housing

(a) Make necessary stud replacements.

(b) Clean all finished surfaces with crocus cloth and kerosene.

(c) Remove all nicks, burrs and the high spots around studs.

(d) Induction housing bushings may be cleaned by light scraping. Care should be exercised that the scraping will not cause the bushing and gear clearances to exceed those established in the table of limits.

(2) Removing and Installing Induction Housing Bushings

(a) Cam and Magneto Drive Shaft Bushing

(1) Lay a piece of tubing approximately 2" I.D. x 2" long on an arbor press and rest the rear side of the induction housing on the tube with the bushing inside of the tube.

(2) Remove bushing by pressing out with rive FA-47-B.

(3) Pull out the 1/8 retaining pin.

(4) To insert new bushing rest the front side of the induction housing on stand FA-47-A with the bushing boss in the large counterbore of the stand.

(5) Push in new bushing with drive FA-47-B making sure oil hole is in line with the oil passage in the crankcase.

Note

When executing this operation the large shoulder of the drift must be pressing against the shoulder of the bushing.

(6) Using a #31 (.120) drill drill a hole 11/32 deep in the shoulder of the bushing.

Note

Make certain the new hole is drilled away from the old retaining pin hole.

(7) Drive in new retaining pin. End of pin must be 1/32 below face of bushing.

(8) Stake retaining pin.

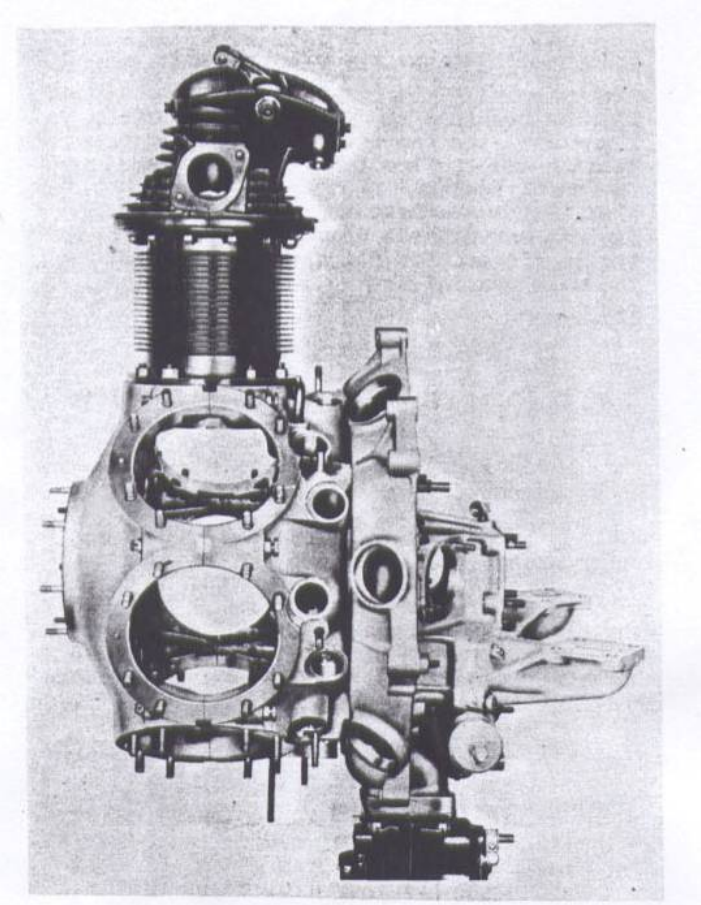


Fig. 19. View of Crankcase, Gearcase and Cylinder assembled as a unit for illustration only.

(b) Cam Drive Idler Gear Bushing

(1) Lay the front side of the induction housing down on an arbor press and press out bushing using drift FA-49.

(2) Pull out bushing retaining pin.

(3) Rest the rear face of the induction housing on the arbor press and press in new bushing with FA-49 making sure that the oil hole in the bushing lines up with the oil passage in the induction housing.

Note
When executing this operation the large shoulder of the drift must be pressing against the shoulder of the bushing.

(4) Using a #31 (.120) drill drill a hole 11/32 deep in the shoulder of the bushing.

Note
Make certain the new hole is drilled away from the old retaining pin hole.

(5) Drive in new retaining pin. End of pin must be 1/32 below face of bushing.

(6) Stake retaining pin.

(c) Tachometer Drive Shaft Bushing

(1) Remove, insert bushing, and drive in new pin using the same procedure as outlined under (b) above, but using drift FA-51. There is no oil hole to line up in this bushing.

(3) Reaming and Spotfacing Induction Housing Bushings and Gearcase Bushings

Note
Since the other bushings in the induction housing are located from the cam and magneto drive bushing it is important that this bushing is reamed before the others; also, if it has not been replaced, that is has the proper limits and clearance.

(a) Reaming Cam and Magneto Drive Shaft Bushings

(1) Assemble gearcase, induction housing, crankcase rear section and crankcase front section together as shown in Figure 20.

drive shaft bushings.

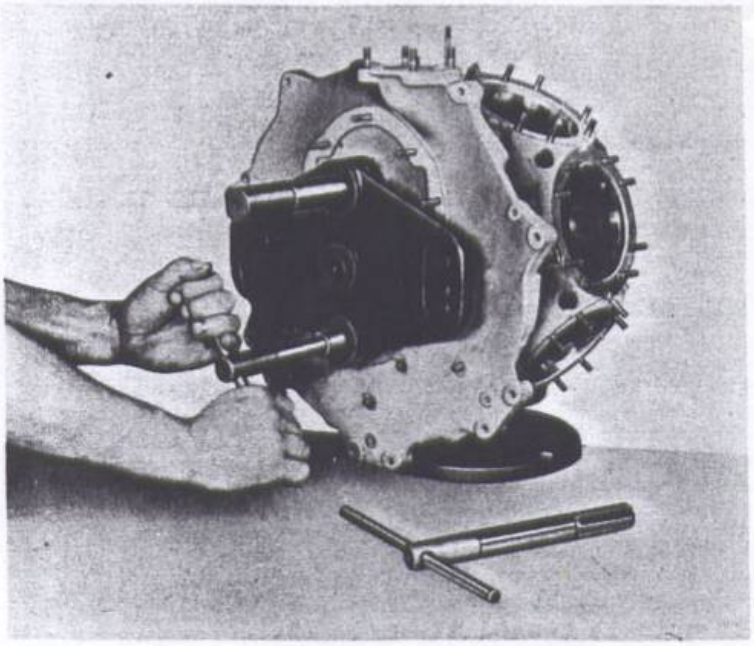


Fig. 20. Front and Rear Crankcase Sections Assembled for Reaming Operation

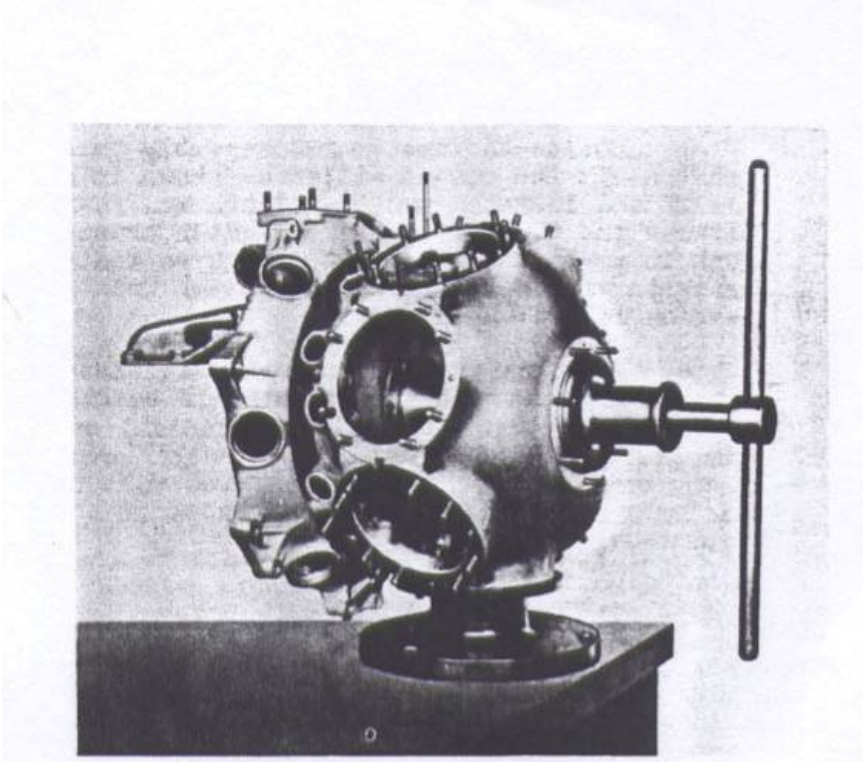


Fig. 21. Front and Rear Crankcase Sections, Induction Housing and Gearcase assembled for Reaming Operation

CAUTION

(2) Install assembly on reaming base No. FA-45-1.

Note
The cam and magneto drive shaft bushings require special reamer No. FA-55-A. This reamer "line-reams" the cam and magneto drive shaft bushings in line with the crankcase main bearing sleeves.

(3) With crankcase set up on a bench carefully install the reamer into place through the crankcase front section as shown in Figure 21.

(4) Ream the cam and magneto drive shaft bushings.

Caution

So as to not cause the reamer to follow the bore in the bushing but to ream true with the centerline of the crankcase, the reamer should be fed into the bushings slowly as it is being rotated. A slow feed of the reamer will give better reamed bushing. Reamer must be fed clear through to the stop.

(5) After the reaming is completed, remove the reamer and the reaming stand from the crankcase, and separate the two crankcase sections, induction housing and gearcase.

(b) Reaming cam idler shaft bushing and tachometer drive shaft bushing (See Figure 20).

(1) Using FA-59-E reaming fixture, insert the pilot into the reamed cam and magneto drive shaft bushing from the rear.

(2) With FA-59-D reamer, ream through the cam drive idler shaft bushing.

Note

If tachometer drive shaft bushing is not being replaced insert reamer FA-59-C into the fixture and bushing to act as a pin for holding the fixture in place while reaming the idler shaft bushing.

(3) Insert pin FA-59-F into the reamed cam drive idler shaft bushing. This pin keeps the fixture from rotating while reaming the next hole.

(4) With FA-59-C reamer, ream the tachometer drive shaft bushing.

(5) Remove fixture.

(c) Spotfacing cam and magneto drive shaft bushing in gearcase with gearcase tool FA-85-H spotface the flange of the bushing in the gearcase to a distance of 1.942 - 1.846" from the gearcase front mounting face to the flanged face of the bushing. The shank of the spotfacing tool is a #2 Morse taper for use in a drill press.

(d) Spotfacing cam and magneto drive shaft bushing in the induction housing.

Note

This bushing must be spotfaced so as to allow .007 minimum end play of shaft when installed. To obtain this, proceed as follows:

(1) Assemble induction housing, cam and magneto drive shafts, gearcase gasket and gearcase.

(2) Determine approximately by the gap between the induction housing face and gearcase face, how much must be removed from the face of the bushing.

(3) Disassemble and measure distance from the face of the flange of the bushing to the rear face of the induction housing before spotfacing.

(4) With the same spotfacing tool FA-85-H spotface the flange of the bushing down equal to the amount of the gap measured between induction housing and gearcase faces. Check by measuring from face of bushing to rear face of induction housing.

(5) To obtain the .007 maximum clearance end of the shaft, continue to spotface slightly.

(6) Again assemble parts and insert a feeler gauge through the magneto drive opening in the gearcase between the bushing and thrust face of the shaft to determine the end play obtained.

(7) Repeat operations 5 and 6 until the desired end play is obtained.

(e) Spotfacing cam drive idler shaft bushing. This bushing must be spotfaced down to allow .007 minimum end play of the shaft and hub. To obtain this proceed as follows:

(1) Using spotfacing tool FA-85-G, spotface flange of bushing to a distance of 2.028 maximum from the face of the bushing flange to face of the boss on the induction housing.

(f) Spotfacing tachometer drive shaft bushing. This bushing must be spotfaced down so as to allow .007 minimum end play of the shaft and gear. To obtain this proceed as follows:

(1) Spotface the flange of the bushing to a distance of 1.457 maximum between the two faces of the bushing.

(4) Cam Drive Idler Shaft and Tachometer Drive Shaft

(a) Stone the teeth of gears to remove nicks and burrs.

(b) Remove all burrs and clean bearing surfaces of the shafts with kerosene and crocus cloth.

(c) If gear is loose on tachometer drive shaft or if either gear on shaft is to be replaced, assemble shaft and gear together setting them in a position so that the distance between the thrust faces is 1.464-1.466. Line up the holes and line ream for a #0 taper pin through the hub and shaft. The standard taper pin which was remove is #00.

c. ASSEMBLY

(1) If the 1/8 pipe plug has been removed, re-install the plug into the primer connection at the top of the induction housing.

(2) Cam Drive Idler Gear

(a) Install the cam drive idler gear into the induction housing from the front.

(b) Install the key to the shaft.

(c) Assemble the cam drive idler gear hub and pump drive coupling to the rear end of the shaft lining up all of the holes in the flange, shaft, and coupling.

(d) Assemble the bolt through the holes and install nut and cotter pin.

(e) Check end play of the shaft with bushing. See table of limits.

(3) Tachometer Drive Shaft

(a) Install the tachometer drive shaft into the induction housing from the rear.

(b) Assemble the tachometer drive gear on the shaft with the face of the gear against the bushing flange.

(c) Drive a new taper pin through the gear flange and spread the end of the taper pin.

(d) Check end play of gear with bushing flange. See Table of Limits.

27. Assembly of Crankcase Front Section And Crankshaft With Master Rod Assembly

a. Place crankshaft and master rod assembly in an upright position on a wood or fiber block, which has a 3-1/8" diameter hole in it, in such a manner that the rear bearing rests on the block and the end of the coupling extends through the hole.

b. Rotate the master rod assembly to approximately the same position as shown in Figure 25 and install crankshaft jack No. FA-202 between the counterweights. Tighten crankshaft jack in position shown just enough so that the crankpin will not be sprung when the front main bearing is driven in place.

c. Coat the inner diameter of the front main bearing race and the front main bearing journal of the crankshaft with colloidal or micrographite,

and install front main bearing on the crankshaft with the chamfered end of its inner race facing the front cheek of the crankshaft.

Note
When installing the hub, the idler shaft should be rested on a solid surface to prevent the key from damaging the bushing.

d. Using the same bearing driver that was used to install the rear main bearing, drive front main bearing on its journal until it is well seated against the shoulder of the front crank cheek.

e. Install bearing spacer on the crankshaft making certain that it is well seated against the inner race of the front main bearing.

f. Next, install the thrust bearing into the sleeve in the crankcase front section. Carefully install the crankcase front section on the crankshaft in such a manner that the master rod will protrude at the No. 1 cylinder opening and the link rods will protrude at their respective cylinder openings.

g. With driving tube resting on thrust bearing inner race, drive until thrust bearing seats solidly against the bearing spacer. This will force the crankcase into place over the front main bearing.

h. Install oil slinger on crankshaft with flange rim of slinger facing toward the splined end of the shaft.

i. Install thrust nut using wrench FA-274, if necessary, to screw down nut against the oil slinger but do not tighten more than finger tight.

j. Install lock ring on the rear main bearing retaining nut.

Warner Engine Handbook: Final Assembly, Timing and Testing

Section XI - Final Assembly, Timing and Testing

1. General

a. Observe the assembly precautions listed in Section III of this handbook as well as those listed below.

b. If the engine is to stand for any length of time before final assembly is completed, all steel parts both inside and outside must be covered with oil to prevent corrosion.

c. Use extreme care to prevent dirt, dust, cotterpins, lockwire, nuts, bolts, washers and any particles or parts from falling inside the engine. Keep all spark plug holes, intake pipe openings, carburetor inlet openings, and all other parts covered until the installation of the respective parts or covers.

d. Observe the following precautions when using a torque wrench:

(1) Make sure that no part of the wrench binds on any part of the engine.

(2) Install the wrench in such a position that the nut or screw may be pulled up to the required torque without interruption.

(3) The torque load should be applied until the nut or screw has ceased to turn. This may require several seconds from the time that the indicator reaches the required torque value.

e. New gaskets and packings will be installed where they are required, replacing those which were removed at disassembly. All mating gears, shafts and bearings will be adequately oiled prior to installation. All safety wiring, hose clamps and cotter pins will be installed where necessary, following the final assembly of each part.

2. Final Assembly of the Major Sub-Assemblies

a. INDUCTION HOUSING

(1) Place and lock mounting plate of engine assembly stand in a vertical position.

(2) Attach induction housing assembly to mounting plate with four 5/16" bolts using flat washers under the retaining bolts to prevent damaging the front face of the mounting lugs.

b. INSTALLING CRANKCASE REAR SECTION

(1) Check to see that the six crankcase bolts and their washers are in place, and the crankcase to induction housing gasket is not omitted.

(2) Attach crankcase rear section to front side of induction housing. Rotate the cam drive shaft and tachometer shaft if necessary, until the gear teeth on the shaft mesh with the gear teeth on the cam ring.

(3) Secure crankcase rear section to induction housing by installing washers and nuts on the studs that protrude through the rear side of the induction housing.

(4) Tighten nuts with desired torque and safety each nut with cotter pin.

c. INSTALLING CRANKCASE FRONT SECTION, CRANKSHAFT AND CONNECTING RODS

(1) Rotate and lock mounting plate of engine assembly stand in a horizontal position, i.e., the rear of the induction housing will face the floor.

(2) Lightly tap down any crankcase bolts that may protrude beyond the parting surface of the crankcase rear section

Caution
Do not try to drive back stud between cylinder Nos. 4 and 5.

(3) Install crankshaft and crankcase front section assembly into place on the crankshaft rear section. Care must be exercised in guiding the crankcase front section of the stud between cylinder Nos. 4 and 5. (Note: No. 1 cylinder is diametrically opposite to this stud).

(4) If the crankcase front section does not immediately seat itself against the rear section, tap the crankcase front section with a rawhide mallet and level the front section until it is seated.

(5) Using driving tube, drive on the thrust nut and bearing until the front section is well seated against the rear section.

Caution
Never attempt to pull the crankcase down by means of the crankcase bolts and nuts.

(6) After the crankcase sections are firmly in place, push the crankcase bolts into the front section and install the flat washers and retaining nuts on the bolts and stud. Tighten nuts evenly and gradually with the desired torque as specified in the table of limits. Safety crankcase nuts with cotterpins.

d. TIGHTENING THRUST NUT

(1) Using the crankshaft turning bar No. FA-182 and thrust nut wrench No. FA-274 in a manner similar to that shown in Figure 7, tighten the thrust bearing nut very tightly (see table of limits). This will prevent wear and damage to the crankshaft when the engine is operated.

e. INSTALLING THRUST COVER

(1) Tap the outer race of the thrust bearing until the bearing is well seated against the shoulder of the crankcase sleeve.

(2) Place the thrust cover over the crankshaft into place on its crankcase mating flange with the cast-in word "top" nearest the No. 1 cylinder pad.

(3) Hold the thrust cover firmly against the thrust bearing and check with a feeler gage the clearance between the cover and the crankcase.

(4) After the clearance is obtained, determine which one of combination of thrust bearing cover gaskets are to be used that will have a combined thickness of .004" to .006" less than the space measured with the feeler. This will cause the outer race of the thrust bearing to be held firmly and kept from rotating when the thrust cover and gaskets are installed in place. Thrust cover gaskets are available in thickness of .003" and .005".

(5) Install gasket or gaskets and thrust cover. Secure cover in place with flat washers, lock washers and retaining nuts. Tighten nuts with required torque as established in table of limits.

f. INSTALLING PISTONS INTO CYLINDERS PRIOR TO ASSEMBLY TO CRANKCASE

Note
The three top rings on each piston should be installed in such a manner that the gaps of all three rings are approximately 120° apart.

(1) Install piston ring clamp No. FA-46-1 over the three top piston rings and compress the rings.

(2) Place cylinder on a bench and install the piston into the end of the cylinder, so that the stamped cylinder number on the head of the piston is forward; i.e., toward the propeller end of the engine.

(3) Push the piston into the cylinder just far enough to cover the piston rings. This will leave the piston pin hole outside of the cylinder skirt, and will allow the mechanic to install the piston pin into the piston and connecting rod bushing when assembling the cylinders to the crankcase.

(4) Install the remaining pistons into their respective cylinders in accordance with the method outlined above.

g. INSTALLING CYLINDERS AND PISTONS TO CRANKCASE

(1) Install new cylinder base gaskets or "O" ring packings (depending on Engine model) and turn the crankshaft to a position in which the connecting rod of No. 1 cylinder extends the maximum distance outside of the cylinder flange.

Editor's Note: There are numerous Service Bulletins post-dating this manual that dictate replacement of all gaskets and cylinders with the O-ring style cylinder base gaskets. Don't assemble an engine using anything but the O-ring style gaskets, since apparently the gasket crush on non-O-ring gaskets was causing the cylinders to work up and down on the mounting studs, which would ultimately break off the studs.

(2) Holding cylinder assembly as shown in Figure 22 line up the piston hole in the piston with the bushing in the rod and inset the piston pin with the stamped end of the pin facing toward the propeller end of the engine.

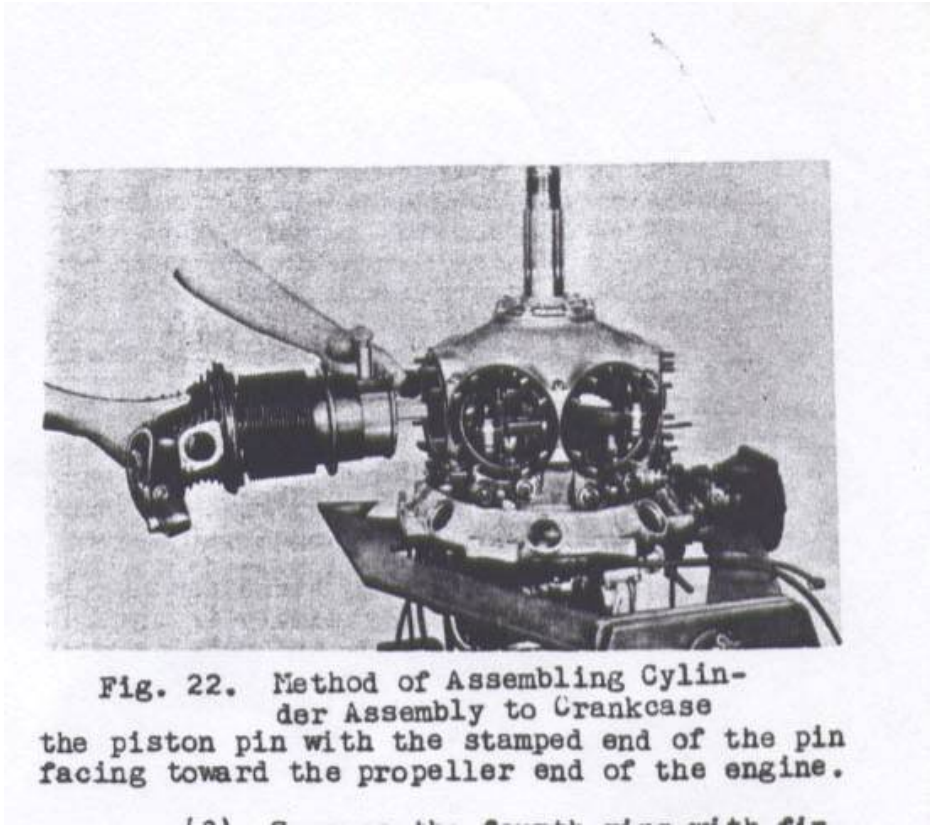


Fig. 22. Method of Assembling Cylinder Assembly to Crankcase the piston pin with the stamped end of the pin facing toward the propeller end of the engine.

(3) Squeeze the fourth ring with fingers and push cylinder just over the ring.

(4) Slip the spring, washer and new packing, in the order named, over the long end of the push rod tube.

(5) Insert a push rod in each of the push rod tubes.

(6) Holding a push rod tube assembly in each hand, push the cylinder into place on the crankcase with the body, at the same time guiding the two push rod tubes into place.

Note
The long end of the push rod with the spring, washer and packing is at the cylinder.

(7) Install and tighten cylinder base nuts using wrench No. FA-33-A. Tighten nuts with desired torque as outlined in table of limits.

Caution
Do not exceed torque limitations.

(8) Next, install and tighten palnuts on the cylinder base retaining studs with the smooth face against the plain nut. Do not tighten less than 60° or more than 90° from the point where they contact the cylinder base retaining nuts as the threads on the studs may be damaged.

(9) Install the remaining cylinders, using the same procedure as outlined above.

(10) On the intake pipe install, in the order named, the spring, gland and new packing.

(11) Install new gaskets on the intake flange of the cylinder.

(12) Insert the end of the induction housing tube into the induction housing opening, and push the flanged end into place over the studs.

(13) Install a plain washer, lockwasher and nut on the inside stud of the intake pipe flange and an ignition wire clip, lockwasher and nut on the outside stud. (Ignition cable clip is not used when breeze shielding is installed).

(14) Tighten the intake pipe nuts to the required torque.

Note
The ignition cable clips must be in a position with the open end facing out.

h. TIMING OF VALVES

(1) Rotate the lock the engine mounting plate of the assembly stand so that the engine is in a normal or flight position.

(2) Install timing disc FA-16-1 and pointer No. FA-16-L to the engine as shown in figure 23. The timing disc must be installed with the omitted spline over the spline blocking screw which is installed on the top and front of the crankshaft when crankshaft is in "Top Center No. 1 Cylinder" position. The pointer is attached to the front cylinder base studs of No. 1 cylinder.

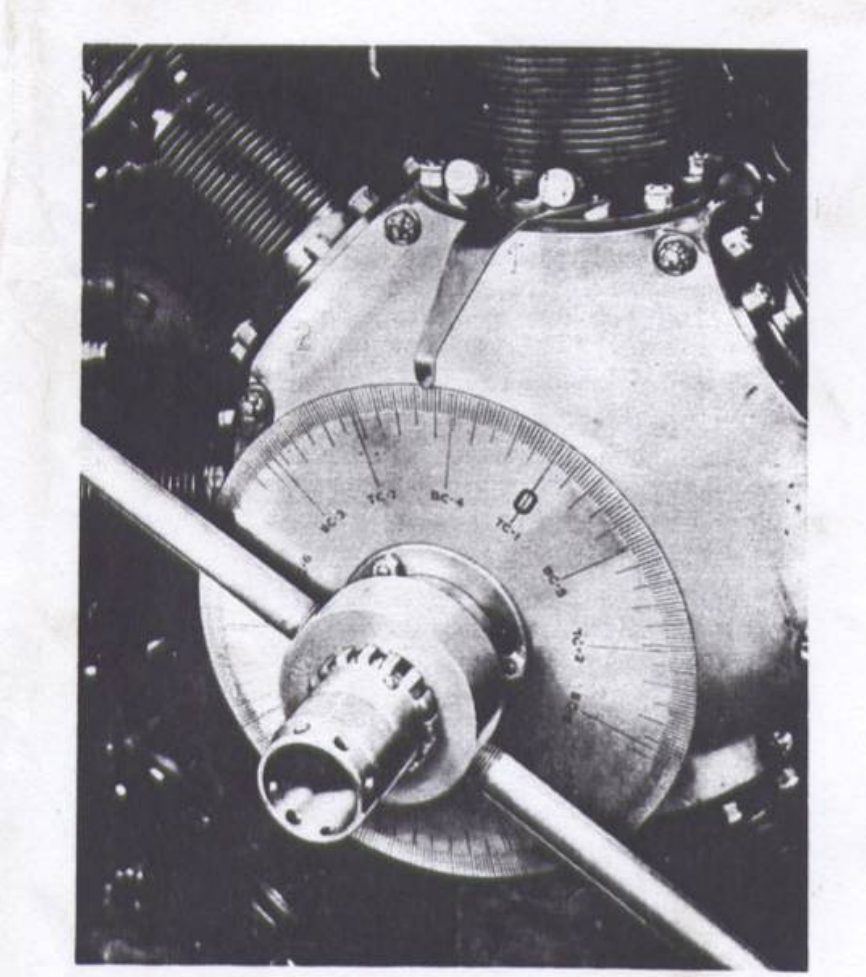


Fig. 23. Method of Installing Timing Plate and Pointer

Note
The proper location of the timing disc on the crankshaft may be checked by the use of a top dead center indicator or by observation of the piston travel in cylinder No. 1. The piston in No. 1 cylinder must be in the top dead center position when the "0" and "TC-1" markings on the disc line up with the pointer.

(3) With the No. 1 piston at top dead center, turn the cam drive idler shaft with a wrench on the tongue of the pump drive coupling until both valves of No. 1 cylinder are closed while the intake valve of No. 7 cylinder and the exhaust valve of No. 2 are both approximately half open.

(4) Using the 5/8 and 3/4 open end wrench FA-39, a screw driver and feeler gages, adjust cylinder No. 1 intake and exhaust valve clearances to .027 inches between the rocker arm roller and the end of the valve stem.

(5) Turn the timing disc to 10° before top dead center of No. 1 cylinder.

(6) Slowly turn the cam drive idler shaft anti-clockwise until No. 1 intake valve starts to open. This can be determined by inserting a .0015 inch feeler gage between the rocker arm roller and the end of the valve stem. When the valve starts to open, the feeler will begin to stick.

(7) Install the cam and magneto drive shaft, engaging slot in the shaft with the tongue in the end of the crankshaft.

(8) Immediately install the gear on the cam drive idler shaft hub by rotating gear until a set of three holes in the gear line up with three holes in the hub.

Note
Do not move either the hub or cam and magneto drive shaft during this operation.

(9) Install the three gear retaining bolts.

Note
Do not fully tighten the bolts at this stage of the timing. The valve opening and closing points should be obtained for the four groups of lobes on the cam ring by repeating the readings on cylinder No. 1 while rotating the crankshaft 8 full turns in direction of propeller rotation. The readings for each group of cam lobes should be taken in the following sequence: 1. Intake opens. 2. Exhaust closes.

3. Intake closes.

4. Exhaust opens.

The approximate average values of the four sets of readings should be used to determine the amount of advance or retard required to time the valves.

(10) The design timing of the engine is as follows:

Exhaust opens	60° before bottom center
Intake opens	10° before top center
Exhaust closes	10° after top center
Intake closes	60° after bottom center

Note

From the above values it can be seen that both valves remain open during 250 degrees of the crankshaft rotation.

(11) Due to a summation of factors (listed below) which effect timing, variations from the design timing can be expected, and the valves should be timed accordingly.

(a) At the point of valve opening and valve closing, the cam lobes are equipped with ramps which give very little valve lift but for small variations of the contours show large variations in readings for valve timing, since they are magnified 8:1 through the timing gears.

Note

The variations outlined above existing at the cam ramp which manifest themselves in rather large timing variations do not affect the power output of the engine since their influence on the effective valve lift is negligible.

(b) The timing values obtained will be affected by the accuracy with which the tappets are set at .027". A decrease in this clearance will result in the valves remaining open longer than 250 degrees of crankshaft rotations, and an increase in this clearance will result in a reduction of the time during which the valves are open as compared to 250 degrees of crankshaft rotation.

(c) If, when timing, the range of valve opening is found to be more or less than 250 degrees this can be attributed to the accuracy of the .027" tappet setting plus the manufacturing limits on the cam, and if it should cause difficulty, it is permissible to increase or reduce the

tappet settings the slight amount required to obtain the 250 degrees valve opening.

(d) In comparing the timing values obtained with the design timing values and considering the necessary timing changes, it must be kept in mind that advancing the ignition timing increase the value in degrees of the "exhaust opens" and "intake opens" points and reduces the values of the "exhaust closes" and "intake closes" points. Conversely, retarding the timing decreases the values in degrees of the "exhaust opens" and "intake opens" points and increases the values for the "exhaust closes" and "intake closes" points.

(12) If it is found necessary to advance or retard the observed actual timing, proceed as follows:

(a) Return the timing disc to cylinder No. 1 top dead center of the firing stroke.

(b) Remove the three gear retaining bolts and gear from the cam drive idler shaft.

(c) Advance or retard the timing disc the required number of degrees.

(d) Reinstall the gear and three bolts as outlined above for preliminary timing.

(e) Recheck the timing as previously outlined.

(f) If timing is found satisfactory, tighten the three bolts to the required torque and lockwire.

Note
Upon completion of the valve timing, immediately proceed with the next operation of installing the gearcase as outlined below, so that the am and magneto drive shaft cannot be pulled out resulting in the loss of timing.

i. INSTALLING GEARCASE

(1) Slip the gearcase gasket over the studs on rear of induction housing and install gearcase assembly.

(2) Install plain washers, lockwashers and nuts on studs and tighten to the torque shown in table of limits.

(3) Install magneto drives in both sides of the gearcase with the word "Top" marked on the housing facing up. The housings are also stamped designating right or left side. Although the drives are not

right and left hand parts, it is advisable to install them on the same side from which they were removed.

(4) Install starter and fuel pump substituting covers.

(5) Install the oil pressure inlet bolt type hose elbow in the bottom of the gearcase using two new gaskets, one on each side of the elbow. Tighten the nut to the required torque limits.

(6) Install, on the right side of the oil pump, the scavenger pump inlet bolt type hose elbow, bolts and two gaskets, one on each side of the elbow.

(7) Install, on the left side of the oil pump, the scavenger pump outlet straight type hose nipple and gasket.

Note
Some installations may be equipped with the bolt hose type elbow same as used on the inlet.

j. INSTALLING BREATHER

(1) Install the breather and tachometer drive housing assembly. Make sure the spring washer and packing are on tachometer drive shaft.

(2) Install the plain washers, lockwashers, and nuts.

k. INSTALLING OIL SUMP AND TUBE

(1) Install the oil sump assembly to the bottom of the crankcase.

(2) Install the plain washers, lockwashers and nuts on studs and the bolt on the front end at the link attached to crankcase. Lockwire bolt to the bottom stud in the crankcase.

(3) Slip the hose with clamps down over the oil sump tube and install tube on the bottom of the sump.

(4) Install, loosely, lockwashers and nuts on the tube. Slip the hose over the fitting on the oil pump. Tighten nuts and hose clamps.

l. INSTALLING MAGNETO

(1) Set the magnetos on the brackets and install, loosely, one plain washer and magneto attaching bolt.

m. TIMING OF THE MAGNETOS

(1) Install timing disc and pointer as it was installed for the valve timing.

(2) Turn the crankshaft in the direction of propeller rotation until the piston in cylinder No. 1 is coming up on the compression stroke and set the timing disc at 31° or 29-1/2° before top center depending on the method of timing.

Note
The 31° setting is to be used when the magnetos are being timed by means of a timing light to indicate the opening of the contact points on the magneto.
Note: von Willer material "A" p. 69 says 28^0 BTDC.

(3) If a timing light is not available use .0015" feeler between the breaker points of the magnetos and set the timing disc at 29-1/2° before top center on the compression stroke of the No. 1 cylinder.

(4) Set each magneto in the fully advanced position by turning the magneto lever in a clockwise direction.

(5) Remove the magneto distributor blocks and set the internal-timing marks on the rear side of the rotor gear to line-up with the corresponding marks on the magneto front housing.

(6) Insert the two plain washers and bolts (for each magneto) in the holes where the scribed lines on the magneto drive shaft flange and the magneto coupling adjusting ring line up.

(7) If mating holes cannot be lined up or they are opposite the adjusting ring rivets, remove the magneto and magneto drive and rotate the magneto drive shaft several tooth spaces. Reinstall drive and magneto as before.

(8) Check the magneto timing by either of the two methods outlined above. See that breaker points on both magnetos open at the same time.

(9) When timing is formed satisfactory, install the remaining magneto to attaching plain washers and bolts, tighten and lockwire. Tighten the adjusting ring bolts and lockwire. Tighten magneto drive nuts.

(10) With the magnetos still in the fully advanced position, install the magneto control levers in position on the magnetos as shown in Figure 2.

(11) Adjust the magneto advance rod to the proper length and assemble to the magneto control levers.

Caution
Magnetos must be in the fully advanced position.

(12) If for any reason a magneto has been removed from the engine for replacement or retiming, it can be retimed with the undisturbed magneto in the following manner:

(a) Turn the engine in direction of rotation until the piston of No. 1 cylinder comes up on the compression stroke and stop rotating when the breaker points of the undisturbed magneto being to open, and the undisturbed magneto is in the fully advanced position.

(b) Accurately determine the opening to the break points on the undisturbed magneto by using .0015" shim or timing light as outlined above in paragraphs on final timing of the magnetos.

(c) After the timing has been determined for the undisturbed magneto install the second magneto as outlined above.

(d) Recheck the magnetos to see that their breaker points open at the same time.

n. SETTING VALVE TAPPETS

(1) Rotate and lock engine mounting plate so that the crankshaft is in a vertical position.

(2) Adjust all rocker arms to have a valve tappet clearance of .010". Proceed as outlined below:

Note
The .010" valve tappet clearance is the cold clearance. When the engine reaches operating temperatures the valves tappet clearance will open up to approximately .027" due to the expansion of the cylinders in a radial direction from the crankcase.

(a) Install timing disc on crankshaft, with the omitted spline in the disc hub in line with the spline blocking screw on the crankshaft.

(b) Turn crankshaft in direction of propeller rotation until the piston in No. 1 cylinder completes the compression stroke and the "TC-1" mark on the timing disc is in line with the centerline of No. 1 cylinder. Then adjust both valve tapped clearances to .010".

(c) Turn the crankshaft in direction of propeller rotation 1-1/7 revolutions. The mark "TC-1" on timing disc should be in line with centerline of No. 2 cylinder. Adjust both the valve tappet clearances to .010" on the No. 2 cylinder.

(d) Continue turning crankshaft 1-1/7 revolutions at a time and adjusting valve tapped clearances to .010" until all the cylinders have had the valve tappet clearances adjusted. Make certain that all the socket lock nuts are tight after the adjustments are completed.

(3) Install rocker box covers.

(4) Lubricate rocker arms with grease using a reliable rocker arm grease.

o. INSTALLING CARBURETOR AIR HEAT CONTROL VALVE

(1) Install and secure carburetor air heat control valve to its mounting flange on the bottom of the carburetor.

p. INSTALLING SPARK PLUGS, IGNITION CABLES AND ATTACHING PARTS

(1) Rotate and lock engine mounting plate of assembly stand so that the engine is in flight position.

(2) Install all front and rear spark plugs and gaskets. Observe torque limits established in table of limits.

(3) Install in place the fourteen cable clips on the intake push rod tubes.

(4) Install ignition cable tube and its supporting hardware.

(5) Attach the terminal ends of the ignition wires to the spark plugs and lead the wires in the proper places through their securing clips and tube.

(6) After the cables are in place in their attaching parts, group the cables, install each cable into its magneto distributor block position and secure to distributor block with the electrode screws.

(7) Install magneto blocks on the magnetos and safety in place, being careful that the grooves on the bottom of each block are against their seating pin in the magneto housing and that the magneto blocks retaining screw is not damaged.

3. Testing of Engine After Complete Overhaul

After complete overhaul the engine must be block, installation or flight tested.

a. The test schedule outlined herein has been worked out under the assumption that no electric "jacking-in" equipment is available.

b. A test club should be used which will allow the engine to turn approximately 2050 R.P.M. at full open throttle under standard atmospheric conditions.

c. If the test is conducted with the engine installed in an airplane in place of a regular test stand, the airplane should be faced into the wind when the test is being conducted.

d. No ring cowling should be installed on the engine for the running test. if inter-cylinder baffles are used they probably can be installed on the engine for the test provided that it has been determined previously, by means of thermocouples installed on at least for rear spark plugs of the engine, that the particular type of inter-cylinder baffles used has no detrimental effect during the ground test on the cylinder temperature.

e. Aviation fuel of 73 octane or better should be used. The following oils should be used:

In summer - Grade 1120
In winter - Grade 1100 or 1100A

f. The following running times are recommended:

R.P.M.	**Minutes of Running**
500	15
600	15
800	30
900	30
1000	60
1200	60
1400	60
1500	60
1600	60
1700	60
1850	30
1950	30

Full open throttle	45
Idling approx 400 R.P.M.	20

Note
If, during the first 60 minutes of running at 1700 R.P.M. it has been determined that the oil consumption is .025 lb/HP/hr or less, 60 minutes of running is sufficient; otherwise the engine should be run for additional time at this speed until the oil consumption reaches .025 lb/HP/hr or less. if the engine is run in an airplane, so that the specific oil consumption cannot be determined, 2.1 lb/hr of oil can be assumed as the maximum permissible oil consumption for the above condition..

Editor's Note: Rather than extended ground running at low RPMs, modern thought is to run a new engine as hard as possible during the initial few hours of break-in so that the rings are forced to seat in. Consult your A&P.

g. The oil pressure should be maintained at 50 to 90 lbs/sq. in. If the oil pump was repaired but not adjusted, and the oil pressure with warm oil is above 90 lbs/sq. in., the oil pressure should be adjusted by adding or removing washers between the spring and the pressure relief valve plug in the pressure relief valve.

h. After the tests are completed, the baffles should be installed into place on the engine in accordance to markings put on the baffles at dismantling of the engine.

4. Preparation of Engines for Storage

a. Unless it is to be installed for operation within 48 hours the engine should be prepared for storage.

Warner Engine Handbook: Parts List

Section XII - Parts List

Part No.	Nomenclature	SS50	SS50A
S-500	Stud - Plain - 1/4 x 5/16 x 1/2 Grip	X	X
S-501	Stud - Plain - 1/4 x 5/16 x 1/4 Grip	X	X
S-502	Stud - Plain - 1/4 x 5/16 x 5/16 Grip	X	X
S-503	Stud - Drilled - 1/4 x 5/16 x 1/2 Grip	X	X
S-504	Stud - Plain - 1/4 x 5/16 x 2-1/8 Grip	X	X
S-505	Stud - Plain - 1/4 x 5/16 x 2-25/32 Grip	X	X
S-506	Stud - Plain - 5/16 x 3/8 x 5/16 Grip	X	X
S-508	Stud - Plain - 5/16 Straight x 1/8 Grip	X	X
N-509	Nut - Slotted - 5/16-24 NF3 Engine - Steel	X	X
N-511	Nut - Plain - 5/16-24 NF3 Special High Steel Cad.	X	X
N-512	Nut - Plain - 5/16-24 NF3 Steel	X	X
N-513	Nut - Shear - 3/8-24 NF3 - Steel - Cad. Plated	X	X
S-515	Stud - Drilled - 1/4 x 5/16 x 15/16 Grip	X	X
N-517	Nut - Shear - 1/16-20 NF3 Aircraft - Steel Cad. Plated	X	X
P-519	Pin - 5/16 Dia. x 9/16 Long - Drill Rod	X	X
P-520	Pin - 3/16 Dia. x 9/16 Long - Drill Rod	X	X
N-521	Nut - Plain - 1/4-28 NF3 SEA Steel - Cad. Plate	X	X
CS-523	Bolt - Hex Head - 3/18-16 NC3 x 23/32 Special Steel	X	X
CS-523-1	Bolt - Hex Head - 3/18-16 NC3 x 27/32 Special Steel	X	X
P-526	Pin - 1/8 Dia. x 5/16 Long - Drill Rod	X	X
W-527	Washer - Plain #12 Steel	X	X
LW-528	Washer - Lock - #12 - Light	X	X
W-529	Washer - Plain - 1/4 Steel	X	X
LW-530	Washer - Lock - 1/4 Std. Regular	X	X
W-531	Washer - Plain - 5/16 Steel	X	X
W-533	Washer - Plain - 3/8 Steel	X	X

Warner Engine Handbook: Table of Limits

Section XIII - Table of Limits

Description of Limits	Min	Max	Replace Beyond
Piston			
Piston in Cylinder (top land) - Dia.	.037L	.041L	.053L
Piston in Cylinder (2nd. land) - Dia.	.032L	.036L	.046L
Piston in Cylinder (3rd. land) - Dia.	.027L	.031L	.041L
Piston in Cylinder (Skirt) - Dia.	.019L	.023L	.035L
Piston in Cylinder (bottom land) - Dia.	.045L	.053L	.065L
Piston Rings - (4 Ring)			
Top Ring in Groove - Side	.006L	.0075L	.011L
2nd. Ring in Groove - Side	.004L	.0055L	.009L
3rd. Ring in Groove - Side	.002L	.0035L	.007L
Bottom Ring in Groove - Side	.002L	.0035L	.007L
Top Ring in Groove - Gap	.030	.040	.075
2nd. Ring in Groove - Gap	.010	.020	.050
3rd. Ring in Groove - Gap	.010	.020	.050
Bottom Ring in Groove - Gap	.010	.020	.050
Top Ring (Gap Closed) - Tension	8 lb.	12 lb.	
2nd. Ring (Gap Closed) - Tension	8 lb.	12 lb.	
3rd. Ring (Gap Closed) - Tension	8 lb.	11 lb.	
Bottom Ring (Gap Closed) - Tension	8 lb.	11 lb.	
Piston Rings - (3 Ring)			
Top Compression Ring in Groove - Side	.005L	.0065L	.010L
2nd. Compression Ring in Groove - Side	.005L	.005L	.009L
Oil Control Ring in Groove - Side	.000	.000	---
Compression Rings (In Gage) - Gap	.010L	.020L	.035L
Oil Control Ring (In Gage) - Gap	.015L	.060L	.093L
Plug in Piston Pin	.003T	.001T	
Piston Pin			

	Piston Pin in Piston - Dia.	.0004L	.0011L	
	Piston Pin in Rod - Dia.	.0008L	.0015L	.003L
	Piston Pin and Plugs in Cylinder - End	.004L	.018L	.035L
Piston Pin Bushing in Rod		.0055T	.0035T	
Rear Main Bearing Sleeve in Crankcase - Dia.		.008T	.005T	
Crankshaft Rear Main Ball Bearing				
	Crankshaft in Rear Main Ball Bearing - Dia.	.0010T	.0002L	
	Rear Main Bearing in Crankcase Sleeve - Dia.	.0002L	.0010L	.0015L
Crankshaft Front Main Ball Bearing				
	Crankshaft in Front Main Bearing - Dia.	.0010T	.0002L	
	Front Main Ball Bearing in Crankcase Sleeve - Dia.	.0002L	.0013L	.0015L
Thrust Bearing Sleeve in Crankcase - Dia.		.008	.005	
Thrust Bearing - Ball				
	Crankshaft in Thrust Bearing - Dia.	.0010T	.0002L	.0015L
	Thrust Bearing in Crankcase Sleeve - Dia.	.0002L	.0010L	.0015L
Thrust Bearing Nut				
	Thrust Nut in Cover - Dia.	.006L	.011L	.020L
Crankpin Plug in Crankpin - Dia.		.0006T	Size	When badly scored
Master Rod				
	Crankpin in Bearing Shell - Dia.	.0015L	.0023L	.004L
	Master Rod to Crankpin - End Play	.004L	.008L	.020L
Wrist Pin				
	Wrist Pin in Link Rod - Dia.	.0010T	.0002T	when push fit
	Wrist Pin in Wrist Pin Bushing - Dia.	.0007L	.0015L	.0028L
	Link Rod in Master Rod - End	.005L	.009L	.015L
Wrist Pin Bushing in Master Rod - Dia.		.005T	.003T	

Cylinder Barrel				
	Cylinder Barrel Bore - Taper (In distance swept by rings)			.005
	Cylinder Barrel Bore - Out-of-Round (In distance swept by rings)			.005
Cam Ring and Bushing				
	Cam Ring on Bushing - Dia.	.0025L	.0041L	.005L
	Cam Ring and Bushing on Rear Main Bearing Sleeve - Combined End Play	.002L	.018L	.035L
Cam Ring Bushing on Rear Main Bearing Sleeve - Dia.		.0020L	.0035L	.0045L
Cam and Magneto Drive Shaft				