WRIGHT AIRCRAFT ENGINES

MODEL TC18EA

SERVICE MANUAL

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CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION
WOOD-RIDGE, NEW JERSEY, U. S. A.

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SERVICE MANUAL

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WRIGHT WARRANTY

The Corporation warrants each new engine and each new engine part manufactured and sold by it to be free from defects in material and workmanship when installed, operated, and maintained in accordance with the applicable recommendations of this Corporation and provided the operation of the power plant installation has been approved in writing by this Corporation.

The obligation of the Corporation is limited to the replacement or repair at its factory of any part or parts which are determined by the Corporation to have been defective, and shall expire after the first three hundred (300) hours of operation or ninety (90) days after installation, whichever shall first occur, and in any event within one year from the date of delivery to the original purchaser. All transportation, removal and installation charges, taxes, or duties with respect to any defective engine, part or parts shall be paid by the purchaser.

This warranty does not cover any charge incurred by the purchaser for the replacement of parts, adjustments, repairs, or any other work done on the engine or parts, and shall not apply to any engine or parts, which shall have been repaired or altered outside of this Corporation's factory in any way, so as in the judgment of the Corporation to affect their performance or reliability, or which have been subject to misuse, neglect, or accident, whether in operation, in transit, or in storage, or which shall have been operated beyond limits.

This warranty is in lieu of all other representations, guarantees, or warranties, express or implied, and any other liability of any nature whatsoever in respect of any defective engine or parts, and this Corporation neither assumes nor authorizes any other person to assume for it any liability other than as set forth herein. Under no circumstances shall the Corporation have any liability for damages from the loss of use or other indirect or consequential damages of any kind in respect of products subject to this warranty, and such products are sold on condition that the purchaser shall not within, or after the expiration of, the term of this warranty make any claim against this Corporation for such damages. Any Engine Parts Service Adjustment Policy of the Corporation now or hereafter in effect shall not be construed to extend or modify the liability of the Corporation as hereby limited.

The Corporation reserves the right to make changes in design of, improvements in, or additions to engines manufactured by it without obligation to make such changes in any product sold and delivered subject to this warranty.

CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION
Wood-Ridge, New Jersey, U.S.A.

Revised November 1953

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Section 1
INTRODUCTION

1-1. This publication comprises the Service Instructions for the model 981TC18EA1 and 988TC18EA1 air-cooled, compound, radial, reciprocating aircraft engines, manufactured by the Curtiss-Wright Corporation, Wright Aeronautical Division, Wood-Ridge, New Jersey. Full engine views of the 988TC18EA1 engine are shown in figures 1-3 through 1-6.

1-2. The following terms will be used throughout this publication:

Front	Propeller end
Rear	Anti-propeller end
Right and Left	As viewed facing rear of engine
Crankshaft, Propeller Shaft, or Propeller Rotation	Clockwise as viewed facing rear of the engine
Accessory Rotation	Clockwise or counterclockwise as viewed facing accessory mounting pad

1-3. The turning speed of a gear or shaft is expressed in terms of the number of revolutions of the gear or shaft in relation to one revolution of the engine crankshaft and is given in decimal form.

1-4. Cylinder hold-down cap screw holes are numbered in a clockwise direction, facing the cylinder mounting pad, with the front end of the engine facing up. See figure 1-1. The first cap screw hole to the right of the vertical center line of the pad is the No. 1 hole. Pads are given the same number as the cylinders which they accommodate.

1-5. Cylinder numbering and firing order are shown in figure 1-2.

1-6. Studs or cap screws in attaching flanges or pads are numbered in a clockwise direction starting with the first stud or cap screw to the right of the top center of the flange or pad with the engine in a horizontal position.

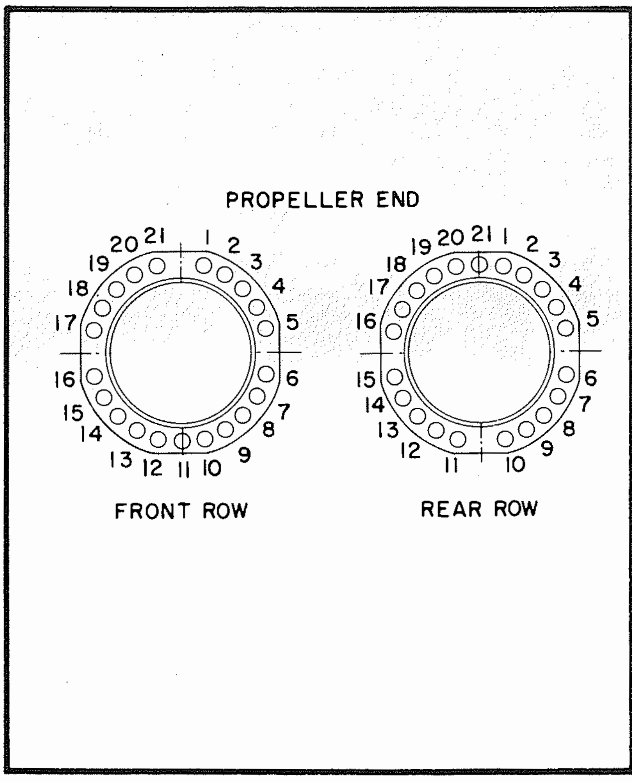


Figure 1-1. Method of Numbering Cylinder Hold-Down Cap Screw Holes

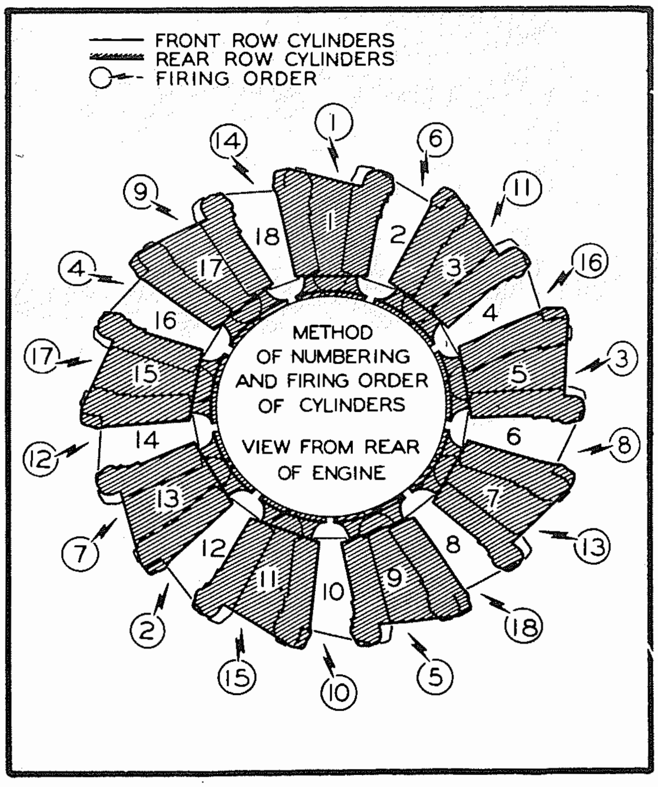
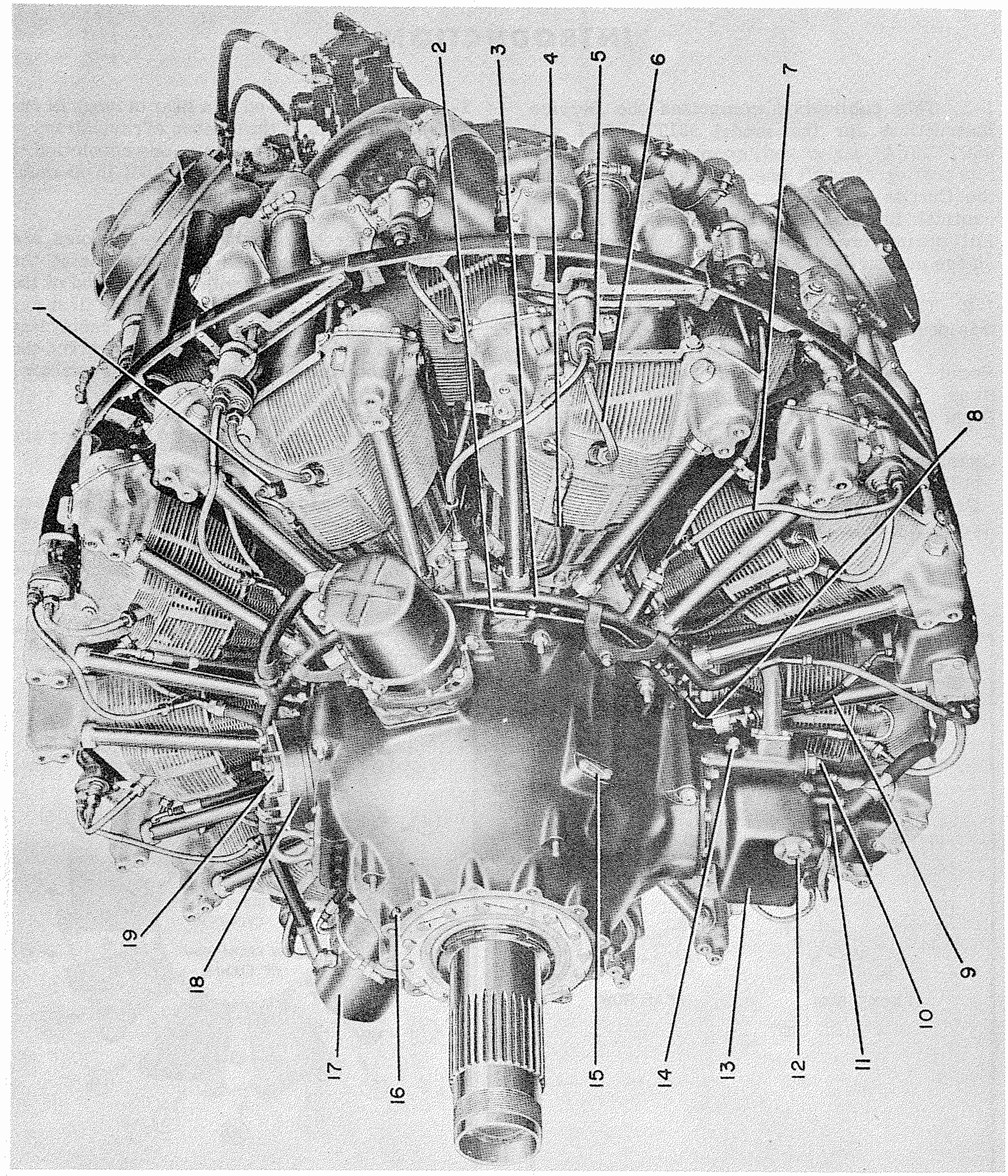


Figure 1-2. Cylinder Numbering and Firing Order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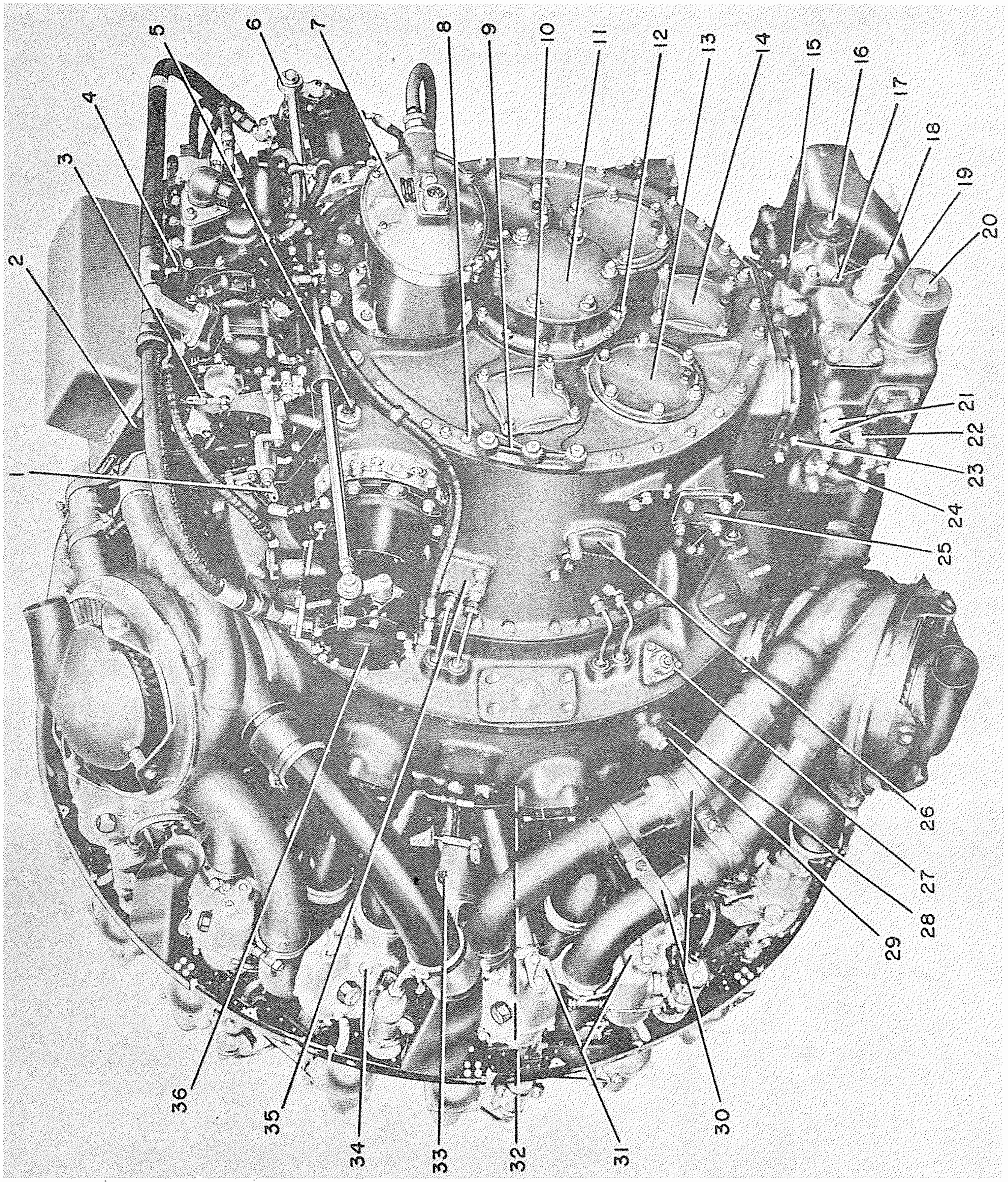
1. Fuel injection tube seal nut
2. Rocker box cover and sump upper vent tube
3. Ignition cable manifold
4. Fuel injection cylinder tube
5. Ignition coil
6. Front spark plug high tension lead
7. Ignition cable manifold to ignition coil low tension lead
8. Rocker box cover and sump lower right vent tube
9. Rocker box cover and sump lower left vent tube
10. Front oil pump and sump pressure control valve
11. Rocker box scavenge pump housing
12. Front oil pump and sump strainer cap plug
13. Front pump and sump housing
14. Front oil pump and sump pressure control valve pressure checking connection (.250 inch ANPT)
15. Torquemeter oil line external tube connector substituting flange
16. Anti-corrosion compound injection connection (.125 inch ANPT)
17. Right hand distributor
18. Governor drive and torquemeter booster pump housing
19. Governor substituting cover

Figure 1-3. Three-Quarter Left Front View - Model 988TC18EA1 Engine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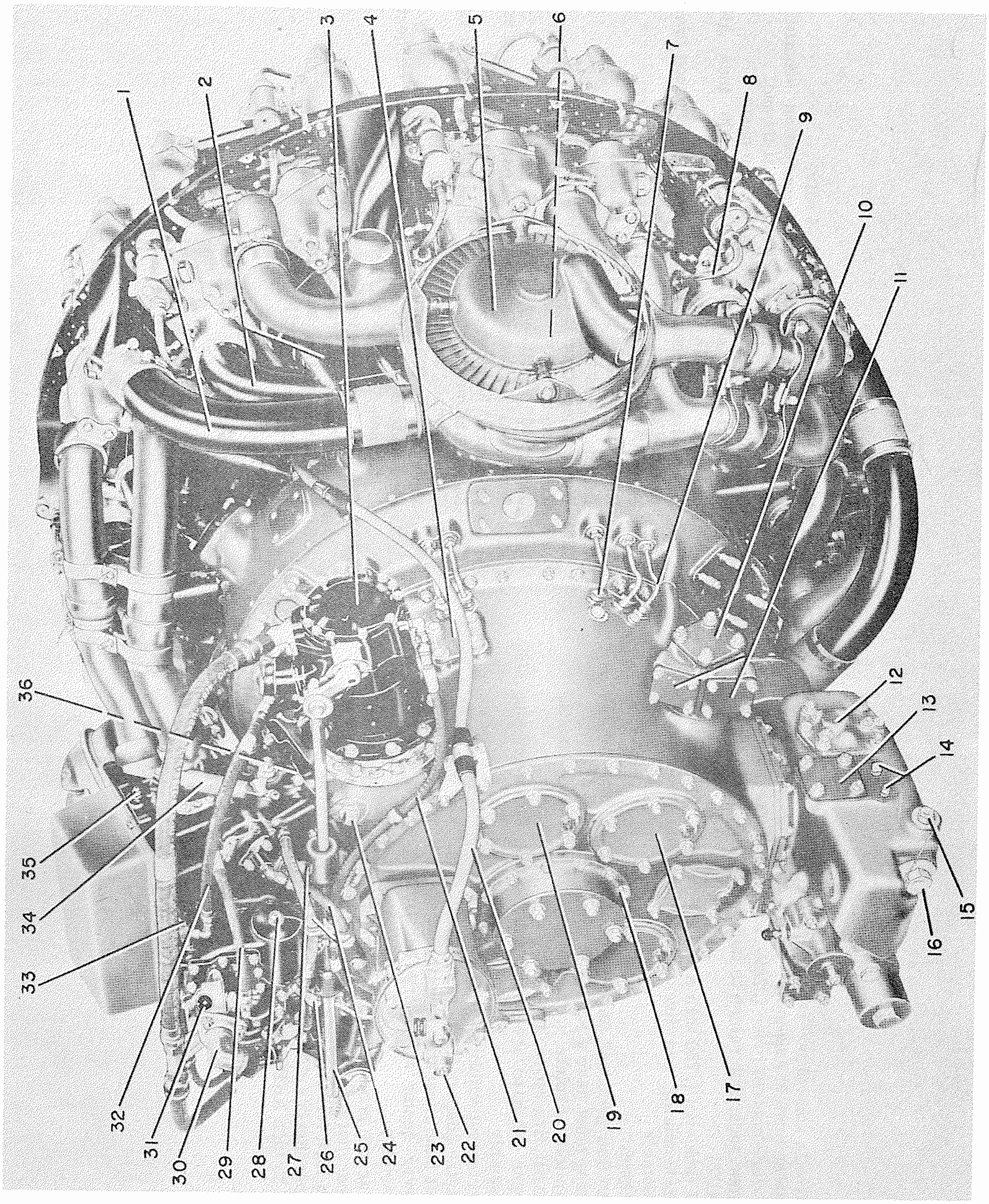
1. Throttle control lever (.249-.250 inch diameter hole)
2. Master control assembly
3. Mixture control lever (.249-.250 inch diameter hole)
4. Vapor separator return to tank connection (.125 inch ANPT)
5. Oil tank vent (.750 inch ANPT)
6. Synchronizing rod fine adjustment cam and bearing assembly
7. Magneto
8. Manifold pressure gage connection (.125 inch ANPT, fitting must have a No. 50 drilled orifice)
9. Manifold absolute pressure regulator adapter housing substituting cover
10. Upper left hand accessory substituting cover and plug assembly
11. Starter substituting cover
12. Starter adapter left hand oil drain plug (.125 inch ANPT)
13. Left hand generator substituting cover and plug assembly
14. Lower center accessory substituting cover and plug assembly
15. Rear oil pressure gage connection (.250 inch ANPT)
16. Supercharger clutch control valve (.3125-24 thread, .56 inch full thread)
17. Supercharger clutch high ratio pressure test connection (.125 inch ANPT)
18. Rear oil pump pressure relief valve
19. Rear pump and sump oil-in connection substituting cover (.3125-24 thread, .62 inch full thread)
20. Rear oil pump pressure strainer cap plug
21. Oil-in thermometer connections (.500 inch ANPT bushed to .625-18 thread)
22. Pre-oiling connection (.375 inch ANPT bushed to .250 inch ANPT)
23. Pre-oiling vent connection (.125 inch ANPT)
24. Rear oil pressure pump gear housing
25. Left hand fuel pump substituting cover
26. Water injection unit substituting cover
27. Torquemeter oil pressure connection (1.0625-12 thread bushed to .125 inch ANPT)
28. Supercharger front housing oil pressure control valve pressure checking connection (.250 inch ANPT)
29. Supercharger front housing oil pressure control valve
30. Exhaust pipe "figure 8" clamps
31. Exhaust pipe brackets
32. Rear tappet annulus oil pressure checking connection (.125 inch ANPT) - not visible
33. Cylinder head thermocouple adapter
34. Rear intake port drain substituting plug
35. Left hand breather substituting cover
36. Left hand fuel injection pump

Figure 1-4. Three-Quarter Left Rear View - Model 988TC18EA1 Engine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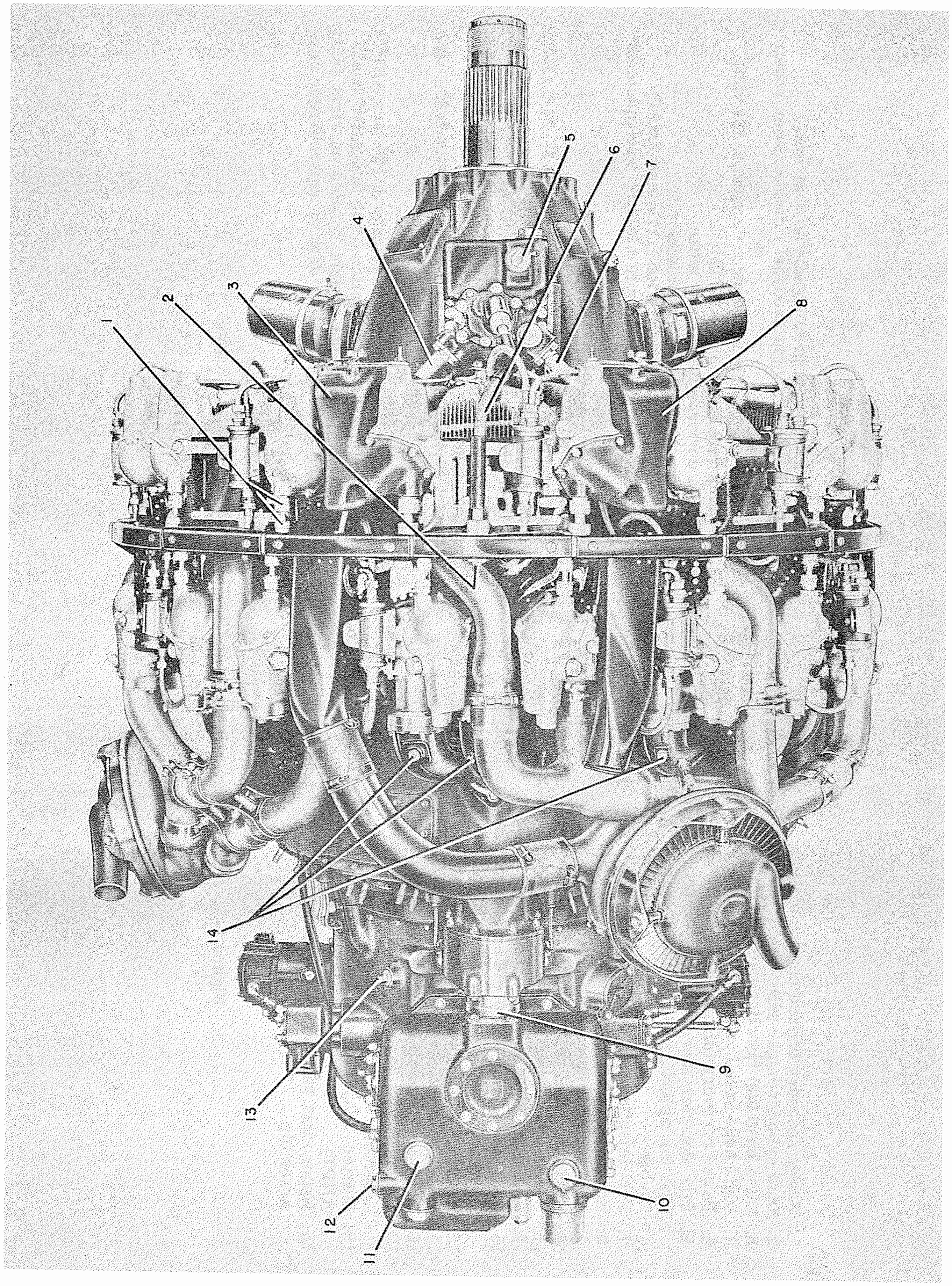
1. Power recovery turbine cooling air tube
2. Dual cylinder intake pipe
3. Right hand fuel injection pump
4. Right hand breather substituting cover
5. Power recovery turbine assembly
6. Fire detector thermocouple connection in dual intake pipe for cylinders No. 5 and 6 (.125 inch ANPT) -not visible
7. Fuel injection tube connector nut
8. Rear spark plug high tension lead
9. Fuel injection intermediate tube
10. Right hand fuel pump substituting cover
11. Upper and lower tachometer substituting covers
12. Rear scavenge pump gear housing
13. Rear pump and sump oil-out connection substituting cover (.3125-24 thread, .62 inch full thread)
14. Accessory drain connections (.375 inch ANPT)
15. Rear pump and sump housing drain plug
16. Rear scavenge oil strainer cap plug
17. Right hand generator substituting cover and plug assembly
18. Starter adapter right hand oil drain plug (.125 inch ANPT)
19. Upper right hand accessory substituting cover and plug assembly
20. Ignition cable main primary and booster lead
21. Master control to right hand fuel injection pump venturi suction tube
22. Ignition switch cable to magneto receptacle (24 volt)
23. Oil tank vent (.750 inch ANPT)
24. Alternate source fuel supply tubes
25. Fuel injection pump synchronizing rod
26. Fuel pressure gage connection (.125 inch ANPT)
27. Alternate source fuel supply electric receptacle (24 volt)
28. Master control fuel strainer
29. Priming fuel tube
30. Master control fuel inlet connection (.3125-24 thread, .625 inch full thread)
31. Primer electric receptacle (24 volt)
32. Right hand fuel injection pump to master control vapor return tube
33. Vapor separator return to tank connection (.250 inch ANPT)
34. Throttle balance assembly
35. Static air scoop pressure connection (.125 inch ANPT)
36. Cabin heater exhaust connection (.500 inch ANPT bushed to .625-18 thread) -not visible; located on right front of master control mounting deck of supercharger rear housing

Figure 1-5. Three-Quarter Right Rear View - Model 988TC18EA1 Engine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1. Rocker box cover to drain manifold gland nuts
2. Rocker box drain manifold system strainer
3. Right hand rocker box cover and sump
4. External oil outlet tube
5. Front pump and sump housing chip detector plug
6. Rocker box drain manifold to scavenge pump tube
7. External oil inlet tube
8. Left hand rocker box cover and sump
9. Rear oil sump inlet connector
10. Rear pump and sump housing drain plug (pressure side)
11. Rear pump and sump housing chip detector drain plug (scavenge side)
12. Rear pump and sump housing drain plug (scavenge side)
13. Supercharger rear housing drain connection (.250 inch ANPT)
14. Drain connections in dual intake pipe for cylinders No. 9, 10, and 11 (.250 inch ANPT)

Figure 1-6. Bottom View - Model 988TC18EA1 Engine

Section II

GENERAL DESCRIPTION

2-1. BASIC ENGINE DESIGN AND CONSTRUCTION.

2-2. The model TC18EA series engine is a turbo-compound 18 cylinder, air cooled, radial, reciprocating power plant. This engine incorporates three blow-down turbines for exhaust gas power recovery, and is equipped with a reverse low flow torquemeter, a two speed supercharger, a cylinder fuel injection system, and a low tension ignition system with manual spark advance.

2-3. The charts in Section IX may be used for reference in conjunction with the following descriptions.

2-4. CRANKCASE. The crankcase front section, rear cam and tappet housing, supercharger front and rear housings, and supercharger rear housing cover are made from magnesium alloy castings. The crankcase main sections are machined from steel forgings. In the case of the EA2 and EA5 model engines, there is no magnesium cam and tappet housing. An integral forged steel rear main crankcase and cam and tappet housing are used.

2-5. PROPELLER SHAFT AND REDUCTION GEARING. The 988TC18EA1, 3, 4, and 6 engine propeller shaft to crankshaft speed ratio is .4375:1. The 988TC18EA2 and 5 engine propeller shaft to crankshaft speed ratio is .355:1. These reduction gear ratios are effected by a planetary gear system housed in the crankcase front section. The system comprises an external-toothed drive gear splined to the crankshaft; twenty pinions on a carrier bolted to the propeller shaft rear flange for 988TC18EA1, 3, 4, and 6 engines, or ten pinions on a carrier which is an integral part of the propeller shaft for 988TC18EA2 and 5 engines; and an internal-toothed stationary gear and adapter assembly floating between the torquemeter piston and stationary gear support. Both the piston and the support are attached to the crankcase front section.

2-6. The propeller shaft is splined and threaded for attaching the propeller. Two propeller shaft bearings, a ball and a roller bearing, are retained in the forward inside diameter of the crankcase front section to take thrust and radial loads during operation.

2-7. The propeller shaft is appropriately drilled for oil transfer, passages for propeller control oil being provided within the shaft. If a hydromatic propeller is used, high pitch operating oil from the governor is delivered through a space between the propeller shaft inside diameter and the outside diameter of a sleeve within the shaft. Low pitch operating oil from the governor is delivered to the propeller through a tube in the center of the propeller shaft.

2-8. CRANKSHAFT AND COUNTERWEIGHTS. The crankshaft consists of three sections: The crankshaft front, center, and rear section. A two-throw center section accommodates the front and rear master rod assemblies. The crankcheeks of the front and rear crankshafts are clamped to the center section crankpins with clamp screws. Each crankcheek accommodates a two-piece bronze counterweight riding on floating pins. These weights are designed to reduce crankshaft vibration stresses.

2-9. The crankshaft assembly rides in three roller bearings located on the inner diameter of the crankcase main front, center, and rear sections, respectively. The crankshaft front extension is splined and threaded externally to receive the propeller reduction driving gear and retaining nut. The rear extension is internally splined and coupled to the power recovery turbine crankshaft drive gear which transmits the drive from the three power recovery turbines.

2-10. The crankshaft assembly is appropriately drilled to transfer part of the main pressure oil from the rear to the front sections. An oil restraining plug is used in the crankshaft front extension. A sludge displacing plug is used in each end of the crankshaft center section. Two transfer tubes and a drilled plug inside the crankshaft center section carry lubricating oil from the rear to the front sludge displacing plug.

2-11. CONNECTING RODS. The bore of a master rod encircles each crankpin, over a master rod bearing. The rear master rod is connected by a piston pin to the piston in cylinder No. 1, and the front master rod is connected by a piston pin to the piston in cylinder No. 2. Eight articulated rods are connected to each master rod by knuckle pins and to their respective pistons by piston pins. Two knuckle pin locking plates, one being splined to engage with the master rod bearing, lock the knuckle pins of each assembly in place. Oil seal discs are at both ends of the master rod bearing.

2-12. CYLINDERS, PISTONS, AND VALVE MECHANISM. The cylinders are constructed of forged aluminum alloy heads and forged steel barrels. Integral cooling fins are machined in the heads, while replaceable aluminum fins are attached to the barrels. Each cylinder head accommodates an intake valve, an exhaust valve, valve springs, rocker arms, a fuel injection nozzle, and two spark plugs. It provides ports and connections for intake and exhaust pipes, connections for push rod housings, a tapped hole for a thermocouple, and miscellaneous attaching holes. The piston is an aluminum alloy forging machined with five ring grooves. It is connected to a master rod or an articulated rod by a piston pin.

2-13. To accommodate the rocker box drain system, special rocker box covers are provided for cylinders No. 7, 8, 9, 10, 11, and 12 intake, and 8, 9, 10, 11, 12, and 13 exhaust rocker boxes. In addition, both the intake and exhaust covers for cylinder No. 10 are the rocker box sumps. See paragraph 2-60.

2-14. CAM AND BALANCEWEIGHT MECHANISMS. The front cam and balanceweight mechanism is enclosed by the crankcase front section in which the valve tappets for the front row cylinders are located. The rear cam and balanceweight mechanism is enclosed in the rear cam and tappet housing, which is attached to the crankcase rear main section. The valve tappets for the rear row cylinders are located in the rear cam and tappet housing.

2-15. The front cam drive gear is splined to the crankshaft front extension and meshes with four intermediate cam drive gears. Each of the four intermediate cam drive gears is splined to a cam drive pinion gear riding in a bearing attached to the cam support. The cam support is splined to the front main bearing sleeve and bolted to the crankcase front main section. The pinion gears drive the cam which rotates on the cam support. The cam is held in place by a retainer screwed to the support.

2-16. The front balanceweight drive gear is splined to the crankshaft front extension. It meshes with the balanceweight drive pinion gear, which is integral with the balanceweight drive intermediate gear. The pinion and intermediate gear ride on bushings mounted on a trunnion bolted to the cam support. The intermediate gear drives the balanceweight and bearing assembly, which rides on the sleeve of the front balanceweight drive gear.

2-17. Four pinions, each retained in a bracket bolted to the front cam support, are driven by teeth on the forward face of the cam and are internally splined to accommodate the drive shafts for the governor and torquemeter booster pump, the two ignition distributors, and the front oil pump.

2-18. The integral rear cam and balanceweight drive gear and rear balanceweight sleeve are bolted to the crankshaft rear extension. The smaller diameter gear teeth of the cam and balanceweight drive gear mesh with four intermediate cam drive gears. The larger diameter teeth of the rear cam and balanceweight drive gear mesh with the balanceweight drive pinion gear. The rear cam and balanceweight and bearing assembly are driven in the same manner as described for the front. No accessories are driven by the rear cam.

2-19. ACCESSORY DRIVE AND STARTER SHAFT. The accessory drive and starter shaft is splined into the power recovery turbine crankshaft drive gear in the supercharger front housing and into the accessory drive gear and impeller drive primary pinion carrier support in the supercharger rear housing and cover. A retaining ring secures the shaft in the support. The starter coupling is splined into the shaft, a spring in the shaft causing the coupling to bear against a thrust ring in a support in the rear cover.

2-20. ACCESSORY DRIVES. The accessory drive gear, which is bolted to the accessory drive gear and impeller drive primary pinion carrier support, transmits power to the drives for the fuel pump, tachometer and fuel pump, fuel injection pumps, rear oil pump and the accessories mounted on the supercharger rear cover.

2-21. IMPELLER AND IMPELLER SHAFT. The impeller is housed in the supercharger front housing and is designed to increase the mass of the air charge to the engine. It is a balanced assembly of an impeller and an inducer splined to a shaft, which encircles the accessory drive and starter shaft.

2-22. TWO-SPEED IMPELLER DRIVE. Basically, the two-speed impeller drive consists of two planetary gear trains (primary and secondary) in series, an intermediate gear, a roller clutch, and an oil operated plate clutch. Figure 2-1 is a schematic view showing the principles of operation with the component parts in their relative positions.

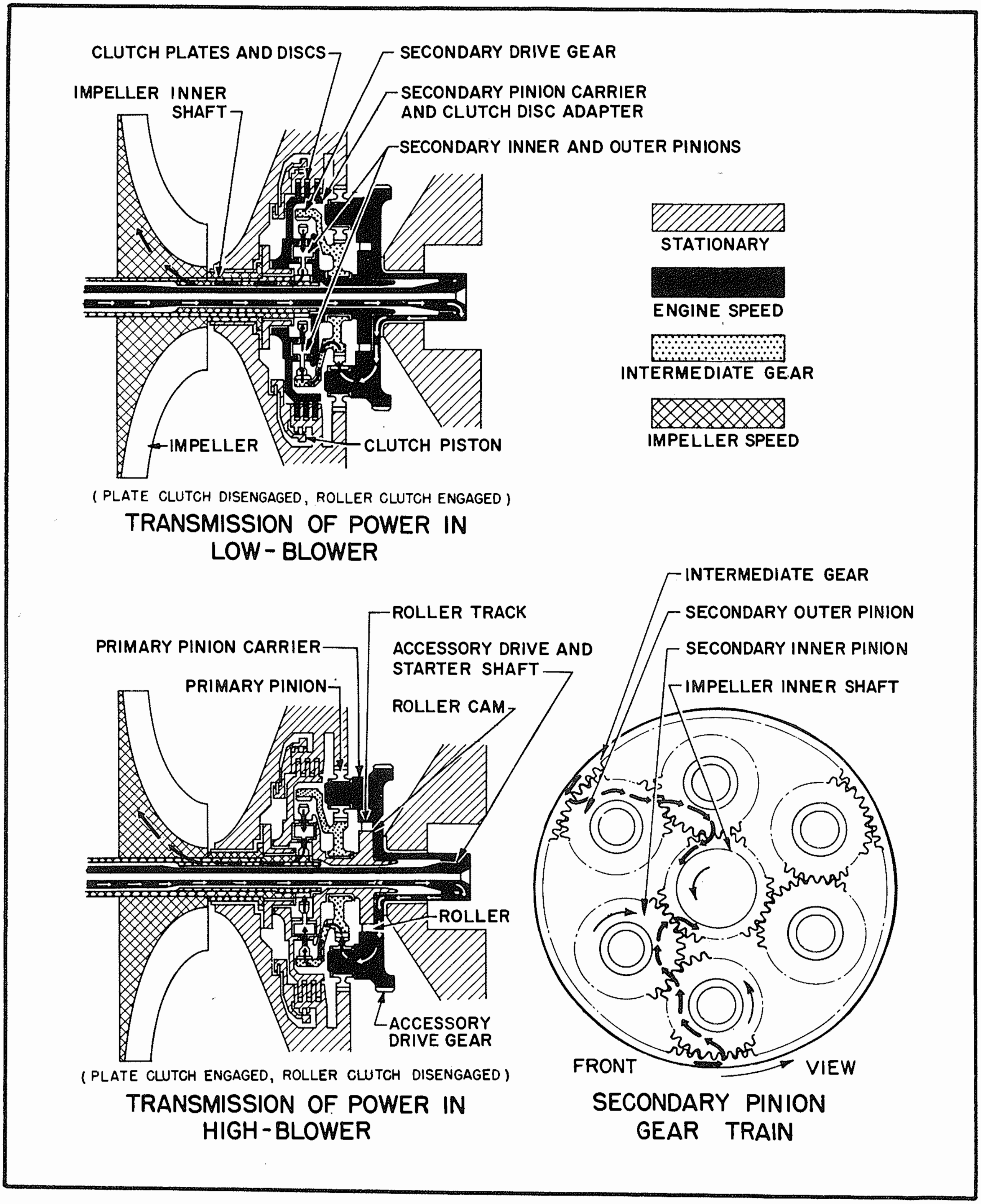


Figure 2-1. Two Speed Impeller Drive

2-23. The primary pinion carrier turns at crankshaft speed, since its support is splined to the accessory drive and starter shaft. As the pinion carrier revolves, the pinions, meshed with the stationary gear, rotate on their trunnions and turn the impeller intermediate drive gear (sun gear) in the direction of crankshaft rotation approximately 2.7 times faster than crankshaft speed.

2-24. The teeth on the ID of the intermediate gear (bell gear) drive three of the pinions in the secondary pinion carrier. These three pinions drive three idler pinions which turn the impeller inner shaft in the direction of the crankshaft. The inner shaft is splined to the outer shaft, which drives the impeller.

2-25. When the supercharger clutch control valve, located in the rear oil pump and sump housing, is pulled to its rearward position, engine pressure oil is admitted to the forward side of the clutch piston. Oil pressure forces the piston to lock the clutch plates, thus holding the secondary pinion carrier stationary. When the secondary pinion carrier is held stationary, the intermediate gear, still turning approximately 2.7 times faster than the crankshaft, turns the impeller shaft through the secondary pinions at a ratio of 8.67 to 1. The impeller is then operating in high blower.

2-26. When the clutch control valve is pushed to its forward position, it shuts off the oil supply to the clutch piston; the clutch plates, with the aid of springs, disengage, and the secondary pinion carrier immediately rotates in the same direction as the primary pinion carrier. The roller clutch then engages, locking the two carriers to turn as a unit at crankshaft speed. Since the intermediate gear, which constantly turns 2.7 times faster than the crankshaft, cannot turn the secondary pinions as fast while their carrier is moving as when their carrier is stationary, the impeller rotates only 6.46 times faster than the crankshaft. The impeller is then operating in low blower.

NOTE

The gear drive is the same for both high and low blower operation. There is no gear shifting, the clutches being holding devices only.

2-27. REVERSE LOW FLOW TORQUEMETER.

2-28. The crankcase front section contains the torquemeter system, which is connected by passages to a BMEP or torque cell gage inside the aircraft. Figure 2-2 shows a cutaway view of the crankcase front section to show torquemeter system components.

2-29. The engine torquemeter system is comprised of the stationary reduction gear and adapter, 24 steel balls, stationary reduction gear support and support oil ring (the adapter and support each have sockets which loosely retain the balls), a stationary piston, two piston oil seal rings, piston to front section oil seal ring, and a torquemeter booster pump.

2-30. A torque cell is formed by the forward face of the stationary reduction gear adapter and the rear face of the torquemeter piston and its rear oil seal ring. With the exception of leakage between the stationary reduction gear adapter and the stationary reduction gear support oil seal ring all of the booster pump oil output is continually entering the torque cell through a hole in the piston. Oil leaves the torque cell through metering slots in the stationary reduction gear adapter and back to the engine pressure oil system through eighteen holes in the piston. There is a definite relationship between the position of the adapter metering slots relative to the piston rear oil seal ring and torque cell oil pressure.

2-31. The reduction driving gear turns in a clockwise direction, and, through the reduction gear pinions, tends to turn the stationary reduction gear and adapter in a counterclockwise direction. However, rotation of the stationary reduction gear and adapter is limited and converted to forward movement by means of the torquemeter balls and ball sockets. Booster pump oil entering the torque cell tends to force the adapter rearward. At a given power setting these two opposing forces attain an equilibrium, and the adapter metering slots regulate the torque cell oil pressure which is transmitted to the BMEP or torque cell pressure gage.

2-32. POWER RECOVERY TURBINE SYSTEM.

2-33. Figure 2-3 shows a cutaway view of a power recovery turbine used in compounding the engine. Three such turbines are clamped to adapters that are mounted on the supercharger front housing, 120 degrees apart. The turbines utilize the energy in the cylinder exhaust gases, transmitting it to the engine crankshaft.

2-34. See figure 2-4 which illustrates the principles of PRT operation. Six cylinders, three front and three rear, supply each turbine with exhaust gases. See figure 2-5. Gases from the six cylinders enter the turbine nozzle through the exhaust pipe in firing order, causing the turbine wheel to turn.

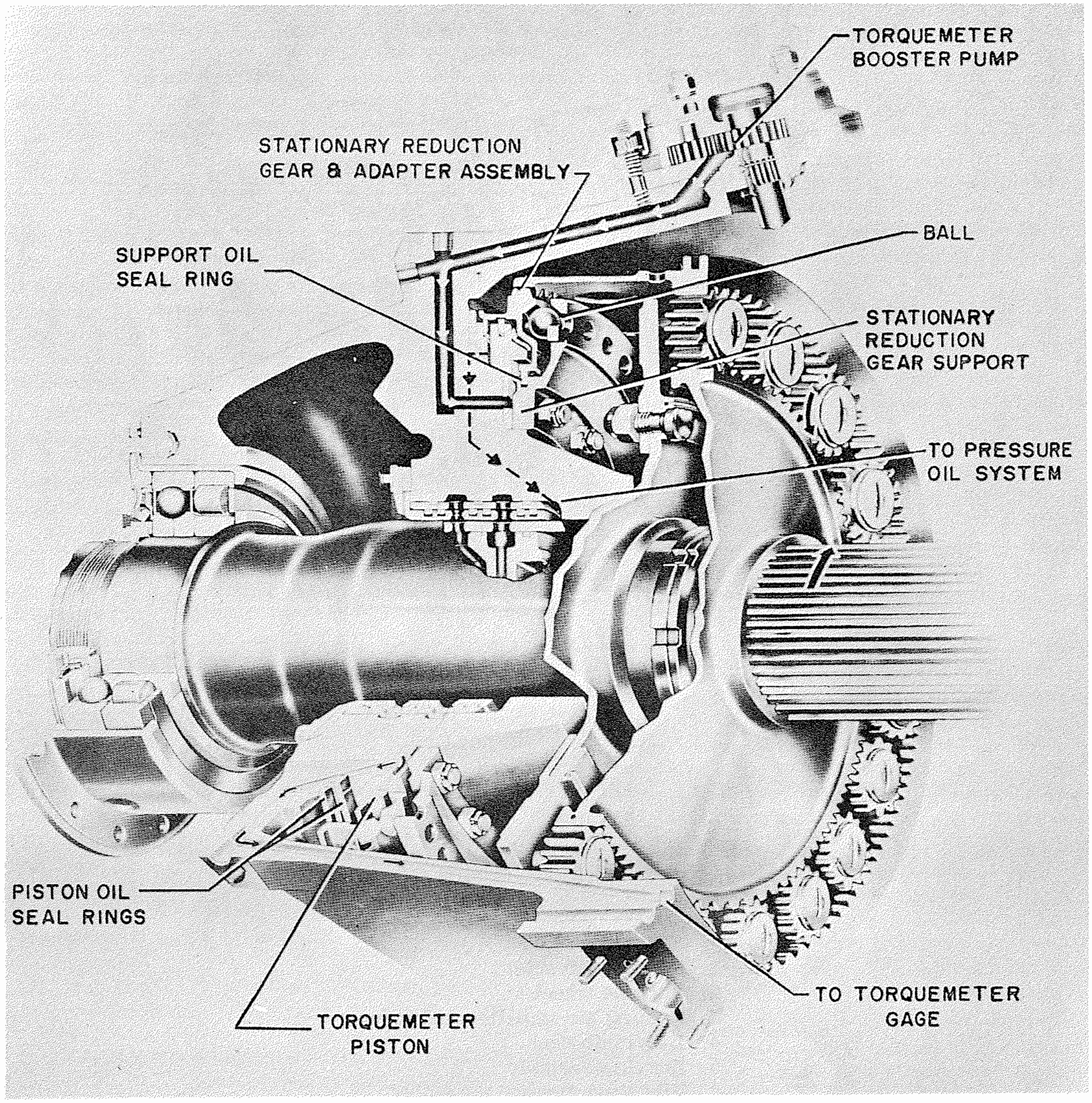
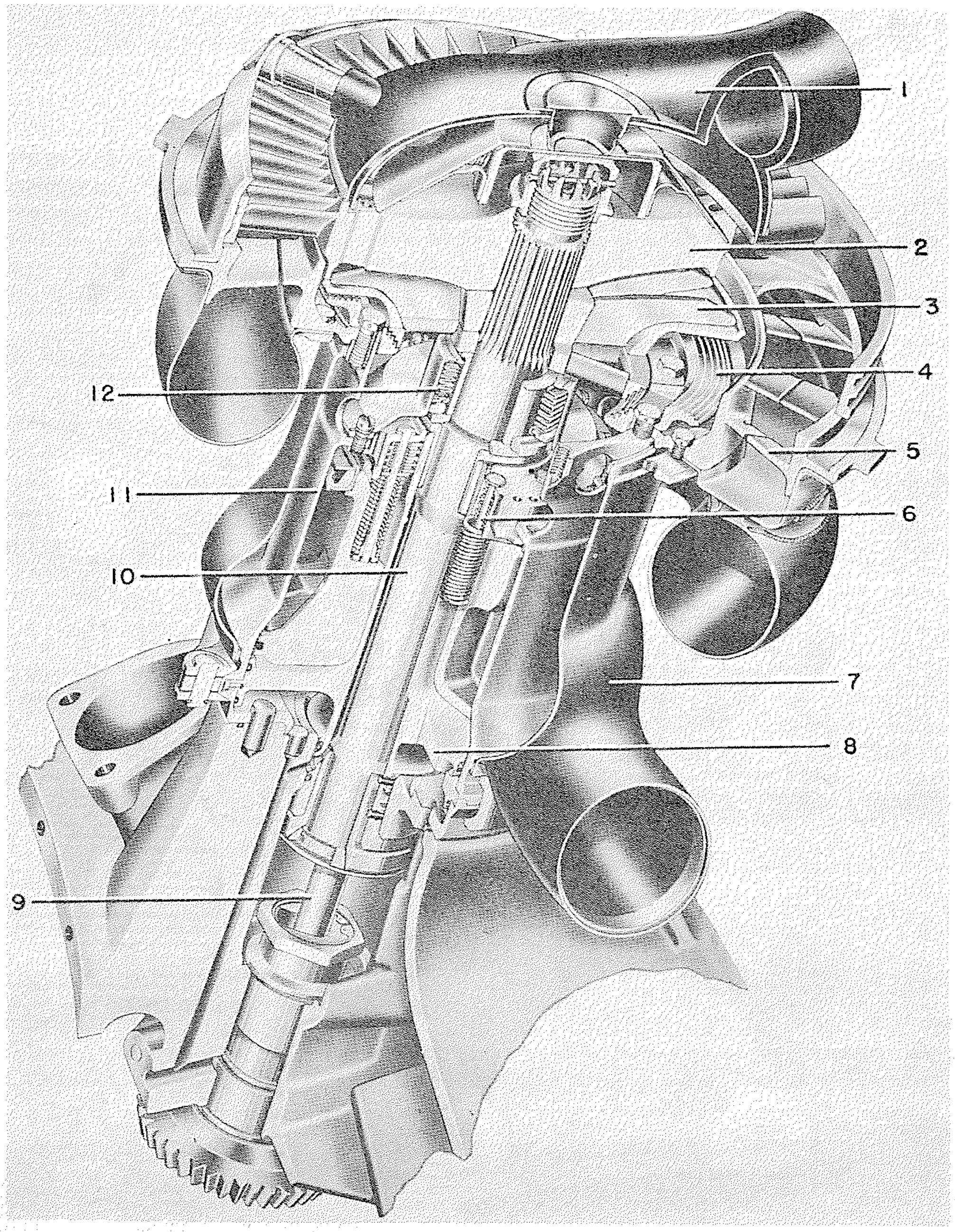


Figure 2-2. Cutaway View Showing Reverse Low Flow Torquemeter System



1. Cooling air shield
2. Turbine wheel
3. Cooling air impeller and inducer
4. Labyrinth seal
5. Nozzle assembly
6. Vibration damper assembly
7. Cooling air duct
8. Turbine shaft support
9. Gear coupling shaft
10. Turbine drive shaft
11. Nozzle support
12. Bellows oil seal

Figure 2-3. Cutaway of Power Recovery Turbine

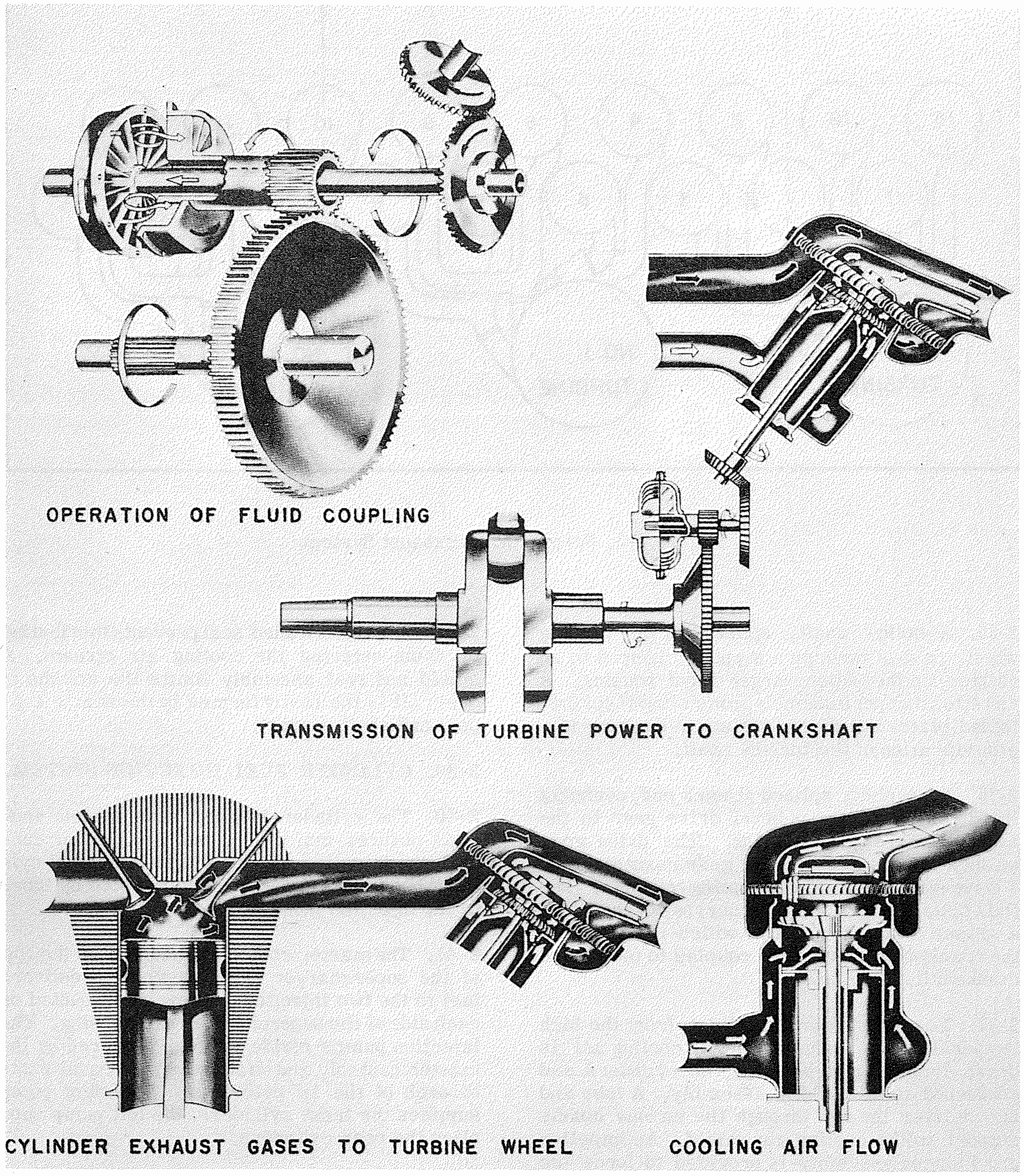


Figure 2-4. Power Recovery Turbine System

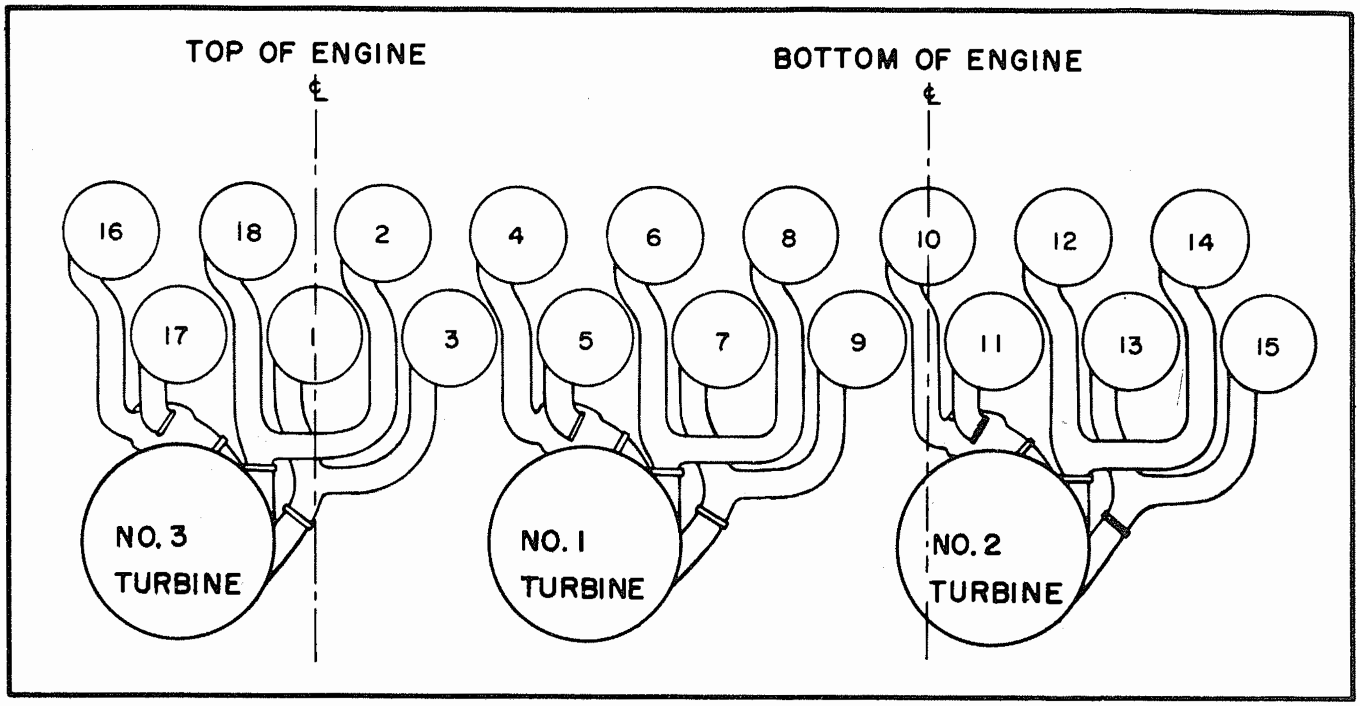


Figure 2-5. Schematic of Exhaust System

2-35. A hollow shaft, splined to the turbine wheel, passes through a support clamped to an adapter on the supercharger front housing. A vibration damper assembly, consisting of spring-loaded plates and discs, assists in damping lateral vibration of the turbine shaft.

2-36. A coupling, splined at each end, connects the turbine shaft to a bevel drive gear in the supercharger front housing. The drive gear meshes with a larger bevel gear connected, by a drive shaft, to the fluid coupling impeller. The fluid coupling rear half (runner) is connected by a splined shaft to a pinion which meshes with the crankshaft drive gear coupled to the engine crankshaft.

2-37. To prevent damaging effects from the high temperatures of exhaust gases, cooling air is drawn from a duct between the cylinders and conducted to the turbine assembly. A tube and duct deliver the air through the turbine nozzle support to the cooling air shield. An impeller and inducer assembly is provided to force the cool air through the turbine wheel hub and discharge it from the cooling air shield. A labyrinth seal facing the underside of the impeller and inducer assembly prevents the mixing of exhaust gases and cooling air until both are discharged into the exhaust system flight hood.

2-38. A bellows loaded seal prevents lubricating oil from entering the cooling air stream. A shield and seal assembly limits the volume of drain oil in the cavity formed by the nozzle support and shaft support.

2-39. CYLINDER FUEL INJECTION SYSTEM.

2-40. The cylinder fuel injection system consists of three major sections: the master control, the injection pumps, and 18 individual cylinder head discharge nozzles connected by tubes to the injection pumps.

2-41. The master control is mounted on the top of the supercharger rear housing. It delivers fuel to the two injection pumps; one mounted on each side of the supercharger rear housing. The injection pumps divide the fuel delivered by the master control, and distribute it in equal parts to each of the 18 cylinders. The right pump supplies the front cylinders; the left pump supplies the rear cylinders.

2-42. Eighteen individual discharge nozzles are screwed into the cylinder heads. The nozzles open when the pressure in the injection tubes is great enough to overcome the force of the nozzle springs. Fuel is then sprayed into the cylinders. The injection pumps are timed to the crankshaft so that injection occurs at the correct moment relative to piston position and the firing event.

2-43. The course of the 18 fuel injection tubes to each cylinder is internal from the fuel injection pumps to the front of the supercharger rear housing. They are external for a short distance from the front of the supercharger rear housing to the rear of the supercharger front housing. The tubes are then internal in the supercharger front housing, emerging again at the front of the supercharger front housing, to continue an external course to each of the discharge nozzles in the cylinders.

2-44. IGNITION.

2-45. The low-tension, high altitude ignition system comprises a magneto generator, two distributors, a harness assembly to transmit the current to the individual high tension coils, and high tension leads to the spark plugs.

2-46. The magneto is mounted on the supercharger rear housing cover. It consists, essentially, of a housing and cover assembly, two sets of double pole shoes, four primary coils, and two rotating magnets in tandem staggered at 45 degrees.

2-47. Figure 2-6 illustrates the principles of the ignition system operation. Each magnet produces four impulses of current in each of the two coils on its pole shoes. Thus there are eight dual current impulses of low voltage per revolution of the shaft. The magnet shaft is driven at 1.125:1, producing nine spark impulses per engine revolution, the requirement of an 18 cylinder four-stroke-cycle engine.

2-48. Current is transmitted from the magneto through the main primary conduit to the ignition manifold attached to the crankcase front section. Two leads from the manifold direct the current impulses to each of two distributors, one on each side of the crankcase front section. The impulses in the two right coils in the magneto are carried to the right distributor, firing the front plug in each cylinder. The two left coils in the magneto are connected to the left distributor, firing the rear plug in each cylinder. Spark advance is controlled manually from within the aircraft.

2-49. With the breaker points closed, the current flows through the circuit of less resistance, through the breaker points to the grounded primary coil.

2-50. When the alternating current reaches its peak value, the cam separates the breaker points, interrupting this circuit. The current then surges into the primary winding of the ignition coil, located on top of the cylinder, and generates in the secondary coil a voltage having enough pressure to cause the current to jump the spark plug gap. The surge of the secondary current falls away rapidly and the breaker points close again, reconnecting the low resistance circuit to the ground.

2-51. Meanwhile, the finger of the distributor has made contact with the proper segment

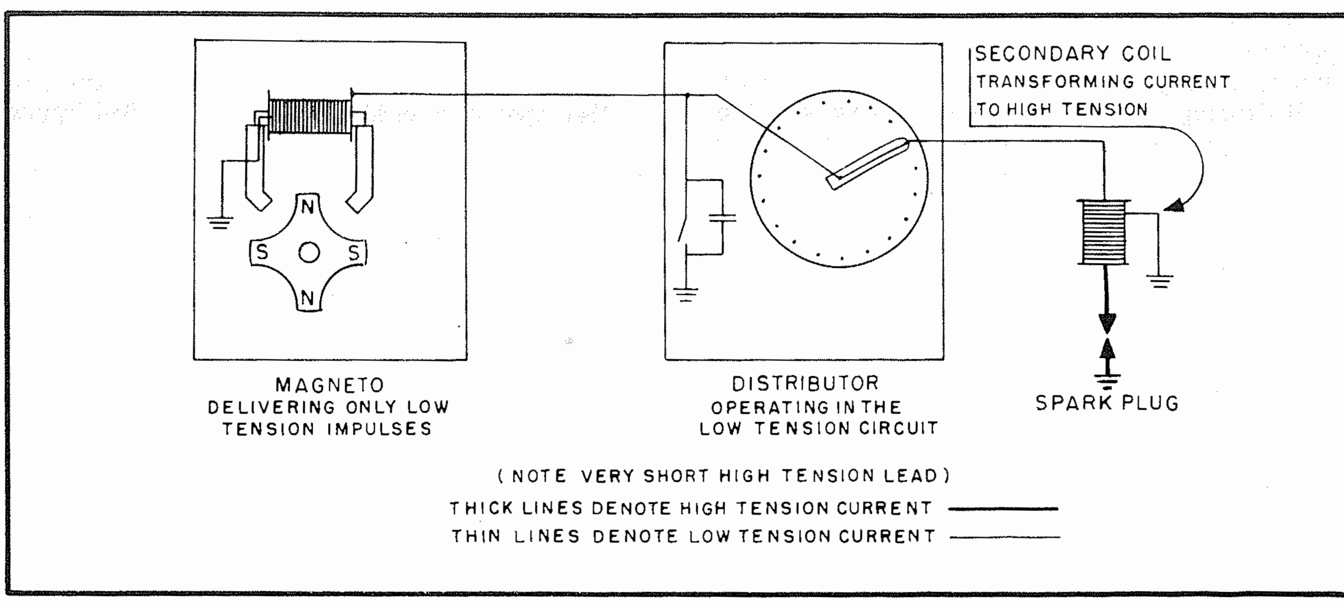


Figure 2-6. Schematic of Ignition System

of the distributor head, so that the surge was directed to fire the proper plug at the proper moment. Also, another impulse is building up in the primary circuit, causing another surge in the secondary circuit. The distributor finger proceeds to the next ring segment, and the next plug in the firing order receives the firing surge. The two distributors are timed together, so that the front and rear plugs of each cylinder fire simultaneously.

2-52. OIL SYSTEM.

2-53. The lubrication system is a pressure, dry sump type. All moving parts are lubricated by oil under pressure except the piston rings, piston pins, cylinder walls, intake and exhaust valves, and crankshaft main bearings, all of which are lubricated by splash or jet. Diagrams of pressure and scavenge oil flow through the engine are shown in figure 2-7 and 2-8. For a cross sectional view of the engine oil system see the lubrication and limits charts in Section IX.

2-54. Oil from an external supply tank enters the pressure pump in the left side of the rear oil pump and sump body. The pump discharges the oil through cored passages in the pump and sump body into the inside of the pressure strainer and then through the outside of the strainer into the strainer cavity. A strainer by-pass valve provides the engine with lubrication if the oil is too cold, or if the strainer should become clogged. A spring loaded check valve at the inlet side of the strainer prevents the flow of oil under gravity pressure from the tank when the engine is at rest.

2-55. The pressure relief valve in the rear pump regulates oil pressure to 70 ± 5 psi during all cruise and higher power settings, the quantity of oil flowing through the valve varying with the engine rpm, oil temperature, or the engine's demand for oil. A pressure control valve in the front pump and sump housing reduces the pressure of the oil passing through it to 35 ± 5 psi. See figure 2-9 for a schematic of the rear oil pump and figure 2-10 for a schematic of the front oil pump. Another pressure control valve in the supercharger front housing reduces the pressure of the oil passing through it to 50 ± 5 psi.

2-56. There is a scavenge oil strainer and a magnetic chip detector drain plug in the front and rear pump and sump housings. In addition, there are two non-magnetic drain plugs in the rear pump and sump housing. Oil passes over the magnetic chip detector plugs and through the strainers before entering the scavenge outlet chamber.

2-57. GOVERNOR AND TORQUEMETER BOOSTER PUMP. The oil in the rear annulus around the propeller shaft flows through a drilled passage in the top of the front section to supply the governor and the torquemeter booster pump. The torquemeter booster pump supplies oil to the torque cell which in turn supplies the torquemeter gage. Oil flowing through the torque cell returns to the engine lubrication system to the annulus around the propeller shaft. See figure 2-2.

2-58. Operating oil for the pitch changing mechanism of hydromatic propellers utilizing crankcase front section mounted governors is delivered in the following manner: Two passages from the governor carry oil to two locations in the propeller shaft. One location delivers oil through a passage in the propeller control front half adapter to the propeller control oil supply tube in the center of the propeller shaft. This oil is referred to as low pitch oil. The other location delivers oil to the space between the OD of the propeller control oil return sleeve and the ID of the propeller shaft. This oil is referred to as high pitch oil.

2-59. SUPERCHARGER CLUTCH CONTROL. The clutch control valve located in the rear pump and sump body, when pulled to its rear position, permits engine pressure oil to flow through drilled passages and tubes to the multi-plate clutch piston. Oil pressure on the forward side of the piston causes the piston to move rearward and engage the clutch. This stops the impeller drive secondary pinion carrier, so that the impeller operates in high speed ratio. See figure 2-1.

2-60. ROCKER BOX DRAIN SYSTEM. The rocker boxes below the engine horizontal center line are drained by an independent system. See figure 2-11. Gravity causes the oil to flow from the rocker boxes through connecting tubes (3) to the drain manifold (2) which is located between the rows of cylinders. Scavenge oil in the drain manifold flows to the sumps (13) incorporated in the configuration of the cylinder No. 10 rocker box covers. The rocker box scavenge pump (8) draws the oil from the sumps and sends it to the rear scavenge pump and sump housing oil-out connection.

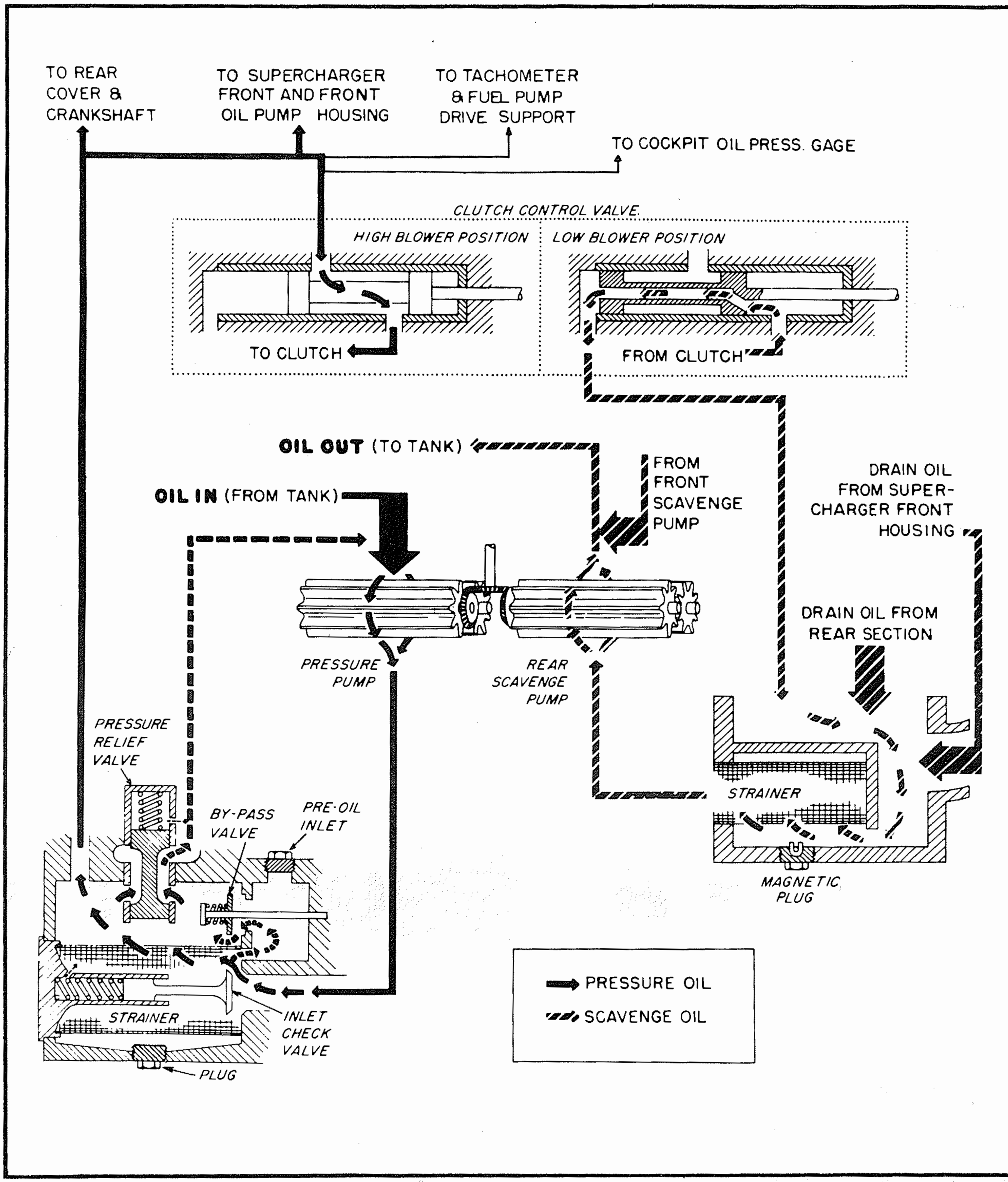


Figure 2-9. Schematic of Rear Oil Pump

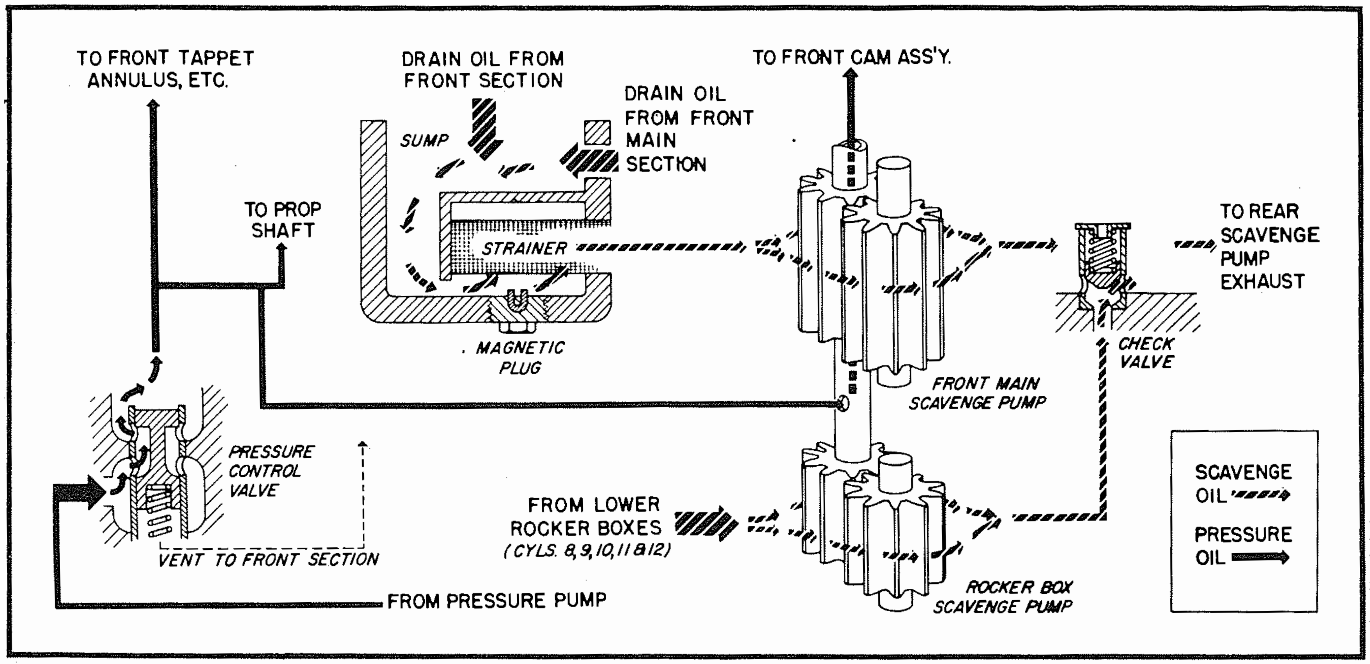
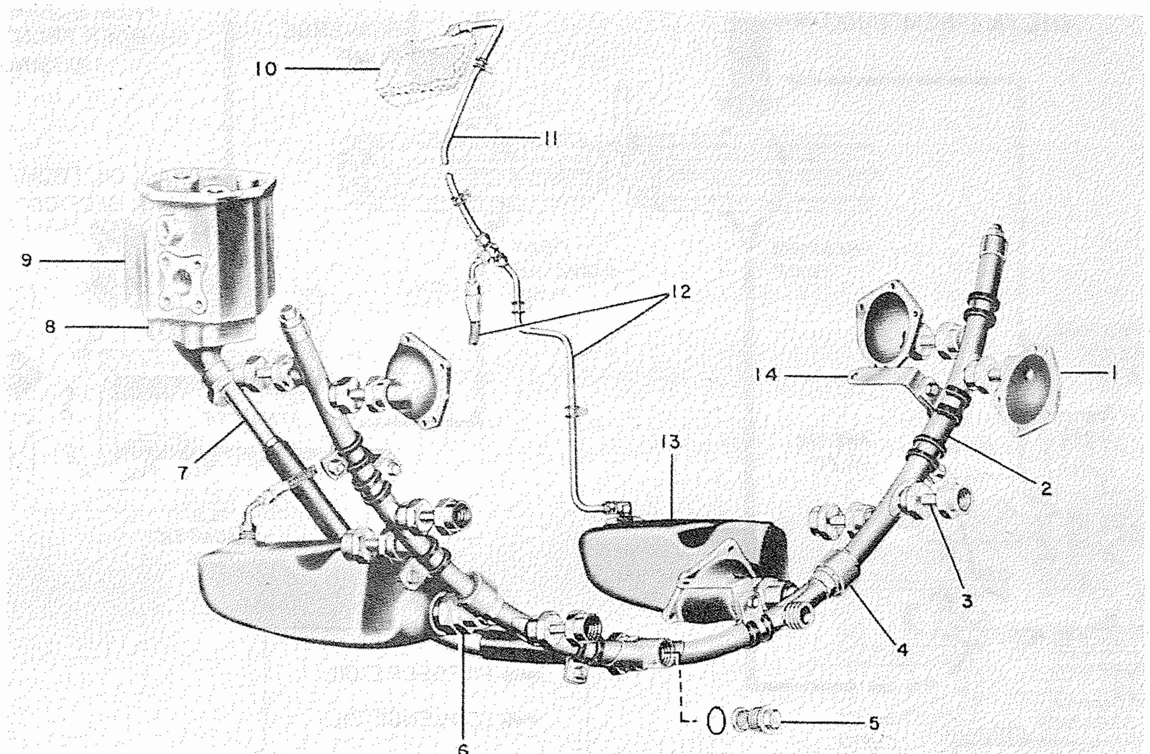


Figure 2-10. Schematic of Front Oil Pump



1. Rocker box cover
2. Drain manifold
3. Cover to drain manifold tube
4. Rocker box drain manifold packing nut
5. Drain manifold strainer
6. Drain manifold to cover and sump tube
7. Drain manifold to scavenge pump tube
8. Rocker box scavenge pump
9. Front oil pump
10. Left distributor pad in front section
11. Cover and sump vent upper tube
12. Cover and sump vent lower left and right tubes
13. Cylinder No. 10 rocker box cover and sump
14. Rocker box scavenge manifold support bracket

Figure 2-11. Rocker Box Drain System

Section III

TABLE OF SPECIFICATIONS

GENERAL

Type	Double row static radial, air cooled, with three exhaust-driven, blow-down turbines geared to crankshaft
Number of Cylinders	18
Bore	6.125 in.
Stroke	6.312 in.
Piston Displacement	3350 cu. in.
Compression Ratio	6.70:1
Supercharger Ratio	6.46:1, 8.67:1
Impeller Diameter	13.5 in.
Turbine Drive Ratio	6.52:1
Turbine Wheel Diameter	11.45 in.
Rotation of Crankshaft (from rear)	Clockwise
Rotation of Propeller Shaft (from rear)	Clockwise
Reduction Gear Ratio	988TC18EA1, 3, 4, and 6 .4375:1
	988TC18EA2 and 5 .355:1
Propeller Shaft Spline Size	60A

DIMENSIONS

Overall Diameter (over cowl seal channel)	56.59 in.
Overall Length	89.53 in.

WEIGHTS

Total Dry Weight of Engine ± 1 per cent	988TC18EA1	3645 lb
	988TC18EA2	3745 lb
	988TC18EA3	3645 lb
	988TC18EA4	3675 lb
	988TC18EA5	3775 lb
	988TC18EA6	3675 lb

LUBRICATING SYSTEM

Type	Dry Sump
Oil Specification	WAD No. 5815 or 5818
Oil Grade	120 or 100
Oil Pressure (rear pump)	70 ± 5 psi
Oil Pressure (front pump)	35 ± 5 psi
Oil Pressure (power recovery turbine)	50 ± 5 psi
Oil Inlet Temperature (normal maximum)	85°C (185°F)

VALVES AND VALVE TIMING

Intake Opens	Front, 45° B.T.C.
	Rear, 55° B.T.C.
Intake Closes	Front, 56° A.B.C.
	Rear, 56° A.B.C.

VALVES AND VALVE TIMING - Continued

Exhaust Opens	Front, 70° B.B.C. Rear, 70° B.B.C.
Exhaust Closes	Front, 45° A.T.C. Rear, 55° A.T.C.
Valve Clearance	
Cam Timing Check	.055 in.
Adjusting	.010 in.

IGNITION SYSTEM

Type	Low Tension
Magneto and Distributor Timing (cylinder No. 1)	25° B.T.C. - Compression Stroke
Magneto	Scintilla DLN-9
Spark Timing	25° B.T.C. - Compression Stroke (RETARD) 30° B.T.C. - Compression Stroke (ADVANCE)
Spark Plugs	
AC 275, 285	.015 - .018 in. gap
Champion R-103, RHA29N	.015 - .018 in. gap

FUEL SYSTEM

Type	Direct Fuel Injection
Master Control	Bendix PR-58-S-2
Fuel Injection Pump	Bendix D9H3
Fuel Specification	AMS 3036A
Fuel Grade	115/145
Fuel Pressure	25 ± 1 psi
Fuel Injection Pump Timing (established on cylinder No. 1)	25° B.T.C. - Compression Stroke

CYLINDER HEAD TEMPERATURE

Ground Operation	260°C (500°F) (Maximum)

CAUTION: Hold all ground operation to an absolute minimum.

ACCESSORY DRIVES

Accessory Drives and Type	Location	Ratio	Maximum Continuous Torque In.-lb	Maximum Static Torque In.-lb	Rotation	Maximum Overhung Moment In.-lb
Fuel Pump, XIII-A	Lower Left Side	1.000:1	25	450	CC	15
Fuel Pump, XIII-A	Lower Right Side	1.000:1	25	450	CC	15
Fluid Power Pump (12 tooth spline drive-shaft provided)	Upper Right	1.400:1	600	2700	C	350
Fluid Power Pump, XI-A	Upper Left	1.400:1	250	1650	C	75
Generator, XII-C	Lower Left	3.110:1	1500	6600	C	400
Generator, XII-C	Lower Right	3.110:1	1500	6600	C	400
Spare Drive, XI-A	Lower Center	1.400:1	250	1650	C	75
Tachometer, XV-A	Lower Right Side	0.500:1	22	50	C	15
Tachometer, XV-A	Lower Right Side	0.500:1	22	50	CC	15
Propeller Governor, XX	Top Front Section	0.857:1	125	825	C	30
Starter, XIV-C (12 tooth spline starter jaw provided)	Center	1.000:1	---	36000	C	350

Section IV

STORAGE INSTRUCTIONS

4-1. GENERAL.

4-2. Procedures for treating engines that are to be stored, shipped or remain idle for a period exceeding 48 hours, are included in this section. The procedures described are applicable to the normal conditions of engine storage and service. If a deviation from these recommended procedures is desired, or necessitated by abnormal conditions or circumstances of engine storage or service, the engine manufacturer should be immediately advised. Refer to paragraph 4-99 for equipment and material sources.

4-3. SHIPPING AND STORAGE CONTAINER.

4-4. Engines are shipped or stored in a wooden shipping box having the following overall dimensions: length, 102 inches; width, 68-1/2 inches; and height, 70-3/4 inches.

4-5. The empty box, with fixtures, weighs approximately 1100 pounds, and is basically composed of two sections. The lower section contains the engine cradle and the upper section serves as a cover. When packed, the two sections are fastened together with four No. 20 gage, 1-1/4 inch wide steel straps secured under tension with clip seals. The four lifting rings, covered by the steel straps when the box is sealed, are intended for lifting the cover only, not the entire box.

4-6. When the box is empty, the cover section can be disassembled, and fitted into the lower section, to provide a more compact unit for storage or shipment.

4-7. REMOVAL OF ENGINE FROM SHIPPING CONTAINER.

4-8. Remove the engine from the shipping container as follows:

a. Release the cover by standing on top of the shipping box and placing the feet on the metal straps on either side of the clip seals. Cut the straps close to the clips with a pair of tin snips. See figure 4-1.

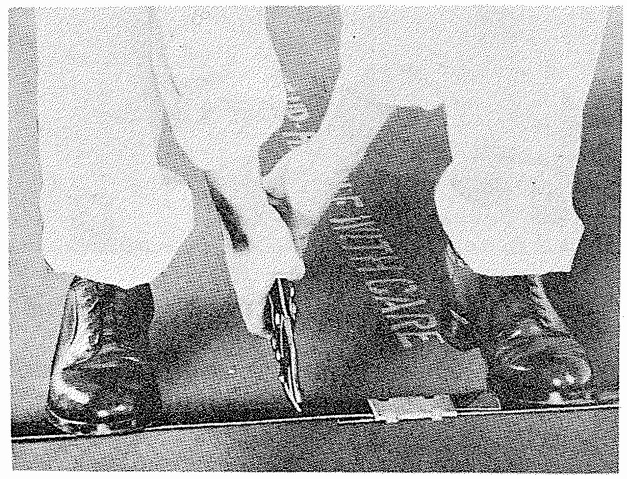


Figure 4-1. Cutting Shipping Box Steel Straps

WARNING

> Do not cut the straps at the side of the box, as upon release of tension the straps will fly outward and may severely injure the person doing the cutting.

b. Break the seals, and lift the cover by means of a sling and chain hoist, using the lift rings provided in the cover.

c. Remove the propeller shaft hold down clamp. Cut the envelope to provide access for attaching the engine sling to the engine. Attach engine sling 923304 to the cowl attaching location on the rocker boxes. See figure 4-2. The sling plates are attached to the cylinder rocker boxes as follows: Front plate to No. 2 exhaust and No. 18 intake; left rear plate to No. 1 exhaust and No. 17 intake; right rear plate to No. 1 intake and No. 3 exhaust. Suspend the engine in flight position from a hoist with a minimum capacity of two tons.

d. Remove the propeller shaft protector sleeve, nut and thread protector cap.

e. Disconnect the engine mounting ring and brackets from the engine.

f. Carefully remove the envelope from the engine as it can be re-used if desired.

g. Remove the layer of protective crepe paper and the bags of dehydrating agent attached to the engine. Do not remove the dehydrator plugs, substituting covers or seals over other openings

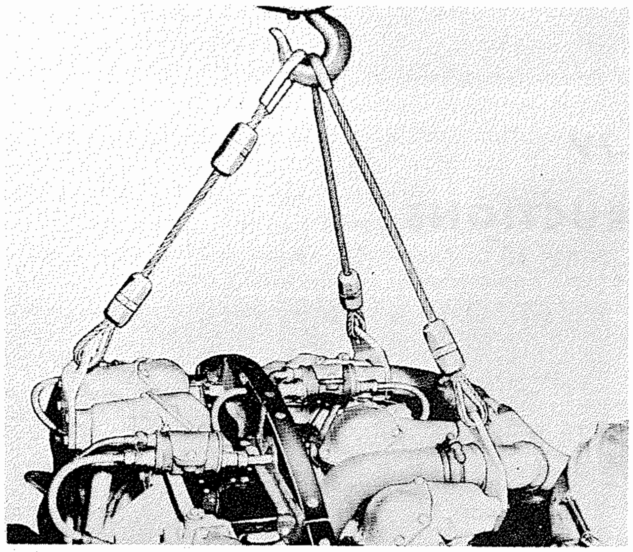


Figure 4-2. Hoist Sling Attached to Engine

until such time as their removal is necessary for installation of engine accessories or engine in the nacelle.

h. Detach the PRT cooling shield assembly containers from the base of the shipping box.

i. Remove the spark plug container, the fuel injection pump lines and the fuel injection pump synchronizing rod from the container.

4-9. PROCEDURES FOR HANDLING ENGINES IN SHIPPING CONTAINERS.

4-10. The engine should be stored in such a manner to provide maximum protection from the weather and to permit convenient inspection of the humidity indicator at periodic intervals not exceeding 30 days. See figure 4-3. In localities where relative humidity is consistently above 65 per cent, or where atmospheric conditions are highly corrosive, shorten the intervals as determined by local experience. Upon receipt of the engine from the manufacturer, check on possible undetected damage to the envelope during the packing operation.

4-11. If inspection of the humidity indicator card reveals a relative humidity below 20 per cent, as determined by comparison of the color of the dehydrating agent within the indicator with the permenant indicator card colors, corrosion protection should be satisfactory under normal conditions until the next periodic inspection.

4-12. If inspection of the humidity indicator card reveals a relative humidity above 20 but below 40 per cent, as determined by comparison of the color of the dehydrating agent within the indicator with the permanent indicator card colors, the relative humidity is approaching but as yet has not reached an unsafe condition. Open the box as instructed in paragraph 4-8, steps a and b. Cut the envelope and replace all bagged dehydrating agent. Reprepare the engine for storage following the instruction, wherever applicable, given in paragraphs 4-18, 4-19 and 4-20.

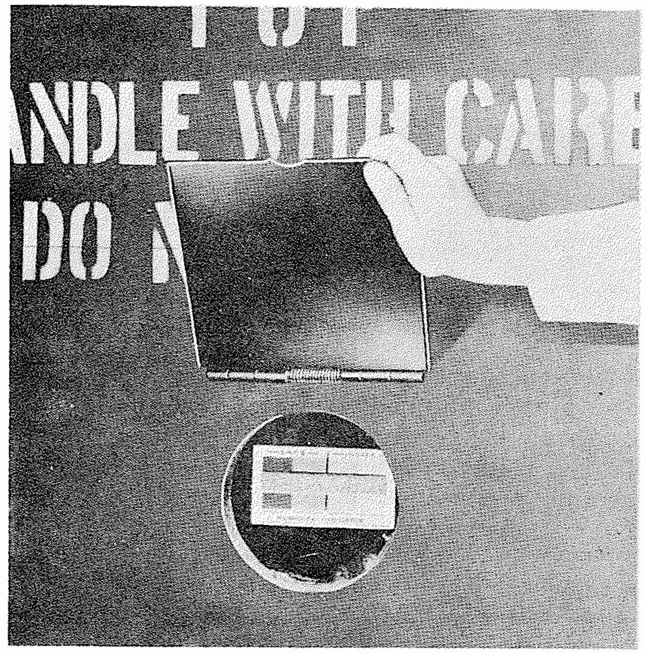


Figure 4-3. Checking Humidity Indicator Card

4-13. If inspection of the humidity card reveals a relative humidity of 40 per cent or higher, the humidity has reached an unsafe condition. If an unsafe condition has been reached it will necessitate removal of the engine and close visual inspection, especially of cylinder bores for evidence of corrosion. Follow the instructions in paragraphs 4-14 through 4-20.

4-14. Remove the shipping box top according to instructions in paragraph 4-8, steps a and b.

4-15. Cut the protective envelopes in a manner to permit access to all dehydrator plugs, bagged dehydrating agent, cylinders for inspection and the crankshaft for rotation, if necessary.

4-16. Unwrap the envelope from the engine carefully to avoid tearing or puncturing. Repair any tears or punctures in the envelope by heat sealing with iron 807813. See figure 4-4. Remove the inner protective layer of crepe paper, as required, to perform inspection of the cylinders and permit access to the bagged dehydrating agent and inspection of dehydrator plugs. Remove all the bagged dehydrating agent and unsafe dehydrator plugs.

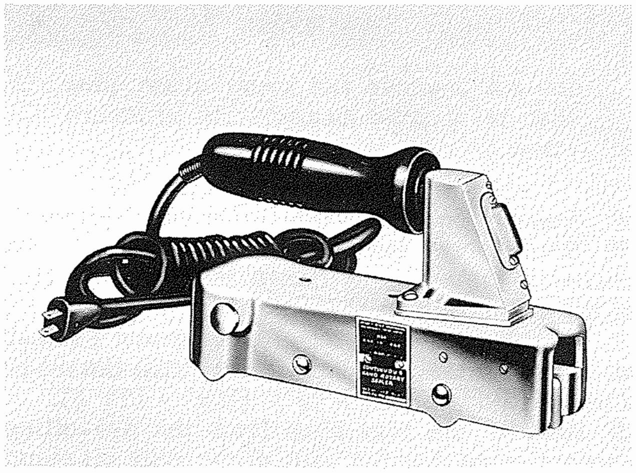


Figure 4-4. Envelope Sealing Iron

4-17. The part from which an unsafe dehydrator plug has been removed should be internally inspected through the opening from which the plug has been removed. If any visible evidence of corrosion is found, the part should be reconditioned as necessary to remove the corrosion or replaced with a satisfactory part. Removal of a cylinder from the engine may be required for the purpose of corrosion removal. Upon completion of the inspection and reconditioning, and if the crankshaft has been rotated, spray internal corrosion preventive compound, heated to 104° - 121°C (220° - 250°F), through a spark plug hole into each cylinder, preferably in the order of firing sequence and with the piston at the bottom of its stroke. Do not move the crankshaft after the last cylinder has been sprayed. With the crankshaft stationary, respray each cylinder to coat the walls above the pistons with the compound. Do not apply an excessive amount of compound. All that is required is a uniform thin coating on all surfaces.

NOTE

Attach a warning tag to the propeller shaft stating that the propeller shaft should not be rotated during storage.

4-18. Install new dehydrator plugs in the affected part and new dehydrator plugs in the oil sumps after drainage of the slushing oil from the engine. Install new bags of dehydrating agent at locations from which they were previously removed. Recoat the propeller shaft with external corrosion preventive compound and reinstall the shaft protector components. Replace the protective layer of crepe paper previously removed. Install a new humidity indicator card in the transparent window of the protective envelope. Rewrap the envelope around the engine, and reseal the envelope with iron 807813, with the exception of a small opening to permit the exhaustion of air from the interior.

4-19. Exhaust as much air from the envelope as feasible, without damage by mechanical suction.

CAUTION

Care must be taken to avoid punctures and tears during this operation. If they do occur, repair the envelope immediately.

4-20. Seal the exhaust opening after the air has been exhausted. Fold the excess material of the envelope around the engine. Do not obstruct the humidity indicator card. Replace the shipping box top.

4-21. MODIFICATION OF ENGINE.

4-22. If modification of stored engines is necessary, the extent of the modification will determine the procedure to be followed in preparing for its return to storage. If the engine part to be modified can be removed from the engine, and the envelope sealed immediately, it will only be necessary to replace the dehydrating agent and humidity indicator card. If the modification is extensive, resulting in exposure of the internal engine parts to the atmosphere for any length of time and an engine test is required because of the modification, the engine should be preserved in accordance with the instructions given in paragraphs 4-48 through 4-68.

4-23. PREPARATION OF ENGINE FOR INITIAL FLIGHT.

4-24. Prepare the fuel injection pumps, master control, and accessories for operation as recommended by the respective manufacturer. Remove the protective seals and coverings from the engine openings. Remove all dehydrating plugs and bagged dehydrating agent.

4-25. Remove the sump drain plugs and allow the internal corrosion preventive mixture to drain from the engine. Rotate the propeller shaft to facilitate adequate drainage.

4-26. Install the spark plugs. Remove the ignition lead protector and attach the ignition leads. Install the sump drain plugs and lockwire.

4-27. Clean the oil strainer to remove the preservative compound. Follow the instructions in paragraph 7-108. Reinstall the strainer.

4-28. Pre-oil the engine in accordance with instructions in paragraph 4-29.

4-29. PRE-OILING.

4-30. Filling the engine oil passages with oil under pressure from an external source while rotating the crankshaft is termed "pre-oiling". This procedure ensures satisfactory lubrication at an initial start when the engine oil system cannot supply adequate pressure.

4-31. A portable oil rig fitted with an electrically driven pump, closed supply tank, pressure relief valve, heating element, and a 10 micron filter to ensure an absolutely clean oil supply is recommended as an external source of oil. If an electric heating element is used, it should be installed so as to prevent direct contact with the oil supply to preclude impairment of the lubricating quality of the oil.

4-32. Pre-oil immediately prior to starting a new engine for the first time in an airplane; when starting a newly overhauled engine on a test stand, or in an airplane; at an initial start of an engine which has been treated for storage; or whenever an engine has been idle for more than 96 hours. After an oil change, or any other operation which would permit air to enter the oil-in line from the supply tank to the pressure pump, it will only be necessary to eliminate such air, as described below in steps a, i and j. Completely pre-oil the engine as follows:

a. Fill the supply tank on the portable rig to a safe operating level with engine lubricating oil Grade 100 or 120, and close the valve on the oil-in line from the engine oil supply tank to the engine pump.

NOTE

The quantity of oil required to pre-oil can be determined initially by measuring the amount necessary to provide a continuous dripping or flow from the upper rocker arms (front and rear row cylinders). This quantity, plus an additional 25 per cent, should be adopted as the standard requirement for the engine.

b. Remove the magnetic plug from the front pump and sump. Remove either of the sump drain plugs adjacent to the scavenge strainer from the rear oil pump and sump.

CAUTION

Do not remove the sump drain plug that is located beneath the pressure strainer.

c. Remove one spark plug from each cylinder.

d. Remove the torquemeter oil external tube connector substituting flange from the left side of the crankcase front section.

e. Use engine oil of the same grade as that used in the main oil supply tank. Heat the oil to a temperature of 38° - 79°C (100° - 175°F).

f. Remove the pipe plug from the pre-oiling connection on the left side of the rear oil pump and sump and connect the pre-oiling supply line to the pre-oiling connection.

g. Maintain a pressure of 30 to 50 psi by means of the pre-oiling pump pressure relief valve and rotate the engine with the starter until engine oil flows evenly from the torquemeter oil external connector passage at the crankcase front section. Permit at least one gallon of oil to drain freely from the engine oil sumps during the pre-oiling operation.

CAUTION

Do not exceed a maximum pressure of 50 psi unless the valve on the oil-in line is closed. If 50 psi is exceeded while the valve is open it will permit oil to return to the engine oil supply tank through the oil-in line.

h. Disconnect the pre-oiling line from the pre-oiling connection on the rear pump and sump and install the pipe plug. Install the sump drain plugs and all the spark plugs. Install the torquemeter oil external tube connector substituting flange and oil seal ring in the crankcase front section.

i. Open the valve on the oil-in line from the engine oil supply tank to the pump and remove the pre-oiling vent plug from the rear oil pump and sump. Allow two or more gallons of oil to drain from this vent to ensure that air does not remain in the oil-in line.

j. Replace the pre-oiling vent plug and replenish the engine oil tank supply.

k. Start the engine as soon as possible after pre-oiling.

4-33. If pre-oiling equipment is not available, pre-oil the engine with oil from the engine oil supply tank. Remove the torquemeter oil external tube connector substituting flange from the crankcase front section, one spark plug from each cylinder, and the sump drain plugs from the front pump and sump and the scavenge side of the rear pump and sump. Turn the engine with the starter and allow the engine pump to force oil into the engine until the oil flows evenly from the torquemeter oil external connector passage. Replace the flange, spark plugs, and sump drain plugs and replenish the oil supply in the oil tank.

NOTE

Since pre-oiling without the use of a pre-oiling rig does not supply oil to the internal engine parts as quickly as the pre-oiling rig method, and requires longer operation of the starter, it should be used as an emergency method only.

4-34. PRELIMINARY PRESERVATION OF THE ENGINE AFTER OVERHAUL TEST

4-35. At tne completion of overhaul test, operate the engine for 15 minutes at 1200 to 1500 rpm with an oil-in temperature of 104° - 121°C (220° -250°F). During this run, the oil-in line shall be supplied from an auxiliary oil tank containing hot internal corrosion preventive mixture. Just prior to shutting down with the propeller in low pitch and an engine speed of 1500 to 1600 rpm, spray hot internal corrosion preventive mixture, at a temperature of 104° - 121°C (220° - 250°F), at the rate of approximately 30 gallons per hour, into the induction system, through an appropriate opening below the master control mounting pad.

CAUTION

Do not spray internal corrosion preventive mixture through the master control.

4-36. Continue to inject the preservative mixture into the induction system until white smoke is emitted from all exhaust outlets. Move the mixture control to the idle cut-off position. Continue to spray the preservative mixture into the induction system until the engine stops, then turn off the ignition. Inject one pint of preservative mixture into the thrust bearing cavity through the fitting provided on the top of the crankcase front section. While the engine is still warm, remove the sump drain plugs, and allow the preservative mixture to drain from the engine. Replace the plugs when drainage is completed.

NOTE

The mixture should be replenished to the original quantity after the preservation of each engine. The replenishing should be made up in such a manner as to adjust to the original concentration, taking into account residual lubricant trapped in the engine. The tank mixture shall be completely replaced at intervals frequent enough to ensure its conformance to the specification requirements.

4-37. PACKING OF ENGINES FOR EXTENDED STORAGE OR SHIPMENT.

4-38. Remove the engine from the test stand, and mount it on a suitable stand for completion of the preservation operation prior to packing. Remove the accessory drive cover plates and spray the drives with the internal corrosion preventive mixture. Replace the cover plates.

4-39. Inject one pint of the internal corrosion preventive mixture into the thrust bearing cavity through the fitting provided on the top of the crankcase front section.

4-40. Remove the governor substituting cover and gasket and inject a half pint of the internal corrosion preventive mixture into the governor drive. Replace the gasket and cover. Replace the pipe plug in the cover with a dehydrator plug and wire the pipe plug to the cover.

4-41. Remove all spark plugs from the cylinders. Following the mechanical checks which require the rotation of the propeller shaft, spray corrosion preventive mixture through a spark plug in each cylinder. Rotate the crankshaft slowly through two complete revolutions while spraying each cylinder. With the crankshaft stationary, respray each cylinder with the same preventive mixture. Adjust the length of the nozzle extending into the spark plug hole so as not to interfere with the piston travel or damage the piston head.

CAUTION

Do not rotate the crankshaft upon completion of this operation. If the crankshaft is moved it will be necessary to repeat the spraying operation given in the above paragraph.

4-42. If the rocker box covers are removed for mechanical checks, thoroughly spray the rocker arm assemblies with corrosion preventive compound prior to replacement of the gaskets and covers. Removal of rocker box covers solely for slushing purposes is not recommended.

4-43. Install dehydrator plugs in each cylinder. Install a protector on each ignition lead and then attach the protectors to the cylinder dehydrator plugs.

4-44. Remove the sump drain plugs from the sumps and allow the residual preservative mixture to drain from the openings. Install dehydrator plugs at these locations. Wire the sump drain plugs to a convenient location on the engine.

4-45. Remove the fuel injection pumps and the master control and install substituting covers on the mounting pads of the detached components. Preserve the master control and fuel injection pumps in accordance with the respective manufacturer's instructions. Remove the substitution cover and install the master control gasket and the master control. Place a gasket on each side of the master control screen assembly and assemble the parts on the master control. Place two 1/4 pound bags of dehydrating agent in the clip of the master control to air scoop substituting cover and attach it to the top deck of the master control. Spray the fuel injection pump drive gears with preservative compound and install the substituting covers.

4-46. Remove the power recovery turbine cooling shield assemblies and install the shipping covers at these locations. Seal all openings with moisture resistant tape.

4-47. Install the magneto ignition switch connector vented thread protector cap.

4-48. Attach one pound bags of dehydrating agent at the following engine locations: One bag on top of the crankcase front section; sixteen bags distributed around the front cylinders and sixteen bags distributed around the rear cylinders; one bag near each of the three power recovery turbine units; two bags on the magneto; one bag on each side of the rear pump and sump housing; one bag on each rear cylinder intake pipe; and one bag on or near each distributor.

4-49. Enclose the front section, center section at the cylinder periphery, and the rear sections of the engine with a protective layer of crepe paper and secure by stapling one piece of crepe paper to another. Leave an opening for installation of and removal of the engine sling. Leave the engine mounting studs on the supercharger front housing exposed for installation of the envelope on the studs.

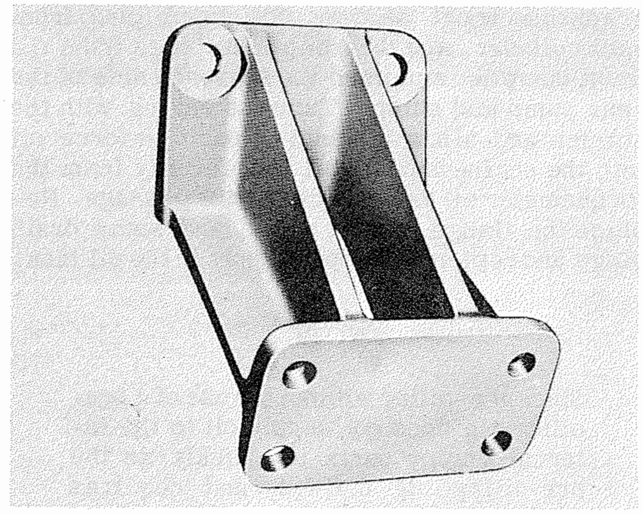


Figure 4-5. Engine Shipping Mount Bracket

4-50. Wrap the envelope around the engine. It will be necessary to cut holes in the envelope gaskets for the propeller shaft and the engine mounting studs on the supercharger front housing.

4-51. Attach the four engine mounting brackets to the supercharger front housing. Torque to a value of 550 - 600 inch-pounds. See figure 4-5.

4-52. Apply fingerprint neutralizer compound to the propeller shaft and blow excess compound off the shaft, using clean compressed air. Coat the shaft with external corrosion preventive compound.

4-53. Install the propeller shaft protector bushing and shipping nut. Place a 1/4 pound bag of dehydrating agent in the front end of the shaft and install the thread protector cap.

4-54. Attach the relative humidity indicator card to the inside of the transparent window in the envelope.

4-55. Seal the envelope, with sealer 807813, as specified on its identification panel, with the exception of an accessible opening for removing the engine sling.

4-56. Slush the power recovery turbine cooling shields in external corrosion preventive compound. Wrap each unit in moisture-proof paper and secure the paper with moisture resistant tape. Place the packages in the wooden shipping container.

4-57. After the preservation of each fuel injection pump is completed, install thread protector caps on all exposed thread connections. Attach the pump shipping envelope to the base of the container. It will be necessary to cut holes in the envelope gaskets for the injection pump retaining bolts. Insert the fuel injection pump into the envelope and attach the pump to the base. Place a one pound bag of dehydrating agent in the envelope. Expel as much air as possible and then seal the envelope in accordance with the instructions on the envelope. Attach the cover to the base of the container.

4-58. Wrap the spark plugs individually in moisture-proof paper and place them in a cardboard container. Wrap the master control to fuel injection pump lines and the fuel injection pump synchronizing rod in moisture-proof paper and secure the paper with moisture resistant tape.

4-59. INSTALLATION OF ENGINE IN THE WOODEN SHIPPING CONTAINER.

4-60. Remove the cover from the accessory receptacle located on the propeller shaft pedestal. Place the spark plug container and package containing the fuel injection pump lines, etc., in the receptacle and then reinstall the cover.

4-61. Attach the brackets for the fuel injection pump containers to the base of the shipping box at their prescribed locations at the front end of the box. Place the fuel injection pump shipping boxes in the brackets and secure them with metal straps nailed to the engine packing case.

4-62. Attach the power recovery turbine cooling shield container to the base of the engine shipping box at the prescribed location at the rear end of the engine packing case.

4-63. Attach the upper and lower halves of the shipping box bulkhead to the engine mounting brackets, taking the necessary precautions not to damage the envelope, and then tighten the bolts to a torque value of 550 - 600 inch-pounds. Attach the two halves of the engine shipping box bulkhead to each other and torque to a value of 825 - 875 inch-pounds.

4-64. Place sufficient gasket material on the recess in the propeller shaft pedestal to wrap the propeller shaft completely. Lower the engine into the shipping box so that the shipping box bulkhead slides into the grooves provided on the sides of the box and the propeller shaft rests in the recess of the pedestal.

4-65. Wrap the gasket material around the propeller shaft and then attach the propeller shaft hold down clamp, using a torque value of 1125 - 1200 inch-pounds.

4-66. Remove the engine sling and secure, by stapling, the ends of the protective layer of crepe paper around the cylinders.

4-67. Gather the opening of the envelope around the suction hose inserted in the envelope and exhaust as much air from the envelope, as feasible, without damaging it by the mechanical suction. After the air has been exhausted, seal the exhaust opening.

4-68. Attach the envelope containing the engine log records to the propeller shaft. Fold excess material of the envelope around the engine, taking care not to obstruct the humidity indicator card.

4-69. Place the shipping box top on the base and secure it with four heavy metal straps.

4-70. SHORT TERM STORAGE OF ENGINE IN NACELLE AFTER REMOVAL FROM SHIPPING CONTAINER.

4-71. Mount the engine in the nacelle with the fuel injection pumps attached to the engine but not depreserved.

4-72. Remove the PRT shipping covers and install the PRT cooling shields and exhaust hood assemblies. Place bagged dehydrating agent in the exhaust hoods and seal the opening with moisture resistant seals. Attach warning tags to indicate the presence of dehydrating agent.

4-73. Disconnect the cooling air inlet tubes and seal the cooling air inlet of the PRT assemblies. Seal the slip joints in the exhaust pipe system with moisture proof paper and moisture resistant tape. Seal all openings with moisture resistant seals to prevent the entrance of moisture or foreign matter into the engine.

4-74. Inject one pint of internal corrosion preventive mixture into the thrust bearing cavity through the fitting provided on the crankcase front section.

4-75. Coat the exposed surfaces of the propeller shaft with external corrosion preventive compound. If available install a propeller shaft shipping sleeve or wrap the shaft with moisture proof paper secured with moisture resistant tape. Install a 1/4 pound bag of dehydrating agent in the end of the propeller shaft and install the thread protector cap. Attach a warning tag to the shaft stating that the propeller shaft shall not be rotated.

4-76. Inspect the dehydrator plugs at least once every seven days. The color of the dehydrator plug should be compared with that on the humidity indicator card. If any dehydrator plug indicates an unsafe condition, follow instructions in paragraph 4-17.

4-77. SHORT TERM STORAGE OF ENGINE IN NACELLE AFTER ENGINE OVERHAUL TEST.

4-78. Mount the engine in the nacelle after the engine has been run-out and aspirated with internal corrosion preventive mixture.

4-79. Prepare the fuel injection pumps, master control and accessories, in accordance with the instructions of the manufacturer, and reinstall the units on the engine.

4-80. Place two 1/4 pound bags of dehydrating agent in the master control substituting cover and then attach it to the air scoop. Attach a warning tag in a conspicuous location, indicating the presence of a dehydrating agent and complete storage by following instructions contained in paragraphs 4-72 through 4-76.

NOTE

When accessories or controls are detached from the engine for preservation, the engine openings should be sealed to prevent the entrance of moisture or foreign material into the engine.

4-81. PROTECTION OF ENGINE IN ACTIVE AIRPLANE.

4-82. Under normal operating conditions, sufficient corrosion protection is afforded by the continuous application of the engine oil to the internal engine parts, and engine operating temperatures are sufficiently high to boil off or evaporate moisture which would normally enter the engine. After the engine is shut down, the internal engine parts will be protected from atmospheric moisture for a short period by a coating of residual oil remaining on the parts. The induction system, cylinders, valves and exhaust systems. however, remain relatively unprotected and susceptible to corrosion. The extent of this corrosion will depend, of course, upon the length of time the engine is to remain idle and the atmospheric conditions to which the engine is subjected. Corrosive effects will appear much more rapidly at locations encountering consistently high relative humidities and at coastal areas. Therefore, if an engine which has not been prepared for storage is to remain idle, the interval between ground run-ups should be sufficiently frequent so as to prevent any discoloration or visible evidence of corrosion on cylinder walls, valves or valve seat surfaces. To minimize the possibilities of corrosion, operate the engine at least once during every 48 hours of idleness as follows:

a. With the airplane facing into the wind to minimize the possibility of excessive cylinder head temperatures, operate the engine at approximately 1200 rpm for a minimum of 15 minutes with oil inlet temperature within recommended operating limits. In cold weather, operation may be discontinued after 30 minutes if normal oil-in temperature cannot be reached by that time. Avoid excessive ground running. Make two complete clutch shifts and operate the propellers throughout their entire pitch range at least three times during run-up.

4-83. SHORT TERM STORAGE IN INACTIVE AIRPLANE.

4-84. TWO TO THIRTY DAYS INACTIVITY. When it is known that the airplane will be stored in such a manner as to permit periodic ground run-up of the engine during the idleness period of from two to thirty days, and when the interval of operation in paragraph 4-82 is impractical, maintain the engine as follows:

a. Drain the lubricating oil from the engine sump and oil supply tank. Replace the drain plugs and fill the oil tank with a mixture of one part internal corrosion preventive compound and three parts of the specified engine lubricating oil.

b. Pre-oil the engine according to instructions in paragraph 4-29 using the prepared mixture.

c. Face the airplane into the wind to minimize the possibility of excessive cylinder head temperatures. Operate the engine at approximately 1200 rpm for a minimum of 15 minutes with the oil-in temperature within recommended operating limits. In cold weather, operation may be discontinued after 30 minutes if normal oil-in temperature cannot be reached at that time. Avoid excessive ground running. Make two complete clutch shifts and operate propellers throughout their entire pitch range at least three times during run-up.

d. Just prior to shut-down, with the propeller in low pitch, and the engine speed 1500 - 1600 rpm, spray hot 104^{o} - $121^{o}C$ (220^{o} - $250^{o}F$) corrosion preventive mixture at the rate of approximately 30 gallons per hour into the induction system through an appropriate opening below the master control.

CAUTION

Do not spray the preservative mixture through the master control.

e. Continue to inject slushing compound into the engine induction system until white smoke is emitted from all exhaust outlets. Move the mixture control to the idle cut-off position. Continue to spray the compound into the induction system until the engine stops. Turn off the ignition.

f. Inject one pint of internal corrosion preventive mixture into the thrust bearing cavity through the fitting provided on the crankcase front section.

g. The interval between ground run-up, as described in paragraphs c through f, shall in no case exceed a seven day period.

NOTE

Do not accumulate more than 30 hours of ground running on a given quantity of mixture.

h. Prior to flight operation, drain the preservative mixture from the engine oil sumps and the supply tank. Clean the oil strainers in petroleum solvent to remove the preservative mixture. After all preservative mixture has drained from the engine, install the oil strainers and sump drain plugs, and lockwire.

i. Accomplish the pre-oiling operation as described in paragraph 4-29, using engine lubricating oil. Perform all pre-starting inspections and ground operations necessary to prepare the engine for flight.

4-85. THIRTY TO SIXTY DAYS. The following procedure is applicable to engines installed on aircraft which will be idle for periods of 30 to 60 days, and for engines idle for lesser periods but which cannot be maintained as directed in paragraph 4-84.

4-86. Run-out the engine on corrosion-preventive mixture as instructed in paragraph 4-84, steps a through f. With the engine still warm, drain the preservative mixture from the engine by removing the sump drain plugs. Replace the sump drain plugs when the drainage is complete. Remove the spark plugs from the cylinders.

4-87. Following the mechanical checks which require the rotation of the propeller shaft, spray the interior of each cylinder through the spark plug hole with the corrosion-preventive mixture. During the spraying operation, rotate the crankshaft slowly through two complete revolutions while spraying each cylinder. Following the initial spraying, respray each cylinder through the holes without rotation of the crankshaft. Adjust the length of the nozzle extending into the spark plug hole so as not to interfere with the piston travel or result in damage to the piston head. Do not rotate the crankshaft upon completion of this operation. If the crankshaft is moved, it will be necessary to repeat the spraying operation outlined in this paragraph.

4-88. If the rocker box covers are removed for mechanical checks, thoroughly spray the rocker arm assemblies with the preservative mixture prior to replacement of the covers. Do not remove the rocker box covers for the sole purpose of slushing.

4-89. Install cylinder dehydrator plugs in each cylinder. Install ignition lead protectors on the leads and attach the protectors to the cylinder dehydrator plugs.

4-90. Remove the sump drain plugs and allow the residual preservative mixture to drain from the engine. Install crankcase dehydrator plugs at these locations. Lockwire the sump drain plugs to convenient points near their installation positions.

4-91. Remove the fuel injection pumps and master control and preserve them in accordance with the instructions of the manufacturer. Reinstall the fuel injection pumps and the master control after preservation is complete. Place two 1/4 pound bags of dehydrating agent in the clips of the master control air scoop substituting cover, and attach the cover to the top deck of the master control. Seal the cover as closely as possible to the master control and attach a warning tag to indicate the presence of the dehydrating agent.

4-92. Disconnect the cooling air inlet tubes, and seal the PRT cooling air inlet with moisture resistant paper and sealing tape. Install bagged dehydrating agent in the PRT exhaust hoods and seal the openings. Seal the joints in the exhaust pipe system with moisture resistant paper and tape. Attach warning tags to the turbines to indicate the presence of the dehydrating agent. Seal the other engine openings with moisture resistant seals. Install the nacelle covering to protect the engine from the weather.

4-93. If the propeller has been removed, coat the exposed surfaces of the propeller shaft with external corrosion-preventive compound. Install a propeller shaft shipping collar and retaining nut. Place a 1/4 pound cloth bag of dehydrating agent in the end of the propeller shaft and install the propeller shaft protector sleeve, nut and thread protector cap.

4-94. Check the condition of the dehydrator plugs every ten days, or more often if local conditions warrant. Remove all unsafe dehydrator plugs and inspect affected parts for internal corrosion. Replace or recondition corroded parts prior to engine operation. At the end of each sixty day period, depreserve and prepare the engine for operation as instructed in paragraph 4-23. Repeat the operations in paragraphs 4-83 through 4-93 for renewal of preservation.

4-95. TREATMENT OF SUBMERGED ENGINES.

4-96. Disassemble and treat submerged engines as soon as possible to prevent corrosion. Drain all water from cavities and passages. If engine submersion has been in salt water, all parts should be thoroughly flushed with warm fresh water to remove all salt deposits. If an oven is available, bake the parts at approximately 104°C (220°F) until thoroughly dry. Coat the parts with corrosion-preventive compound. The engine may be reassembled or the components may be wrapped in moisture-proof paper and packed in an appropriate box for shipment to an overhaul activity.

4-97. STORAGE OF INOPERABLE OR SEIZED ENGINE.

4-98. No preliminary treatment of inoperable or seized engines is required when disassembly is performed within 48 hours. If disassembly does not occur within this time, set the engine in flight position and drain the lubricating oil from the engine. Spray internal corrosion-preventive compound into the cylinders through the spark plug holes and install cylinder dehydrating plugs. Introduce a quantity of internal corrosion-preventive compound into the engine, through a suitable opening, to coat the internal parts of the engine. Using a suitable stand, slowly revolve the engine about its longitudinal axis at least one complete revolution, and end over end, at least once, to coat the internal parts. After completion of this operation, perform the operations in paragraphs 4-37 and 4-59 as closely as possible.

4-99. EQUIPMENT AND MATERIAL.

4-100. SLUSHING AND ASPIRATING AUXILIARY OIL TANK. The engine test stand should be equipped with an auxiliary oil tank for the slushing and aspiration of the engine at the completion of the overhaul test. This auxiliary oil tank should incorporate provisions for heating and maintaining the slushing compound at a temperature sufficient to produce and maintain an oil outlet temperature of 104° - 121°C (220° - 250°F) and with adequate breathers to permit escape of water vapor during the slushing run at the completion of the overhaul test. Provisions should also be made for spraying slushing compound at a temperature of 104° - 121°C (220° - 250°F) at the rate of approximately 30 gallons per hour into the induction system of the engine during aspiration.

4-101. SPRAY EQUIPMENT (for spraying slushing compound). Refer to specification AS11.

4-102. INTERNAL CORROSION-PREVENTIVE COMPOUND.

K-875
Bray Oil Company
3344 Medford Street
Los Angeles 63, California

Anti-Corrode - 204
Cities Service Oil Company
60 Wall Tower
New York 5, New York

Rust Ban 626
Esso Standard Oil Company
15 West 51st Street
New York 19, New York

Humble Oil Refining Company
Box 2180
Houston 1, Texas

Tectyl 896 (TD #24)
Valvoline Oil Company
Division of Ashland
Oil and Refining Company
Freedom, Pennsylvania

Gulflite No-Rust Concentrate (X-7213-D1)
Gulf Oil Corporation
Box 7409
Philadelphia, Pennsylvania

Cosmoline 1039
E. F. Houghton and Company
303 West Lehigh Avenue
Philadelphia 33, Pennsylvania

Nox Rust 327
Nox Rust Chemical Company
2429 South Halstead Street
Chicago 8, Illinois

Code No. 10851
Pennsylvania Refining Company
Karns City, Pennsylvania

Stanavo Rustpruf Oil 52572-A
Standard Oil Company of California
225 Bush Street
San Francisco, California

4-103. EXTERNAL CORROSION-PREVENTIVE COMPOUND - AMS 3078A.

202E30C
Nox Rust Chemical Company
2429 South Halstead Street
Chicago,8, Illinois

Tectyl 502C
Valvoline Oil Company
Division of Ashland
Oil and Refining Company
Freedom, Pennsylvania

Pakoil No. 2
Pennsylvania Refining Company
104 South Main Street
Butler, Pennsylvania

Compound 70436-C
R. M. Hollingshead Corporation
840 Cooper Street
Camden, N. J.

4-104. FINGERPRINT NEUTRALIZER COMPOUND - AMS 3065.

Compound 72252
Pennsylvania Refining Company
104 South Main Street
Butler, Pennsylvania

4-105. CYLINDER DEHYDRATOR PLUGS.
Chandler Evans Corporation
South Meriden, Connecticut
(or equivalent)

4-106. SUMP DEHYDRATOR PLUGS.
Chandler Evans Corporation
South Meriden, Connecticut
(or equivalent)

4-107. ENGINE DEHYDRATOR BAGS.
Davison Chemical Corporation
Baltimore, Maryland

4-108. HUMIDITY INDICATOR CARDS.
Davison Chemical Corporation
Baltimore, Maryland

4-109. ENGINE PACKING ENVELOPES - VINYL ALUMINUM.
Kennedy Car Liner and Bag Company
New York, New York

4-110. ENVELOPE SEALING IRON.
Pack-Rite Continuous Hand Rotary Sealer No. 269
Pack-Rite Machines
Milwaukee, Wisconsin

4-111. PRE-OILING EQUIPMENT.
Pre-Oiler
Durham Aircraft Service, Inc.
56-15 Northern Blvd.
Woodside 77, New York

4-112. PARTS AND MATERIAL FOR PACKING.

Specification No.	Title
AMS 3420 Grade E	Dehydrating Agent
AMS 3540	Protective Crepe Paper
AMS 3610	Moisture Resistant Paper
AMS 3810	Sealing Tape
AS 6	Engine Envelope
AS 7-1	Engine Cylinder Dehydrator Plug
AS 8-2	Front and Rear Sump Dehydrator Plugs
AS 8-3	Crankcase Dehydrator Plug
AS 10	Relative Humidity Indicator Card
AS 160-60	Propeller Shaft Protector Shipping Bushing
AS 172-60	Propeller Shaft Shipping Nut
AS 173-60	Propeller Shaft Thread Protector Shipping Cap
AS 338	Wooden Shipping Container

WAD Part No.	
119193	Power Recovery Turbine Cooling Shield Substituting Shipping Cover
119298	Engine Mounting Bracket
129692	Master Control to Air Scoop Substituting Shipping Cover
139912	Magneto Ignition Switch Connector Vented Thread Protector
410358	Power Recovery Turbine Cooling Shield Substituting Shipping Cover Band

Section V

ENGINE TROUBLES AND THEIR REMEDIES

5-1. GENERAL.

5-2. Trouble-shooting consists of analyzing all available information about the defective engine, determining the cause, and remedying it.

5-3. Engine trouble-shooting may be simplified by prepared statistics on normal operation of the engine at each operating base. One of the best ways of doing this is to make a series of propeller load curves. These curves are made by recording the rpm, manifold absolute pressure, BMEP, and fuel flow at 100 rpm intervals from closed throttle to field barometric pressure. The propeller should be in full increase rpm (low pitch stops) and run-up should be made first in "Auto Rich" and then in "Auto Lean." It may be desirable to continue the curve in "Auto Rich" only up to rated rpm.

5-4. A sample propeller load curve is shown in figure 5-1. The shape of the curve for engines run in the field will usually resemble this example. However, the curve may vary in manifold absolute pressure/rpm relationship due to differences in airport altitude, temperature, humidity, wind effect, low pitch stop setting and master control metering. These variables point out the necessity for each operation to make a number of propeller lead curves at each operating base recording wind, temperature, and humidity, so that compensation for atmospheric effects can be made.

5-5. Always examine the pressure (oil-in) and scavenge (oil-out) strainers and the magnetic plugs, before running the engine, for indication of internal damage.

5-6. Metal particles found in a scavenge strainer or on a scavenge magnetic plug come directly from the inside of the engine. Anything found on the pressure strainer has come directly from the oil supply tank. Analyze particles on the pressure strainer to determine whether they are from a dirty oil tank or are fine enough to have passed through a scavenge strainer to the supply tank and back to the engine.

5-7. Generally. metal particles found on the front pump strainer or on the front magnetic plug have come from the crankcase front section or from the forward half of the crankcase main section. Metal particles found on the scavenge strainer in the rocker box drain manifold, generally have come from one of the rocker boxes connected to the manifold.

5-8. Foreign particles found on the rear oil pump scavenge strainer, or the magnetic plug under the strainer usually come from the rear power section, the rear cam and tappet housing, the supercharger front housing, or the supercharger rear housing.

5-9. The pressure strainer by-pass valve will open if the oil-in strainer is clogged with dirt or congealed oil. The importance of keeping the oil supply tank, connecting lines, and disc type strainer clean cannot be over emphasized as an open by-pass valve will allow unscreened and possibly contaminated oil to pass directly into the engine oil system. This can result in engine malfunction.

5-10. Ensure that the trouble is not a failure and that the engine is safe to run. Operate the engine through its various ground checks. First assemble all available information about the reported troubles. If possible, talk to the flight crew reporting trouble so that a clear picture of what is wrong may be obtained. If past experience does

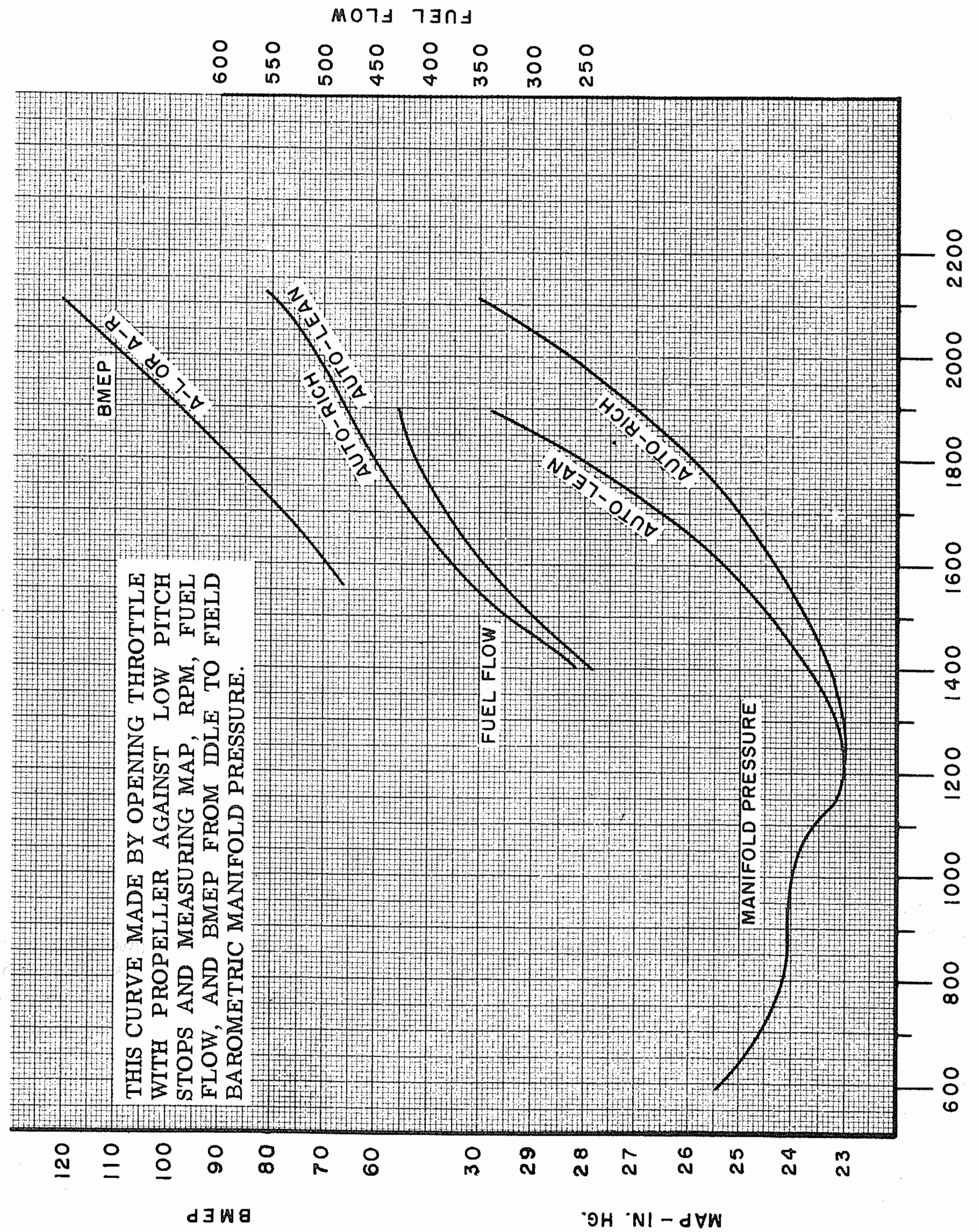


Figure 5-1. Typical Ground Propeller Load Curve

not immediately indicate from the trouble report what discrepancy exists, then it will be necessary to operate the engine according to the procedures listed here.

5-11. Before starting a malfunctioning engine it is important to pay particular attention to the various instruments to note whether their pre-starting readings are normal. This is especially true of the MAP gage, which should agree with the field barometric pressure with the engine dead. If the MAP gage does not agree with the field barometer a correction should be made to compensate for the difference, or the MAP gage should be changed. Start the engine in accordance with the instructions in Section VI. During run-up pay particular attention to any instrument which does not seem to indicate a normal reading. An instrument may be malfunctioning and thus indicate engine trouble which does not exist. If at all in doubt, check all gages, transmitters, gage lines and electric connections for possible trouble before proceeding.

NOTE

It is also important when making instrument checks to ensure that the needles do not stick and give erroneous readings. Tapping the instruments lightly may prevent the needles from sticking in one position and then suddenly dropping or rising.

5-12. MAGNETO AND BREAKER POINTS CHECK.

5-13. After starting, warm up the engine until the cylinder head temperature is 125°C (257°F) or more. With the throttle closed, the engine should idle at approximately 600 rpm. Move the mixture control into idle cut-off, and then when the engine slows down to 300 rpm move the mixture control back to "AUTO RICH." The engine should return smoothly to 600 rpm. Make this check with the magneto switch on right (R) and then on left (L). The engine should be capable of performing this test on either magneto switch if the magnets and breaker points are in good condition. This test should not be made until the engine is warmed-up and temperatures are stabilized.

5-14. CYLINDER CHECK.

5-15. This check is used to locate trouble by indicating which cylinder is affected. Checks must be made as soon as possible after stopping the engine so that the heat will not be dissipated from the cylinders in which combustion has been regular. Prolonged operation will allow the heat generated by the entire engine to be transferred to cylinders in which combustion has not been satisfactory.

5-16. When instrument readings indicate faulty ignition, warm-up the engine with the ignition switch on "BOTH", if it is defective on both sides, or, on the side that is faulty.

5-17. The purpose of this warm-up is to create a considerable heat differential between the good and bad cylinders. Therefore, from a cold start, or immediately after running the Magneto and Breaker Points Check, and with the engine operating on one or both magnetos as covered in paragraph 5-16, perform these operations:

a. With the propeller at full increase rpm and the mixture control in "AUTO RICH" open the throttle to field barometric pressure.

b. With the mixture control, lean the mixture until the engine starts to hesitate. Then enrich until the engine smooths out.

c. Run the engine with this setting for three minutes or until the cylinder head temperature is 190°C (374°F), whichever occurs first.

d. Stop the engine. Check, as rapidly as possible, the temperature of each cylinder with cold cylinder indicator 807237. Take the temperature at the same point on each cylinder, near the exhaust port if possible. Straddle a fin with the indicator prongs. Then twist the instrument so the prongs make good contact as close to the cylinder head as possible. Record the readings. After checking all cylinders, recheck the first one and note how much the engine has cooled.

5-18. If the temperature of one cylinder is excessively low, that cylinder has not been firing. A cylinder that has been firing intermittently will be cooler than a normal cylinder, but warmer than a dead one. A hot cylinder may be the result of excessive exhaust valve clearance causing the valve to restrict the exhaust flow. A large difference in bank to bank cylinder temperatures indicates poor fuel distribution. See the list of troubles at the end of this section.

5-19. STANDARD MAGNETO AND POWER CHECK.

5-20. Warm-up the engine in accordance with instructions in Section VI. When the engine has warmed sufficiently, open the throttle until the MAP is the same as it was before the engine was started. Refer to paragraph 5-11. Observe the rpm and BMEP and compare them with the engine statistics.

5-21. GENERAL IGNITION CHECK.

5-22. Having warmed the engine as directed in Section VI, make trouble-shooting checks at three different speed points to test the condition of the ignition system.

a. Make a general ignition system check as described in Section VI. If there is an excessive rpm drop, pay close attention to the tachometer and the manner in which it drops. Bad spark plugs will generally cause the tachometer to drop rapidly or erratically. For such an indication make a cylinder check as described in paragraph 5-14. Late magneto distributor timing will cause a gradual smooth but excessive drop.

NOTE

It is important in making instrument checks that the needles do not stick and give erroneous readings. Tap the instrument lightly to prevent a needle from sticking in one position and then suddenly dropping or rising.

b. Make the ignition check described in step a at the speed of 1500 - 1600 rpm. Faulty breaker points may check out all right at the high rpm encountered at field barometric pressure. Upon reducing engine speed, unsatisfactory breaker points may cause the engine to cut out completely when operating on that set of points only. A large magneto drop at this rpm is not necessarily indicative of faulty ignition.

c. If not already done, make the check described in paragraph 5-12.

5-23. IDLE MIXTURE SETTING CHECK.

5-24. Check the idle mixture adjustment as described in Section VI. In conjunction with this check the following information is to be noted:

a. The MAP reading at 600 rpm will reflect the overall condition of the engine. To obtain the lowest MAP reading at 600 rpm the engine must be in excellent condition. The MAP at 600 rpm will vary in degree on different engines when performance is satisfactory.

b. To fully evaluate the degree of engine malfunctioning, it is necessary to keep a record of the MAP reading at 600 rpm on each engine. This record should be kept in the cockpit of the aircraft to ascertain what MAP is normal.

c. A frequent review of the idle setting will make it possible to detect any abnormal MAP reading at 600 rpm. When MAP reading at 600 rpm has increased more than two inches Hg. above the normal MAP reading at 600 rpm, the engine should not be flown until the engine malfunctioning has been corrected and the MAP at idle has returned to normal.

d. Engine malfunctioning should be detected and corrected before the MAP has increased as much as two inches Hg. when familiarity with this idle check is attained.

e. A compression check in accordance with paragraph 6-20 will determine whether or not the high MAP reading is caused from low compression in the cylinders.

f. If loss of compression in the cylinders is not causing the high MAP reading, standard trouble shooting should be performed as outlined in this section and in Section VI.

5-25. MIXTURE CHECK AT 2050 RPM.

5-26. Mixture difficulties may be indicated by the following check: With the mixture in "RICH", run the engine at 2050 rpm and 30 inches MAP. Do not fail to correct the gage differences observed before starting the engine. Lean manually to best power. The BMEP should increase. If the increase is more than three BMEP, the mixture is too rich. If there is no increase in the BMEP, return the control to "RICH". Check for a lean mixture by engaging the primer intermittently and noting the BMEP. An increase in the BMEP indicates the mixture is too lean. If this check indicates a rich or lean mixture, eliminate all other reasons for the incorrect mixture before changing the master control.

5-27. PRIMER VERSUS FUEL INJECTION CHECK.

5-28. Warm the engine until the cylinder head temperature is 150°C (302°F). Adjust the speed to about 1100 rpm. Apply full prime and place the mixture control on "IDLE CUT-OFF". While operating on primer only, adjust the throttle to get the highest rpm and lowest MAP. Record the rpm, the MAP, and the fuel flow. If minimum MAP is exceeded by further opening of the throttle the engine may cause induction backfire due to lean mixture.

5-29. Place the mixture control in "AUTO RICH" and release the primer. Manually adjust the mixture control to obtain the same fuel flow as obtained by the primer.

5-30. The rpm and MAP should be about the same in paragraphs 5-28 and 5-29. If the engine operates decidedly better on the primer, the test indicates trouble in the injection system.

5-31. TORQUEMETER CHECK.

5-32. If a torquemeter is thought to be giving faulty readings, check the BMEP gage, its transmitter, and their connecting wires and connections. When it has been established that the trouble cannot be in the instrument, check the MAP gage, the tachometer, their transmitters, connections, etc.

5-33. An internal torquemeter oil line leakage check can be made with the engine static or running.

5-34. With the engine static, make the following internal line leakage check: Remove the torquemeter oil external tube connector substituting flange and its attaching parts on the crankcase front section. Install a connector and attach the hose of fixture 807019 to it. Plug the internal oil line at the torquemeter gage connection adapter with an engine plug or a standard .125 inch NPT plug. See figure 5-2.

5-35. Check all connections for tightness. Use fixture 807019 and a hand pump capable of supplying engine oil at 200 psi. Install a needle valve and a 10 micron filter on the supply line. Pump oil into the line until the gage reads 200 psi. Close the needle valve. The recorded pressure drop must not exceed five psi per minute for a period of two minutes.

5-36. With the engine running at magneto check power setting, make the following internal leakage check: Assemble and install a gage, hose and adapter on the supercharger front section in place of the torquemeter transmitter adapter. A correct reading here would indicate that the trouble is in the transmitter or gage. A faulty reading here would point to a faultv torquemeter or a leaking seal ring in the engine. Another adapter-hose-gage assembly should then be attached to the torquemeter external oil tube connector on the crankcase front section of the engine. A correct reading here would indicate a leaking oil seal ring. A high or low reading here would indicate a faulty torquemeter.

5-37. Once it has been determined that these parts are not malfunctioning, the following comparative check should be made with an engine containing properly calibrated instruments. Start and warm-up the two engines, the faulty one and the good one. Synchronize the suspected engine with the good engine at 2300, 2400 and 2500 rpm with the propellers in full low pitch (high rpm). Record the BMEP, the rpm and the MAP of both engines at each of the three settings. Shut down the engines and exchange the propellers. Repeat the above run, synchronizing the two engines at the same three points. Write down the readings again. Compare with those made before the propellers were exchanged. If in both cases, regardless of the propeller used, the BMEP on the suspected engine is lower than that of the good engine at each synchronized rpm, the torquemeter is at fault. Approximately six BMEP difference would be considered within tolerances in the high cruise range.

NOTE

Do not remove engines for high BMEP readings in the idle ranges, if torquemeter correlation is satisfactory throughout the flight operating range of the engine.

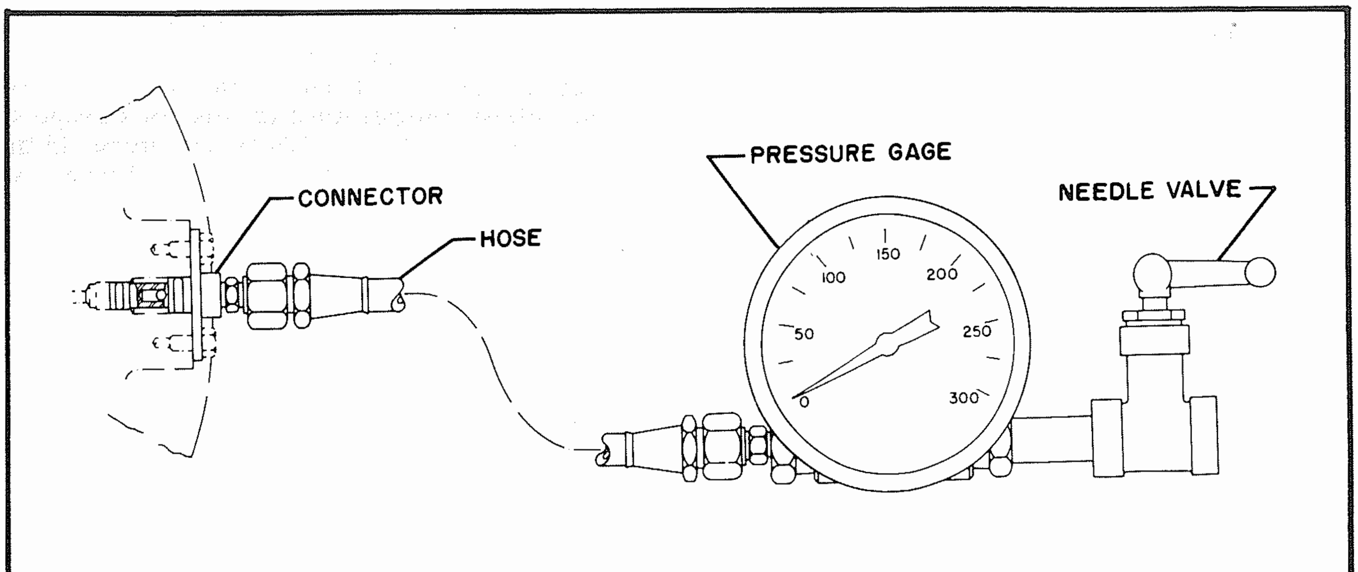


Figure 5-2. Torquemeter Oil Internal Tube Leakage Check

5-38. GENERAL TROUBLE-SHOOTING INFORMATION.

5-39. IGNITION SYSTEM. Inspect the breaker points for cleanliness and proper action. They should be synchronized in accordance with instructions given in paragraph 7-226. If the points appear to be burned or oily, replace the distributor. Point burning or pitting is usually caused by the accumulation of oil in and around the breaker assembly or by a faulty primary condenser. If a condenser is the cause of point burning, replace the distributor. Refer to paragraph 7-224.

5-40. Ensure that the magneto ground leads are attached to the correct terminals at the switch. When the wiring is correct and the engine is running with the ignition switch on "BOTH", neither side of the magneto is grounded. When operating with the switch in right (R) position, the engine is running on the right side of the magneto and the left side of the magneto is grounded and vice versa. In the "OFF" position, both sides of the magneto are grounded. Check to see that the connections are good, clean and tight. Loose connections may cause a "live" magneto even when the switch is turned off. If the insulation on a ground lead is chafed through, the lead wire may touch some part of the airplane and ground the magneto.

5-41. Clean the spark plug contact sleeves with acetone, or unleaded gasoline. If the sleeves are cracked, perforated, burned, or have carbon tracks, all of which will cause flashover, replace them.

5-42. Test the ignition harness when necessary, in accordance with the manufacturer's instructions.

CAUTION

Do not test a low tension ignition harness with high tension test equipment, as it is likely to cause serious damage.

5-43. If an engine will not start and the induction vibrator is suspected, remove the vibrator and check it in accordance with applicable vibrator manufacturer's instructions.

5-44. Fouled or partly fouled spark plugs can cause satisfactory operation at magneto check power or during cruise, but may short out under the high cylinder pressure encountered during take-off, giving rise to reports of low power range fluctuation in BMEP and/or after burning in the exhaust. Spark plug fouling may be minimized by the proper setting of idle mixtur as described in Section VI. Once encountered, spark plugs may be cleaned by the following procedure:

a. Adjust the engine speed to 1200 rpm with the mixture control in "AUTO RICH".
b. Lean toward idle cut-off until the rpm starts to fall off, and run from two to five minutes
c. Place the mixture control in "AUTO RICH" and move the throttle to field barometric magneto check.
d. Spark plugs that do not clean out satisfactorily at field barometric check should be changed.
e. If there are continued reports of low power or badly fluctuating BMEP on subsequent take-off, spark plugs must be replaced.
f. Test the new spark plugs on a spark plug bomb tester and visually check for cracks before installation.

5-45. The threads of a spark plug and the insert in the cylinder must be in good condition. Refer to paragraph 7-216 for cleaning the insert. The importance of using a torque wrench and tightening the spark plug to the correct value of 300 - 360 inch-pounds cannot be over emphasized. An overtorqued spark plug is hard to remove and its gap clearance might be changed by stretching the steel shell. Finger tight plugs may overheat to the point of causing pre-ignition leading to detonation, burned pistons, split cylinder heads, and broken connecting rods.

5-46. Copper run-out from the center electrode of a spark plug, is one type of failure which can be attributed to sources other than the plug itself. If the copper is missing from a plug which is otherwise in a satisfactory condition (no cracked ceramic), it may be assumed that an excessively high cylinder temperature existed as a result of some other condition. The temperature, in the vicinity of the center electrode should never exceed approximately 872°C (1600°F). Cylinders which have plugs involved in copper run-out must be carefully inspected prior to further operation. A compression check, as described in paragraph 6-20, and visual inspection with a borescope should be made and appropriate action taken when unusual conditions are detected. These checks will catch any incipient trouble and prevent possible major failures at a later date.

5-47. MASTER CONTROL. Master control difficulties may sometimes be traced directly to contaminated fuel. Check the condition of the fuel. Always use the grade of fuel specified for the engine. See Section III.

5-48. A leaking primer will cause the engine to run rich. Ensure that the solenoid valve does not leak when it is in the "OFF" position. If one of the priming connection nipples in the supercharger rear housing is replaced, be sure to use a similar nipple. These nipples incorporate a special restriction which causes the fuel to spray as it enters the impeller chamber when the engine is being primed.

5-49. Poor idling characteristics are usually indicated by torching, rough engine operation, black smoke, or poor acceleration in the idling range which may reach as high as 1400 or 1500 rpm. Before making an idle adjustment, ensure the engine is in good condition. Have the ignition system properly timed and working efficiently. Eliminate all leaks in the induction system. The master control and the injection pumps must function satisfactorily. The primer must not leak when turned off. Use the correct fuel.

5-50. There are two idle adjustments: the minimum idle speed adjustment and the idle mixture adjustment. Refer to Section VI. Master control troubles, as mentioned in paragraph 5-49, can be corrected usually by adjusting the idle mixtures. Further master control adjustments should be attempted by authorized overhaul activities only. Eliminate all other possible sources of engine malfunction, adjust the idle mixture, and then, if a rich or lean mixture condition still exists, replace the master control.

5-51. Inspect and clean all fuel strainers. Check the induction system and the fuel system for leaks. An induction system leak between the master control and cylinders, such as may be caused by a loose intake pipe, can result in a lean mixture if the manifold pressure is less than the outside air pressure, and a rich mixture if the manifold pressure is more than the outside air pressure.

5-52. Too rich a mixture is indicated by black smoke, torching, low power, and excessive fuel consumption. Check for correct fuel pressure when the engine is running with the booster pump turned off. Test or replace the gage and transmitter if their accuracy is questionable. Adjust the pressure relief valve on the engine driven fuel pump, if necessary, See Section III. If the fuel pump installation includes a balance line from the fuel pump to the master control air scoop, a ruptured fuel pump diaphragm will bypass fuel down through the master control venturi. Disconnect the balance line. When the booster pump is turned on, there should be no fuel in this line. On some installations fuel pressure transmitter, and fuel pressure warning light switches, are vented to the master control top deck. Any leakage in these units will result in fuel leakage into the induction system. This can be checked by removing vent lines and pressurizing the fuel system with the fuel boost pump. There should be no fuel accumulation in these lines. Leakage may often be noted as fuel leakage from the supercharger drain with the engine static, and the boost pump operative. Check the priming solenoid by pressurizing the fuel system and ensuring that there is no leakage at the primer discharge nipples when the primer is turned off.

5-53. Lean mixtures can be caused by low fuel pressure, improper mixture control rigging, vapor in the fuel system, or leaks in the induction system. Adjust or replace the fuel pump, if necessary. Replace packings or gaskets at locations where there are leaks. Inspect the operation of the vapor vent system of the master control and injection pumps. With the engine shut down and the fuel system under booster pump pressure, the vapor vent valves should by-pass air, but not fuel. When all else fails, replace the master control.

5-54. On some fuel pumps, it is possible at installation, to reverse the relief valve and the bypass valve. If this should happen, the engine may not run, even with the primer and the booster pump in operation.

5-55. BACKFIRING. Backfiring is the burning of fuel from the combustion chamber back through the induction system and master control. It is usually caused by a lean mixture. A leaking intake valve can cause it also. Check the valve action and clearance. Make a compression check, if necessary. If backfiring takes place when the engine is being started on the primer, adjust the throttle again, using a small degree of throttle opening to obtain the correct fuel-air ratio. If the difficulty occurs in the idle range with the mixture control cut in, check with the primer and adjust the idle mixture as necessary. If backfiring occurs above 1400 rpm, look over the induction system for air leaks. Inspect the master control vapor separator floats and valves to ensure that they by-pass air but not fuel when they are pressurized with the engine dead. If backfiring still persists, ensure that all exhaust valves are opening. If oil wetted air filters are being used, study the master control impact tubes for the presence of oil from the filter. If oil enters the impact tubes, it can restrict air passages in the master control and upset its metering characteristics, making a master control change necessary.

5-56. AFTERFIRING. Indications of engine troubles may be apparent from afterfiring in the exhaust system. Afterfiring, an explosion of a charge of fuel and air in the exhaust system, is sometimes confused with backfiring. What may seem like backfiring is usually a type of afterfiring and can be due to late magneto timing, a faulty ignition system (such as bad breaker points, misplaced ignition lead, a cracked distributor block) or an incorrectly timed distributor. Afterfiring may also be attributed to valve clearance or timing faults. Any of these things may cause fuel, which should burn in the cylinder, to pass into the exhaust system and burn there. Quite often these troubles will result in torching instead of audible explosions.

5-57. FLAME PATTERN. In flight, flame pattern can point out engine abnormality. Normally, during take-off, exhaust flames are either very brilliant or completely absent. Absence of flame at take-off power is not abnormal and is due to a mixture in the exhaust which is too rich to burn. The long brilliant flame, which is normal during high power operation in "AUTO RICH", is caused by the extra fuel injected in the cylinders for cooling purposes being ejected unburned into the exhaust system, where it mixes with turbine cooling air to give a blow torch effect as it exhausts from the turbine hood. This bluish flame will be present at any normal operating power in "AUTO RICH", but should fade out to a straw color when the engine is properly manually leaned. If a constant blue flame still exists at cruise power, and the engine is manually leaned, there is an indication of an incorrectly calibrated master control. It should be noted that the No. 2 turbine exhaust flame has an orange base. This is due to slightly higher oil consumption by the bottom cylinders which lead to this turbine. However, an abnormally gray and orange flame by a turbine denotes high oil consumption for either the turbine itself or the cylinders leading to the turbine. Sparks emitting from the turbine may be caused by either carbon deposits, turbine wheel rubbing, or if accompanied by oil discharge, possible turbine failure. An abnormal amount of sparks from the turbine should be investigated. Mild torching during "AUTO RICH" descent is not abnormal. Afterfiring during low power descent may be due to rich mixture in the idle range which usually can be corrected by adjusting the idle mixture. A dead cylinder will cause abnormal torching, usually intermittent, in flight, and can be detected by engine roughness at low RPM. At cruise RPM under flight conditions one dead cylinder may cause torching, but is not likely to cause engine roughness.

5-58. DETONATION. The normal burning of fuel inside the cylinder of an internal combustion engine is burning which, from the beginning of combustion, the flame propagation is uniformly progressive and the pressure build-up is rapid but regular. It reaches its peak value with the piston slightly past top center and a fairly high pressure is maintained throughout the power stroke.

5-59. Detonation is the effect of an abnormal combustion of part of the fuel mixture as compared to normal combustion. When detonation occurs, the flame propagation during the initial combustion of the charge is normal until approximately 80 per cent of the charge is burning. At this point the combustion accelerates with great rapidity and the remaining charge is burned almost instantaneously, causing an unusually rapid rise and then a rapid drop in pressure. When detonation occurs, the BMEP is reduced. The engine is subjected to mechanical shocks that may cause serious damage. Principal factors contributing to detonation are the anti-knock value of the fuel, high cylinder temperatures, incorrect fuel-air ratios, high master control air temperatures, or excessively high manifold pressures in relation to rpm.

5-60. Detonation is usually indicated by high cylinder head temperatures and rough engine operation. It is frequently accompanied by puffs of black smoke and sharp white exhaust flames appearing in the form of intermittent flashes.

5-61. It is unlikely that detonation will occur if the engine is properly maintained, the correct fuel is used, and the engine is operated in accordance with instructions.

5-62. LIQUID LOCK (Hydraulic lock). When liquid, oil or gasoline enters the combustion chamber in sufficient quantity to prevent the piston from traveling through its stroke unimpeded, it is known as liquid or hydraulic lock. If the engine were started or even pulled through with force, the incompressible liquid can do considerable damage to the engine.

5-63. If means were not provided to prevent it, or if that means should fail, a liquid lock behind an oil control valve would interfere with that valve's action. A liquid locked pressure relief valve, for example, in the rear oil pump of the engine will cause high oil pressure in the rear of the engine. If the oil pressure control valve in the front pump housing is liquid locked, it will cause high oil pressure in the front section.

5-64. LUBRICATION. Regardless of climatic conditions, use the grade of oil specified for the engine. See Section III. Other grades of oil may lead to improper lubrication with resultant parts failure.

5-65. High oil-in temperatures may be caused by a restriction in the oil cooler air scoop. The oil cooler shutters or flaps may be binding or restricted in their travel. The oil cooler may be clogged or frozen. Its relief valve or its temperature control valve may be inoperative.

5-66. Oil foaming is usually controlled in the design of the lubricating system by providing a foam expansion space in the supply tank. Do not exceed the oil tank capacity. Check all oil lines for air leaks and repair or replace all leaking parts. Foaming can result from a contaminated oil supply or from the mixing of different oil brands. If this condition is suspected, drain and flush the lubricating system and replenish the oil supply with the specified grade of oil. See Section III.

5-67. Excessive oil consumption may be experienced when a large amount of oil is being burned in the combustion chamber, when oil is expelled through the engine breather and when there are external oil leaks. External leaks usually can be found by washing the engine, running it a few minutes and then visually inspecting it.

5-68. If large quantities of oil are expelled from the engine breather, stop the engine as soon as possible and determine the trouble. Inspect the screens and magnetic plugs for evidence of a burned piston. Check the oil dilution valve for leakage when closed. Ensure that the oil supply vent line to the engine is open. Inspect the scavenge pumps.

5-69. Oil may enter the combustion chambers past defective pistons and rings, worn valve stems and guides and through the induction system by way of the impeller oil seals. Oil will go through a defective bellows oil seal in the power recovery turbine assembly.

5-70. Oil smoke from idle to 1400 - 1500 rpm can be caused by clogging of the drain holes in the valve tappet guides or an inoperative rocker box drain system scavenge pump or a clogged strainer. When any of the above mentioned conditions occur, excess oil is forced down the valve stem guide clearance, and oil smoke from idle up to 1400 - 1500 rpm is quite heavy. Such a smoking condition may lead to unnecessary cylinder removals or looking for broken or inverted piston rings.

TROUBLE SHOOTING CHART

Trouble	Probable Cause	Correction
1. Failure of engine to start.	Battery malfunction.	Check terminals, recharge or replace.
	Faulty ignition switch.	Replace.
	Faulty induction vibrator.	Replace.
	Fouled or iced spark plugs.	Replace. Refer to paragraph 7-214. Refer to Section III for correct plugs.
	Magneto or distributor incorrectly timed.	Refer to paragraph 7-221 and 7-224.
	Defective service or booster points in distributors.	Replace distributor. Refer to paragraph 7-224.
	Low fuel pressure.	Refer to Section III.
	Lack of fuel.	Fill tank with fuel. Refer to Section III for grade of fuel.
	Improperly operated primer.	Refer to Section VI.
	Faulty primer.	Replace.
	Water in fuel.	Drain fuel until water is removed. Refill tank with proper grade of fuel. Refer to Section III.
	Liquid lock.	Drain lower cylinders.
	Incorrect throttle setting.	Reset throttle.
	Negative valve clearance.	Refer to paragraph 7-22 and Section III.
2. Failure of engine to continue running after starting.	Defective magneto.	Replace. Refer to paragraph 7-221.
	Incorrect throttle setting.	Reset throttle.
	Underpriming or overpriming.	Increase or decrease as necessary.
	Lack of fuel.	Check fuel gage. Refill with correct fuel.
	Vapor lock.	Remove the vapor vent pipe plug from the top of the fuel control unit in master control. Turn on the booster pump and rotate the propeller shaft until fuel runs freely from the vent.
	Defective fuel pump.	Replace with a similar pump. Refer to Section III and paragraph 5-54.
	Fuel strainer clogged.	Wash and replace. Refer to paragraph 7-259.
	Obstruction in master control air scoop.	Inspect and remove obstruction.
	Malfunctioning master control.	Replace. Refer to Section III and paragraph 7-262.
	Water in fuel.	Drain fuel until water is removed. Refill tanks with proper grade of fuel. Refer to Section III.
3. Failure of engine to idle properly.	Faulty or loose spark plug.	Replace. Refer to Section III and paragraph 7-214.
	Defective spark plug contacts.	Replace spark plug lead. Refer to paragraph 7-212.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
3. Failure of engine to idle properly (cont)	Defective high tension coil.	Replace. Refer to paragraph 7-209.
	Defective or improperly adjusted breaker points.	Replace. Refer to paragraph 7-224.
	Magneto or distributor timing wrong.	Reset. Refer to paragraphs 7-223 and 7-226.
	Incorrect idle mixture adjustment.	Adjust. Refer to paragraph 5-23.
	Leaking primer.	Check primer solenoid valve for leakage. Replace primer.
	Leak in induction system.	Refer to paragraph 5-51.
	Vapor vent valves leaking in fuel injection pumps or master control.	Replace faulty unit. Refer to paragraphs 7-252 or 7-262.
	Improper valve clearance.	Reset. Refer to Section III and paragraph 7-22.
	Sticking valves.	Replace cylinder. Refer to paragraph 7-163.
	Restriction in the exhaust system.	Remove restriction.
	Low compression on one or more cylinders.	Replace cylinder. Refer to paragraph 7-163.
	Broken valve spring.	Replace cylinder. Refer to paragraph 7-163.
4. Engine runs rough.	Loose spark plugs.	Tighten. Refer to paragraph 7-214.
	Defective spark plugs.	Replace. Refer to paragraph 7-214.
	Defective spark plug lead.	Replace. Refer to paragraph 7-212.
	Defective breaker points.	Replace distributor. Refer to paragraph 7-224. Return distributor to manufacturer.
	Defective magneto.	Replace. Refer to paragraph 7-221.
	Defective high tension coil.	Replace. Refer to paragraph 7-209.
	Dead cylinder.	Refer to paragraphs 5-14 and 7-163.
	Faulty ignition switch.	Replace.
	Pre-ignition.	Refer to paragraph 5-39. Reset timing.
	Leak in induction system.	Repair. Refer to paragraph 5-52.
	Automatic mixture control valve sticking.	Replace control unit.
	Faulty master control.	Replace. Refer to paragraph 7-262.
	Master control icing.	Pre-heat or de-ice depending on climatic condition. Replace if necessary. Refer to paragraph 7-262.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
4. Engine runs rough (cont)	Ruptured fuel pump diaphragm on installation incorporating a balance line from fuel pump to master control top deck.	Replace.
	Faulty fuel injection nozzle.	Replace. Refer to paragraph 7-240.
	Primer leaking.	Replace primer.
	Incorrect idle mixture adjustment.	Adjust. Refer to paragraph 5-23.
	Water in fuel.	Drain fuel until water is removed. Refill tank with proper grade of fuel. Refer to Section III.
	Detonation.	Refer to paragraph 5-59.
	Low compression.	Refer to paragraph 5-14. Replace cylinder. Refer to paragraph 7-163.
	Improper synchronizing rod adjustment.	Refer to paragraph 7-244.
	Bent or broken connecting rod.	Replace engine.
	Sticking valves or valve tappets.	Replace cylinder or valve tappets. Refer to paragraphs 7-163 and 7-136.
	Improper valve clearance.	Refer to Section III and paragraph 7-22.
	Broken valve spring.	Replace cylinder. Refer to paragraph 7-163.
	Internal part failure.	Replace engine.
	Worn thrust bearing.	Replace engine.
	Loose thrust nut.	Tighten nut. Refer to paragraph 7-27.
	Loose propeller.	Remove propeller. Inspect the propeller shaft splines for galling and cracking.
	Propeller out of balance or track.	Replace propeller.
	Bent propeller shaft.	Replace engine.
	Worn engine mounts.	Replace engine mounts.
5. Dead Cylinder.	Fouled spark plugs.	Replace. Refer to paragraph 7-214. Refer to Section III for correct plugs.
	Faulty high tension coil.	Replace defective coil. Refer to paragraph 7-209.
	Faulty wires in harness.	Replace harness. Refer to paragraph 7-207.
	Intake valve not opening.	Check valve clearance. Refer to paragraph 7-22.
	Broken rocker arm.	Replace. Refer to paragraph 7-140.
	Plunger stuck in fuel injection pump.	Replace fuel injection pump. Refer to paragraph 7-252.
	Faulty fuel hose to cylinder.	Replace. Refer to paragraph 7-227.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
5. Dead Cylinder (cont)	Faulty fuel injection nozzle.	Replace. Refer to paragraph 7-240.
6. Engine tends to run lean.	Incorrect idle mixture adjustment.	Re-adjust. Refer to paragraph 5-23.
	Defective master control.	Replace. Refer to paragraph 7-262.
	Defective vapor vent valve.	Replace master control. Refer to paragraph 7-262.
	Manual mixture control linkage out of adjustment.	Re-adjust.
	Defective fuel injection pump.	Replace. Refer to Section III and paragraph 7-252.
	Clogged fuel line or master control strainer.	Wash and replace. Refer to paragraph 7-259.
	Low fuel pressure.	Replenish fuel tank. Replace fuel pump. Refer to Section III.
	Oil in master control air passages.	Replace master control. Refer to paragraph 7-262.
	Automatic mixture control sticking.	Replace master control. Refer to paragraph 7-262.
7. Engine tends to run rich.	Incorrect idle mixture adjustment.	Re-adjust. Refer to paragraph 5-32.
	Defective master control.	Replace. Refer to paragraph 7-262.
	Primer leaking.	Replace primer.
	High fuel pressure.	Refer to Section III.
	Automatic mixture control defective.	Replace master control. Refer to paragraph 7-262.
	Partially clogged master control top deck screen.	Wash screen with petroleum solvent and dry with air blast.
	Ruptured fuel pump diaphragm on installations incorporating a balance line from fuel pump to master control top deck.	Replace fuel pump. Refer to Section III.
8. Torching (Afterfiring).	Faulty ignition.	Refer to paragraph 5-39.
	Incorrect magneto or distributor timing.	Refer to paragraphs 7-223 and 7-226.
	Dead cylinder.	Refer to paragraph 5-14. Replace cylinder. Refer to paragraph 7-163.
	Primer leaking.	Replace primer.
	Rich idle mixture adjustment.	Refer to paragraph 5-23.
	Fuel-air mixture too rich.	Lean mixture. Refer to paragraph 5-23.
	Automatic mixture control unit defective.	Replace master control. Refer to paragraph 7-262.
	Torching on deceleration.	Refer to paragraph 5-52.
	Improper valve clearance.	Refer to Section III and paragraph 7-22.
	Synchronizing rod binding.	Check for obstruction. Replace if necessary. Refer to paragraph 7-244.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
9. Failure of engine to develop power.	Incorrectly adjusted breaker points.	Replace distributor. Refer to paragraph 7-224.
	Instruments or transmitter defective.	Replace defective unit.
	Late magneto or distributor timing.	Refer to paragraph 7-223 and 7-226.
	Propeller stops incorrectly set.	Reset.
	Improper fuel.	Refer to Section III for correct fuel.
	Leaks in induction system.	Refer to paragraph 5-47. Replace.
	Restriction in master control air scoop.	Remove restriction or replace master control. Refer to paragraph 7-262.
	Master control icing.	Pre-heat or de-ice, depending on climatic conditions. Replace master control if necessary. Refer to paragraph 7-262.
	Leaks in master control pre-heat system.	Repair or replace pre-heat system.
	High CAT.	Check alternate air control.
	Throttle improperly rigged.	Reset throttle.
	Faulty master control.	Replace. Refer to Section III and paragraph 7-262.
	High humidity.	Reset throttle.
	Damaged impeller vanes.	Replace engine.
	Low compression.	Refer to paragraphs 5-14 and 6-20. Reset valve clearance. Refer to paragraph 7-22.
10. Loss of compression.	Loose spark plug.	Tighten spark plug. Refer to paragraph 7-214.
	Negative valve clearance.	Refer to paragraph 7-22.
	Warped or sticking valves.	Replace cylinder. Refer to paragraph 7-163.
	Warped valve seats.	Replace cylinder. Refer to paragraph 7-163.
	Collapsed valve.	Replace cylinder. Refer to paragraph 7-163.
	Worn or stuck piston rings.	Locate trouble by compression check. Refer to paragraph 6-20. Replace piston and cylinder assembly. Refer to paragraph 7-163.
	Cracked piston or cylinder.	Refer to paragraphs 5-14, 6-20 and 7-163.
	Synchronizing rod binding.	Remove obstruction. Refer to paragraph 7-244.
11. No oil pressure.	Faulty transmitter or gage.	Replace defective unit. Refer to paragraph 5-32.
	Inadequate oil supply.	Replenish oil supply. Refer to Section III for proper grade.
	Plugged oil-in line.	Remove, wash or replace oil-in line, if necessary.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
11. No oil pressure (cont)	Relief valve stuck open.	Repair and reset. Refer to paragraphs 7-87 and 7-90.
	Internal oil leak.	Replace engine.
	Oil pump drive shaft sheared.	Replace pump. Refer to paragraph 7-117.
	Air lock in pressure pump.	Remove by bleeding.
	Master rod bearing failure.	Replace engine.
12. Low oil pressure.	Defective transmitter or gage.	Replace defective unit. Refer to paragraph 5-32.
	Inadequate oil supply.	Replenish oil supply. Refer to Section III for proper grade.
	High oil temperature.	Inspect oil cooler control.
	Improper setting of the pressure relief valve.	Reset relief valve. Refer to paragraph 7-17.
	Stuck pressure relief valve.	Remove, polish and replace. Refer to paragraph 7-90.
	Defective relief valve spring.	Replace spring. Refer to paragraph 7-87.
	Faulty oil-in line.	Inspect and remove fault.
	Internal oil leak.	Replace engine.
	Oil foaming.	Drain, flush and refill oil tank. Refer to Section III for proper grade.
	Leaking oil dilution valve.	Replace.
	Scored oil pump pressure gear cavity.	Replace oil pump housing. Refer to paragraph 7-117.
	Worn bushings or bearings.	Replace engine.
13. High oil pressure.	Defective transmitter or gage.	Replace defective unit. Refer to paragraph 5-32.
	Cold oil.	Pre-heat oil. Refer to Section III for proper grade of oil
	Excessive oil in the tank.	Drain excess oil.
	Pressure relief valve improperly set.	Refer to paragraph 7-17.
	Pressure relief valve stuck or shut by liquid lock.	Replace. Refer to paragraphs 5-63 and 7-87.
14. Oil accumulation in crankcase.	Engine idle rpm to low.	Increase idling.
	Air lock in the scavenge system.	Disconnect oil line close to oil pump and bleed.
	Excessive oil dilution.	Refer to Section VI.
	High oil temperature.	Inspect oil cooler temperature control. Refer to paragraph 5-65.
	Congealed oil in the cooler.	Apply heat to oil cooler.
	Excessive oil in the tank.	Drain excess oil.
	Plugged scavenge screens.	Remove, wash and replace. Refer to paragraphs 7-81 and 7-100.
	Defective front or rear scavenge pump.	Replace. Refer to paragraphs 7-73 and 7-117.
	Wrong grade of oil.	Refer to Section III for proper grade of oil.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
14. Oil accumulation in crankcase (cont)	Oil pressure relief valve remaining open.	Replace. Refer to paragraph 7-87.
	Internal leaks.	Replace engine.
15. Oil loss through engine breather.	Oil accumulation in the crankcase.	Check oil inlet and scavenge pump.
	Oil tank to engine vent passage restriction.	Remove restriction.
	Leaking oil dilution valve.	Replace valve.
	Defective front or rear scavenge pump.	Replace. Refer to paragraphs 7-73 and 7-117.
	Plugged scavenge screens.	Remove and wash screens. Dry screen with air blast. Refer to paragraphs 7-81 and 7-100.
	Piston-cylinder "blow-by".	Replace cylinder and piston assembly. Refer to paragraph 7-163.
	Hole burned in piston.	Replace engine.
16. Excessive oil consumption.	External oil leak.	Repair.
	Internal oil leak.	Replace engine.
	Incorrect installation of piston rings.	Refer to paragraph 7-163.
	Worn or broken piston rings.	Refer to paragraph 7-163.
	Burned pistons.	Replace engine.
	Worn impeller oil seal.	Replace engine.
	Worn valve guides.	Replace cylinder. Refer to paragraph 7-163.
17. Engine overheats.	Faulty gage or transmitter.	Replace faulty unit.
	Loose spark plugs.	Tighten. Refer to paragraph 7-214.
	Improperly timed magneto or distributor.	Refer to paragraphs 7-223 and 7-226.
	Wrong grade of fuel.	Refer to Section III for proper grade.
	Improper fuel-air mixture.	Adjust fuel-air mixture. Refer to paragraph 5-25.
	Air leak in induction system.	Repair.
	Pre-ignition.	Reset timing.
	Detonation.	Refer to paragraph 5-58.
	Improperly installed oil cooler flaps.	Re-install.
	Clogged or frozen oil cooler.	Refer to Section VI.
	Restricted oil cooler scoop.	Remove restriction.
	Oil cooler by-pass temperature control unit defective.	Refer to Section VI.
	Oil foaming.	Drain, flush and refill tank. See Section III for proper grade.
	Improperly installed alternate air control.	Re-install.
	Improperly adjusted cowl flaps.	Readjust.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
17. Engine overheats (cont)	Improperly fitted air deflectors.	Refer to paragraphs 7-144 and 7-148.
	Bearing failure.	Replace engine.
18. One cylinder overheated.	Loose spark plugs.	Refer to paragraph 7-214.
	Pre-ignition.	Set magneto timing. Refer to paragraph 7-223.
	Detonation.	Refer to paragraph 5-58.
	Excessive exhaust valve clearance.	Reset. Refer to paragraph 7-22.
	Loose intake pipe.	Tighten. Refer to paragraph 7-127.
	Improperly fitted air deflector.	Refer to paragraphs 7-144 and 7-148.
19. Noise in one cylinder when idling or when pulling through by hand.	Out-of-round tappet roller.	Replace tappet assembly. Refer to paragraph 7-136.
20. Improper valve clearance.	Incorrectly timed valve.	Refer to paragraph 7-22.
	Loose lockscrew in rocker arm.	Tighten. Refer to paragraph 7-22.
	Stretched valve stem.	Replace cylinder. Refer to paragraph 7-163.
	Defective bushing in rocker arm.	Replace rocker arm. Refer to paragraph 7-140.
	Defective tappet roller bushing.	Replace tappet assembly. Refer to paragraph 7-136.
	Bent rocker arm.	Refer to paragraph 7-140.
	Valve collapsed.	Replace cylinder. Refer to paragraph 7-163.
21. Damaged intake push rod.	Broken exhaust rocker arm in same cylinder causing excessive pressures.	Replace cylinder. Refer to paragraph 7-163.
22. Both push rods bent on same cylinder.	Broken connecting rod allowing piston hang up in combustion chamber.	Replace engine.
23. Detonation.	Loose spark plugs.	Tighten. Refer to paragraphs 7-214.
	Spark too far advanced.	Set magneto timing. Refer to paragraph 7-223.
	Pre-ignition.	Set magneto timing. Refer to paragraph 7-223.
	Wrong grade of fuel.	Refer to Section III for proper grade.
	Incorrect fuel-air ratio.	Adjust fuel-air ratio. Refer to paragraph 5-23.
	High master control air temperatures.	Inspect alternate air system.
	High cylinder head temperatures.	Check magneto timing. Refer to paragraph 7-223.
	Excessive MAP.	Reduce throttle setting.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
24. Pre-ignition.	Wrong type spark plugs.	Refer to Section III for proper type of plugs.
	Hot spot in cylinder.	Refer to paragraph 5-46.
25. Faulty distributor.	Incorrect timing.	Refer to paragraph 7-226.
	Breaker points worn or burned.	Replace distributor. Refer to paragraph 7-224.
	Points not properly tightened when installed.	Replace distributor. Refer to paragraph 7-224.
	Distributor finger loosened on shaft.	Replace distributor. Refer to paragraph 7-224.
	Replacement points not properly adjusted.	Replace distributor. Refer to paragraph 7-224.
	Distributor attaching screws not tight.	Tighten. Refer to paragraph 7-224.
	Mounting flange case holding screw loose.	Replace distributor. Refer to paragraph 7-224.
26. Burned breaker points.	Point clearance too small.	Reset point clearance.
	Faulty condenser.	Replace.
	Oil on points.	Replace and reset. Refer to paragraph 5-39.
27. One spark plug cutting out or dead.	Fouled plug.	Replace. Refer to paragraph 7-214.
	Spark plug lead or contact point defective.	Refer to paragraph 7-212.
	Defective high tension coil.	Replace coil. Refer to paragraph 7-209.
	Faulty wires in harness.	Replace harness. Refer to paragraph 7-206.
	Fouled distributor segments.	Replace distributor. Refer to paragraph 7-224.
28. Both plugs in one cylinder cutting out or dead.	Fouled plugs.	Replace. Refer to paragraph 7-214.
	Faulty high tension coil.	Replace. Refer to paragraph 7-209.
	Faulty wires in harness.	Replace. Refer to paragraph 7-206.
	Fouled distributor segments.	Replace distributor. Refer to paragraph 7-224.
	Cylinder pumping oil.	Refer to paragraph 5-69.
	Foreign particles in cylinder.	Replace cylinder. Refer to paragraph 7-163.
29. One or both plugs of each of two cylinders supplied by the same "Y" lead cutting out or dead.	Faulty ignition harness.	Replace harness. Refer to paragraph 7-206.
30. Nine plugs cutting out or dead on the front or on the rear of one bank of cylinders.	One set of service points fouled.	Replace distributor. Refer to paragraph 7-224.
	Condenser malfunction.	Replace distributor. Refer to paragraph 7-224.

TROUBLE SHOOTING CHART (CONT)

Trouble	Probable Cause	Correction
30. Nine plugs cutting out or dead on the front or on the rear of one bank of cylinders (cont)	One magneto coil defective.	Replace magneto. Refer to paragraph 7-221.
	Ground wire in magneto broken.	Replace magneto. Refer to paragraph 7-221.
	Ignition switch defective.	Replace switch.
	Distributor malfunction.	Replace distributor. Refer to paragraph 7-224.
31. Front or rear plugs cutting out on all cylinders.	Faulty right or left distributor.	Replace distributor. Refer to paragraph 7-224.
	Broken ground wires in magneto.	Replace magneto. Refer to paragraph 7-221.
	Ignition switch defective.	Replace. Refer to paragraph 5-12.
	Distributor malfunction.	Replace. Refer to paragraph 7-224.
32. On magneto check, all front plugs or rear plugs firing but engine does not develop power.	Distributor timing off.	Retime. Refer to paragraph 7-226.
33. All plugs in one bank of cylinders cutting out.	One magnet dead in magneto.	Replace magneto. Refer to paragraph 7-221.
34. Thirty six plugs cutting out or dead.	Faulty ignition switch.	Replace.
	Ground wires in magneto broken.	Replace magneto. Refer to paragraph 7-221.
	Both magnets weak or dead in the magneto.	Replace magneto. Refer to paragraph 7-221.
	Defective impeller oil seals permitting oil to enter the induction passage.	Replace engine.
35. All thirty six plugs firing but engine does not develop power.	Magneto not timed close enough.	Refer to paragraph 7-223.
	Distributor not timed close enough.	Refer to paragraph 7-226.
36. Metal or foreign material in strainer, screens, or sumps.	Lack of care in assembling engine.	Replace engine.
	Damaged engine parts.	Replace engine.
	Foreign material in the oil or oil system.	Replace engine.
	Contaminated oil cooler.	Change cooler.
37. Unstable operation while taxiing.	Fouled spark plugs.	Replace. Refer to paragraph 7-214.

Section VI

SERVICE INSPECTION AND ASSOCIATED MAINTENANCE

6-1. GENERAL.

6-2. The work outlined in this section is a normal function of operating activities. It consists of inspection procedures and such maintenance work as is associated with the routine inspection system.

CAUTION

It is possible for a fuel injection engine to fire after it has been shut down and is supposedly cold. A cold fuel injection engine should be regarded as a hot engine even though the ignition switch is at the "OFF" position.

6-3. The engine manufacturer recommends four inspection periods: Installation, Pre-Flight, Post-Test Flight, and Periodic. The periodic check will be performed at any time during a span of not more than 100 hours, at the operator's discretion.

6-4. INSTALLATION INSPECTION.

6-5. Immediately after an engine has been installed in an aircraft, make the following inspections:

a. Locking Devices - Inspect all cotter pins, locking plates, and lock wire for security.

b. Connections - Inspect all fuel and oil line connections. Check all pressure line connections. Ensure that magneto and spark plug connections are secure.

c. Hoses, Lines, and Leads - Inspect all hoses, lines, and ignition leads for general condition and security.

d. Leaks - Inspect the entire engine for oil leaks and the fuel system for fuel leaks.

e. Accessories - Ensure that all accessories are secure.

f. Deflectors - Inspect the general condition of deflectors, checking carefully for broken, worn, or abnormally bent deflectors. Ensure that some clearance exists between deflectors and cylinder fins and that fasteners are secure.

g. Cylinder Fins - Inspect cylinder fins for cleanliness, cracks, or damage.

h. Thrust Bearing Nut - Inspect the thrust bearing nut for tightness. If necessary, torque the nut as instructed in paragraph 7-27.

6-6. PRE-FLIGHT INSPECTION.

6-7. PRE-STARTING PROCEDURE.

a. Pre-oil the engine if necessary.

b. Ensure that no tools or equipment are lying loose on or about the engine or airplane and that all fastenings are properly secured.

c. Check the fuel and oil supply for proper grade and quantity.

d. Check the engine controls for smooth movement and full travel.

e. Ensure that all engine instruments are functioning properly.

f. Head the aircraft into the wind.

g. Set the following controls as indicated:

Cowl Flaps	"OPEN"
Oil Cooler Flaps	"AUTO"
(If manually operated)	"CLOSED"
Master Control Air	"DIRECT"
Ignition Switch	"OFF"
Spark	"RETARD"
Mixture	"IDLE CUT-OFF"
Propeller . . . (low pitch)	"INCREASE RPM"
Supercharger . . . (locked)	"LOW"
Alternate Fuel Metering System	"OFF"

h. Note the MAP reading before starting for use during ground checks. Compare the reading to field barometric pressure.

NOTE

Turn the propeller through at least two revolutions with the engine starter. If there is unusually high compression, remove the spark plugs from the lower cylinders and drain all liquid, as the presence of any quantity of liquid in a combustion chamber is likely to cause serious damage. Never turn the propeller opposite engine rotation as this may force liquid into an intake pipe where it is apt to be drawn into the cylinder when the engine is started.

6-8. STARTING PROCEDURE. Set the following controls as indicated:

Throttle . . . . Set for 1200 rpm

NOTE

In temperatures below freezing, starting is improved by setting the throttle nearer the closed position.

Fuel Boost Pump . . . . "ON" (low)
Starter . . . . "ENGAGE"
Ignition Switch . . . . "BOTH"
(after propeller has turned two revolutions)
Ignition Booster . . . . "ON"
Mixture Control . . . . . Move from "IDLE CUT-OFF" to "AUTO RICH" for normal engine starts.

NOTE

If a warm engine does not fire after two revolutions, or if the engine loads up, move the mixture control to "IDLE CUT-OFF" momentarily. Return the mixture control to "AUTO RICH" after firing occurs. Hot engines will often start with the mixture in "IDLE CUT-OFF". If firing does not occur after two revolutions, move the mixture control to "AUTO RICH". Should the engine fail to start within 30 seconds, let the starter cool and then repeat the starting procedure.

Throttle . . . . Reset for 1200 rpm (do not allow engine to exceed 1400 rpm on start)

NOTE

Observe the oil pressure gage. Stop the engine if the oil pressure does not register within 10 seconds or reach 40 psi within 20 seconds.

Fuel Boost Pump . . . . "OFF"

6-9. Cold weather starts should be made with the throttle closed using either the mixture control or primer. If primer starts are made, the mixture control should remain in "IDLE CUT-OFF" until a positive start with smooth operation is obtained. Simultaneous use of both primer and mixture control during starting often results in exhaust system fires.

6-10. Following initial firing, and disengagement of the starter, the engine will often "motor" at low speed, rather than accelerate to the normal idle speed. Allow the engine to run at this condition until speed increases to normal idle speed. Premature application of throttle, or attempts to vary the mixture will stop the engine. Such a false start results in "iced" spark plugs, preventing successful starting on following attempts.

6-11. ENGINE WARM UP. Operate the engine at 1000 - 1400 rpm until the oil inlet temperature reaches 40°C (104°F) or if already above 40°C (104°F) at start, until a definite rise over the pre-starting temperature is indicated, and the oil pressure is stable.

NOTE

The minimum torque pressure with the reverse flow torquemeter is dependent on the crankcase front section oil pressure. This pressure in turn is affected by crankcase main and front section oil pressure settings as well as the oil inlet temperature. Therefore oil pressure should be set as recommended and oil inlet temperature be above 40°C (104°F) to complete a satisfactory auto-feathering system check prior to take off.

6-12. GROUND OPERATION. Unless otherwise specified to accomplish ground run-up checks, all warm-up and ground operation of the engine should be accomplished with the controls set as follows:

Ignition switch. . . . . "BOTH"
Mixture. . . . . "AUTO RICH"
Alternate Fuel Metering Source . . . . "OFF"
Water Injection . . . . "OFF"
Spark . . . . "RETARD"
Propeller . . . (low pitch) "INCREASE RPM"
Supercharger . . . . (locked) "LOW"
Cowl Flaps . . . . "OPEN"
Oil Cooler Flaps. . . . . "AUTO"
(if manually operated maintain within limits)
Fuel Boost Pump . . . . "OFF"
Master Control Air . . . . "DIRECT"

NOTE

Prolonged ground operation under severe icing conditions may require use of "ALTERNATE-AIR" and/or "HEAT." Shift to "DIRECT" prior to take-off.

6-13. GROUND CHECKS.

6-14. OIL PRESSURE. At 1500 - 1800 rpm with an oil inlet temperature of 80-85° C (176-185° F) the main oil pressure should be 65-75 psi.

6-15. FUEL PRESSURE. At 1500 - 1800 rpm, the fuel pressure should be 24-26 psi.

6-16. PROPELLER.

a. Set 1600 rpm with the propeller in full "INCREASE RPM" (low pitch).

b. Place the propeller control in full "DECREASE RPM" (high pitch) and note the rpm reaction.

c. Return the control to full "INCREASE RPM" (low pitch).

d. Check for reduction and full recovery of rpm.

e. Conduct additional propeller system checks as required.

6-17. SUPERCHARGER.

a. Set 1600 rpm with the throttle and shift to "HIGH" ratio and lock.

b. Advance throttle to approximately 30 inches MAP, stabilize and shift to "LOW" ratio. A sudden decrease of MAP indicates proper operation.

6-18. POWER PERFORMANCE.

a. Set the MAP equal to field barometric pressure with the throttle, and note the rpm, BMEP, and fuel flow obtained to cross-check engines of a multi-engine airplane.

b. In a multi-engine airplane, a variation greater than 100 rpm between engines should be investigated and corrective action taken.

6-19. MAGNETO.

a. Set the MAP equal to field barometric pressure with the throttle and note rpm and BMEP obtained.

b. Switch ignition to "LEFT" and note rpm and BMEP change.

c. Return ignition switch to "BOTH" and allow rpm to stabilize.

d. Repeat the procedure for the "RIGHT" ignition switch position.

e. Atmospheric conditions and spark timing will influence the readings obtained.

f. A drop of 75 rpm or less when operating on one magneto switch position is satisfactory providing no engine roughness is encountered.

NOTE

The use of BMEP as a measure of power loss during the magneto check is recommended to substantiate the rpm variation observed. A drop of 7-8 BMEP is considered equivalent to 75 rpm drop.

g. In cases of known richer than normal carburetion and for the presence of high atmospheric absolute humidity which effectively richens the fuel-air ratio, the following procedure is recommended, if the previous limits are exceeded:

1. Set MAP equal to field barometric pressure with the throttle.

2. Lean the mixture manually to best power setting (maximum BMEP).

3. Richen the mixture to obtain approximately 2 BMEP drop.

4. Conduct the magneto check as before. If the previous limits continue to be exceeded, the conditions should be investigated and corrective action taken.

6-20. MANUAL SPARK ADVANCE.

a. Set throttle to obtain 2000 rpm and lock.

b. Manually lean mixture to obtain 1900 rpm.

c. With the ignition switch on "LEFT," select "ADVANCE" spark and note change in rpm and BMEP. Return spark to "RETARD" and ignition switch to "BOTH".

d. Repeat the above procedure with the ignition switch on "RIGHT".

e. Check for a definite rise of 3-6 BMEP or approximately 25 rpm. If no rise occurs, the mechanism may be locked in either "RETARD" or "ADVANCE" and the discrepancy should be corrected prior to the use of any power setting above 2400 rpm.

NOTE

In lieu of the previous procedure the spark advance system may be checked with an ignition analyzer by noting the pattern shift when switching from "ADVANCE" to "RETARD". If it is established by the ignition analyzer that a distributor is locked in "RETARD", but not in "ADVANCE", the airplane may continue to schedule termination at which time the distributor should be corrected.

6-21. ALTERNATE FUEL METERING SOURCE (AFMS)

a. Set 2000 rpm with the throttle.

b. Switch AFMS "ON" momentarily.

c. Check for a definite increase in fuel flow.

6-22. WATER INJECTION.

a. Set 2000 rpm with the throttle.

b. Place water injection switch "ON".

c. Advance throttle to approximately 50 inches MAP. At approximately 45 inches MAP, fuel flow should definitely decrease.

d. Place water injection switch "OFF". Check for fuel flow increase and power decrease.

6-23. IDLE MIXTURE.

a. Check at closed throttle and above 150°C (302°F) CHT.

b. Check for a stable idle speed of 500-800 rpm.

c. If the idle speed is not in this range with the throttle in the "CLOSED" position, adjust the rpm by unscrewing the throttle stop until the 500-800 rpm range is obtained.

d. Momentarily energize the primer and check for:

1. Increase in MAP and decrease in rpm, or
2. Slight MAP decrease and rpm increase (25 rpm).

e. A lean best power setting is desirable for spark plug anti-fouling purposes, however, increases in rpm in excess of approximately 25 rpm indicates that the mixture is too lean.

f. Slowly move the mixture control toward "IDLE CUT-OFF" and check for MAP increase and rpm decrease.

g. A decrease in MAP accompanied by an increase in rpm indicates the mixture is too rich.

6-24. IDLE MIXTURE ADJUSTMENTS. If these checks prove that the idle mixture adjustment is incorrect, make the adjustment as follows:

a. Adjust the master control throttle stop to give an engine speed of 500-800 rpm. Lock the throttle control to hold this speed.

b. Loosen the idle mixture adjustment lock screw. See figure 6-1. Turn the idle mixture adjuster, one notch at a time (clockwise to enrich the mixture, counterclockwise to lean the mixture), until the lowest manifold pressure and the highest rpm can be obtained.

c. Readjust the idle speed to the rpm in step a with the master control stop and relock the throttle control.

d. Again move the idle mixture adjuster until the lowest manifold pressure and the highest rpm are reached. Tighten and lockwire the idle mixture adjustment lock screw.

e. Ensure that the cylinder head temperatures are above 150°C (302°F).

f. With the throttle control in the "CLOSED" position, reset the master control stop to give the minimum idle speed desired.

NOTE

Wind conditions, which effect the load on the propeller and, therefore, the rpm reading, should be taken into consideration when making this idle speed setting.

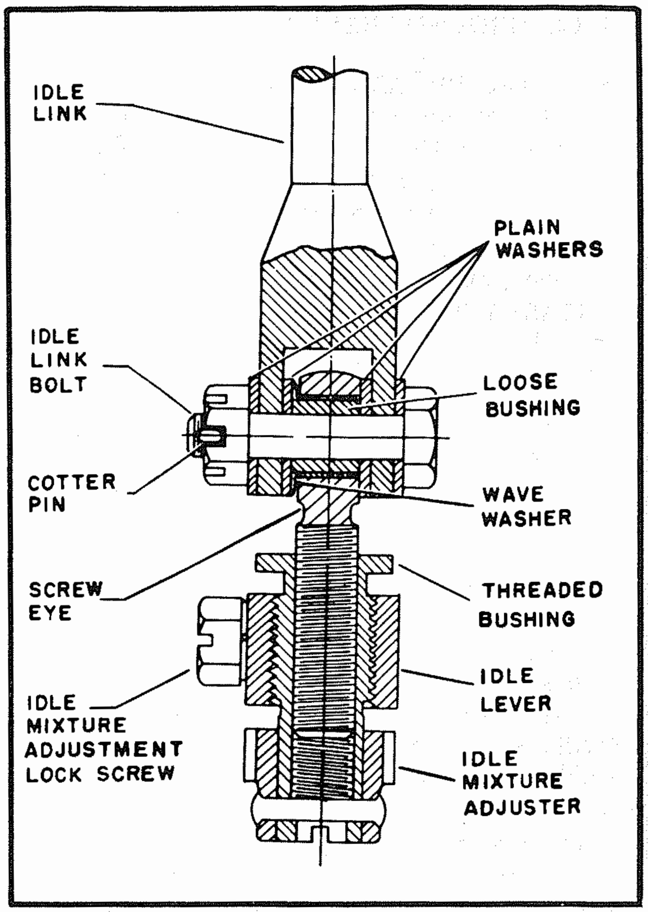


Figure 6-1. Cross-Section of Idle Mixture Adjustment

6-25. IGNITION SWITCH CIRCUIT.

a. At idle speed, place the ignition switch in the "OFF" position momentarily and return the switch to "BOTH".

b. Check to see that the engine ceases to fire with the switch "OFF".

NOTE

This check is made to assure that the magneto ground has not been broken, for without this ground connection, the ignition system cannot be made inoperative and the engine would be dangerous for ground handling. The check is normally not necessary when a drop in rpm is experienced during the magneto check, for if either the "LEFT" or "RIGHT" magneto switch position is not grounded, no drop will occur when checking the opposite magneto switch position.

6-26. SPARK PLUG ANTI-FOULING METHODS. In the event of prolonged ground operation, the following procedures are recommended to prevent spark plug fouling:

Low Power Operation

rpm	800-1200 rpm
mixture	Lean until the rpm drops slightly (25 rpm). There is no time limit for this operation; however; it is recommended that the CHT not exceed 200°C (392°F).
1340 BHP Operation.	Operate at this power one minute for each 15 minutes of ground operation. If the rpm, when operating on propeller low pitch stop, violates propeller ground running restrictions, select another suitable rpm - BMEP setting to obtain 1340 BHP. It is recommended that the CHT not exceed 200°C (392°F).

6-27. OIL DILUTION. When oil dilution is mandatory, dilute the oil before stopping as follows:

a. Idle the engine until the oil temperature falls to 40°C (104°F).

b. Dilute at 1000 to 1200 rpm.

c. Maintain the oil temperature below 50°C (122°F) and the oil pressure above 15 psi during this procedure.

d. Hold the oil dilution switches "ON" for the time specified by the aircraft manufacturer.

NOTE

If a hydromatic propeller which uses engine oil is used, the propeller governor control and feathering system should be operated several times during the dilution process to ensure that properly diluted oil is left in the propeller dome, governing system, and feathering lines. When operating the governor control, ensure that the engine rpm is above the minimum governing speed. When operating the feathering system, pull out the feathering switch after a 300 to 400 rpm drop has been obtained, wait for recovery of rpm, and then repeat this procedure.

CAUTION

The oil supply of an engine in which the oil has been diluted should be checked after a thorough warm-up, prior to repeating the dilution cycle or proceeding to take off on the next flight.

6-28. ADJUSTMENT OF IDLE MIXTURE LINKAGE TO SHIFT THE MIXTURE ADJUSTMENT RANGE. See figure 6-1. When the idle mixture adjuster has insufficient travel to obtain the correct idle mixture, readjust as follows:

a. Disconnect the idle link from the screw eye by removing the link bolt.

b. For leaner mixture, screw the eye into the threaded bushing. For richer mixture, screw the eye out of the bushing. One revolution of the screw eye is equivalent to approximately 13 notches of the idle mixture adjuster.

c. Reconnect the idle link and the screw eye (figure 6-1). Ensure that the wave washer fits over the OD of the loose bushing between the screw eye and the plain washer.

d. Tighten the castellated nut until the idle link yoke and the plain washers clamp the loose bushing. The wave washer allows freedom of movement without looseness.

e. Operate the engine and make the mixture checks and adjustments as instructed in paragraph 6-23. In extreme cases, it may be necessary to adjust the screw eye several turns before it is correctly located. The idle mixture will be correct when the mixture adjuster is at about the center of its travel.

6-29. REVERSE PITCH OPERATION.

6-30. Reverse pitch operation should be accomplished as early as possible during the landing roll to achieve maximum braking at normal power with minimum effect on engine cooling.

CAUTION

Reverse operation for taxi purposes is to be avoided if possible. If such operation is required, it must be limited to a maximum period of 30 seconds.

6-31. ENGINE SHUT-DOWN

6-32. If the engine has been warmed by taxiing, idle until the cylinder head temperatures drop to at least 150°C (302°F) or to a value consistent with existing ambient temperature. Operate engine below 1000 rpm for a minimum of 30 seconds to ensure optimum crankcase scavenging and reduce the possibility of hydraulic lock on a subsequent start. Taxiing the airplane below this rpm will further improve oil system scavenging. Shut down the engine as follows:

a. Throttle . . . . "CLOSED"
b. Mixture . . . . "IDLE CUT-OFF"
c. Ignition Switch .(after engine stops) "OFF"

CAUTION

There is some tendency for a hot fuel injection engine to fire when being pulled through with the ignition switch "OFF". Therefore, it is recommended that manually positioning the propeller after shut-down be prohibited to avoid possible injury to ground crew. If positioning of the propeller is required, it is recommended that it be accomplished with the engine starter.

NOTE

Do not close cowl flaps, regardless of weather, until the engine has cooled. Closing the cowl flaps immediately after shut-down may cause damage from excessive soak temperatures. If the engine is to be idle for an extended period of time or if dusty conditions exist, cover all openings after the engine has cooled.

6-33. POST-TEST FLIGHT INSPECTION.

6-34. After initial test flight, inspect the engine as instructed in paragraph 6-5 and, in addition, as follows:

6-35. STRAINERS AND MAGNETIC PLUGS. Dirt will collect on the outside of all scavenge strainers since the oil passes from the outside inward. Dirt will collect on the inside of the pressure strainer since the oil passes from the inside outward. Except for the rocker box drain manifold strainer, all scavenge oil flows over a magnetic drain plug on its way to a scavenge strainer. Analyze any material caught by the oil strainers or the magnetic plugs for indication of internal trouble. Silver flakes or chips may be distinguished from aluminum in that small particles of aluminum will dissolve in a caustic solution (50 per cent sodium hydroxide). Wash strainers and magnetic plugs before reinstallation. Use new oil seals and apply Lubriplate 130A to all plugs before installation. Inspect the following strainers and magnetic plugs:

a. Fuel strainer in master control (item 28, figure 1-5).

b. Scavenge strainer in rear oil pump (item 16, figure 1-5).

c. Scavenge strainer in front oil pump (item 12, figure 1-3).

d. Scavenge strainer in rocker box drain manifold (item 2, figure 1-6).

e. Pressure strainer in rear oil pump (item 20, figure 1-4).

NOTE

The disc type pressure oil strainer must be completely disassembled for inspection as instructed in paragraph 7-103. Since dirty oil may by-pass a clogged pressure strainer and foreign particles may spill out of the strainer at removal, thoroughly inspect the pressure strainer cavity in the pump, both with a light and with the fingers.

f. Magnetic drain plugs in front and rear pumps (items 5 and 11, figure 1-6).

6-36. PERIODIC INSPECTION.

6-37. GENERAL. Periodic inspection consists of an external visual check of the engine. Inspect as instructed in paragraphs 6-4, 6-33 and 6-38 through 6-42.

6-38. PRESSURE OIL STRAINER. The disc type pressure oil strainer must be completely disassembled for cleaning and inspection. If a 65 mesh screen with .0065 inch openings is used, it must be cleaned at intervals of 10 to 20 hours, unless pressure differential checks indicate that this time limit may be extended. The following cleaning intervals are recommended when using a pressure oil strainer incorporating a 40 mesh screen with .0115 inch openings in conjunction with a 40 psi by-pass valve setting:

Single element strainer	20 hours
Single element strainer with external disc type scavenge filter	50 hours
Double element strainer	30 hours
Double element strainer with external disc type scavenge filter	100 hours

NOTE

It is recommended that the external scavenge filter be cleaned when the oil-in filter is cleaned, or if the pressure differential across it reaches 9 psi.

6-39. POWER RECOVERY TURBINES. Remove the flight hood and the cooling shield assembly from the turbine and make the following inspection:

a. Rotate the turbine wheel by hand. The wheel must rotate freely. If binding is encountered, take up all end float by pulling the wheel away from the engine and then rotating the wheel by hand. If binding is not evident when the wheel is rotated in this manner, the condition is acceptable. If binding still exists, remove the turbine and turn the PRT gear coupling to determine if the binding is caused by the PRT or the fluid coupling.

b. Check the turbine wheel and buckets for any nicks, cracks, burrs or any odd condition that will indicate damage.

6-40. POWER RECOVERY TURBINE NOZZLE.

a. Cracks in nozzle casting outer flange. Cracks less than 5/8 inch in length, measured in one plane at any point on the circumference, are acceptable. There is no restriction on the number of cracks permitted as long as no crack exceeds the 5/8 inch limit.

b. Cracks in solid vane of nozzle casting are not acceptable.

c. Cracks in split vane of nozzle casting. Cracks which do not exceed 1/4 inch in length are acceptable. There is no restriction on the number of cracks permitted provided that no crack exceeds the 1/4 inch limit specified.

d. Cracks in inner vane wall of nozzle casting are acceptable.

e. Cracks on nozzle inlet pipe ball joints are not acceptable.

f. Replace a turbine assembly if the gap is completely closed on any of the split vanes in the nozzle.

6-41. POWER RECOVERY TURBINE COOLING AIR SHIELD.

a. Cracks in the tubular supports are not acceptable.

b. Cracks in tubular support bushing welds. One or more cracks around any bushing weld is acceptable, providing the crack, or cracks, or any combination thereof, does not extend beyond 180 degrees around the bushing.

c. Cracks in inner flange to inner shield brace. Cracks in the shield braces, or their attaching welds to shield and inner flange, are not acceptable.

d. Cracks in the outer flange at the locating lug. Cracks from the locating lug holes to the OD of the flange are acceptable. Cracks from the locating holes to the ID of the flange are not acceptable.

e. Outer shield to cooling air outlet weld seam. Individual cracks which do not exceed one inch in length are acceptable. Cracks which are less than one inch in length should be stopped by drilling a hole. Use a No. 50 drill for this purpose.

f. Wear on the intermediate or outer cooling shield reinforcing ring is acceptable if it does not exceed one-half the original metal thickness.

g. Replace PRT cooling shields as necessary. If clearances are such that the shield cannot be readily installed in the groove on the nozzle flange, light tapping is permitted. Do not file the shield.

6-42. ACCESSORIES. Inspection of accessories, except for security, is not considered necessary unless the part is involved in trouble shooting procedures.

6-43. SPECIAL INSTRUCTIONS.

6-44. POWER RECOVERY TURBINES. Daily ensure that the power recovery turbine wheels turn freely by hand.

NOTE

Paragraphs 6-44 through 6-61 cover operations and inspections that may be performed, as necessary, at the operator's discretion.

6-45. SPARK PLUGS. Due to basic differences in design, spark plugs may be changed in accordance with the operator's experience.

6-46. VALVE CLEARANCE. (See paragraph 7-22).

6-47. OIL CHANGE. Oil changes are recommended at intervals not to exceed 400 hours. However, engine operating conditions determine the need for a complete oil change. Therefore, an oil change period greater than 400 hours can be established at the operator's discretion. Drain the oil while it is hot to dispose of the greatest amount of sludge and foreign particles. Following an oil change, bleed the line from the supply tank to the pressure pump as instructed in paragraph 4-32.

6-48. CYLINDER COMPRESSION CHECK. Refer to figure 6-2. If a cylinder compression check is necessary, proceed as follows:

a. Connect two pressure gages to the transformer of fixture 803763. Connect the fixture hose to one end of the transformer and a pressure air line to the other end.

b. Remove the front spark plug from each cylinder and bring the piston in cylinder No. 1 to top center on the compression stroke.

NOTE

If dummy plugs are installed in the rear spark plug ports, ensure that they are not vented.

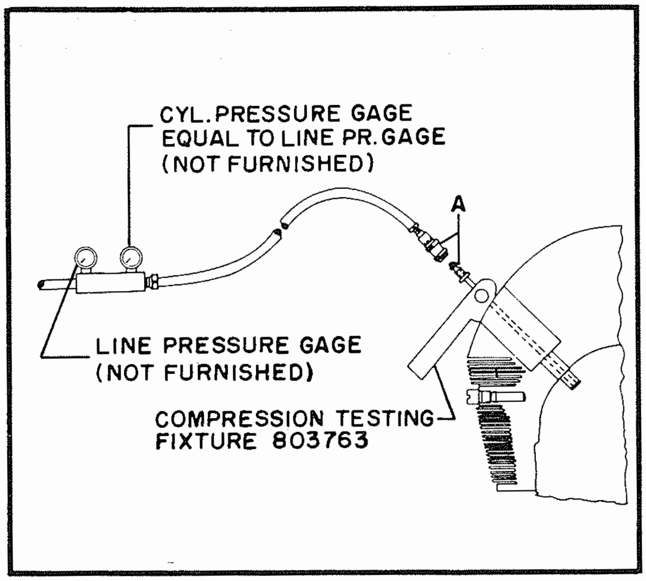


Figure 6-2. Cylinder Compression Test Equipment

c. Install the expansion plug of the fixture in cylinder No. 1 front spark plug port. Attach the gage and hose assembly to the plug at point A, figure 6-2.

d. Install a method of stabilizing the propeller shaft to ensure that the propeller shaft does not turn during the compression check.

e. Allow a line pressure of 80 psi to enter the fixture assembly. The cylinder pressure gage will drop.

f. If there is no excessive leakage in the cylinder, cylinder pressure will gradually build up to equal line pressure.

g. If cylinder pressure does not build up, it is evident that there is leakage. Excessive leakage at the exhaust valve can be heard by listening for escaping air at the exhaust port, at the intake valve by escaping air at the master control, and past the piston rings by escaping air at the engine breather.

h. Test the rest of the cylinders in the same manner, following the firing order of the engine.

6-49. INTAKE PIPE CONNECTION NUT. At the periodic check closest to 100 hours, and not to exceed 100 hours after overhaul, check all the intake pipe connection nuts for tightness. Tighten as necessary as instructed in paragraph 7-127. This check need not be repeated again unless new packings are installed on the intake pipes. In this case, the nuts associated with the new packings must be checked for tightness and tightened again as necessary, approximately 100 hours after installation.

6-50. FUEL INJECTION TUBE LEAKAGE PRESSURE TESTING. If a fuel injection pump or any external tubes have been replaced, or if leakage is suspected, the tubes should be pressure tested, using one of the methods described in paragraphs 6-51, 6-52, or 6-53.

6-51. PRESSURE TEST WITH FUEL BOOST PUMP. Turn the fuel boost pump "ON". Move the manual mixture control to "AUTO-RICH". Ensure the magneto switch is "OFF" and turn the engine not more than six propeller revolutions with the starter. Inspect for fuel leakage.

CAUTION

It is possible for a supposedly cold engine to fire during this check. Ensure that the propeller area is clear when turning the engine with the starter.

6-52. PRESSURE TEST WITH TUBES AND PUMPS ON ENGINE. With the tube assemblies and the fuel injection pumps installed on the engine, a complete individual line check can be made on two lines simultaneously from the tube seal nuts disconnected at the nozzles to and including the adapter flange seals. See figure 6-3, view A, and proceed as follows:

a. Using a 9/16 inch wrench, disconnect the lines at the fuel injection nozzles by removing the connector tube seal nuts. Install an oil seal ring into each adapter 808629 (A) and attach the connector tube seal nuts of each of the two lines to be tested to an adapter (A). Use a 9/16 inch and a 3/4 inch wrench.

b. Attach each adapter (A), with tubes, to one end of an adapter 807514 (B) and, using a 3/4 inch wrench connect the other end of the adapter (B) to hydraulic fixture 807070.

c. Ensure that all connections are tight and that the fixture needle valve is open.

d. Using engine fuel, build up 1500 psi pressure with the fixture pump. Close the needle valve and check the pressure gage reading. Pressure should be maintained for two minutes.

e. If the pressure drops, inspect the lines for leakage. Replace a section of defective line or tighten the connections, as necessary.

f. Repeat the check if repairs have been made.

6-53. PRESSURE TEST OF TUBES WITHOUT PUMPS ON ENGINE. With the tube assemblies installed on the engine and the pumps removed, a complete individual line check can be made on two lines simultaneously from the pump ends of the lines to the nozzle ends, the nozzle connector tube seal nuts being capped. See figure 6-3, view B, and proceed as follows:

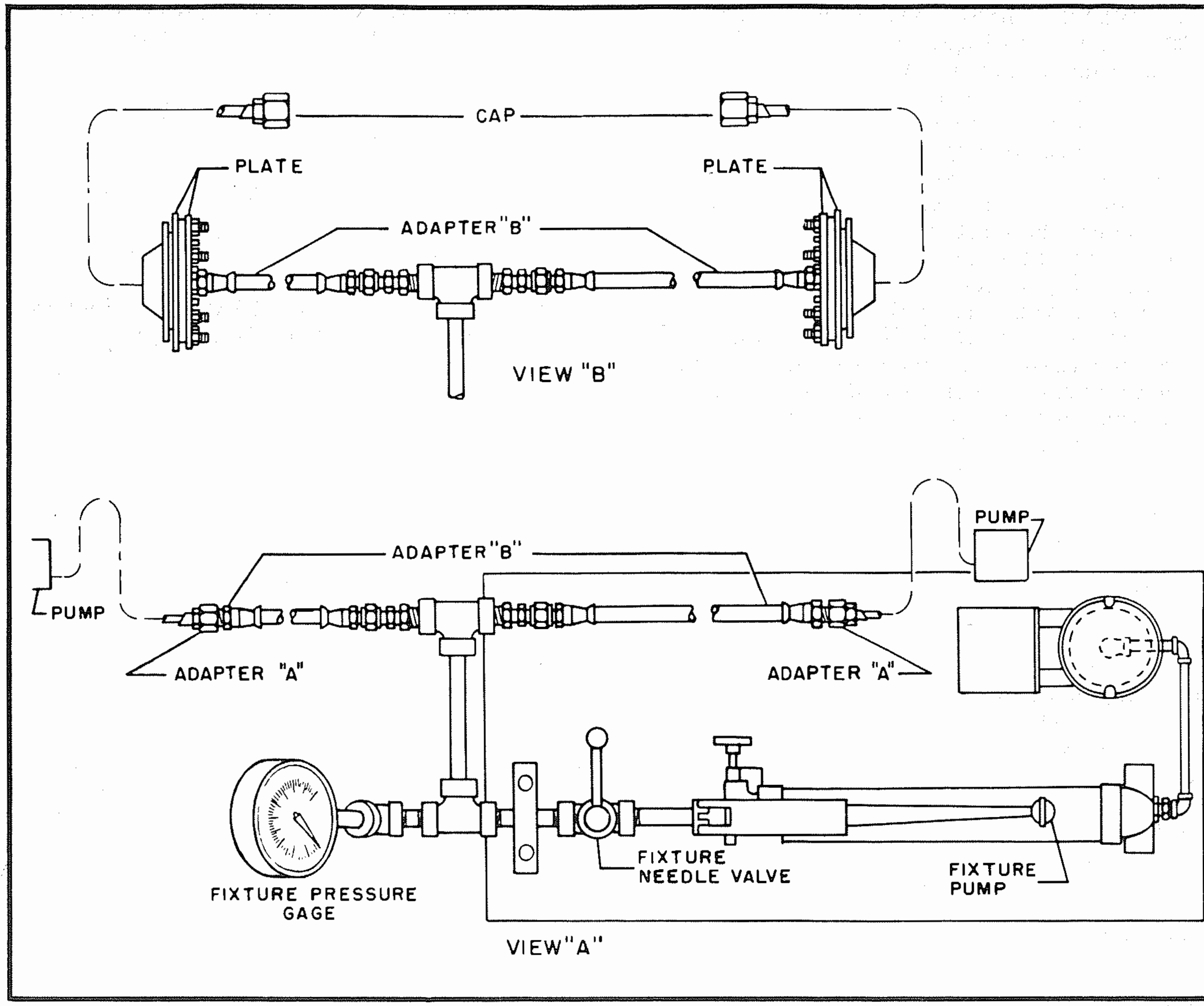


Figure 6-3. Fuel Injection Lines Pressure Leakage Test Equipment

a. Using a 9/16 inch wrench, disconnect the lines at the fuel injection nozzles by removing the tube seal nuts. Install a cap 807071 to the tube seal nuts of each of the two lines to be tested. Use a 9/16 inch and a 7/8 inch wrench.
b. Install an oil seal ring in the counterbore of the nine test holes in the bottom of the base of each of two pressure test plates 808630, and attach a test plate assembly to each fuel injection pump adapter.
c. Attach one end of an adapter 807514 (B) to the fitting for the line being tested on each pressure test plate. Connect the other end of adapters (B) to hydraulic fixture 807070.
d. Ensure that all connections are tight and that the fixture needle valve is open.
e. Perform the test as instructed in paragraph 6-52, steps d through f.

6-54. INSPECTION AFTER PROPELLER DAMAGE AND SUDDEN STOPPAGE. Sudden stoppage is interpreted to mean complete stalling of the engine due to the propeller colliding with any object. It may cause overstressing and distortion of internal engine parts or assemblies. Further operation of the engine in this condition may result in extensive damage to the engine. Therefore, when an engine has had such an accident, remove it from aircraft and return to overhaul.
a. If the collision results in the propeller being bent outside of permissible alignment limits, replace engine even though it may not have stalled.
b. If the propeller has been only slightly damaged, as evidenced by nicks, dents, and scratches, with no indication of blade bending or misalignment, and sudden stoppage is not experienced, inspection of the damage should be made by competent personnel to determine further action.

6-55. MASTER ROD AND ARTICULATED RODS. The service limits established for overhaul activities are outlined in the following steps to help the operator evaluate engine reliability.

a. If valve damage is experienced to the extent that the resultant damage to the piston is cause for rejection of the piston, the articulated or master rod is to be rejected.

b. If a piece is broken from the piston, the articulated rod or master rod is to be rejected.

c. If a piston pin should break, the articulated rod or master rod is to be rejected.

d. If a cylinder should experience difficulties that would cause damage to the piston, to the extent of necessitating rejection of the piston, the articulated rod or master rod is to be rejected.

e. If an articulated rod or master rod is damaged, it is cause for rejection of all rods in the row of cylinders in which the mishap occurred.

6-56. If power trouble is experienced due to valve, piston or piston pin, cylinder, master rod or articulated rod malfunction, the engine should be repaired or replaced immediately. If any of the discrepancies are noted at an overhaul station the master rod and the articulated rod or rods must be rejected. If the malfunction should occur at a station where a replacement engine is not available and, due to the difficulties that may be experienced, repairs cannot be made, the trouble, at that time, will be evaluated, according to standard checks and inspections, to determine the feasibility of continued service operation of the engine. A thorough inspection of the affected articulated rod or master rod, its piston pin and bushing, and piston underside should be made. Inspect all the components for possible breaks, nicks, distortion and any other evidence of abnormal stress or wear.

6-57. If after a thorough inspection, the associated components are deemed satisfactory, the engine, at the discretion of the operator, may be continued in operation until such time as the aircraft arrives at a facility where the engine change can be accomplished. A further discretion is possible in this matter at the option of the operator. If an examination of the effected cylinder and/or piston proves conclusively that the articulated rod or master rod and its associated components could not have been subjected to abnormal loading as a result of the difficulty experienced, and a thorough visual inspection of these latter parts reveal no discrepancy, the engine then may be continued in service until the expiration of its normal overhaul period. The authorization for time extension in either case is solely the responsibility of the operator.

6-58. BREAKAGE OR LOOSENING OF CYLINDER HOLD-DOWN CAP SCREWS. If at any time after engine operation, one or more of the cylinder hold-down cap screws are found to be loose or broken at any location, the cylinder involved must be replaced and all hold-down cap screws used on that cylinder scrapped. A tag bearing the reason for removal should be attached to the removed cylinder and the cylinder returned to an overhaul base for appropriate disposition.

6-59. CYLINDER HEAD CRACKS. Cylinders may be considered serviceable if they meet with the following conditions:

a. Cracks must be confined to the rear spark plug boss area.

b. Cracks must not cross a fin from one fin groove to the next.

c. The crack must not exceed two inches in length.

d. There must be no exhaust or oil leakage from the crack.

e. Log book entries must be made to identify the cylinder, the cracked area and the extent of the crack.

f. Follow-up inspections must be made at major check periods.

g. The cracked cylinders must be removed at the end of the engine overhaul cycle.

h. No cracked cylinders are to be installed during line maintenance.

6-60. Cylinders that evidence leakage, are cracked in areas other than the rear spark plug boss location, fail to meet any one of the conditions listed above or exhibit cracks that are too long or too deep, should be removed from service.

6-61. CYLINDER INVOLVED WITH BURNED PISTON.

a. A cylinder in which a piston has experienced a hole burned through the dome or down the side must be rejected.

b. A cylinder in which piston aluminum material has been fused to the cylinder barrel ID must be rejected.

NOTE

The above conditions may reject a cylinder that visual and magnetic inspection may prove satisfactory, but it must be rejected regardless.

c. A rejected cylinder can be rebarreled and used. The removed barrel must be scrapped.

Section VII

ADJUSTMENT REPLACEMENT AND MINOR REPAIRS

7-1. GENERAL.

7-2. The work outlined in this section can be performed with facilities available at operating activities.

7-3. The engine parts considered in this section may be removed, replaced, or adjusted while the engine is installed in an airplane. The airplane should, therefore, be placed in a hangar to protect the engine from dust, dirt, and inclement weather conditions. The importance of covering an opening immediately upon exposure cannot be over-emphasized.

7-4. Remove all parts of the cowling that would interfere with the work to be done. Many paragraph headings in this section are immediately followed by a list of engine parts. Each item in the list will correspond to a heading located elsewhere in the section. When it becomes necessary to remove a part that cannot be taken from the engine without disturbing other parts, use this list as a guide. Remove each part in the order in which it appears in the list and according to instructions under the corresponding head, then remove the part in question. Unless otherwise specified, parts should be replaced in the reverse order.

7-5. Wash all parts to be installed on the engine. Use one of the following petroleum solvents:

Varsol (Colonial Beacon Oil Co., Boston, Mass.)
Sovasol No. 5 (Socony - Mobil Oil Co., New York, N.Y.)
Oleum (The Texas Co., New York, N.Y.)
Stoddard Solvent (Standard Oil Co. of California, San Francisco, Cal.)

7-6. Carefully inspect all parts to ensure that:
a. Dust or chips are not present.
b. Oil passages are free from obstructions.
c. Threads of all studs, bolts, etc., are free from nicks and burrs. Coat all moving parts with clean engine oil.

7-7. Always use new hose connections, packing rings, cotter pins, lock wire, gaskets, and lock washers.

7-8. Do not tap fiber lock nuts. They may be re-used until such time as the fiber portion has taken sufficient thread set to permit their being screwed down over a stud or bolt by hand. When this point is reached, the nuts must be replaced. Fiber lock nuts should show at least one and one-half threads of the end of the stud or bolt beyond the fiber material when the nut has been tightened to its final torque value. Fiber lock nuts should not be subjected to temperatures in excess of 121°C (250°F).

7-9. The Table of Limits, Tables of Tightening Torque Values, and general instructions for the use of a torque wrench are included in Section IX.

7-10. Always apply sealing compound to the male thread of threaded joints and, when desired, apply sparingly to the female thread. Apply compound only to the metal fitting for hose connections. Use the compounds listed in the following Table unless otherwise specified.

Compound	Application
Rubber Cement Goodrich A75B (B. F. Goodrich Co., Akron, Ohio)	Threaded joints, such as screw bushings, fittings, cylinder cap screws, metal fittings of hose connections.
Sealing Compound, Titeseal (lightweight) (Radiator Specialty Co., Charlotte, N.C.)	Gaskets
Anti-seize Compound, Lubriplate 130A (The Lubriplate Corp., 20 Exchange Place, New York, N.Y.)	Rubber oil seal rings to facilitate installation and pipe thread plugs.

7-11. When it is necessary to remove the propeller before performing any of the operations in this section, do so in accordance with the propeller manufacturer's instructions. Use protector 801332 (figure 7-1) on the propeller shaft whenever the propeller is removed. Whenever it is necessary to turn the propeller shaft, use turning tool 806917 (figure 7-2).

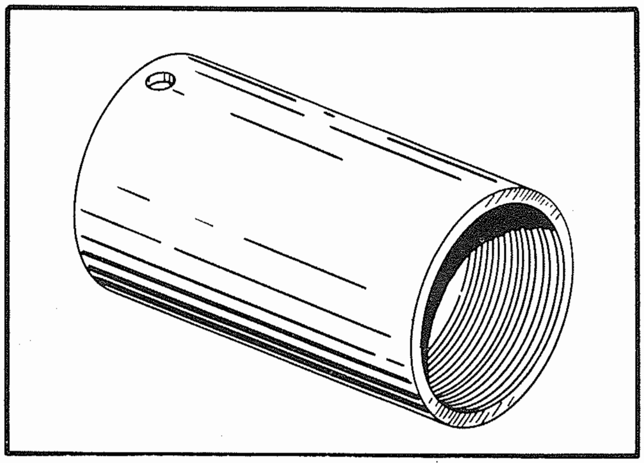


Figure 7-1. Propeller Shaft Thread Protector

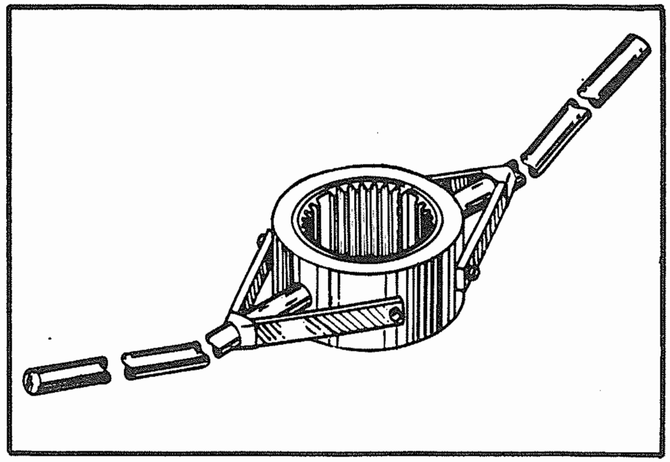


Figure 7-2. Propeller Shaft Turning Tool

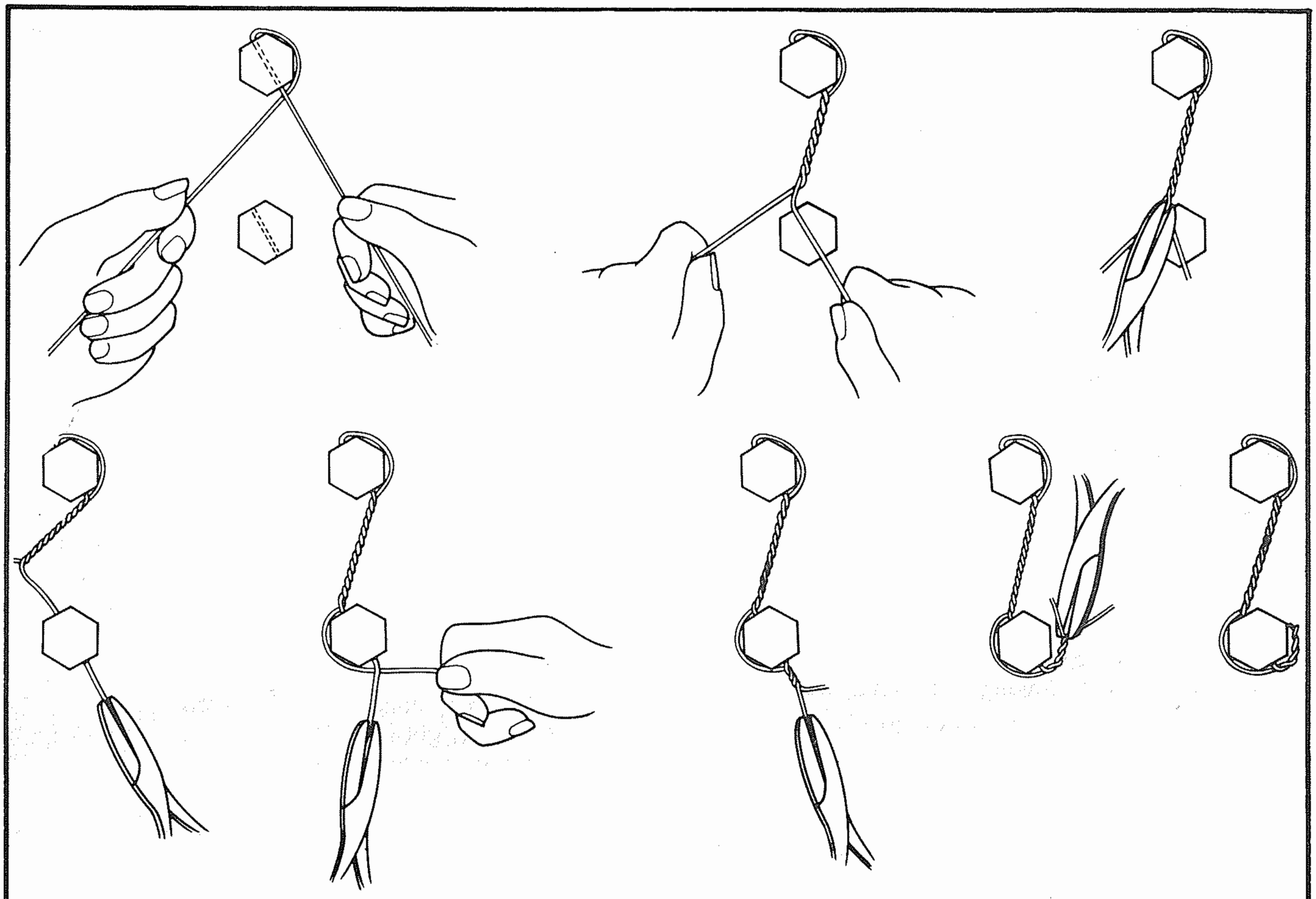


Figure 7-3. Lockwiring Examples

7-12. LOCKWIRING. See figure 7-3. New lockwire shall be used in each installation. The alignment of holes and/or slots in screws, studs, bolts, and nuts shall be accomplished only by tightening within the specified torque ranges. Always wire through holes which tend to tighten the parts. Plier marks, nicks, cuts or digs on the wire remaining on the assembly are not acceptable. Proceed as follows:

a. The wire held by the right hand shall be over that which is held in the left hand and twisted 180 degrees in a clockwise direction until the twisted wire is of appropriate length.

b. Tighten the twisted length to between six and eight twists per inch with smooth face pliers.
c. Pull one strand of wire through the second of the parts to be lockwired together. Keep the wire straight as it is drawn through the hole.
d. Keeping the strand taut through the hole with the left hand, grasp the free strand with the right hand and turn it around the hex and underneath. Twist strands counterclockwise and tighten as described in step b.
e. Cut the twisted wire between three and five twists from the nut and bend the twists toward the part.

7-13. SPECIAL APPLICATIONS. Applications other than that mentioned in paragraph 7-12 are as follows:
a. When a screw or nut must be wired to a part other than another screw or nut, lockwire as illustrated in figure 7-4.
b. When three units are to be lockwired together, lockwire the three units together with the twists between the second and third part in a counterclockwise direction. See figure 7-5.
c. Various designs of parts to be fastened together are illustrated in figure 7-6.
d. The second view in figure 7-6, identified with an "X" shows the alternate locking procedure, to be used only when the favored procedure is impractical.
e. When double stranded lock wire is specified, two wires are twisted together and applied as described in paragraphs 7-12, steps a through e, and steps a through c above.
f. Since securement at the cylinder hold-down screw locations involves several special alternate methods which are applied only at these locations, refer to paragraph 7-169.

7-14. TAB WASHERS. See figure 7-7. The following principles and steps shall be applied when installing tab washers:
a. New tab washers must be used at each new installation. When using single hole tab washers, the tab "A" which is bent down against the stationary part, shall be positioned at an angle of 90 degrees or less on the side.
b. Bend the remaining tab, "B", up across the bottom of one face of the hex until it is against the face. The two bottom views in figure 7-7 show acceptable and unacceptable bends.
c. Bend the tab up against the hex face with which its junction line is 75 per cent more of the tab width.
d. The number of tabs for bending up will vary according to design. In cases of two or more, the tab which is most favorably aligned shall be bent as described in steps b and c above.

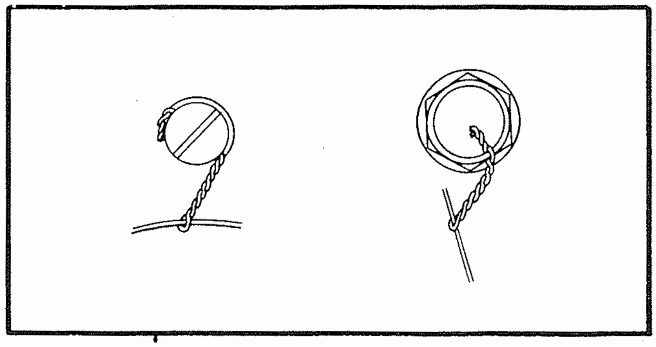


Figure 7-4. Lockwiring to Special Parts

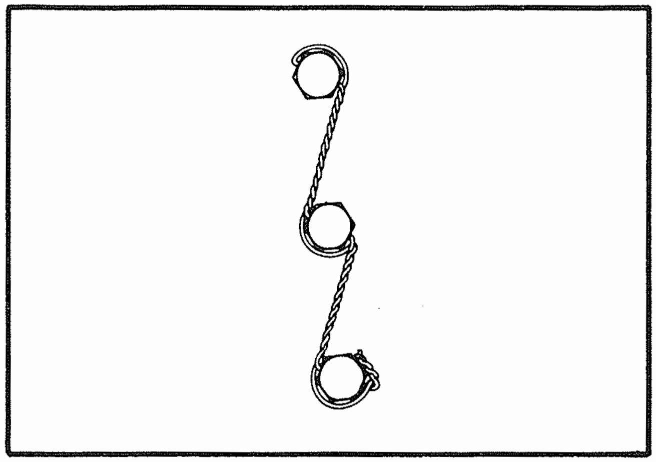


Figure 7-5. Lockwiring Three Units Together

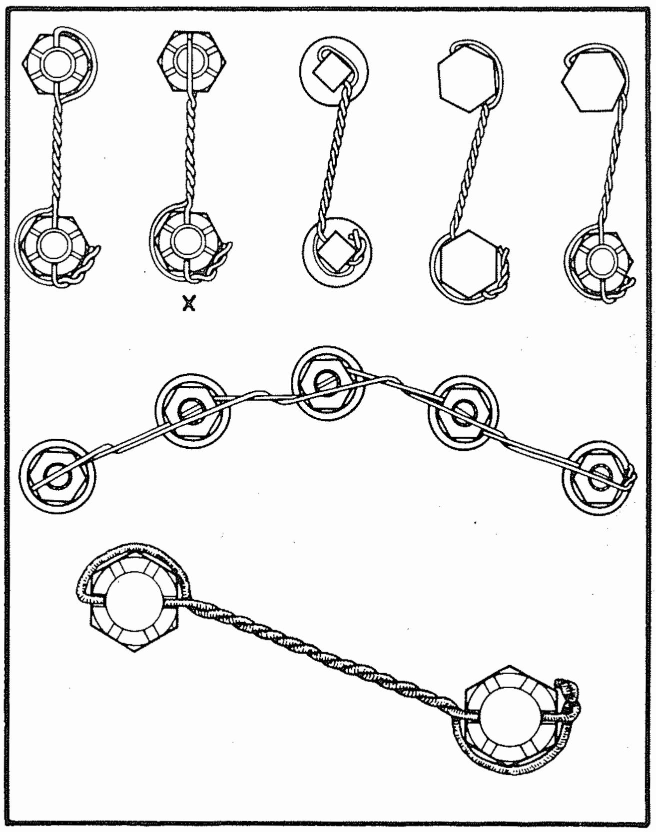


Figure 7-6. Lockwiring Parts of Various Designs

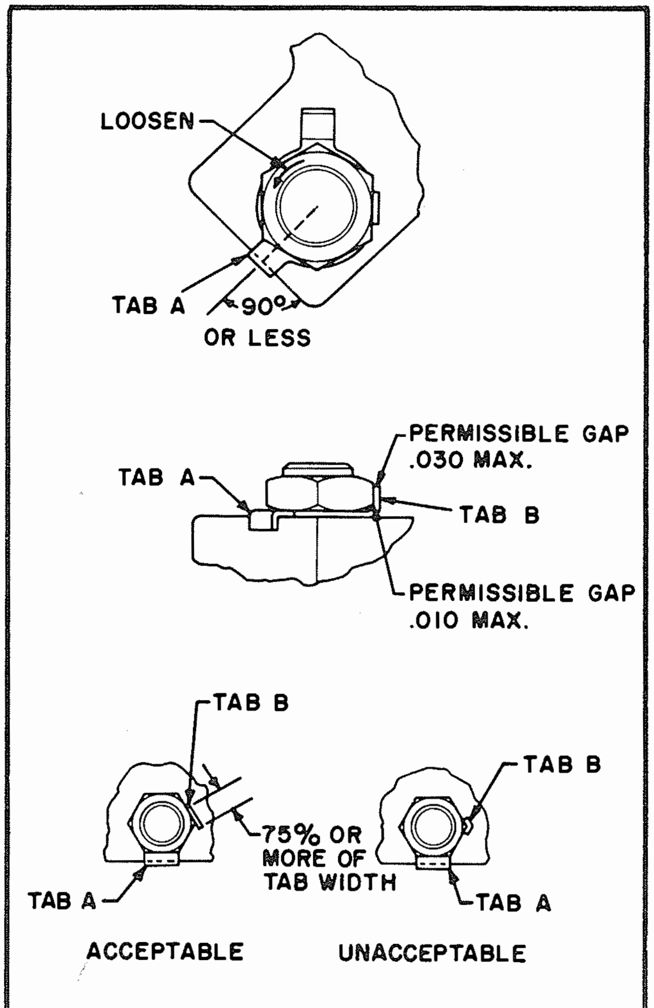


Figure 7-7. Tab Washer Applications

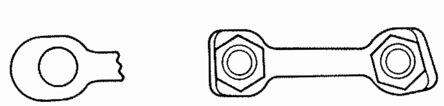


Figure 7-8. Multiple Hole Tab Washers

e. Do not leave a gap at the end of the tab greater than .030 inch. The gap between the tab and the face of the hex must not be greater than .010 inch at the bottom of the hex face.

f. In the application of multiple hole tab washers, the installation shall be as above, except the tab "A" provision of step a is not required. See figure 7-8.

g. The installation of 180 degree elliptical tab washers shall be accomplished by bending up across one whole face of the hex head.

7-15. COTTER PINS. See figure 7-9. The following principles and steps shall be applied when installing cotter pins.

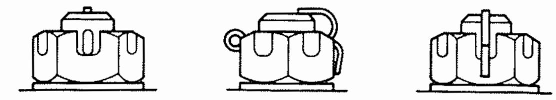


Figure 7-9. Cotter Pin Application

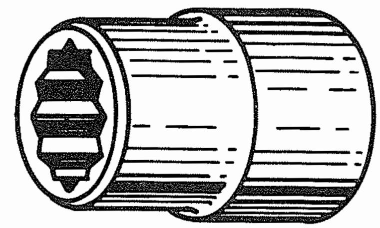


Figure 7-10. Oil Pressure Relief Valve Cap Wrench

a. New cotter pins must be used at each installation. Insert cotter pins with the plane of the eye parallel to the axis of the bolt or stud.

b. Bend the short prong of the pin down over and alongside of the flat of the nut. The long prong of the pin shall be bent up over the end of the bolt unless otherwise specified.

c. When a tolerance condition causes slight interference between the eye of the cotter pin and the bottom of the nut castellation, the cotter pin may be deformed slightly by forcing it into the nut castellation.

d. When other parts are so close that the cotter pin prong over the end of the bolt can cause interference, cut it off flush with the end of the bolt and bend it toward the bolt.

7-16. OIL PRESSURE - REAR PUMP.

7-17. ADJUSTMENT. Operate the engine between 1500 - 1800 rpm with an oil inlet temperature of 85°C (185° F) and observe the main oil pressure. If the oil pressure is not within the specified limits of 70 ± 5 psi, adjust as follows:

a. Remove the oil pressure relief valve cap, using wrench 802139 (figure 7-10). Remove the packing ring.

b. Loosen the adjusting screw lock nut with a one inch wrench. Adjust the oil pressure by turning the adjusting screw in a clockwise direction to increase, or in a counterclockwise direction to decrease pressure. Use a broad blade screwdriver.

c. When the correct pressure is obtained, tighten the adjusting screw lock nut to 25 inch-pounds. Install a new packing ring over the relief valve body and install and tighten the cap. Tighten to 75 - 100 inch-pounds with wrench 802139 and lockwire.

7-18. OIL PRESSURE - FRONT PUMP.

7-19. ADJUSTMENT. Remove the pressure gage substituting plug from the front pump and sump housing with a 9/16 inch wrench. This plug is located above the external oil inlet tube mounting pad. Connect an oil pressure gage at this location. Operate the engine between 1500 - 1800 rpm with an oil inlet temperature of 85°C (185°F) and observe the oil pressure. If it is not within the specified limits of 35 ± 5 psi, adjust as follows:

a. Remove the pressure control valve cap using a 5/8 inch wrench. Remove the gasket.

b. Push out the locking pin which passes through the holes in the valve body and the slots in the valve spring seat.

c. Using socket wrench 807005 (figure 7-11), turn the valve spring seat in a clockwire direction to increase pressure, or in a counterclockwise direction to decrease pressure.

d. When the correct pressure is obtained, insert the body and seat locking pin. Install a new gasket and the control valve cap. Torque the cap to 75 - 100 inch-pounds.

e. Remove the oil pressure gage. Apply Lubriplate 130A to the plug threads and install the plug in the oil pump and sump housing. Tighten the plug to 60 - 90 inch-pounds. Lockwire the control valve cap to the plug.

7-20. OIL PRESSURE - SUPERCHARGER FRONT HOUSING.

7-21. ADJUSTMENT. Remove the plug located directly above the pressure control valve in the supercharger front housing using a 9/16 inch wrench. Connect an oil pressure gage at this location. Operate the engine between 1500 - 1800 rpm with an oil inlet temperature of 85°C (185°F) and observe the oil pressure. If it is not within the specified limits of 50 ± 5 psi, adjust as follows:

a. Remove the pressure control valve cap using a 5/8 inch wrench. Remove the gasket.

b. Push out the locking pin which passes through the holes in the valve body and the slots in the valve spring seat.

c. Using socket wrench 807005, turn the valve spring seat in a clockwise direction to increase pressure or in a counterclockwise direction to decrease pressure.

d. When the correct pressure is obtained, insert the body and seat locking pin. Install a new gasket and the control valve cap. Tighten to 75 - 100 inch-pounds.

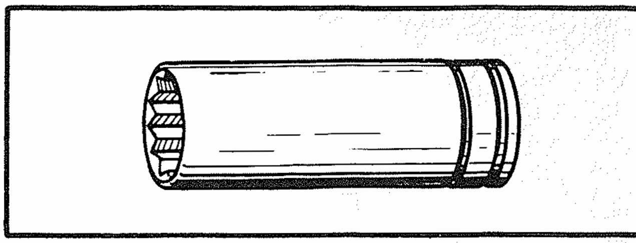


Figure 7-11. Oil Pressure Control Valve Spring Seat Socket Wrench

e. Remove the oil pressure gage. Apply Lubriplate 130A to the plug threads and install the plug in the supercharger front housing. Tighten the plug to 60 - 90 inch-pounds. Lockwire the control valve cap to the plug.

7-22. VALVE CLEARANCE ADJUSTMENT.

7-23. When adjusting valve clearances on any one cylinder, remove and replace the following parts:

	Paragraphs
Rocker Box Covers	7-48, 7-49, 7-132

NOTE

One spark plug in the cylinder may be removed to relieve compression. Refer to paragraph 7-214.

7-24. To adjust the valve clearances on an individual cylinder, proceed as follows:

a. Turn the propeller shaft in the direction of rotation until the piston in the cylinder in which the valves are to be adjusted is approximately at top center on the compression stroke. Raise the adjusting screw end of the rocker arm slightly to make certain the valve tappet ball socket slides freely in its guide.

b. With both valves in the cylinder closed, loosen the adjusting screw lock screw with wrench 807004. See figure 7-12. Turn the adjusting screw out one or two turns with a broad blade screwdriver.

c. Insert the .010 inch gage of feeler gage assembly 806890 between the valve tip and the adjusting screw and turn down on the adjusting screw with a broad blade screwdriver. See figure 7-13. When any further turning of the screw would open the valve slightly, there will be an appreciable increase in torque and the feeler gage will be tightly clamped. Loosen the screw only enough to allow the feeler gage to be withdrawn.

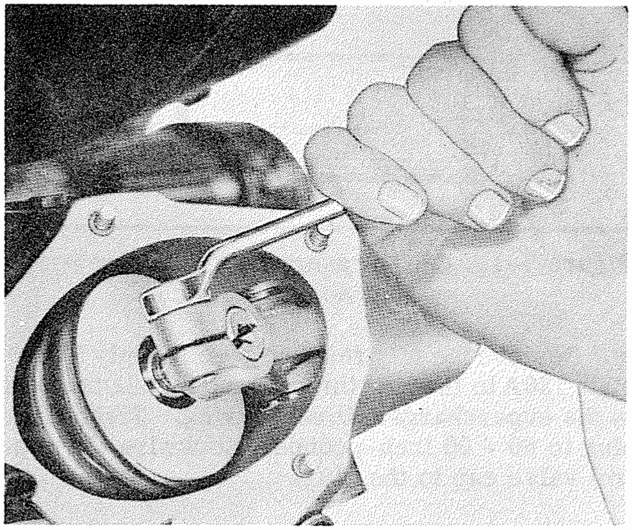


Figure 7-12. Loosening Adjusting Screw Lock Screw

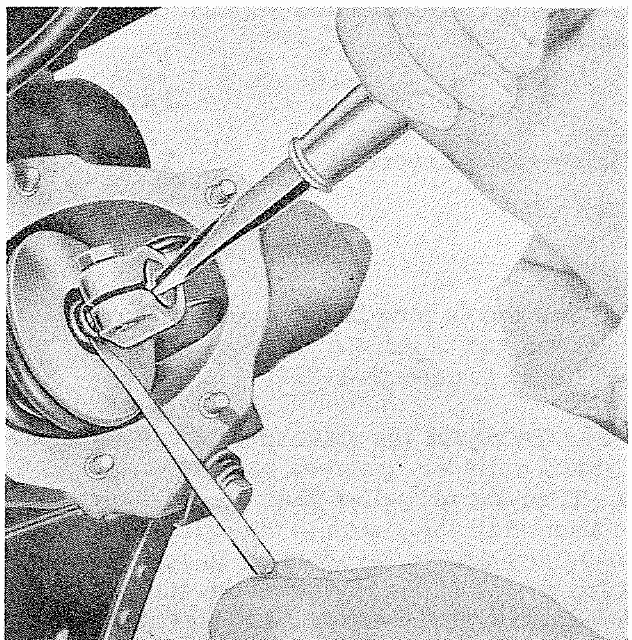


Figure 7-13. Adjusting Valve Clearance

d. Tighten the adjusting screw lock screw to 275 - 325 inch-pounds. Check the clamping action of the lock screw by using a torque wrench and screwdriver 805971 in the adjusting screw. See figure 7-14. If the adjusting screw turns when a torque of 350 inch-pounds is applied, reset the clearance to .010 inch and tighten the lock screw further. Do not exceed 325 inch-pounds.

7-25. When it is necessary to adjust valve clearances on all cylinders, remove and replace the following parts:

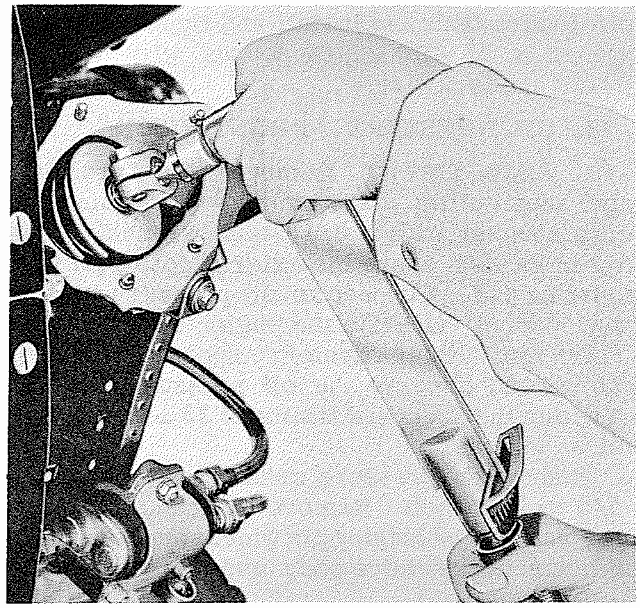


Figure 7-14. Making Torque Check on Adjusting Screw

	Paragraphs
Rocker Box Drain Manifold	7-52, 7-53
Rocker Box Covers	7-48, 7-49, 7-132

NOTE

One spark plug in each cylinder may be removed to relieve compression. Refer to paragraph 7-214.

7-26. To adjust the valve clearances on all cylinders, proceed as follows:

a. Turn the propeller shaft in the direction of rotation until the piston in cylinder No. 1 is approximately 90 degrees before top center on the compression stroke.

b. Install piston position indicator 805977 with pivot arm 805946 and scale 805942 in the front spark plug hole of cylinder No. 1. Refer to paragraph 7-218.

c. Remove the fuel pump or substituting cover from the tachometer and fuel pump drive housing. Install timing disc 807890 on the fuel pump pad so that the zero degree mark is at the top of the disc. Secure with engine nuts and washers. Install the timing disc pointer in the fuel pump drive gear. See figure 7-15.

d. Set the piston in cylinder No. 1 at 25 degrees before top center on the compression stroke as described in paragraph 7-218. Set the timing disc pointer at the 335 degree mark on the disc. Tighten the pointer in the fuel pump drive gear until the pointer cannot be moved.

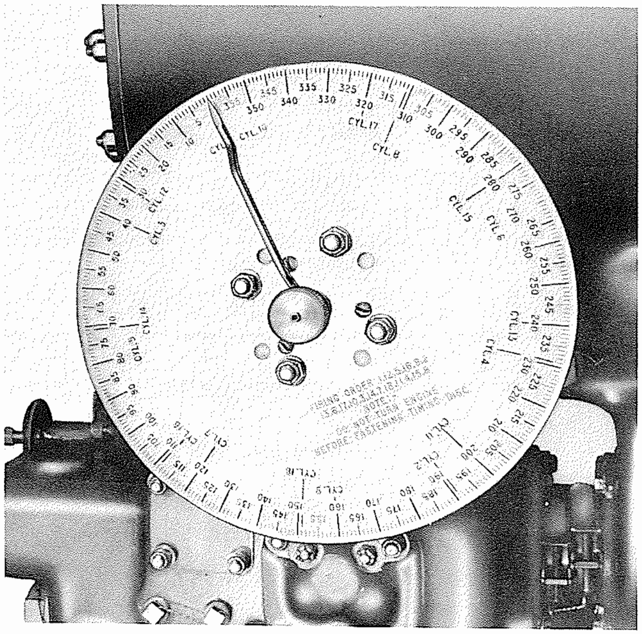


Figure 7-15. Timing Disc Installed on Fuel Pump Pad

e. Turn the propeller shaft in the direction of rotation until the timing disc pointer indicates zero on the disc.

f. Loosen the adjusting screw lock screws in cylinder No. 1 using wrench 807004. Turn the adjusting screws out one or two turns using a broad blade screwdriver.

g. To adjust the valve clearances in cylinder No. 1, insert the .010 inch gage of feeler gage assembly 806890 between the valve tip and the adjusting screw and turn down on the adjusting screw with a broad blade screwdriver. When any further turning of the screw would open the valve slightly, there will be an appreciable increase in torque and the feeler gage will be tightly clamped. Loosen the screw only enough to allow the feeler gage to be withdrawn. Turn the adjusting screw lock screw far enough to hold the adjusting screw in this position. Use wrench 807004.

h. Turn the propeller shaft in the direction of rotation until the timing disc pointer indicates 31 degrees on the disc. This will position the piston in cylinder No. 12 at top center. Adjust the valves in cylinder No. 12 as described in steps f and g.

i. Adjust the valves in the remaining cylinders in the order listed in the following Table. Turn the propeller shaft in the direction of rotation to obtain the disc readings and make the adjustments as described in steps f and g.

Cylinder No.	Pointer Reading on Timing Disc (Degrees)
1	0
12	31
5	80
16	111
9	160
2	191
13	240
6	271
17	320
10	351
3	400 (360 + 40)
14	431 (360 + 71)
7	480 (360 + 120)
18	511 (360 + 151)
11	560 (360 + 200)
4	591 (360 + 231)
15	640 (360 + 280)
8	671 (360 + 311)

j. Turn the propeller shaft in the direction of rotation for approximately 769 degrees from the 671 (360 + 311) degree position on the timing disc used for adjusting the valves in cylinder No. 8. The piston in cylinder No. 1 will now be at approximately top center on the compression stroke.

k. Recheck and readjust all valves as necessary by repeating steps e through i.

l. Repeat steps j and k to conduct a third check of clearances and readjust any valve clearance which is not .010 inch.

m. Tighten all the adjusting screw lock screws as instructed in step d of paragraph 7-24.

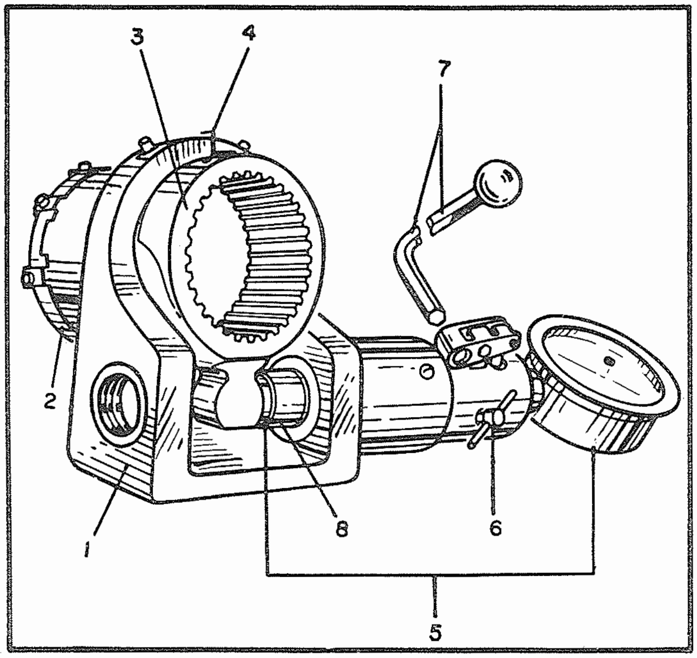
n. Remove the timing disc pointer and timing disc. Use a new gasket and replace the fuel pump or the substituting cover, washers, and self-locking nuts. Tighten the nuts to 125 - 140 inch-pounds.

7-27. PROPELLER SHAFT THRUST BEARING NUT.

7-28. REMOVAL. Use hydraulic wrench 806956 to loosen the thrust bearing nut. See figure 7-16. The wrench consists of the following details: adapters 806957 and 806959, housing 806958, and jack and gage 806960. Use protector 801332 on the propeller shaft threads when the hydraulic wrench is used.

a. Assemble housing 806958 and thrust nut adapter 806957. Slide this assembly over the propeller shaft so that the adapter engages with the thrust nut lugs and the scale on the housing is at the top.

b. Install splined adapter 806959 over the propeller shaft splines, ensuring that the ball arm of the adapter is approximately at bottom center.



1. Housing
2. Thrust Nut Adapter
3. Propeller Shaft Adapter
4. Finger and Scale
5. Jack and Gage Assembly
6. Relief Valve
7. Jack Handle
8. Jack Ram

Figure 7-16. Thrust Bearing Nut Hydraulic Wrench

c. Screw jack and gage 806960 all the way into the hole at the left of the housing. Close the jack relief valve.

d. Build up ram pressure by pumping the jack handle until the force of the ram acting against the ball arm causes the housing to turn in a counterclockwise direction, backing the thrust bearing nut off its threads.

e. When the splined adapter reaches its limit of travel, open the jack relief valve and permit the jack ram to retract. Remove the splined adapter and reinstall it with the ball arm to the right. Close the relief valve and repeat the operation described in step d.

7-29. Remove the hydraulic wrench and turn the thrust bearing nut the remainder of the way using lug wrench 83403 (figure 7-17).

7-30. REPLACEMENT.

7-31. Coat the threads on the nut and the propeller shaft with anti-seize compound, Lubriplate 130A.

7-32. Turn the nut on the propeller shaft as far as it will go by hand. Use wrench 83403 for the initial tightening prior to torquing.

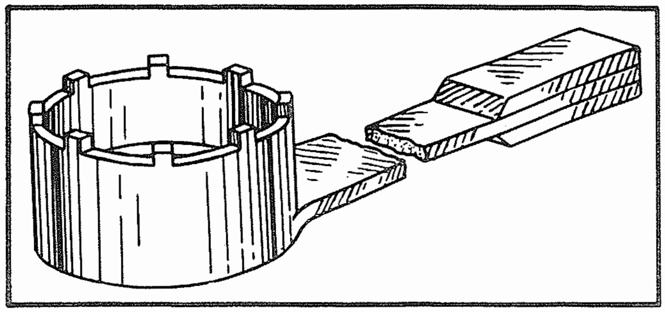


Figure 7-17. Thrust Bearing Nut Lug Wrench

7-33. Use hydraulic wrench assembly 806956 to torque the thrust bearing nut.

a. Install housing 806958 and adapter 806957 over the propeller shaft so that the adapter engages with the thrust bearing nut and the scale on the housing is at the top.

b. Install splined adapter 806959 over the propeller shaft so that the ball arm is to the right.

c. Screw jack and gage 806960 all the way into the hole at the left of the housing so that the jack ram is against the ball arm of the splined adapter. Close the jack relief valve.

d. Pump the jack handle while watching the needle on the gage. Torque the nut to 26400 - 28800 inch-pounds.

NOTE

The final gage reading must be taken when the ball arm on the splined adapter is approximately at bottom center.

e. When approaching the specified torque value and the ball arm of the splined adapter is not at approximate bottom center, open the relief valve and release the ram pressure. Remove the splined adapter and reinstall it with the ball arm in approximate bottom center. Close the relief valve and continue to torque. When the torque is within the specified limits, open the relief valve and withdraw the wrench assembly.

7-34. CRANKCASE FRONT SECTION FLANGE AND SEAL ASSEMBLY.

7-35. This operation requires removal and replacement of the following part:

	Paragraph
Propeller Shaft Thrust Bearing Nut	7-27

7-36. REMOVAL.

a. Remove the crankcase front section flange cap screws using a 5/8 inch wrench. Break the flange loose from the front section using pullers

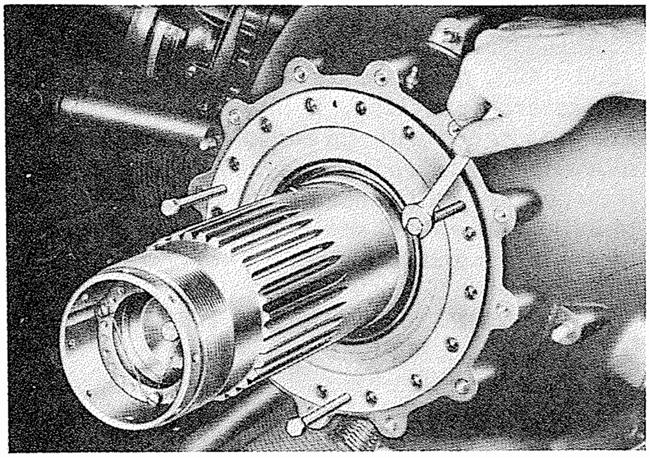


Figure 7-18. Removing Crankcase Front Section Flange

806962 and a 1/2 inch wrench. See figure 7-18. Remove the flange and seal assembly and gasket.

b. Remove the seal assembly from the flange using plug and base 808080.

7-37. REPLACEMENT.

a. Install a new oil seal assembly in the crankcase front section flange using plug and base 808080. See figure 7-19.

b. Swab the oil seal with engine oil and install a gasket and the flange and seal assembly over the propeller shaft and on the crankcase front section. Install the flange cap screws, using a 5/8 inch wrench. Tighten to 425 - 450 inch-pounds and lockwire.

7-38. PROPELLER CONTROL OIL SUPPLY TUBE AND SUPPORT.

7-39. REMOVAL.

NOTE

The engine parts mentioned in the following steps a, b, c, and d may or may not be used, depending on the type of propeller used.

a. Break the lock wire and remove the screws and washers that secure the tube cover nut lock. Pull the lock straight out of the shaft.

b. Remove the tube cover nut using wrench 83607 with handle 81402 and a soft hammer. See figure 7-20.

c. Remove the tube cover using impact puller 806916. See figure 7-21.

d. Remove the cover gasket.

e. Remove the tube and support assembly from the propeller shaft using puller 805568. See figure 7-22.

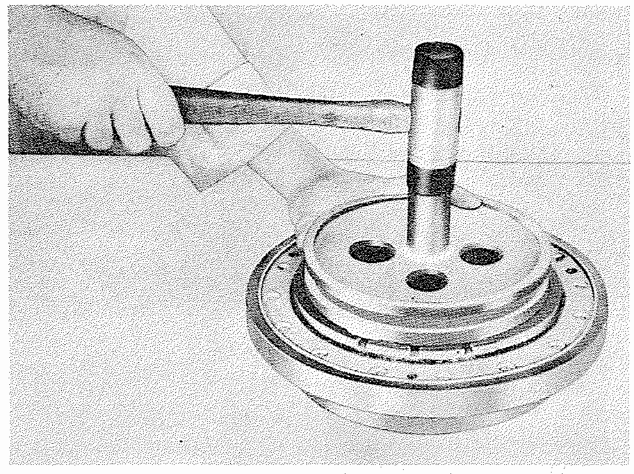


Figure 7-19. Installing Crankcase Front Section Flange Seal

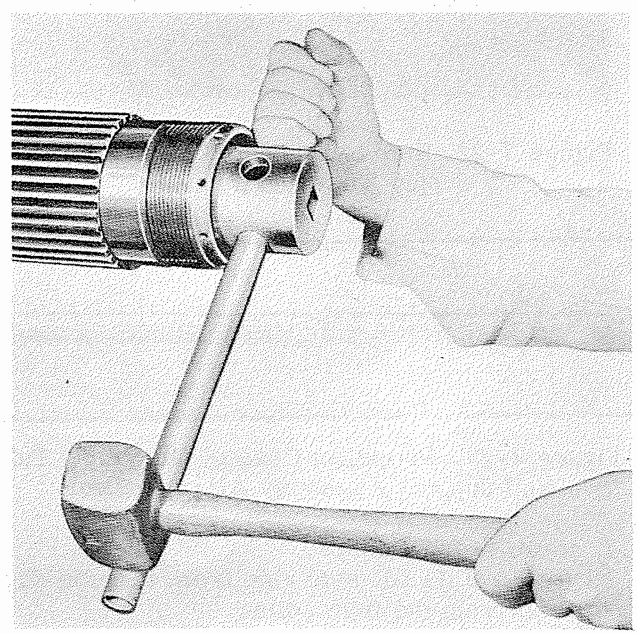


Figure 7-20. Loosening Tube Cover Retaining Nut

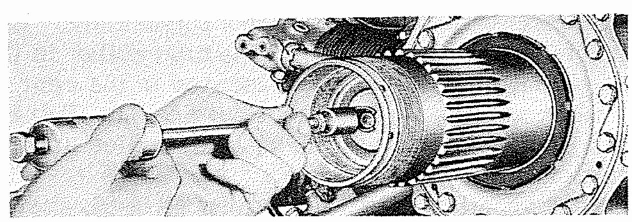


Figure 7-21. Removing Tube Cover

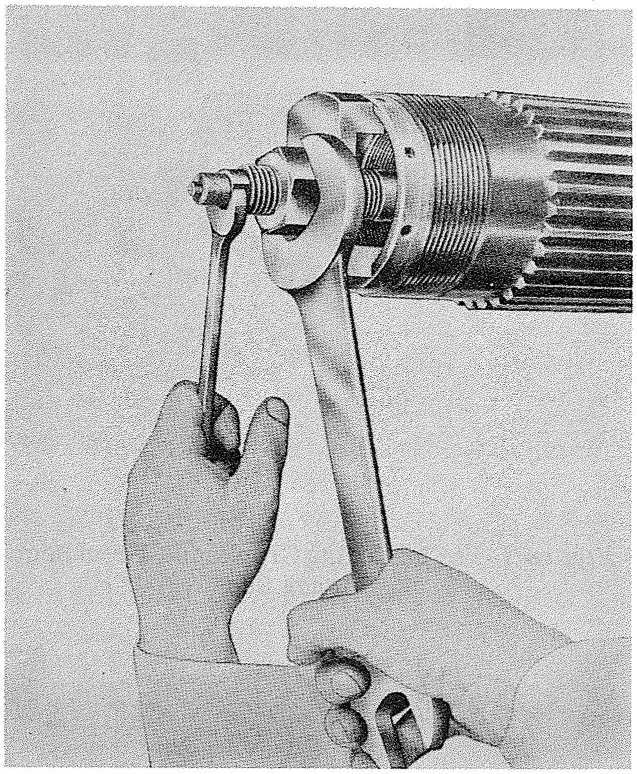


Figure 7-22. Removing Propeller Control Oil Supply Tube and Support

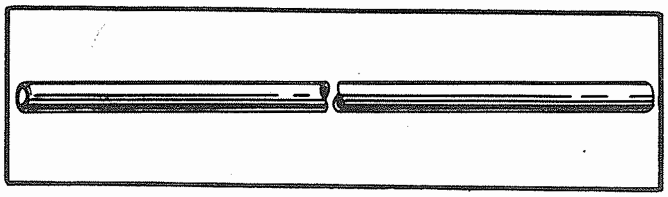


Figure 7-23. Propeller Control Oil Supply Tube and Support Assembly Aligning Tool

f. Remove the washer.
g. Remove the oil seal ring from the tube support and from the tube collar.

7-40. REPLACEMENT.
a. Install an oil seal ring in the groove on the propeller control oil supply tube collar. Install an oil seal ring in the groove on the tube support. Place the large washer inside the propeller shaft and install the tube and support assembly. Use aligning tool 923479 to align the tube collar in the center hole of the adapter located in the rear of the propeller shaft. See figure 7-23. Tap the assembly with a soft drift and mallet until it bottoms.
b. If an oil supply tube cover is used, install the gasket and cover.
c. If an oil supply tube cover retaining nut is used, coat the threads of the retaining nut with anti-seize compound, Lubriplate 130A, and install the nut in the propeller shaft. Tighten to 4000 - 4200 inch-pounds using wrench 83607.
d. Insert the nut lock. If three holes in the lock are not aligned with three holes in the nut, remove the lock, turn it 180 degrees, and reinstall. If three holes still do not match, reverse the lock. Install washers and screws. Tighten to 18 - 20 inch-pounds and lockwire.

7-41. GOVERNOR DRIVE AND TORQUEMETER BOOSTER PUMP.

7-42. REMOVAL.
a. Remove the fiber-lock nuts and washers that secure the governor drive and torquemeter booster pump assembly to the crankcase front section. Use a 1/2 inch socket wrench. Install three pullers 806963 in the puller holes of the adapter. Turning the pullers down evenly, separate the housing, adapter and governor drive shaft from the engine. Leave the pullers in the adapter. Remove the oil seal ring from the crankcase front section.
b. Remove the circlet from the torquemeter booster pump drive gear and remove the governor drive shaft. Remove the oil seal ring from the shaft.
c. Using the three pullers to support the housing and adapter, hold one hand under the housing and tap lightly with a soft face mallet on the projecting end of the drive gear until the housing and adapter are separated.
d. Remove the three pullers.
e. Remove the torquemeter booster pump drive gear, driven gear, and housing to adapter oil seal ring. It is not necessary to remove the circlet from the upper annulus in the drive gear.

7-43. REPLACEMENT.
a. Install the drive gear in the governor drive and torquemeter booster pump adapter. Place a new oil seal ring in the groove on the adapter.
b. Install an oil seal ring in the groove on the governor drive shaft. Install a circlet over the splines of the governor drive shaft and install the shaft in the booster pump drive gear. Push the circlet on the shaft into position in the lower annulus of the drive gear.
c. Lubricate the torquemeter booster pump driven gear and install it in the housing. Position the housing on the adapter.

CAUTION

Since there is no positive retention of the governor drive and torquemeter booster pump parts until the assembly is installed on the engine, hold the parts together and handle them carefully.

d. Place an oil seal ring in the groove on the crankcase front section.
e. Install the governor drive and torquemeter booster pump assembly on the engine and secure with washers and self-locking nuts. Tighten the nuts to 125 - 140 inch-pounds.

7-44. ROCKER BOX DRAIN SYSTEM.

7-45. GENERAL.
a. Either of the rocker box integral cover and sump assemblies located on cylinder No. 10 intake and exhaust rocker boxes or any one rocker box cover that is connected to the rocker box drain manifold may be removed without removing the manifold. When it is necessary to remove both cover and sump assemblies or more than one rocker box cover, remove and replace them one at a time. This will preserve the original position of the manifold and lessen the possibility of disturbing the seals at other locations. Whenever a drain manifold tube packing is disturbed in any way, the tube must be removed and reinstalled with new packing.
b. The drain manifold may be removed and replaced as a complete unit, or, any one section of the three sections that comprise the unit may be removed and replaced separately. If a section of the manifold is to be removed, use the instructions in this paragraph and also in the following paragraphs where applicable. Use wrench 807013 on the packing nut on the right or left hand section while holding the wrench flats on the center section right or left hand connector with a 3/4 inch wrench. When replacing a section use lubricating oil on the connector and packing nut threads and tighten to 250 - 275 inch-pounds. Lockwire the packing nuts to the connectors.

7-46. ROCKER BOX TO DRAIN MANIFOLD TUBE-REMOVAL.
a. Loosen the gland nuts at the rocker box cover and at the drain manifold, using wrench 807012. See figure 7-24.
b. Push the tube into the rocker box using a screwdriver. See figure 7-25.
c. Remove the rocker box cover attaching nuts and washers. Wrench 80449 may be used on the nuts, and removing tool 84770 may be used to remove the washers. Remove the rocker box cover and tube.
d. If the gland, washers, and packing were not removed from the drain manifold with the tube, remove them.
e. Install protector 806547 on the tube adapter.

7-47. ROCKER BOX TO DRAIN MANIFOLD TUBE-REPLACEMENT.
a. Remove tube adapter protector 806547.
b. The rocker box to drain manifold tube as-

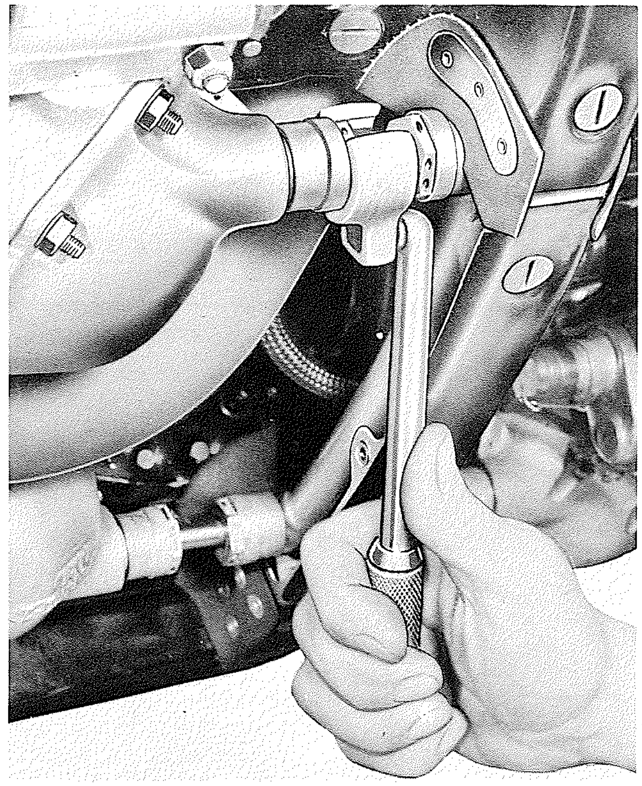


Figure 7-24. Loosening Rocker Box to Drain Manifold Tube Nut

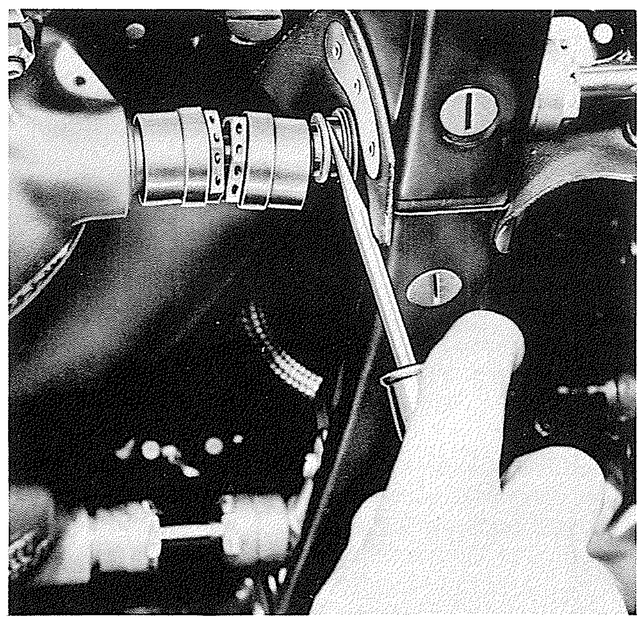


Figure 7-25. Pushing Tube into Rocker Box Cover

sembly is shown in figure 7-26. Install the gland nuts over the tube from the rocker box end. The collar on the tube is located nearer to the manifold end. Assemble a gland, washer, packing, and another washer over each end of the tube.

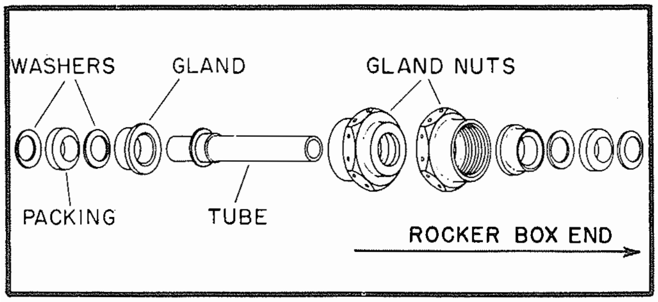


Figure 7-26. Rocker Box to Drain Manifold Tube Assembly

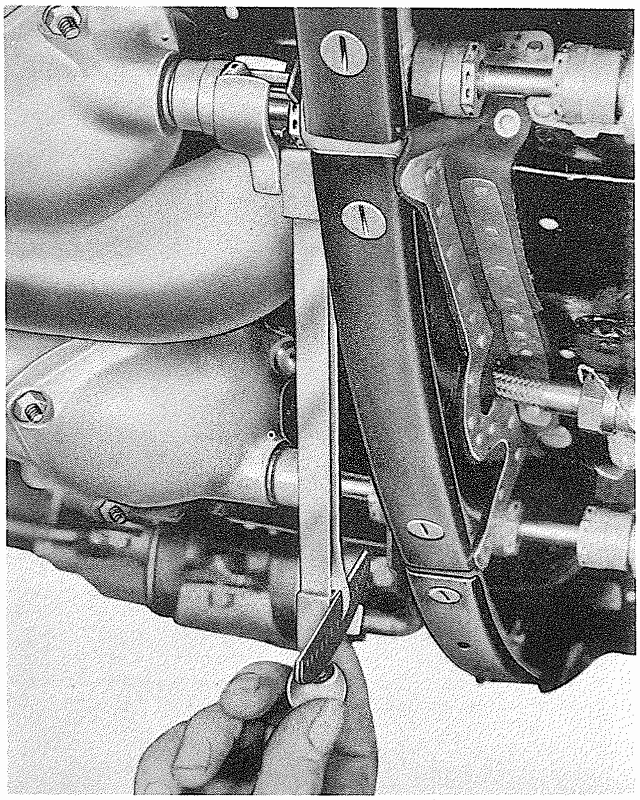


Figure 7-27. Torquing Rocker Box to Drain Manifold Tube Gland Nut

c. Install the rocker box cover gasket on the rocker box. Insert the tube in the rocker box cover boss as far as it will go. Install the cover and tube assembly on the cylinder and slide the tube into the manifold. Install the rocker box cover lock washers and nuts. Tighten to 80 - 85 inch-pounds. Torque the tube gland nuts to 40 - 45 inch-pounds using wrench 807112. See figure 7-27. Lockwire.

7-48. ROCKER BOX DRAIN MANIFOLD TO INTEGRAL COVER AND SUMP ASSEMBLY TUBE - REMOVAL.

a. Loosen the nuts at the cover and sump assembly and at the drain manifold using wrench

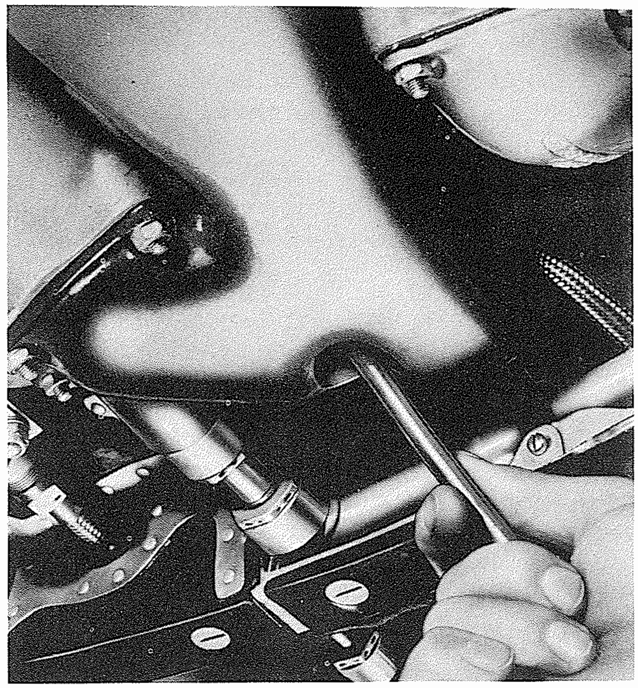


Figure 7-28. Removing Hidden Nut from Rocker Box Cover and Sump Assembly

807013. Back off the nut all the way at the manifold end of the tube.

b. Push the tube into the cover and sump assembly carefully, using a screwdriver.

c. Remove the cap screws and washers from the cover and sump assembly to cylinder head support bracket and remove the bracket. Use a 1/2 inch wrench on the cap screws. Disconnect the sump vent line at the sump, using a 9/16 inch wrench.

d. Remove the cover and sump assembly to cylinder rocker box attaching nuts and washers, including the hidden nut in the formed portion of the sump. Wrench 80449 may be used on the nuts. See figure 7-28. Use magnetic tool 84770 for removing the lock washers. Remove the sump.

e. Remove the tube assembly from the cover and sump assembly and remove the gland, washers and packing from the drain manifold if those parts did not remain with the tube.

f. Install protector 806546 on the tube adapter.

7-49. ROCKER BOX DRAIN MANIFOLD TO INTEGRAL COVER AND SUMP ASSEMBLY TUBE - REPLACEMENT.

a. Remove the tube adapter protector 806546.

b. Assemble the drain manifold to cover and sump assembly tube as shown in figure 7-26 for the rocker box cover to drain manifold tube. Install the tube in the rocker box cover and sump assembly.

c. Place a new gasket over the cylinder rocker box studs and install the cover and sump assembly. Install the lock washers and nuts. Tighten the nuts to 80 - 85 inch-pounds.

d. Position the drain manifold to cover and sump assembly tube in the manifold. Tighten the tube gland nuts to 40 - 45 inch-pounds using wrench 807013. Lockwire.

e. Install the cover and sump assembly to cylinder head bracket, washers and cap screws. Tighten the cap screws to 125 - 140 inch-pounds and lockwire. Connect the vent line at the sump and tighten to 135 - 150 inch-pounds.

7-50. ROCKER BOX DRAIN MANIFOLD TO SCAVENGE PUMP TUBE - REMOVAL.

a. Loosen the gland nuts on both ends of the drain manifold to scavenge pump tube, using wrench 807013. Remove the tube.

b. Disassemble the washers, packing, gland, and nut from each end of the tube.

c. Install protector 806546 on the tube adapter.

7-51. ROCKER BOX DRAIN MANIFOLD SCAVENGE PUMP TUBE - REPLACEMENT.

a. Remove tube adapter protector 806546.

b. Assemble a nut, gland, washer, packing, and a second washer on each end of the manifold to scavenge pump tube.

c. Install the tube to the manifold and to the scavenge pump. Tighten the gland nuts 40 - 45 inch-pounds using wrench 807013. Lockwire.

7-52. ROCKER BOX DRAIN MANIFOLD - REMOVAL.

a. This operation requires removal and replacement of the following parts:

	Paragraphs
Cylinder Head Air Deflector for Cylinders No. 7, 9, 11, and 13	7-148
Rocker Box Drain Manifold to Scavenge Pump Tube	7-50, 7-51

b. Disengage the spiral lock fasteners retaining the head deflectors of front cylinders No. 8, 10, and 12 to the cowl seal channel.

c. Loosen the gland nuts on both ends of the rocker box cover to drain manifold tubes, using wrench 807012. Loosen both gland nuts on the drain manifold to cover and sump assembly tubes, using wrench 807013. Push the tubes into the rocker box covers, and cover and sump assemblies.

d. Remove the front cylinder head air deflector cap screw and washer that secure each manifold supporting bracket at the intake side of cylinders No. 8, 10, and 12. Use wrench 80449.

e. Separate the cowl seal channel at the joints adjacent to cylinders No. 7 and 13 and remove the drain manifold and cowl seal channel as an assembly.

f. Remove the rocker box to drain manifold, and cover and sump to drain manifold tube assemblies.

7-53. ROCKER BOX DRAIN MANIFOLD - REPLACEMENT.

a. Assemble two gland nuts (back to back), gland, washer, packing, and a second washer on the rocker box end of each rocker box to drain manifold, and cover and sump assembly to drain manifold tube.

b. Install the tube assemblies into the rocker box covers, and cover and sump assemblies. Loosely attach the gland nuts to the intake and exhaust rocker box covers, or cover and sump assemblies of cylinders No. 8, 9, 10, 11, and 12; in the intake rocker box of cylinder No. 7; and in the exhaust rocker box cover of cylinder No. 13.

c. With the drain manifold and the three attached sections of cowl seal channel in position between the cylinders, align the manifold supporting brackets at the cylinder head air deflector attaching location under the deflector on the intake side of cylinders No. 8, 10 and 12 and connect the sections of the cowl seal channel at cylinder locations No. 7 and 13.

d. Loosely install a cap screw and washer through each deflector and manifold supporting bracket at cylinders No. 8, 10, and 12.

e. Install a gland, washer, packing, and a second washer on manifold end of the rocker box to manifold, and cover and sump assembly to manifold tubes. Loosely attach the gland nuts to the manifold.

f. Tighten the following parts in the order given and to the torque specified, and lockwire.

1. Drain manifold supporting bracket to cylinder head cap screw, 80 - 85 inch-pounds.
2. Gland nut at manifold side of tube locations, 40 - 45 inch-pounds. Use wrench 807012.
3. Gland nut at rocker box cover locations, 40 - 45 inch-pounds. Use wrench 807012.
4. Gland nut at sump and cover assembly locations, 40 - 45 inch-pounds. Use wrench 807013.

g. Attach the front cylinder head deflectors to the cowl seal channel by means of the spiral lock fasteners.

7-54. ROCKER BOX DRAIN MANIFOLD STRAINER - REMOVAL. Remove the strainer in the rear side of the drain manifold at the cylinder No. 10 location using a 1/2 inch wrench.

7-55. ROCKER BOX DRAIN MANIFOLD STRAINER - REPLACEMENT. Install a new oil seal ring over the strainer and plug assembly, and install the strainer in the manifold. Tighten to 175 - 200 inch-pounds and lockwire.

7-56. ROCKER BOX COVER AND SUMP VENT TUBE - REMOVAL.

a. Disconnect the clamp that supports the lower right vent tube at the exhaust push rod housing of cylinder No. 10 using a 3/8 inch wrench. Disconnect the clamps that support the lower left and lower right hand tubes at the intake push rod housing of cylinder No. 10 using a 3/8 inch wrench. Disconnect the two clamps that support the upper tube at the intake push rod housing adapters of cylinders No. 12 and No. 14. Use a 7/16 inch wrench.

b. Loosen the lower left and lower right hand vent tube coupling nuts from the "T" connection at the junction of the three vent tubes. Use a 9/16 inch wrench. Leave the "T" connection attached to the upper vent tube.

c. Loosen the coupling nuts at the exhaust and intake cover and sump assemblies of cylinder No. 10 using a 9/16 inch wrench. Loosen the nut at the bleed nozzle elbow adjacent to the left hand distributor mounting pad with a 9/16 inch wrench and remove the three sections.

7-57. ROCKER BOX COVER AND SUMP VENT TUBE - REPLACEMENT.

a. Install the upper vent tube, with the "T" connection installed, on the engine, connecting the coupling nut at the bleed nozzle elbow adjacent to the left hand distributor mounting pad. Attach the two upper vent tube clamps under the front left hand nuts on the intake push rod housings of cylinders No. 12 and 14. No washers are used at these locations. Tighten the nuts to 80 - 85 inch-pounds.

b. Align the lower right hand vent tube in position, connecting the tube coupling nuts at the "T" connection and at the right hand cover and sump. Install one lower right hand tube clamp to the clamp on the exhaust push rod housing of cylinder No. 10. Install the other lower right hand tube clamp to the clamp on the intake push rod housing of cylinder No. 10. Tighten the clamp nuts to 60 - 65 inch-pounds.

c. Align the lower left hand flexible vent tube in position, ensuring that it passes between the external oil inlet tube and cylinder No. 10. Connect the tube coupling nuts at the "T" connection and at the left hand cover and sump. Install the vent tube clamp to the clamp on the intake push rod housing of cylinder No. 10. Tighten the clamp nut to 60 - 65 inch-pounds.

d. Tighten to 135 - 150 inch-pounds; the coupling nuts at the bleed nozzle elbow, the nuts at the junction of the three tubes at the "T" connection, and the nuts at the right and left hand cover and sump assemblies of cylinder No. 10.

7-58. EXTERNAL OIL TUBES.

7-59. This operation requires removal and replacement of the following part, only when the external oil outlet tube is to be removed:

	Paragraph
Cylinder No. 8 Fuel Injection Hose at Nozzle Connector	7-227

7-60. REMOVAL.

a. If the external oil outlet tube is to be removed, lift the cylinder No. 8 fuel injection hose from the clip at cylinder hold-down screw No. 2, and the two clips attached to the external oil outlet tube. Tie the fuel injection hose to a convenient location where it will not interfere with the tube removal.

b. Loosen the external oil tube connection nut at the supercharger front housing, using wrench 806535. Push the nut backward on the tube. Remove the external tube to front sump cap screws with a 1/2 inch wrench. Push the external tube rearward until the tube can be removed from the front sump. Move the external tube clear of the flange at the supercharger front housing and remove from the tube the oil seal ring, washer and nut.

c. Withdraw the tube from the front of the engine. Remove the oil seal ring from the front end of the tube.

7-61. REPLACEMENT. See figure 7-29.

a. Place a new oil seal ring in the groove at the forward end of the external oil tube assembly.

b. Position the tube between the cylinders, inserting it from the front of the engine.

c. Install the connection nut on the external oil tube and screw the nut past the threads on the tube. Install the washer and oil seal ring on the rear end of the tube.

d. Insert the rear end of the tube into the flange on the supercharger front housing, pushing it rearward until sufficient clearance is obtained for the installation of the tube front end into the front sump. Push the front end of tube against the front sump and install the tube to front sump cap screws.

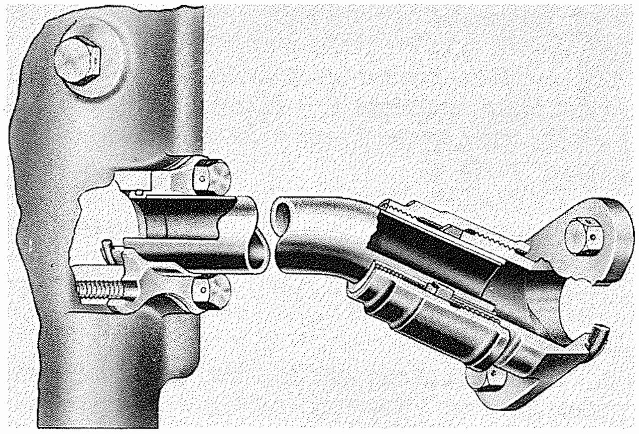


Figure 7-29. External Oil Tube Connection

e. Run the connection nut at the tube rear end onto the threads of both the tube and the flange.
f. Tighten the four tube to front sump cap screws to 125 - 140 inch-pounds and lockwire.
g. Using wrench, 806535, tighten the connection nut at the tube rear end to 550 - 575 inch-pounds and lockwire.
h. If the external oil outlet tube was reinstalled, replace the fuel injection hose for cylinder No. 8 in the two clips on the tube, and the clip at cylinder hold-down screw No. 2.

7-62. CRANKCASE FRONT MAIN SECTION OIL DRAIN TUBE.

7-63. This operation requires removal and replacement of the following parts:

	Paragraphs
Cylinder No. 10 Exhaust Rocker Box Cover and Sump	7-48, 7-49
External Oil Outlet Tube	7-58

7-64. REMOVAL.
a. Remove the cap screws from the drain tube to front sump attaching flange with a 1/2 inch wrench.
b. Using a 7/16 inch wrench, remove the two nuts and washers that secure the inter-cylinder crankcase seal air deflector to the combination screws at the flange on the drain tube elbow. Remove the deflector.
c. Using a 1/2 inch wrench, remove the two combination screws that secure the drain tube to the front main section connector.
d. Withdraw the drain tube rearward from the front sump and then remove the tube from the engine.
e. Remove the oil seal rings from both ends of the drain tube.

7-65. REPLACEMENT.
a. Install a new oil seal ring in the drain tube flange recess which attaches to the crankcase connector. Slip the drain tube to front sump attaching flange over the front end of the tube and install a new oil seal ring.
b. Position the drain tube in its approximate location. Move the tube rearward until the front end can be slipped into the front sump. Install, finger tight, the tube flange to front sump cap screws. Install the tube flange to main section connector combination screws. Tighten the combination screws to 125 - 140 inch-pounds and lockwire. Tighten the tube flange to front sump screws to 125 - 140 inch-pounds and lockwire.
c. Attach the inter-cylinder crankcase seal air deflector, aligning it on the combination screws at the drain tube elbow. Install the washers and self-locking nuts to the combination screws and tighten the nuts to 80 - 85 inch-pounds.

7-66. CRANKCASE REAR MAIN SECTION OIL DRAIN TUBE.

7-67. This operation requires removal and replacement of the following parts:

	Paragraphs
Cylinder No. 10 Intake Pipe	7-129, 7-130
Inter-Cylinder Crankcase Seal Deflector (between cylinders No. 10 and 12)	7-152
Rear Spark Plug Lead at Cylinder No. 10	7-212
Cylinders No. 9 and 10 Fuel Injection Hose at Supercharger Front Housing Connectors	7-227

7-68. REMOVAL.
a. Remove the fuel injection lines from the two dual clips attached to the rear oil drain tube and tie the lines to a convenient location where they will not interfere with the tube removal.
b. Loosen the tube to supercharger front housing nut, using wrench 923459.
c. Remove the two cap screws from the drain tube flange at the crankcase rear main section using a 1/2 inch wrench and extension handle. Withdraw the drain tube rearward.

d. Remove the oil seal ring from the front end of the tube. Remove the oil seal ring and gland from the rear end of the tube or from the drain tube flange at the supercharger front housing.

7-69. REPLACEMENT.

a. Install and tighten to 125 - 140 inch-pounds, the two tube flange to main section connector screws. Lockwire.

b. Position the oil drain tube and start the nut at the supercharger front housing.

c. Tighten the tube to supercharger front housing nut to 600 - 650 inch-pounds, using wrench 923459. Lockwire.

d. Install the fuel injection hoses for cylinders No. 9 and 10 in the dual clips attached to the rear drain tube.

7-70. DRAIN PLUGS.

7-71. Two chip detector drain plugs are used; one is located in the bottom of the front pump and sump housing and the other is located beneath the oil scavenge strainer in the rear pump and sump housing. In addition, two plain drain plugs are used in the rear pump and sump housing; one is located on the right side of the housing and the other is located beneath the oil pressure strainer.

7-72. Use wrench 805043 to remove or replace any of the drain plugs. Use a new gasket when a drain plug is reinstalled. If a 1.44 inch OD gasket is used, the use of the oil seal ring is optional. If the 1.25 inch OD gasket is used, the oil seal ring must be used. Torque the plug to 150 - 175 inch-pounds. Lockwire.

7-73. FRONT OIL PUMP ROCKER BOX SCAVENGE GEAR HOUSING.

7-74. This operation requires removal and replacement of the following part:

	Paragraphs
Rocker Box Drain Manifold to Scavenge Pump Tube	7-50, 7-51

7-75. REMOVAL.

a. Remove the scavenge gear housing attaching nuts using a 1/2 inch wrench.

b. Remove the fillister head screws from the two puller holes. Use two pullers, 806961, and break the housing loose from the front oil pump. Remove the housing, being careful that the scavenge gear coupling or check valve assembly does not fall from the pump. Remove the check valve assembly and the scavenge gear coupling.

7-76. REPLACEMENT.

a. Install a new oil seal ring on the check valve body flange. Coat the valve assembly with oil and insert it in the front pump housing.

b. Install the rocker box scavenge gear coupling in the main scavenge driven gear. Place a new packing ring in the groove on the gear housing parting surface.

c. Position the gear housing over the studs on the front oil pump. Turn the gear to mesh with the coupling. Secure the scavenge gear housing to the front pump and sump with washers and self-locking nuts. Tighten to 125 - 140 inch-pounds.

d. Install washers and the two puller substituting screws. Tighten to 30 - 35 inch-pounds and lockwire.

7-77. FRONT OIL PUMP OIL PRESSURE CONTROL VALVE.

7-78. REMOVAL.

a. Remove the control valve cap using a 5/8 inch wrench and remove the gasket.

b. Insert wrench 806987 so the slots are over the valve spring seat locking pin and the lugs are in the slots in the valve body and loosen the assembly. Remove the assembly from the pump.

c. Push out the locking pin which passes through the holes in the valve body and the slots in the valve spring seat.

d. Unscrew the valve spring seat from the body using wrench 807005. Remove the spring and the valve.

7-79. REPAIR. If necessary, polish the control valve and the bore of the valve body with crocus cloth and engine oil. Wash the valve and body thoroughly in petroleum solvent and then coat the parts with clean engine oil.

7-80. REPLACEMENT.

a. Measure the tension of the control valve spring. The load at 1.55 inch height should be 13 - 15 pounds.

b. Install the control valve body in the bore of the pump and sump housing and torque to 350 - 400 inch-pounds using wrench 806987.

c. Lubricate and install the control valve. Install the spring and the spring seat. Turn the seat in using wrench 807005. Adjust the oil pressure as described in paragraph 7-19.

d. Insert the seat locking pin through the holes in the valve body and the slots in the spring seat.

e. Install a new gasket and the valve cap. Torque the cap to 75 - 100 inch-pounds and lockwire.

7-81. FRONT OIL PUMP AND SUMP STRAINER.

7-82. Remove the strainer using a 1-1/8 inch wrench. Use a new copper gasket when replacing the strainer. Tighten the strainer plug to

175 - 200 inch-pounds. Lockwire the strainer plug to the hole in the pump and sump housing.

7-83. FRONT OIL PUMP AND SUMP.

7-84. This operation requires removal and replacement of the following parts with the exception as noted:

	Paragraphs
Rocker Box Drain Manifold to Scavenge Pump Tube	7-50, 7-51
External Oil Tubes (Do not remove the tubes; let them remain between the cylinders and clear of the front oil pump and sump.)	7-58

7-85. REMOVAL.

a. Disconnect the crankcase front main section oil drain tube at the sump. Use a 1/2 inch wrench.

b. Remove the oil pump and sump attaching screws and washers with a 1/2 inch wrench. Remove the two fillister head locating screws.

CAUTION

Do not use the locating screw holes as puller holes.

c. Tap the pump lightly with a fiber mallet to break the seal and remove the pump with a turning motion to work it free from the crankcase front main section oil drain tube. Be careful that the pump drive shaft does not fall as the pump is removed. If it remains in the crankcase front section, remove it.

d. Remove the oil seal ring from the front end of the front main section oil drain tube.

7-86. REPLACEMENT.

a. Install new oil seal rings in the two transfer hole grooves and the two vent holes on the top of the pump. Place a new gasket on the pump flange.

b. Install new oil seal rings on the oil pump drive shaft. Insert the double splined end of the shaft in the pinion in the crankcase front section. Slowly rotate the shaft until the small splines on the inner end mesh with the splines in the pinion cap.

c. Install a new oil seal ring over the front end of the crankcase front main section oil drain tube.

d. Install the pump with a twisting motion to ensure insertion of the crankcase front main section oil drain tube in the pump. Place washers over the two fillister head locating screws and locate the pump with these screws.

e. Install washers and the pump attaching screws. Tighten the attaching screws to 125 - 140 inch-pounds. Tighten the locating screws to 40 - 45 inch-pounds. Lockwire the locating and attaching screws.

f. Install the crankcase drain tube attaching screws and tighten to 125 - 140 inch-pounds. Lockwire.

7-87. REAR OIL PUMP OIL PRESSURE RELIEF VALVE.

7-88. REMOVAL.

a. Remove the pressure relief valve cap using wrench 802139. See figure 7-30.

b. Loosen the pressure relief valve body using wrench 805925. Remove the valve assembly from the pump.

7-89. DISASSEMBLY.

a. Loosen the adjusting screw lock nut with a 1 inch wrench and remove the nut. Unscrew the adjusting screw from the valve body. Remove the inner and outer springs. Remove the three oil seal rings from the valve body.

b. Dislodge the circlet from the groove on the ID of the valve body by inserting a suitable piece of drill rod through one of the three holes in the valve body. See figure 7-31. Remove the circlet with long-nose pliers. Remove the valve from the valve body.

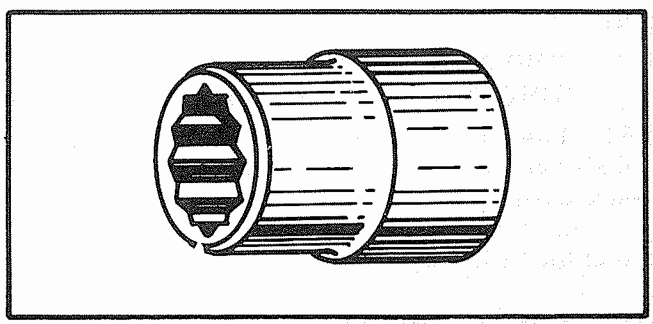


Figure 7-30. Oil Pressure Relief Valve Cap Socket Wrench

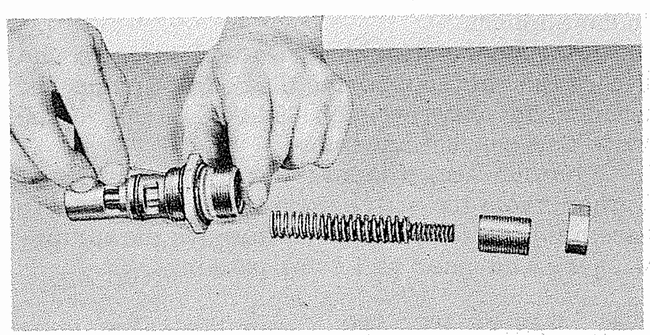


Figure 7-31. Dislodging Oil Pressure Relief Valve Retaining Circlet

7-90. REPAIR. Polish the relief valve and the bore of the valve body with crocus cloth and clean engine oil. Wash thoroughly in petroleum solvent and coat the parts with clean engine oil.

7-91. REASSEMBLY.

a. Check the tension of the relief valve inner and outer springs. The inner spring load at 2.24 inch height should be between 10.60 - 13.00 pounds. The outer spring load at 2.08 inch height should be between 18.00 - 21.90 pounds.

b. Install the valve in the body. Install the relief valve retaining circlet in the groove on the ID of the valve body using long-nose pliers. Install the inner and outer springs.

c. Turn the adjusting screw about halfway into the lock nut and install the adjusting screw in the valve body.

7-92. REPLACEMENT.

a. Install a new packing ring in the groove between the oil relief openings in the valve body and another under the hexagon flange. Install the assembly in the rear pump. Torque the valve body to 350 - 400 inch-pounds using wrench 805925.

b. Adjust the rear oil pump oil pressure as described in paragraph 7-17. Tighten the lock nut to 25 inch-pounds.

c. Install a new packing ring and the relief valve cap. Torque the cap to 75 - 100 inch-pounds using wrench 802139. Lockwire the cap to the valve body.

7-93. SUPERCHARGER CLUTCH OIL CONTROL VALVE AND SLEEVE.

7-94. The supercharger clutch oil control valve and sleeve normally do not require attention between overhauls. In the event oil leakage or sticking is encountered, they should be removed and inspected.

7-95. VALVE REMOVAL.

a. Disconnect the linkage at the clutch oil control valve and temporarily install a washer and nut on the end of the valve stem to retain the valve in the support.

b. Remove the attaching nuts and washers that secure the valve support to the rear oil pump and sump body using wrench 804885. Remove the valve and support assembly.

c. Remove the temporary retaining nut and washer from the valve stem and pull the valve assembly from the support. Remove the spring, washer, and inner and outer packings.

7-96. VALVE REPAIR. Clean the valve stem with crocus cloth, and clean engine oil. Wash the valve thoroughly in petroleum solvent and coat with clean engine oil.

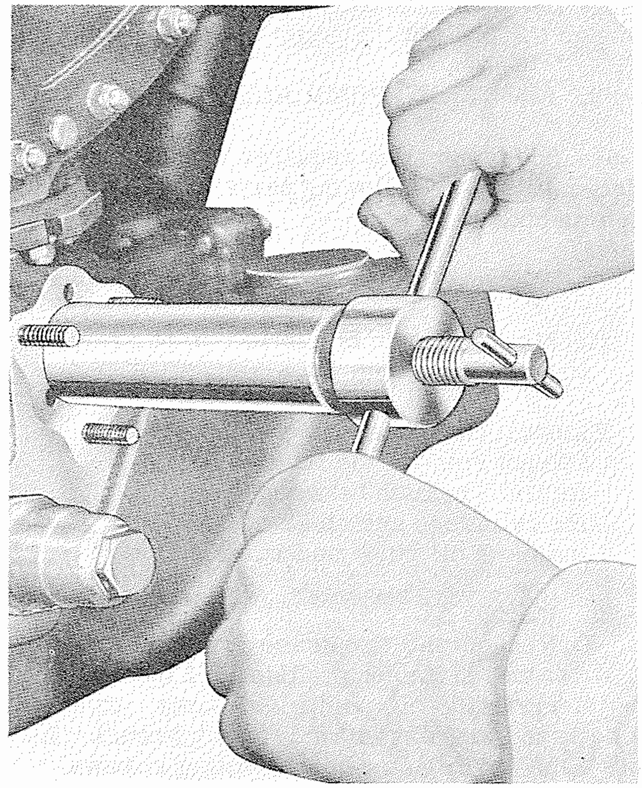


Figure 7-32. Removing Supercharger Clutch Oil Control Valve Sleeve

7-97. SLEEVE REMOVAL.

a. Use puller 806474 to remove the valve sleeve. Back off the tool long handle until the nut is almost contacting the short handle. Insert the puller in the valve sleeve and align it by engaging the pin in the puller bushing with the slot in the sleeve.

b. With the tool sleeve and bearing held back against the nut with one hand and with a finger of the other hand pushing against the tool bushing flange, pull the tool sleeve rearward. This will force the plunger in the tool bushing into the hole in the valve sleeve.

c. Position the tool sleeve over the bushing flange against the rear oil pump body. Turn the long handle and withdraw the sleeve from the pump. See figure 7-32.

d. To remove the puller from the valve sleeve, press the plunger from the hole in the valve sleeve and withdraw the tool from the sleeve.

7-98. SLEEVE REPLACEMENT.

a. Place the clutch control valve sleeve over the plug of installing tool 807319 (figure 7-33) so the pin in the tool is located in the slot on the end of the sleeve.

b. Insert the sleeve in the pump so the sleeve enters its bore and the locator on the installing tool enters the oil hole at the top of the mounting pad simultaneously.

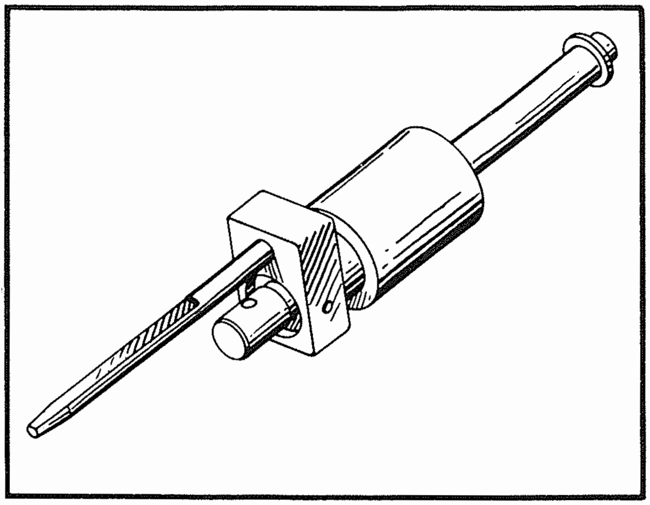


Figure 7-33. Supercharger Clutch Oil Control Valve Sleeve Installing Tool

7-99. VALVE REPLACEMENT.

a. Check the tension of the control valve spring. The load at 2.12 inch height should be 16.00 - 19.70 pounds.

b. Assemble the spring, spring washer, and inner and outer packing over the valve stem and insert the valve in the support. Install a washer and nut on the valve stem threads to retain the valve in the support. Check the assembly to ensure that the valve does not bind in the support and has full travel.

c. Place a new gasket on the rear oil pump and sump housing and install the valve and support assembly. Secure with washers and self-locking nuts. Tighten the nuts to 125 - 140 inch-pounds, using wrench 804885.

d. Again check the valve for freedom of operation. Remove the nut and washer from the valve stem and connect the control valve linkage.

7-100. REAR OIL SUMP SCAVENGE STRAINER.

7-101. REMOVAL. Loosen the sump strainer plug using a 1-1/4 inch wrench. Withdraw the strainer. See figure 7-34.

7-102. REPLACEMENT. Place a new gasket under the flange on the strainer plug and install the strainer and plug. Tighten the plug to 175 - 200 inch-pounds. Lockwire.

7-103. REAR OIL PUMP PRESSURE STRAINER.

7-104. REMOVAL.

a. Loose the strainer cover with a 1-1/4 inch socket wrench.

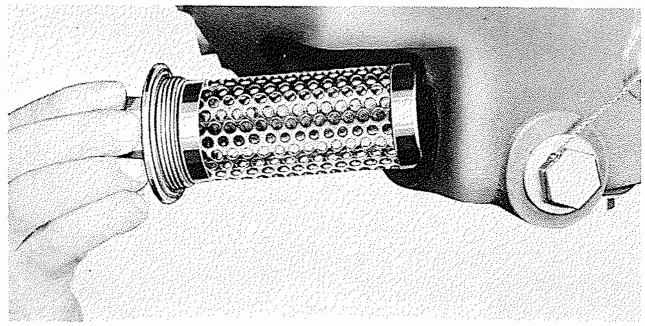


Figure 7-34. Removing Rear Oil Sump Strainer

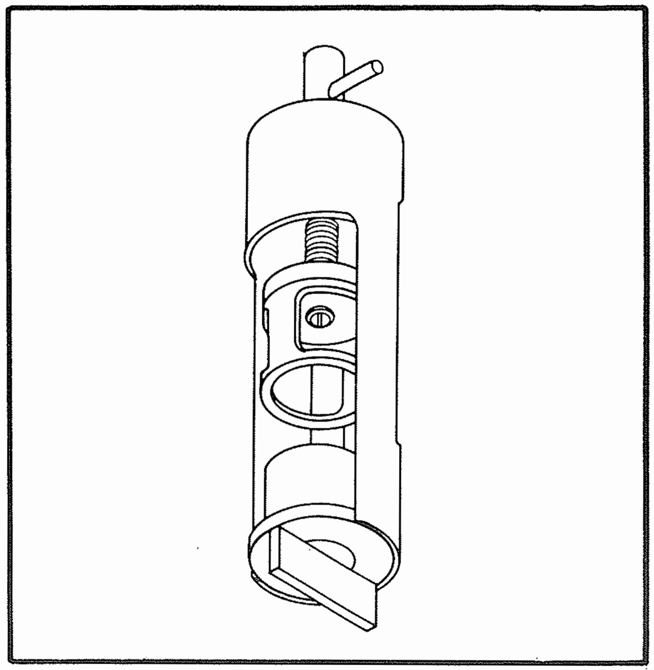


Figure 7-35. Rear Oil Pump Pressure Strainer Disassembly and Assembly Fixture

b. Remove the strainer cover, oil seal and rear half strainer assembly from the rear pump and sump housing.

c. Withdraw the front half strainer assembly from the pump and sump housing.

CAUTION

Ensure that the strainer assembly is withdrawn horizontally from the pump and sump housing to prevent foreign material, which may have collected in the strainer from falling into the oil chamber surrounding the strainer.

7-105. DISASSEMBLY OF REAR OIL PUMP PRESSURE STRAINER.

7-106. FRONT HALF STRAINER.

a. Place the flat end of fixture 808709, shown in figure 7-35 in a vise.

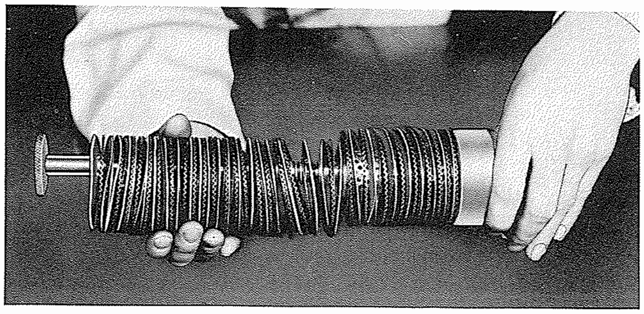


Figure 7-36. Spreading Rear Oil Pump Pressure Strainer Screens and Spacers

b. Install the front half strainer assembly in the fixture, lock ring end up.
c. Turn the fixture handle and compress the strainer stack just enough to permit removal of the lock ring with pliers 806990 through the opening in the clamp portion of the fixture.
d. Remove the lock ring and back off on the clamp handle.
e. Remove the strainer assembly from the fixture and set aside the retainer washer.
f. Slide the strainer elements, as a complete unit, without changing the sequence, from the strainer core onto a suitable cleaning rod as shown in figure 7-36.

7-107. REAR HALF STRAINER. Remove the rear half strainer assembly from the strainer cover and proceed as instructed in paragraph 7-106.

7-108. CLEANING OF DISC TYPE STRAINER. The disc type strainer may be cleaned in one of the following methods.

7-109. CLEANING WITH ULTRA-SONIC WASHING MACHINE. Excellent results may be obtained with an Ultra-Sonic cleaning unit, which may be procured from the Industrial and Scientific Products Division, Curtiss-Wright Corp., Caldwell, N. J. Specific information may be obtained by contacting the above address.

7-110. CLEANING WITH SOLUTIONS. Paragraph 7-111 describes methods when using Brent Chemical Cleaners. Paragraph 7-112 describes methods when using Turco Chemical Cleaners.

CAUTION

Whenever using any of the following chemicals, either Ardrox or Turco products, caution must be taken to prevent contact with the skin or eyes. Use protective equipment at all times.

7-111. BRENT CHEMICAL CLEANERS.
a. Immerse the screens and discs in a bath of trichlorethylene for 10 minutes. Remove the screens and discs from the trichlorethylene bath and allow to drain back to minimize drag-out loss and consequent dilution of the next solution.
b. Place the screens and discs in a tank containing Ardrox 640 (Brent Chemical Products Ltd., Commerce Road, Brentford, Middlesex, England) and maintain the temperature of Ardrox 640 solution at 71°C (160°F). Place the cover over the tank. Apply air pressure to agitate the solution for a period of one hour. Remove the screens and discs and allow to drain.
c. Wash the screens and discs with a high pressure steam jet and allow to drain.
d. Immerse in Ardrox 39/1 solution to remove any water. This will also preserve the filters by preventing rust.

7-112. TURCO CHEMICAL CLEANERS.
a. Soak the screens and discs in Turco Transpo (Turco Products, Inc., Los Angeles, California), for approximately 15 to 20 minutes. Remove the screens and discs and allow to drain.
b. Soak the screens and discs in trichlorethylene for 10 minutes. Remove and allow to drain completely.
c. Immerse the screens and discs in Turco Solution 3823 for 15 minutes. Maintain the temperature of the solution at 71°C (160°F). Remove and allow to drain.
d. Wash the screens and discs with a high pressure steam jet. Dip the screens and discs in petroleum solvent to remove any trace of water. Coat the screens and discs with corrosion-preventive compound. This will preserve the elements by preventing rust.
e. Repeat the cleaning procedure, if necessary.

7-113. REASSEMBLY OF REAR OIL PUMP STRAINER.

7-114. FRONT HALF STRAINER.
a. Transfer the screens and discs in their proper sequence from the cleaning rod to the strainer core.

NOTE

The assembling sequence of the strainer element is a spacer fluted on the inside diameter, a screen, a spacer fluted on the outside diameter and a screen. Repeat in sequence finishing with a screen and a spacer fluted on the inside diameter. See figure 7-37.

b. Position the retainer washer and the lock ring on the strainer stack.
c. Install the strainer assembly in fixture 808709 lock ring end up.
d. Insert a torque wrench in the square drive socket in the fixture handle.

NOTE

The compressive load on assembled strainers must be sufficient to prevent rotation of the screens and spacer discs by hand, however, the compressive load should not exceed 700 pounds. The related comparison between the torque value and a compressive axial load of 700 pounds, when using fixture 808709 is 45 inch-pounds. Add or remove complete sets of strainer units as required, in their proper sequence, or add screens as shims to obtain the specified axial load.

e. Compress the strainer stack to expose the lock ring groove sufficiently to enable the lock ring to be installed, but do not exceed 45 inch-pounds torque on the fixture handle.

CAUTION

Do not compress the strainer stack any more than necessary to install or remove the lock ring in the lock ring groove. Ensure that the strainer elements do not catch in the lock ring groove when compressing the strainer stack.

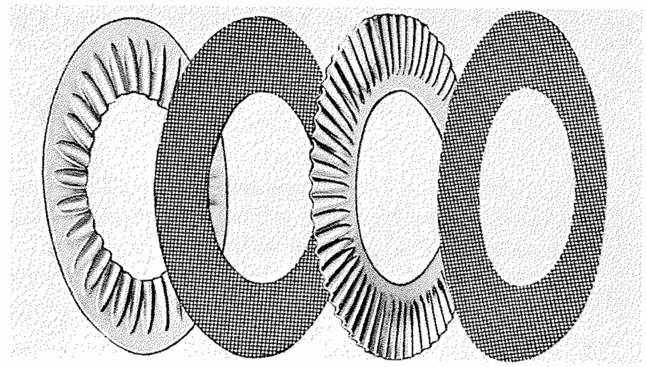


Figure 7-37. Arrangement of Strainer Screens and Spacers

f. Install the lock ring with pliers 806990 and loosen the fixture handle.
g. Remove the assembled strainer from the fixture and attempt to rotate the strainer elements by hand.

7-115. REAR HALF STRAINER. Reassemble the rear half strainer assembly as instructed in paragraph 7-114.

7-116. REPLACEMENT.
a. Install a new oil seal ring on the strainer cover.
b. Insert the front half strainer assembly into the rear pump and sump housing.
c. Install the cover and rear strainer assembly into the rear pump and sump housing. Ensure that the front end of the rear strainer assembly aligns with the rear end of the front strainer assembly, and the cover engages the sump threads.
d. Tighten the strainer cover to 300 - 350 inch-pounds and lockwire.

7-117. REAR OIL PUMP AND SUMP PRESSURE AND SCAVENGE GEAR HOUSINGS.

7-118. REMOVAL. Remove either the pressure or scavenge gear housing without removing the pump and sump body in the following manner:

a. Remove the drain plugs from the rear sump using wrench 805043. Allow the oil to drain from the sump.

b. Remove the rear oil pump body cover lockwire, cap screws and washers with a 1/2 inch wrench. Remove the cover to provide access to the pump drive gears. Remove the oil seal ring from the cover.

c. Remove the fiber-lock nuts retaining the gear housing to the pump and sump body, using a 1/2 inch wrench. Remove the puller screw hole plugging screws from the gear housing cover and install pullers 806962. Break the seal between the gear housing and the pump and sump body.

d. Reach through the opening in the bottom of the pump and sump body and remove the drive gear as the gear housing is being withdrawn. Remove the packing ring from the gear housing end plate. Remove the cover to sump housing gasket.

7-119. REPLACEMENT.

a. Ensure that the numbers on all components of the gear housing match, and check the gears for freedom of action.

b. Install a new packing ring in the groove on the gear housing end plate, and place a new gasket over the attaching studs in the pump and sump body.

c. Install the gear housing approximately half way into the bore of the pump and sump body. Position the drive gear assembly in the end of the gear housing drive gear shaft, installing it through the hole in the bottom of the pump and sump body. See figure 7-38. Complete the installation of the gear housing over the attaching studs.

d. Secure the housing with self-locking nuts tightened to 125 - 140 inch-pounds. Place copper washers on the puller screw hole plugging screws, and install them on the housing cover. Tighten the screws to 40 - 45 inch-pounds.

e. Install a new oil seal ring on the rear oil pump body cover and install the cover. Install washers and cap screws. Tighten to 125 - 140 inch-pounds and lockwire.

f. Reinstall the drain plugs. Tighten the plugs to 150 - 175 inch-pounds, using wrench 805043 and lockwire.

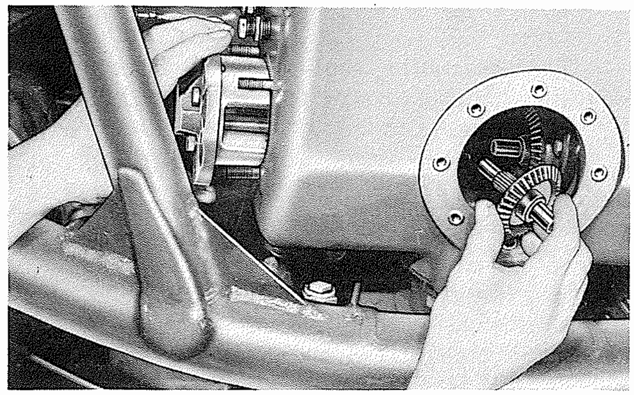


Figure 7-38. Positioning Drive Gear through Hand Hole in Rear Oil Pump and Sump Housing

7-120. REAR OIL PUMP AND SUMP.

7-121. REMOVAL.

a. Remove the cap screws from the oil sump inlet connector flange on the supercharger rear housing using a 1/2 inch wrench. Loosen the clamps on the connector hose.

b. Remove the pump and sump front attaching nuts using wrench 805567. Remove the rear attaching nuts using wrench 805566. See figures 7-39 and 7-40. Remove the pump and sump housing and gasket.

c. Remove the pump to rear housing oil dowels.

d. Remove the cap screws from the oil sump inlet connector flange on the pump and sump housing using a 1/2 inch wrench and remove the connector.

7-122. REPLACEMENT.

a. Install a new oil seal ring in the oil connection tube hole counterbore. Install a new oil seal ring on each end of the two pump to supercharger rear housing oil dowels. Install the dowels in the supercharger rear housing. Place a new gasket over the pump mounting studs.

b. Install a new oil seal ring on the rear oil sump inlet connector. Place the connector on the center front pad of the rear oil pump and sump housing and attach with four washers and screws, tightened to 125 - 140 inch-pounds. Lockwire. Install the connector hose and two clamps. Do not tighten the clamps at this time. Place a new oil seal ring in the front inlet connector and insert the connector in the hose.

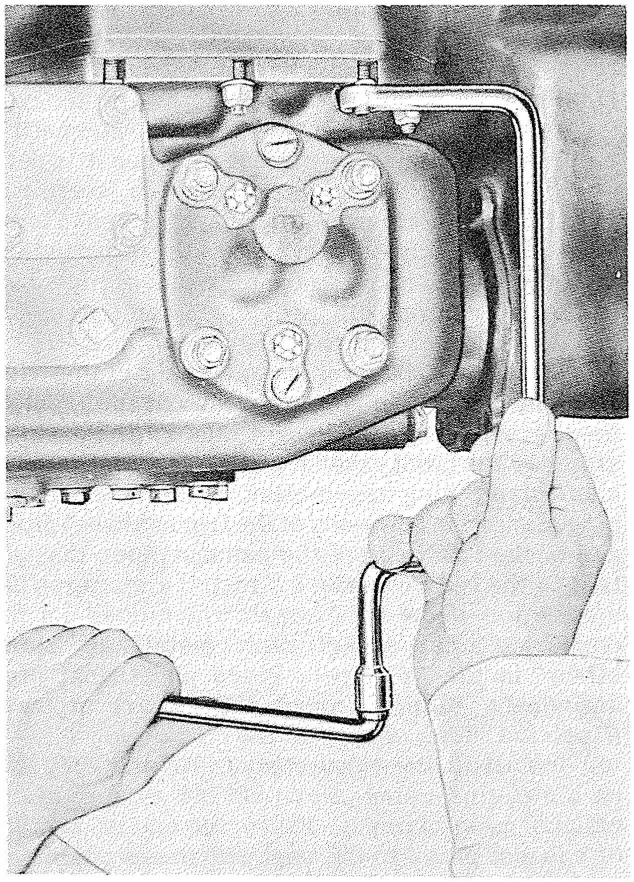


Figure 7-39. Removing Rear Oil Pump and Sump Housing Front Attaching Nuts

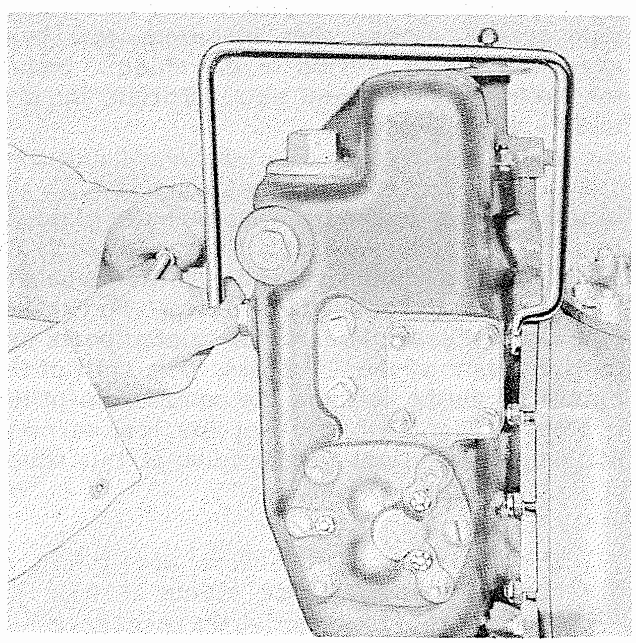


Figure 7-40. Removing Rear Oil Pump and Sump Housing Rear Attaching Nuts

c. Position the oil pump and sump over the mounting studs, aligning the oil sump inlet connector over the opening on the supercharger rear housing. Secure the oil pump and sump with washers and self-locking nuts. Tighten the nuts to 125 - 140 inch-pounds using wrenches 805566 and 805567.

d. Install the inlet connector cap screws and washers at the supercharger rear housing and tighten to 125 - 140 inch-pounds. Lockwire in pairs. Tighten the connector hose clamps to 80 - 85 inch-pounds. Lockwire the screws to each other.

7-123. EXHAUST PIPES.

7-124. The following instructions are for the replacement of the complete exhaust pipe system. For any one exhaust pipe replacement use the information wherever applicable. Note that in order to remove a front exhaust pipe the rear exhaust pipe serving the same cylinder must first be removed.

7-125. REMOVAL. This operation requires removal and replacement of the following part:

	Paragraph
Cylinder Head Air Deflector (for front cylinder exhaust pipes)	7-144

a. Remove the rear exhaust pipe "figure 8" clamp attaching nuts and bolts, anti-chafe plates, the sleeve at the short bolt location, and the swivel spacers. Remove the "figure 8" clamps.

b. Remove the screws that secure the exhaust pipe left and right hand brackets to the bosses on the rear cylinder rocker boxes. Remove the brackets.

c. Remove the nut and bolt from the clamps that secure the rear exhaust pipes to the front exhaust pipes, the clamps at the front and rear cylinders and the clamp at each power recovery turbine. Use pliers 923180 to separate the clamps. See figure 7-41. Slide the clamps onto the exhaust pipes, with the exception of the clamp at the turbine nozzle which slides onto the nozzle.

d. Remove the rear exhaust pipes. Pull the front exhaust pipes rearward and lift out. Plug the cylinder exhaust ports and the straight inlet nozzle connection of the PRT assemblies with covers 808400D6. Plug the ball joint nozzle connections of the PRT assemblies with covers 808400D7.

7-126. REPLACEMENT. To simplify the instructions on exhaust pipe installation, terminology that does not conform to part nomenclature is used as follows: Dual exhaust pipes to cylinders

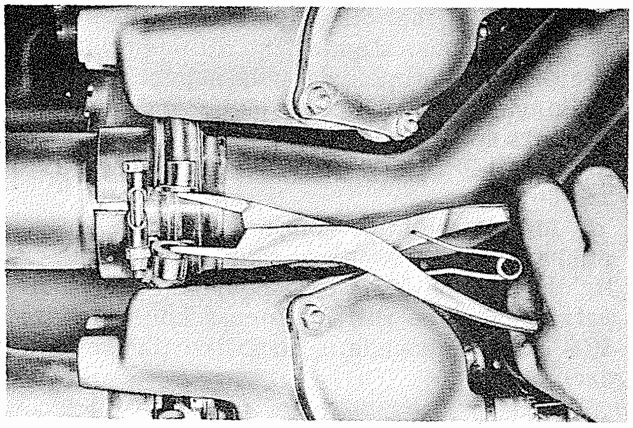


Figure 7-41. Separating Exhaust Pipe Clamp

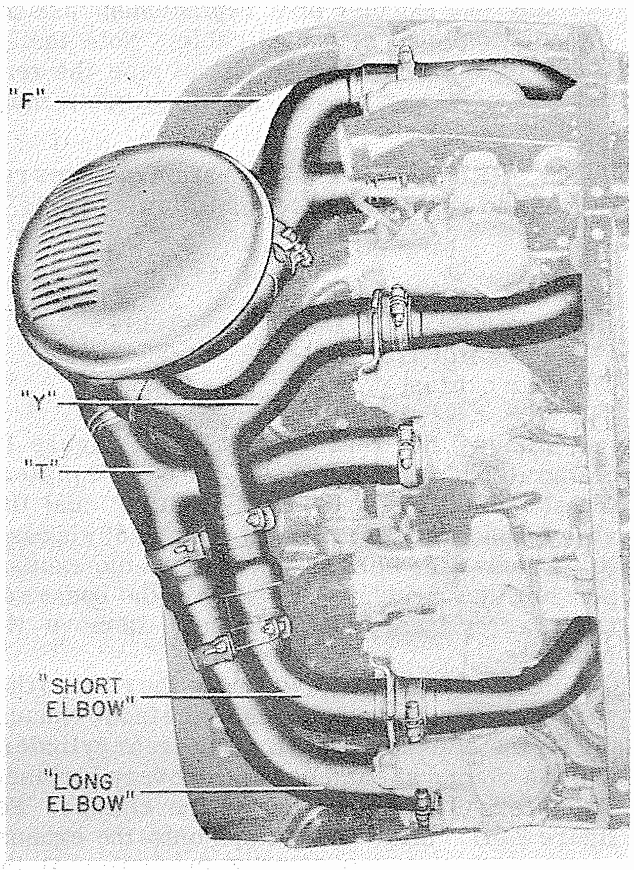


Figure 7-42. Exhaust Pipe Configuration

No. 4-5, 10-11, and 16-17, which resemble the letter **F**, are called "F" pipes; dual pipes to cylinders 2-18, 6-8, and 12-14, which resemble the letter Y, are called "Y" pipes; dual pipes to cylinders 1-3, 7-9, and 13-15 which resemble the letter T, are called "T" pipes. The rear single pipes to cylinders 2, 8, and 14 are called "short elbows" and the single pipes to cylinders 3, 9, and 15 are called "long elbows". See figure 7-42.

a. Prepare the following mixture: Add three parts (by volume) of Ucon Oil, type 50HB-280X (Carbide and Carbon Chemical Corp., N. Y., N. Y.) to two parts (by volume) of Molykote, type Z (Alpha Corp., Greenwich, Conn.). Stir until a homogenous mixture is obtained. When it is necessary to store the prepared mixture, keep it in an air tight container away from extremes in temperature. Always stir the mixture before using.

b. Apply this mixture on all exhaust pipe ball joints and clamp bolt threads and on the inside of all clamps except the "figure 8" clamps.

c. Place an exhaust pipe anti-chafe clamp ring assembly, with the bolt boss toward the front of the engine, around the legs of the "Y" pipes which attach to the front exhaust pipes. Install the anti-chafe clamp ring assemblies. Place the exhaust pipe clamps on both ends of the front exhaust pipes and on the front end of the exhaust pipes that attach to the rear cylinders. Install a clamp on the connection of the PRT nozzle which does not incorporate a ball socket joint. Install the "short elbow" in the "Y" pipe. Place an exhaust pipe anti-chafe clamp around the "short elbow". Place the "long elbow" in the "T" pipe.

d. Install all the exhaust pipes for one PRT unit on the engine using pliers 923180 to spread the exhaust pipe clamps. Place the entire system of exhaust pipes in the best alignment possible. Install the bolts in the clamps and tighten the nuts sufficiently to prevent the exhaust pipes from moving freely. Ensure that the exhaust pipe clamp dimple engages in its respective notch.

e. Locate the anti-chafe clamps on the exhaust pipes between the rear cylinders so the exhaust pipe bracket arms, when installed, will bear against the ring portion of the clamp. Install the bolts, washers, and nuts. Torque the nuts to 30 - 40 inch-pounds.

f. Attach the right and left hand exhaust pipe brackets to the rocker boxes loosely with the bracket arms around the anti-chafe clamps. Position the front exhaust pipe assembly centrally between the cylinders and push the brackets tight against the anti-chafe clamp. No exhaust pipe bracket assemblies or associated parts are installed against the "F" pipes. The split of the clamp should be between the outer arms of the brackets. Tighten the bracket attaching screws, but not to their final torque value at this time.

NOTE

Ensure that the brackets are tight against the anti-chafe clamp at this time in order to establish the necessary clearance later.

g. Torque the clamp bolt self-locking castellated nuts to 100 - 125 inch-pounds, or, if clamp

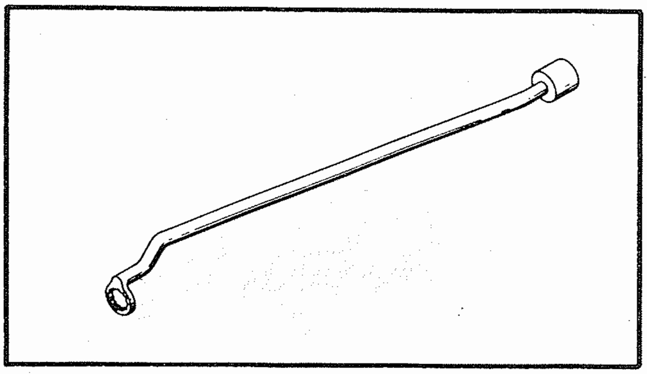


Figure 7-43. Exhaust Pipe Clamp Bolt Nut Wrench

bolt elastic stop nuts are used, torque them to 125 - 150 inch-pounds. Use wrench 807749 (figure 7-43) and follow the sequence outlined in succeeding steps h through p, to ensure correct alignment of the exhaust pipes.

h. Ensure that the "T" pipe is centrally aligned with the ball joint of the PRT nozzle outlet. Maintaining the alignment, torque the clamp nut on the pipe at cylinder No. 1, 7, or 13 depending on which PRT exhaust system is being installed.

i. Align the "long elbow" pipe extending from the "T" pipe and torque the clamp nut at cylinder No. 3, 9, or 15.

j. Position one of the "figure 8" clamps over the "T" and "Y" pipes and the other over the long and short "elbows" at the locations shown in figure 7-42. They must be over the anti-chafe strips welded to the pipes. Install the short bolt, spacer sleeve and nut at the outer end of each "figure 8" clamp. Install the long bolt, with an anti-chafe plate under the bolt head, through the center spacer. Add an anti-chafe plate to the threaded end of the bolt, and secure with a nut finger tight. Ensure that the curved area of the spacer is flush with the curved area of the exhaust pipe. At this time torque the short outer bolts only. This centers the exhaust pipes within the two "figure 8" clamps.

k. Maintaining alignment, torque the clamp nut on the front to rear pipe connectors at the "Y" pipe, the "short elbow" and the "F" pipe.

l. Ensure that the self-locking nut of the long center bolts at the "figure 8" clamps does not bottom on the last thread. If it does, add washers under the nut. Torque the nut.

m. Torque the exhaust pipe clamp nut at all the front cylinders ensuring that the pipe is centered between the rocker boxes.

n. Torque the clamps on the "F" pipe at the rear cylinder and at the PRT nozzle.

o. Loosen the attaching screws on the exhaust pipe brackets. Reset them with .015 inch wire stock between the brackets at the throat location and the anti-chafe clamps. Torque the bracket attaching screws to 125 - 140 inch-pounds. Remove both pieces of wire stock. See figure 7-44.

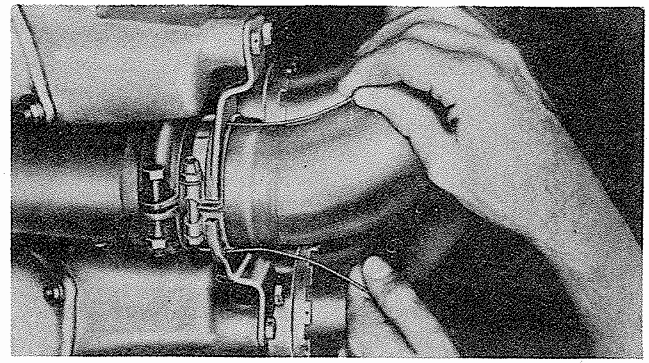


Figure 7-44. Removing Wire Stock from Exhaust Pipe Brackets

p. Check the entire system for alignment. Lockwire the exhaust pipe bracket assembly bolts.

NOTE

Should misalignment exist at any location, especially at the "T" pipe and the PRT ball joints, all pipes and clamps affecting the locations must be loosened prior to re-alignment. Re-aligning the trouble spot only, by forcing or other means, without loosening other components will place the joint under stress load. This usually results in subsequent misalignment since the parts spring back to the unloaded position when the exhaust system undergoes a temperature change.

7-127. INTAKE PIPES.

7-128. REAR INTAKE DUAL PIPES - REMOVAL. This operation requires removal and replacement of the following part:

	Paragraph
Exhaust Pipes	7-123

a. Loosen the intake pipe connection nuts between the front and rear pipes and at the rear cylinders using wrench 805569. See figure 7-45. Slide the nuts back on the pipe.

b. Remove the intake pipe flange to supercharger front housing bolts, washers, and lock washers using a 1/2 inch wrench.

c. Remove the rear pipe and remove the sleeve, packing, flanges, and gasket from the rear end and the nut, packing, and sleeves from the front end of the pipe. Install cover 808400D8 on the

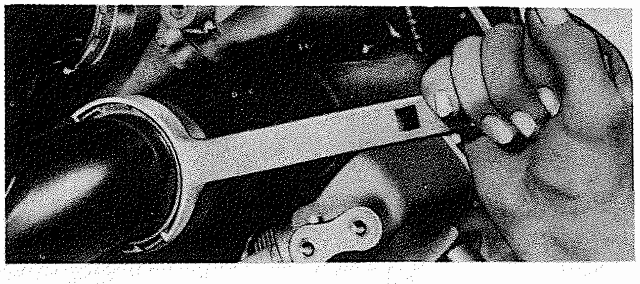


Figure 7-45. Loosening Front to Rear Intake Pipe Connection Nut

rear cylinder pipe connection. Install cover 808400D6 in the rear end of the front intake pipe. Install cover 808400D5 on the port in the supercharger front housing.

7-129. FRONT INTAKE PIPE - REMOVAL. This operation requires removal and replacement of the following part:

	Paragraphs
Rear Intake Dual Pipe	7-128, 7-131

a. Disconnect the connection nut at the front cylinder using wrench 805569. Withdraw the pipe a short distance and remove the packing, sleeves, and connection nut from the front end of the pipe. Remove the pipe.

b. Install cover 808400D8 on the front cylinder intake pipe connection.

7-130. FRONT INTAKE PIPE - REPLACEMENT. The intake pipe connection at the front cylinder is shown in figure 7-46.

a. Remove the cover from the connection in the front cylinder Coat the threads of the intake pipe to cylinder connection nut with anti-seize compound, Lubriplate 130A.

b. Position the front intake pipe between the two rear cylinders and install the connection nut, the two sleeves, and the packing on the front end of the pipe. Coat new packing with Lubriplate 130A and position it over the bead on the pipe.

c. Start the nut on the front cylinder connection. Tighten the nut after the rear intake pipe is installed as described in paragraph 7-131.

7-131. REAR INTAKE DUAL PIPE - REPLACEMENT. The connection at the rear cylinder and between the front and rear pipes is the same as the connection shown in figure 7-46. The connection at the supercharger front housing is shown in figure 7-47. A plug is installed in the fire detector boss on the dual pipe to cylinders No. 5 and 6. If the plug is removed, upon replacement use Lubriplate 130A on the threads, tighten the plug to 35 - 50 inch-pounds and lockwire. Plugs are installed in drain connections on the following rear intake pipes. One in the pipe to cylinders No. 11 and 12; two in the pipe to cylinders No. 9 and 10. If the plugs are removed, upon replacement use Lubriplate 130A on the threads, tighten the plugs to 60 - 90 inch-pounds and lockwire.

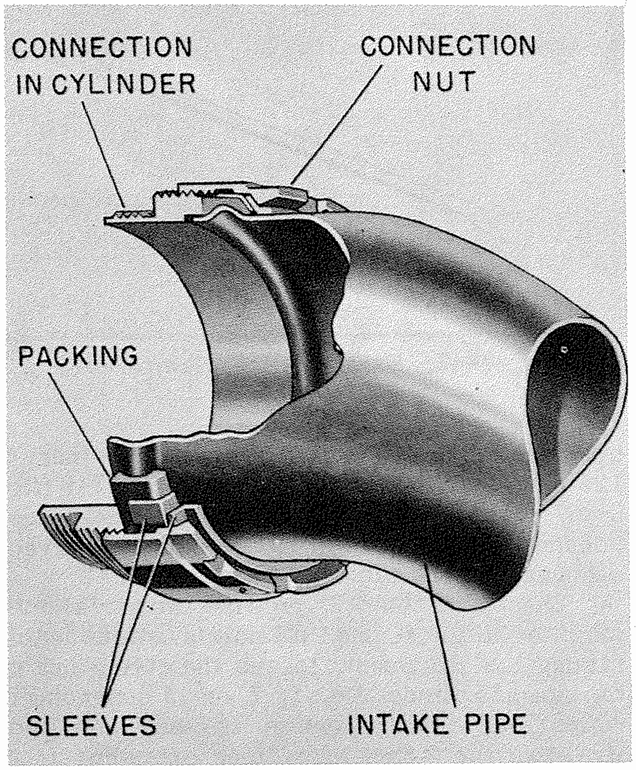
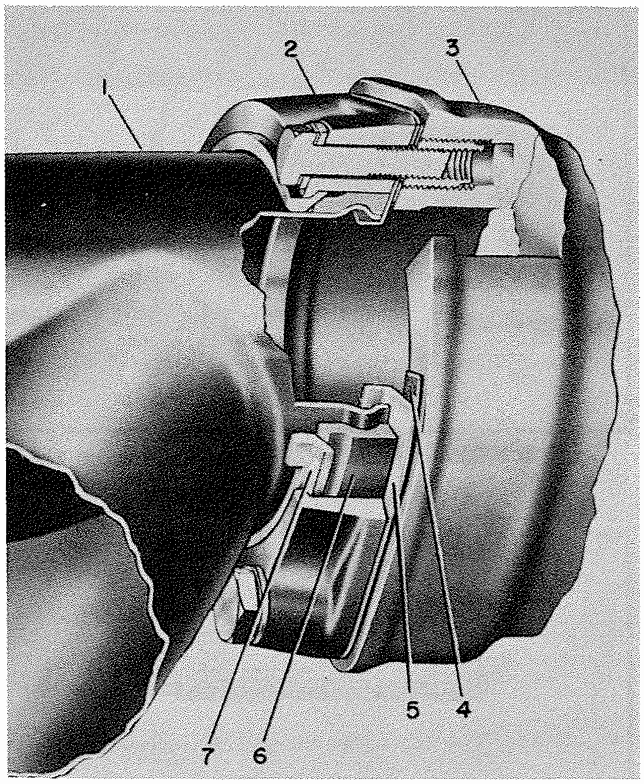


Figure 7-46. Intake Pipe Connection at Cylinder

a. Coat the threads on the nuts that connect the rear pipe to the rear cylinder and to the front pipe with Lubriplate 130A. Install the connection nuts and the sleeves over the front ends of the dual pipe. Coat new packing with Lubriplate 130A and position it over the bead on the pipes.

b. Install the attaching flange, and then the sleeve over the rear end of the dual pipe and past the bead. To provide ample clearance, position the non-pilot portion of the sleeve over the dual pipe throat weld. Coat new packing with Lubriplate 130A and position it over the bead on the pipe.

c. Remove the covers from the ports in the supercharger front housing and the rear cylinder. Position the packing retaining flange and gasket at the rear end of the pipe, aligning the holes with the holes in the attaching flange. Place a lock washer and plain washer on an attaching bolt and insert the bolt to keep the parts properly aligned. Locate the pipe on the engine



1. Dual intake pipe
2. Attaching flange
3. Supercharger front housing
4. Gasket
5. Packing retaining flange
6. Packing
7. Packing sleeve

Figure 7-47. Intake Pipe Connection at Supercharger Front Housing

and start the three attaching bolts at the supercharger front housing. Engage the two dimples on the front end of the rear pipe with the respective notches in the front pipe.

NOTE

When the dual intake pipe for cylinders No. 3 and 4 is replaced, the ignition cable main primary lead clamp is substituted for the plain washer at the attaching flange upper bolt location.

d. Start the connection nuts at the front pipe and at the rear cylinder. Tighten the flange to supercharger front housing attaching screws to 125 - 140 inch-pounds.

e. Torque the connection nuts using wrench 805569 with a torque handle inserted in the wrench to become an extension as shown in figure 7-48.

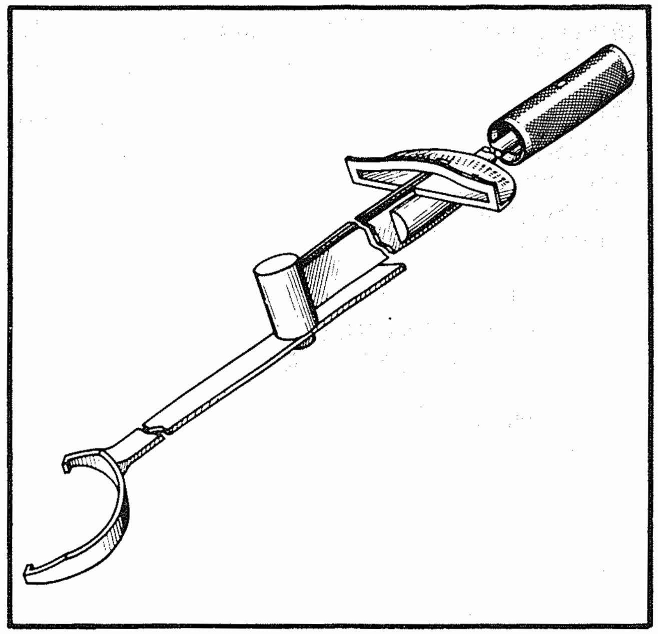


Figure 7-48. Intake Pipe Connection Nut Wrench with Torque Handle

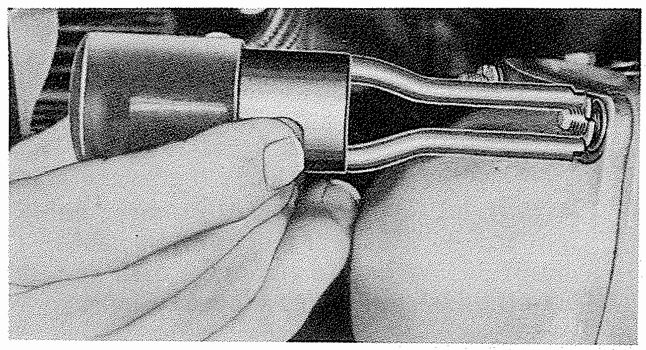


Figure 7-49. Removing Rocker Box Cover Nut Washers

Torque the nuts to an indicated 380 - 400 inch-pounds which translates to a torque at the nut of 570 - 600 inch-pounds.

7-132. ROCKER BOX COVERS.

7-133. This instruction applies only to those rocker box covers which are not associated with the rocker box drain system. For instructions concerning removal of rocker box covers connected to the rocker box drain system refer to paragraph 7-44.

7-134. REMOVAL. Remove the rocker box cover nuts using wrench 80449. Remove the washers using magnetic tool 84770. See figure 7-49. Remove the covers and gaskets.

7-135. REPLACEMENT.

a. Clean the parting surfaces of the cover and rocker box thoroughly. Lubricate the valve mechanism in the rocker box with clean engine oil.

b. Install a new, dry gasket on the rocker box and install the cover. Secure with lock washers and nuts. Tighten the nuts to 80 - 85 inch-pounds, in a sequence that will compress the gasket uniformly.

7-136. PUSH ROD HOUSING, PUSH ROD, VALVE TAPPET SOCKET AND SPRING, VALVE TAPPET AND GUIDE.

7-137. This operation requires removal and replacement of the following parts:

	Paragraphs
Rocker Box Cover	7-132
Exhaust Pipe (for rear cylinder exhaust push rod housing)	7-123
Front Intake Pipe (for rear cylinder intake push rod housing)	7-127

NOTE

It may be necessary to disconnect an ignition coil lead at the ignition cable manifold in order to remove a push rod housing assembly from a front cylinder.

7-138. REMOVAL.

a. Turn the propeller shaft until the valves in the cylinder being worked on are closed.

b. Loosen the valve clearance adjusting screw lock screw using wrench 807004. Turn the adjusting screw all the way out using a broad blade screwdriver.

c. Loosen the push rod housing connection nut at the cylinder. Use wrench 805964. Back the nut all the way off the cylinder connection.

d. Loosen the nut at the adapter using wrench 805965, (figure 7-50). Use wrench 806487, universal joint 806517, and extension 806518 (figure 7-51) on rear cylinders when intake pipes interfere. Do not disconnect the nut from the adapter.

e. Remove the push rod housing adapter attaching nuts and washers. Use wrench 806644, (figure 7-52). Remove the upper vent tube clamps from the front left hand stud for the adapter on the intake side of cylinders No. 12 and 14. Tap the adapter lightly with a fiber mallet to break the seal. Slide the adapter and push rod housing nut back on the housing as far as they will go.

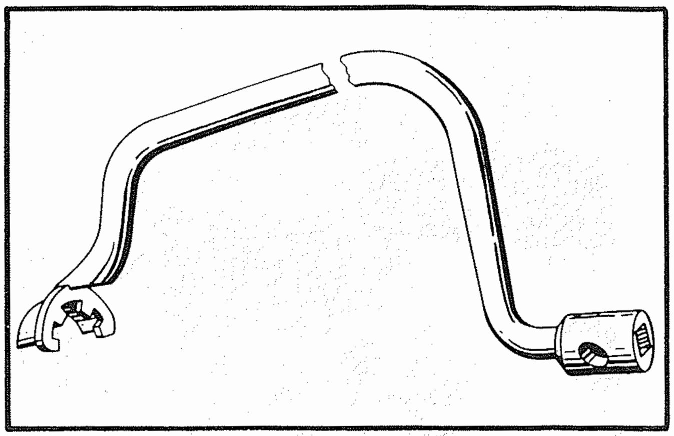


Figure 7-50. Push Rod Housing Inner Nut Wrench

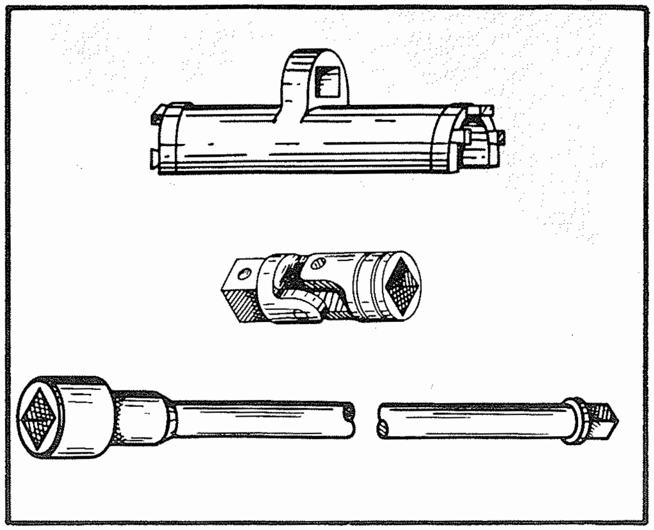


Figure 7-51. Push Rod Housing Nut Wrench, Universal Joint, and Extension

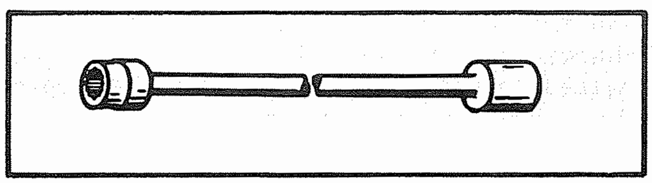


Figure 7-52. Push Rod Housing Adapter Attaching Nut Wrench

Screw the nut back on the adapter threads to telescope the assembly enough to clear the studs.

f. Pull the adjusting screw end of the rocker arm up. When this is done, the push rod pushes the tappet socket down far enough to clear the adapter and the push rod can be moved sideways out of the tappet socket. Remove the adapter, push rod housing, and push rod as an assembly. Remove the tappet socket and spring. Remove the attaching parts from the push rod housing.

CAUTION

Observe care in removing the push rod housing, since the push rod can drop out with resultant damage to the part.

g. Install holding clip 804849 in the holes in the tappet and guide. The clip will hold the tappet and guide together and prevent the circlet from becoming dislodged with possible loss of the tappet roller, pin, and bushing in the engine. Remove the tappet and guide assembly using adapter 805564 and puller 806784. See figure 7-53.

h. Remove the circlet and remove the tappet from the guide. Remove the tappet roller pin and remove the roller from the tappet. Remove the roller bushing.

7-139. REPLACEMENT.

a. Coat the threads of the push rod housing connection nuts with Lubriplate 130A. Slip an oil seal ring on the push rod housing against the flared end of the housing. Install the push rod housing to cylinder connection nut on the housing. Install the housing to adapter connection nut on the push rod housing.

b. Coat the ID of two new push rod housing lower nut washers and a packing ring with Lubriplate 130A. Slip a washer, the packing ring, then the other washer on the pilot of installing tool 807210. Insert the pilot in the lower end of the push rod housing so the shoulder on the pilot butts against the end of the housing. Push the washers and packing ring off the pilot and onto the push rod housing using the sleeve of the installing tool. See figure 7-54.

c. Intake and exhaust push rod housing adapters for either a front or rear cylinder are not interchangeable. One adapter is provided for front cylinder intake and rear cylinder exhaust; a second adapter is provided for front cylinder exhaust and rear cylinder intake. Place the adapter over the lower end of the push rod housing and start the connection nut. Insert the push rod in the housing.

d. Wipe the parting surfaces of the tappet guide clean and free from oil. Install a new gasket on the inner side of the tappet guide. Install the valve tappet roller bushing in the roller. Install the roller in the tappet and insert the roller pin. Coat the tappet assembly with castor oil and install in the tappet guide. Install the tappet retaining circlet using installing tool 803777. See figure 7-55.

e. Wipe the mounting pad on the crankcase front section or cam and tappet housing clean and free from oil. Install holding clip 804849 in the tappet and guide and install the assembly in the engine.

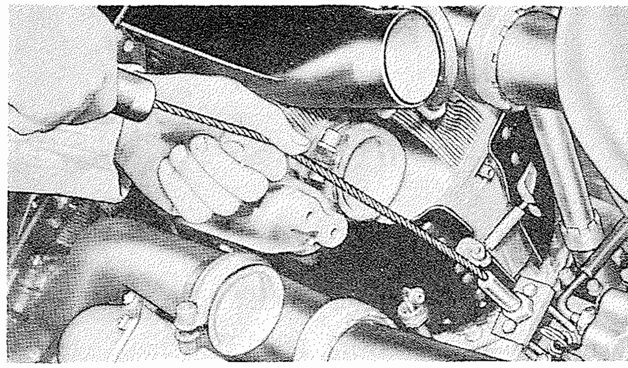


Figure 7-53. Pulling Valve Tappet and Guide

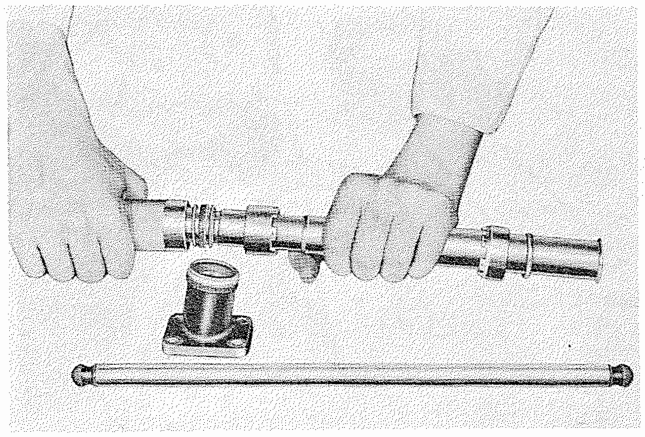


Figure 7-54. Installing Lower Packing onto Push Rod Housing

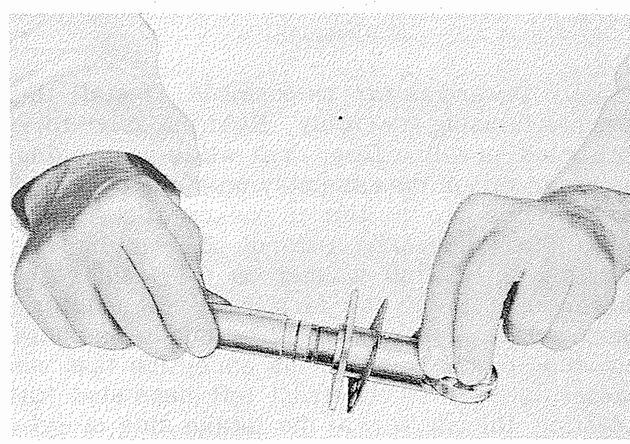


Figure 7-55. Installing Valve Tappet Retaining Circlet

Remove the holding clip when the tappet guide flange is against the housing.

f. Check the tension of the tappet spring; the load at 2.14 inch height should be between 9 - 12 pounds. Install the tappet socket and spring.

g. Install a new push rod housing adapter gasket over the attaching studs. To insert the push rod and housing, it is necessary to have the tappet

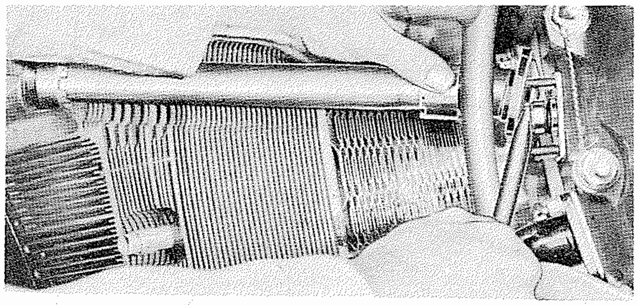


Figure 7-56. Installing Push Rod and Housing Assembly

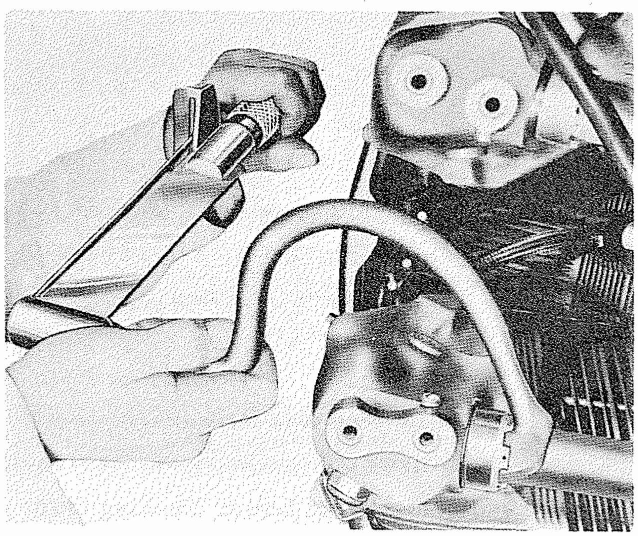


Figure 7-57. Torquing Push Rod Housing Nut at Cylinder

radially inward as far as possible. Install the push rod housing assembly. Hold the valve tappet socket in with a fiber drift while positioning the lower end of the assembly until the push rod has dropped into the tappet socket. See figure 7-56. Start the connection nut at the cylinder. Install a drilled tab washer on the front right hand mounting stud for each front row adapter. Use the plain washers at all other adapter mounting stud locations, with the exception that no washer is used on the front left hand stud for mounting the adapter at the intake side of cylinders No. 12 and 14. Install the upper vent tube clamps at these two locations. Install the self-locking adapter attaching nuts and tighten to 80 - 85 inch-pounds, using wrench 806644.

h. Tighten the nut at the cylinder to 400 - 500 inch-pounds using wrench 805964. See figure 7-57.

i. Torque the nut at the adapter to 100 - 125 inch-pounds using wrench 805965. See figure 7-58. Use wrench 806487, universal joint 806517, and extension 806518 at a rear cylinder when intake pipes interfere.

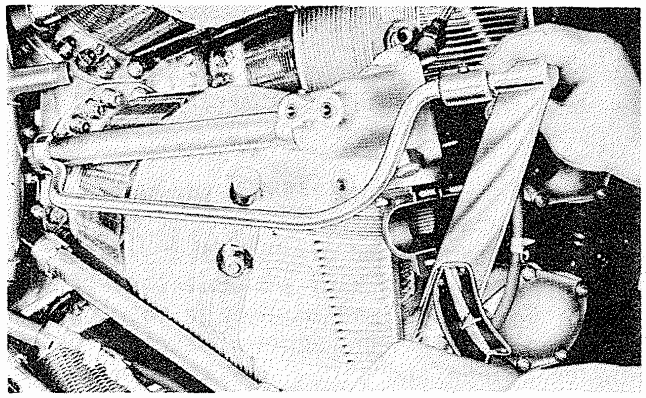


Figure 7-58. Torquing Push Rod Housing Nut at Adapter

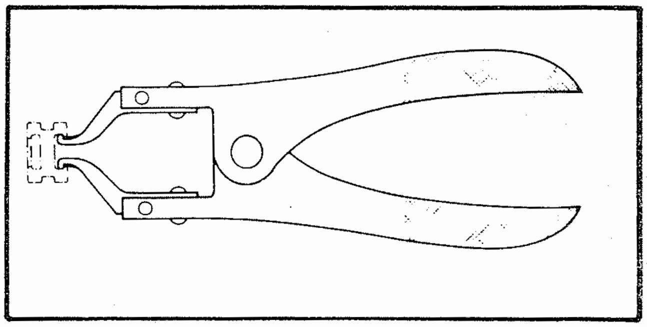


Figure 7-59. Rocker Arm Shaft Spacer Pliers

j. Lockwire the push rod housing nut at the cylinder to the lock wire screw in the cylinder head. Lockwire the nuts at the rear adapters together. Lockwire the nuts at the front adapters to the drilled tab washers on the front right hand adapter mounting studs.

k. Adjust the valve clearance as described in paragraph 7-22.

7-140. ROCKER ARM.

7-141. This operation requires removal and replacement of the following part:

	Paragraph
Rocker Box Cover	7-132

7-142. REMOVAL.

a. Turn the propeller shaft until the valve is closed and the spring load is off the rocker arm.

b. Remove the rocker arm shaft cap and washer, using 1-1/16 inch wrench. Remove the rocker arm shaft spacer using pliers 806553 (figure 7-59). Remove the seal from the spacer.

c. Loosen the adjusting screw lock screw using wrench 807004. Back the adjusting screw all the way out using a broad blade screwdriver. Install compressor 806993 on the rocker box

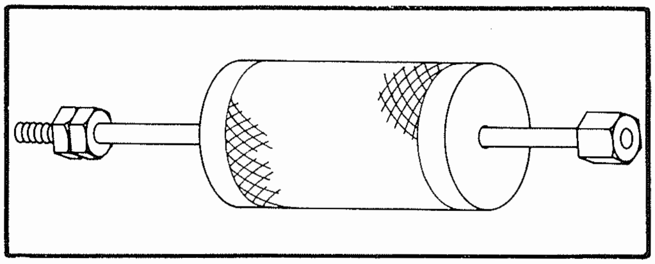


Figure 7-60. Rocker Arm Shaft Impact Puller

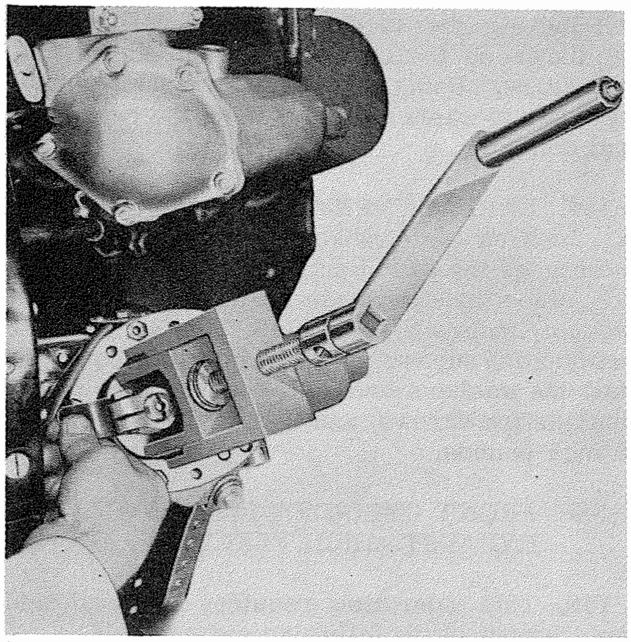


Figure 7-61. Withdrawing Metal Strip used to Position Push Rod during Rocker Arm Installation

and compress the valve springs. Remove the rocker arm shaft using a puller with a .250-20 thread size. If the shaft does not come out with the hand puller, use impact puller 923483 (figure 7-60). Remove the rocker arm as the shaft is withdrawn.

7-143. REPLACEMENT.

a. To facilitate installation of rocker arms below the horizontal center line of the engine, it is usually necessary to use a flat strip of metal to position the push rods. Insert the strip of metal so it rests against the tip of the push rod ball end. Push the rod into the engine. If it does not go all the way in, the tappet socket may be caught on the adapter. Slight shaking of the push rod will release the socket so that the rod will go into the proper position. Hold the rod in place with the metal strip and slide the rocker arm in over the strip. This will compress the tappet socket spring and permit the push rod ball end to enter the rocker arm socket as the metal strip is withdrawn. See figure 7-61.

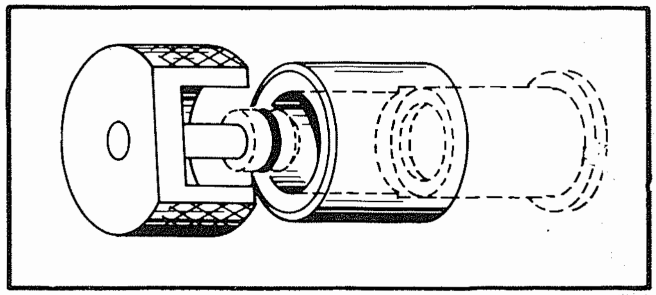


Figure 7-62. Rocker Arm Shaft Spacer Installing Tool

NOTE

Exhaust rocker arms are identified by a drilled hole in the boss accommodating the rocker arm floating shaft. When the intake and exhaust rocker arms are installed correctly, the adjusting screw lock screw head will be to the outboard side of the rocker box.

b. Align the holes in the rocker arm and rocker box and insert the rocker arm shaft.

c. Roll a new packing ring on the shaft spacer and install the spacer using installing tool 806605 (figure 7-62). Lubricate the threads of the rocker arm shaft cap with clean engine oil, and install the washer and cap. Tighten the cap to 350 - 400 inch-pounds, using wrench 806277. Lockwire. Remove the valve spring compressor.

d. Adjust the valve clearance as described in paragraph 7-22.

7-144. FRONT CYLINDER HEAD AIR DEFLECTOR.

7-145. This operation requires removal and replacement of the following part:

	Paragraphs
Rocker Box Drain Manifold to Scavenge Pump Tube (for cylinder No. 10)	7-50, 7-51

7-146. REMOVAL.

a. Disconnect the rear spark plug lead at the ignition coil using a 7/8 inch wrench. Install a protector on the loose end of the lead. Pull the lead through the hole in the head deflector.

b. Unsnap the fasteners on the rubber tabs which attach the head deflector to the barrel deflector, and disengage the spiral snap lock fasteners which attach the head deflector to the cowl seal channel.

c. Remove the cap screws and washers that retain the head deflector to the cylinder head using wrench 80449. Remove the deflector.

7-147. REPLACEMENT.
a. Position the front cylinder head air deflector, and install the deflector to cylinder washers and cap screws. Tighten the cap screws to 80 - 85 inch-pounds.
b. Engage the spiral snap lock fasteners between the head deflector and barrel deflector, and the head deflector and cowl seal channel. Engage the snaps on the rubber tabs that connect the head and barrel deflectors.
c. Lockwire the deflector to cylinder head cap screws.
d. Insert the rear spark plug lead through the hole in the head deflector and remove the protector from the lead. Attach the lead to the coil. Tighten to 165 - 175 inch-pounds and lockwire.

7-148. REAR CYLINDER HEAD AIR DEFLECTOR.

7-149. This operation requires removal and replacement of the following parts:

	Paragraphs
Ignition Coil and Supporting Saddle	7-209
PRT Cooling Air Tube (for cylinders No. 3, 9, and 15)	7-194

7-150. REMOVAL.
a. Pull the ignition cable manifold to coil lead and the front spark plug lead through the holes in the head deflector.
b. Unsnap the fasteners on the rubber tabs that attach the head deflectors to the barrel deflector and disengage the spiral snap lock fasteners that attach the deflector to the cowl seal channel and to the barrel deflector.
c. Remove the cap screws and washers that retain the deflector to the cylinder using wrench 80449. Remove the deflector.

7-151. REPLACEMENT.
a. Position the rear cylinder head deflector and install the deflector to cylinder washers and cap screws. Tighten the cap screws to 80 - 85 inch-pounds.
b. Engage the spiral snap lock fasteners between the head deflector and barrel deflector, and the head deflector and cowl seal channel. Engage the snaps on the rubber tabs that connect the head and barrel deflectors.
c. Insert the ignition cable manifold to coil lead and the front spark plug lead through the holes in the head deflector.

7-152. INTER-CYLINDER CRANKCASE SEAL DEFLECTOR.

7-153. REMOVAL.
a. Disengage the spiral snap lock fasteners holding the crankcase seal deflector to the front cylinder intake and exhaust air deflectors and remove the crankcase seal deflector.
b. The crankcase seal deflector between cylinders No. 8 and 10 is attached by washers and self-locking nuts to the combination screws at the flange on the crankcase front main drain tube elbow. Using a 7/16 inch wrench, remove the nuts and washers, and remove the crankcase seal deflector.

7-154. REPLACEMENT.
a. Position the crankcase seal air deflector and engage the spiral snap lock fasteners.
b. Attach the crankcase seal air deflector between cylinders No. 8 and 10, aligning it on the combination screws at the drain tube elbow. Install the washers and self-locking nuts to the combination screws, and tighten the nuts to 80 - 85 inch-pounds.

7-155. FRONT CYLINDER INTAKE AND EXHAUST AIR DEFLECTORS.

7-156. This operation requires removal and replacement of the following parts:

	Paragraphs
Front Cylinder Head Air Deflector	7-144
Inter-Cylinder Crankcase Seal Air Deflector	7-152
External Oil Tubes (cylinder No. 8 exhaust, No. 10 intake and exhaust, No. 12 intake)	7-58
Rocker Box Cover and Sump Assemblies (cylinder No. 10)	7-48, 7-49
Push Rod and Housing Assembly	7-136

7-157. REMOVAL. Disengage the spring-loaded clamp joining the intake and exhaust air deflector using tool 804504 (figure 7-63). Unsnap the fasteners in the rubber pad seal. Remove the attaching screws using a 7/16 inch wrench. Work the deflector around to the front of the cylinder, and remove.

7-158. REPLACEMENT. Position the deflector and install and tighten the attaching screws.

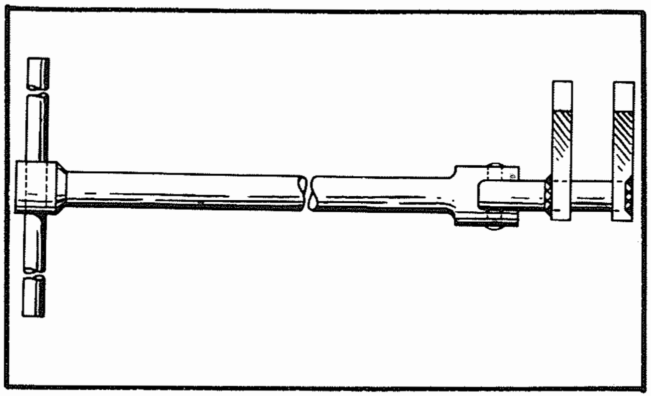


Figure 7-63. Cylinder Intake and Exhaust Air Deflector Installing Tool

Ensure that the bracket for the rear ignition coil lead is installed under the head of the intake air deflector attaching screw. Use a washer under the head of the exhaust air deflector attaching screw. Tighten the attaching screws to 80 - 85 inch-pounds and lockwire. Engage the spring-loaded clamp at the rear of the deflector using installing tool 804504. Engage the snaps on the rubber pad.

7-159. REAR CYLINDER INTAKE AND EXHAUST AIR DEFLECTORS.

7-160. This operation requires removal and replacement of the following parts:

	Paragraphs
Intake Pipes	7-127
Rear Cylinder Head Air Deflector	7-148
Inter-Cylinder Crankcase Seal Deflector	7-152
External Oil Tubes (cylinder No. 9 exhaust, No. 11 intake and exhaust, No. 13 intake)	7-58
Push Rod and Housing Assembly	7-136

7-161. REMOVAL. Disengage the spring-loaded clamp that joins the intake and exhaust deflectors using tool 804504. Unfasten the snaps on the rubber pad seal. Remove the attaching screws using a 7/16 inch wrench and remove the deflector.

7-162. REPLACEMENT. Position the deflector and install the attaching washers and screws. Tighten the attaching screws to 80 - 85 inch-pounds and lockwire. Engage the clamp using tool 804504. Snap the fasteners on the rubber pad seal.

7-163. CYLINDER AND PISTON.

7-164. This operation requires removal and replacement of the following parts:

	Paragraphs
Cylinder Fuel Injection Hose	7-226
Intake Pipes	7-127
Front and Rear Cylinder Intake and Exhaust Air Deflectors	7-155, 7-159
Rocker Box Drain Manifold (for lower cylinders)	7-52, 7-53
External Oil Outlet Tube (for cylinders No. 8, 9, 10 and 11)	7-58
Crankcase Front Main Section Oil Drain Tube (for cylinders No. 10 and 12)	7-62
Crankcase Rear Main Section Oil Drain Tube (for cylinders No. 9 and 11)	7-66
Spark Plugs	7-214
Push Rod Housing, Push Rod, Valve Tappet Socket and Spring	7-136

7-165. REMOVAL.

a. Remove the cap screws retaining the fuel injection hose clips, using a 3/8 inch wrench, and remove the clips. Break the lockwire on the cylinder hold-down cap screws using puller 806791. Use puller 808171 (figure 7-64) to remove the cylinder hold-down cap screw lock plates, if used.

b. Loosen all cylinder hold-down cap screws using wrench 807586. With the exception of two cap screws spaced 180 degrees apart, remove all cap screws with speed wrench 83130. See figure 7-65. If pneumatic equipment is available, pneumatic speed wrench 806996 may be used.

c. Ensure that the piston is at the top of the cylinder, and remove the two remaining cap screws. Withdraw the cylinder far enough to expose the connecting rod. Hold the rod while the cylinder is removed to prevent it from hitting the crankcase main section. See figure 7-66.

d. Remove the piston pin plug. Install puller 806888, shown in figure 7-67, in the piston pin and pull the pin. Remove the piston.

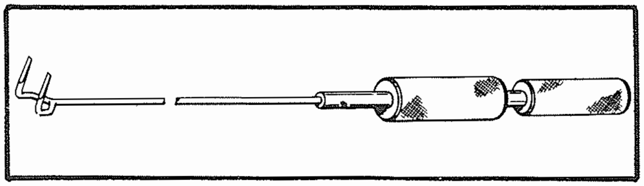


Figure 7-64. Cylinder Hold-Down Cap Screw Lock Plate Puller

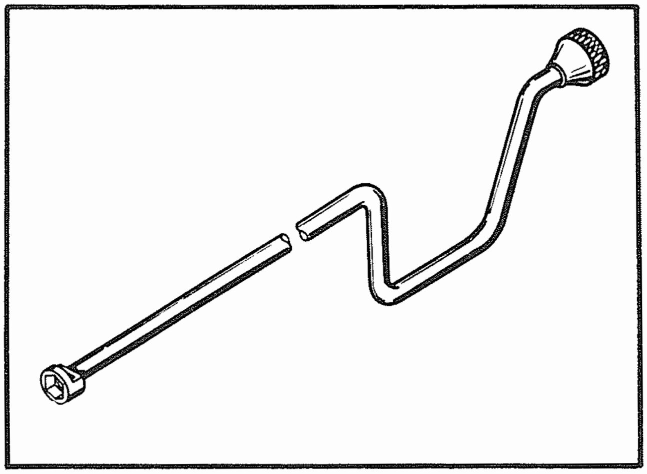


Figure 7-65. Cylinder Hold-Down Cap Screw Speed Wrench

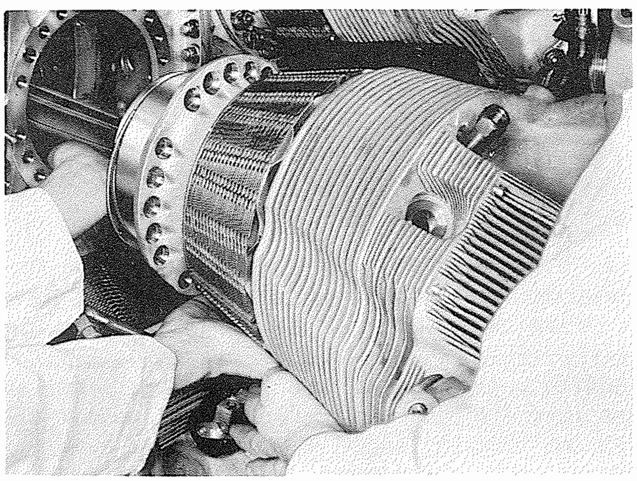


Figure 7-66. Removing Cylinder

e. Install protector 808576, shown in figure 7-68, on the articulated rods, or guide plate 806915 (figure 7-69) on cylinder No. 1 or 2 mounting pad for master rod protection.

7-166. CYLINDER HEAD FIN PROFILING LIMITS. Vertical fins on a cylinder head are considered to be those on top of the head between the rocker boxes. Horizontal fins on a cylinder head are considered to be those fins encircling the head, below the rocker boxes. Horizontal fins are divided into quadrants with center lines

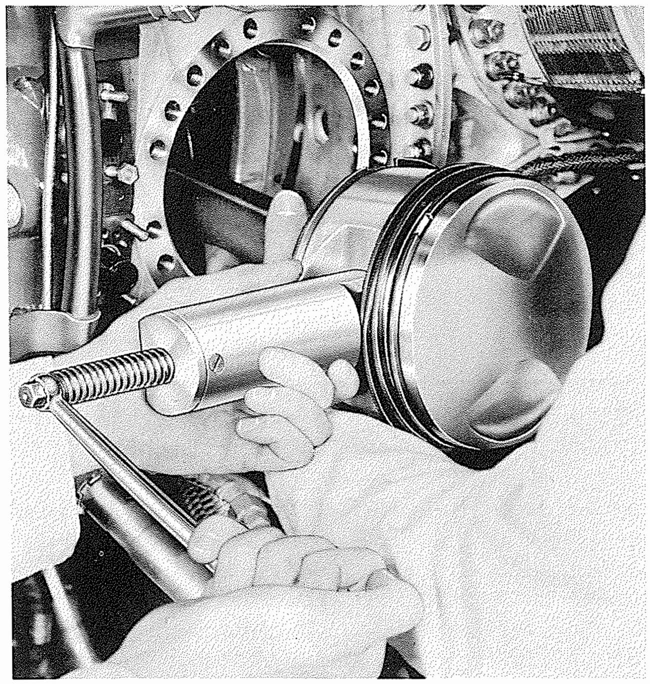


Figure 7-67. Pulling Piston Pin

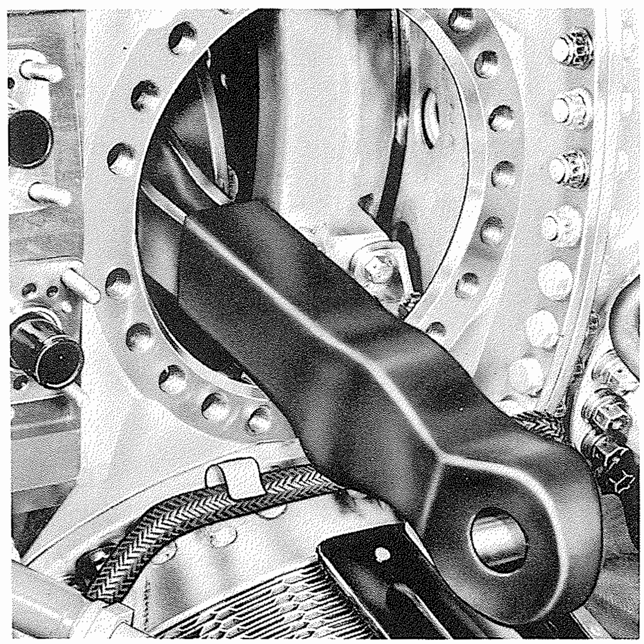


Figure 7-68. Protector Installed on Articulated Rod

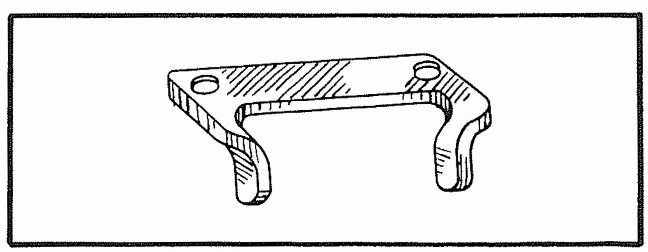


Figure 7-69. Master Rod Guide Plate

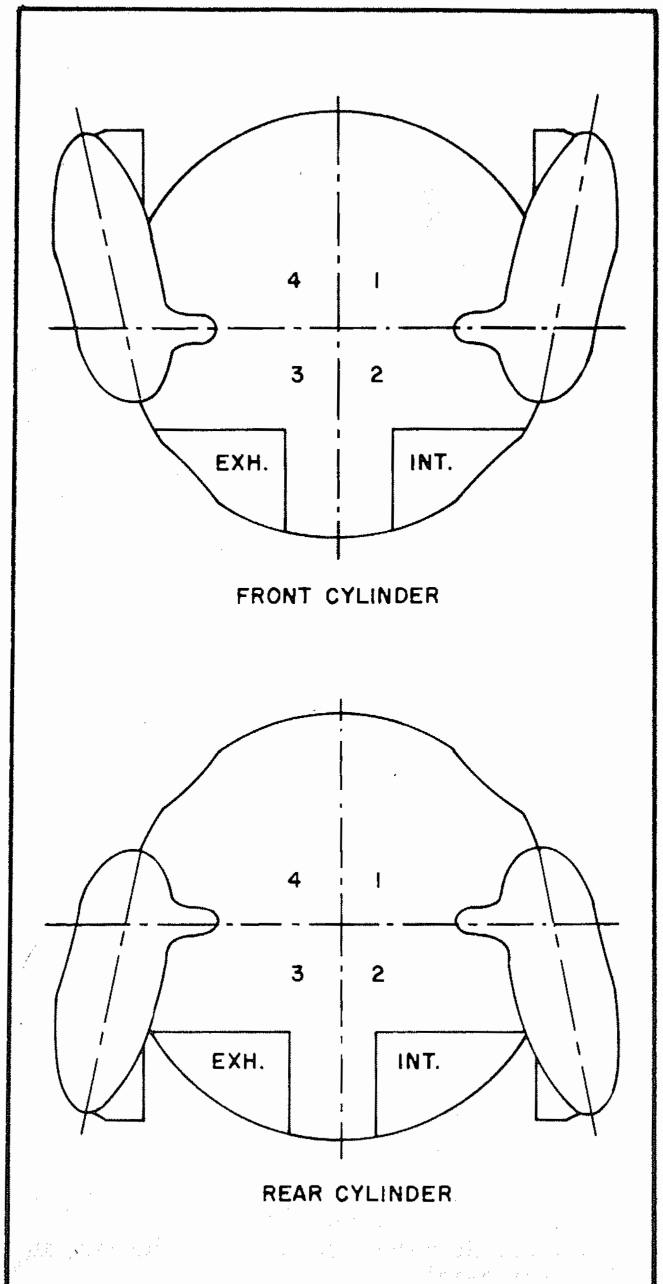


Figure 7-70. Cylinder Head Quadrants

through the valve guides and spark plug inserts. See figure 7-70. The quadrants are numbered 1, 2, 3, and 4 starting with the upper right quadrant and proceeding clockwise. Quadrants 1 and 4 are on the forward side of the cylinder head. The fins are coarse in these quadrants. Quadrants 2 and 3 are on the rearward side of the cylinder head. The fins are fine in these quadrants.

7-167. Remove the cracked portion of a cylinder head fin by drilling down through the fin at the end of the crack, using a 1/8 inch diameter drill and jig 806078 (figure 7-71) to pilot the drill. After removing a portion of a fin, break sharp

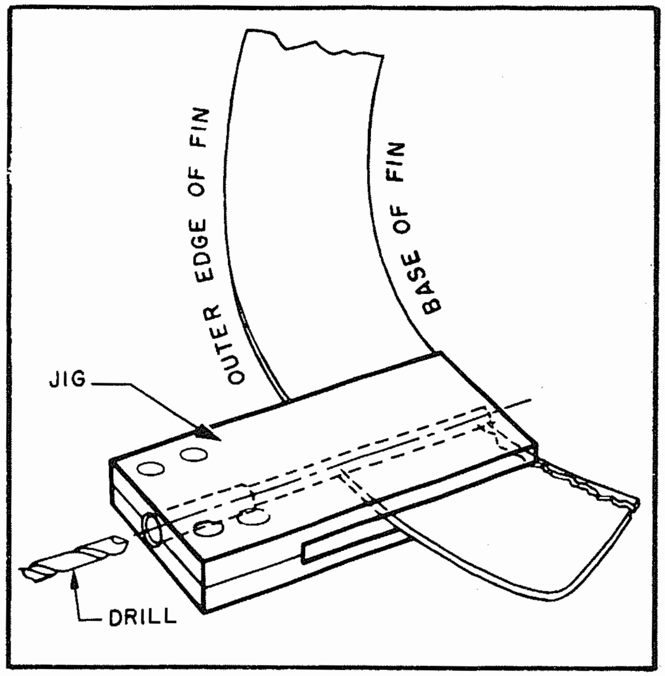


Figure 7-71. Cylinder Head Fin Profiling Drill and Jig

edges. It is permissible to remove portions of vertical and horizontal fins from any cylinder up to the following maximum areas, measured on one side of the fin:

Fin Direction Horizintal Fins	Maximum Permissible Removal Area
Quadrant No. 1 - coarse	8 square inches
Quadrant No. 2 - fine	20 square inches
Quadrant No. 3 - fine	20 square inches
Quadrant No. 4 - coarse	35 square inches
Vertical Fins	*60 square inches

*Not over 25 square inches may be removed from any number of consecutively adjacent vertical fins; not over 20 square inches may be removed from that section of vertical fins above and adjacent to the exhaust rocker boxes.

7-168. REPLACEMENT.

a. Wipe the cylinder barrel, flange, and skirt of the cylinder with a clean, lintless cloth. Ensure that there are no burrs on the cylinder skirt. Apply castor oil to the first four inches of the cylinder barrel. Ensure that the old oil seal ring is removed from the cylinder skirt. Coat a new oil seal ring lightly with Titeseal sealing compound. Install the ring over the skirt against the mounting flange.

b. Place a spherical washer over each cylinder cap screw. Apply Goodrich A75B rubber cement

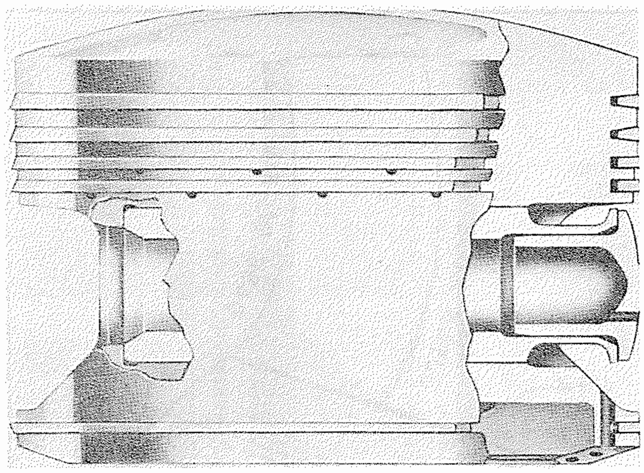


Figure 7-72. Piston Configuration

to the first few threads of the cap screws. Ensure that the spherical washer, the neck and the underside of the cap screw head, and the spherical seal in the cylinder attaching flange are entirely free of cement.

NOTE

The .4375-20 thread cylinder hold-down cap screws are used at locations 5, 6, 16, and 17 in the front row, and 5, 6, 15, and 16 in the rear row. The .500-20 thread cap screws, identified by a slot milled across the head, are used at all other cylinder hold-down cap screw locations.

c. Ensure that piston rings are installed correctly prior to installation of the piston. See figure 7-72 for correct ring installation.

d. Check the piston ring fits against Reference Nos. 235 through 240 in the Table of Limits, Section IX. The side clearance of ring No. 1 is measured radially inward from the second land, and ring No. 2 from the third land to the ring face with the ring bottomed in the groove. Check around the entire periphery. Close side clearance for rings No. 1 and 2 is obtained when the largest possible ring fits in its groove by bottoming on the taper faces of the groove without extending beyond the lower land at any point on its periphery. The land above groove No. 1 being of smaller diameter should not be used to check ring position.

e. Remove the protector from the articulated rod or guide from the cylinder mounting pad. Locate the piston on the connecting rod. Install the piston pin plug in the necked end of the piston pin. Slide the unplugged end of the pin through the piston and connecting rod, and bottom the pin against the boss within the piston. See figure 7-73. There is no positive retention of the pin until the cylinder is installed. The piston pin

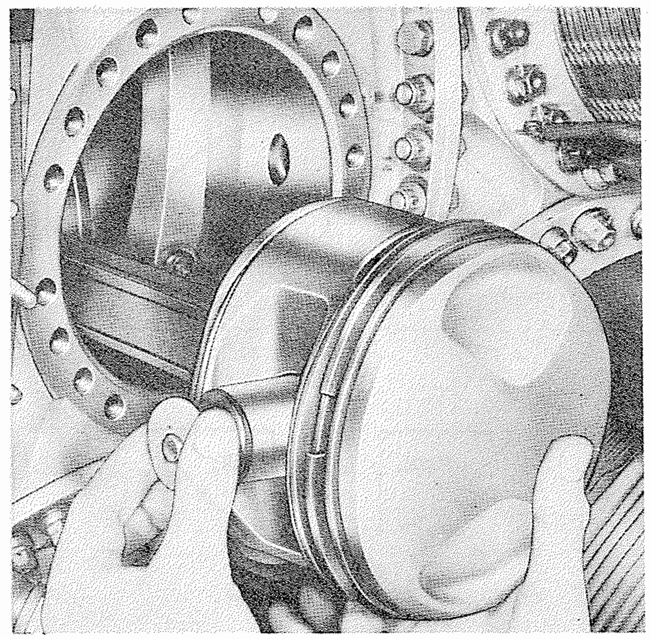


Figure 7-73. Installing Piston Pin

plug will then bear against the cylinder wall, holding the pin in place. See figure 7-72. Coat the piston rings with castor oil and stagger the gaps.

f. Compress the top four piston rings, using clamp 803145, and carefully slide the cylinder over them. Compress the bottom ring with the clamp and slide the cylinder over it. Remove the clamp.

g. Position the cylinder against the mounting pad and secure it with two locating cap screws, 802177 (.4375-20 thread) approximately 180 degrees apart. Start the 19 cylinder cap screws in the remaining holes. Torque the two locating cap screws with wrench 807586 to 300 - 325 inch-pounds. Run the cap screws all the way in with wrench 83130.

h. Torque the two cap screws 90 degrees from the locating screws to 300 - 325 inch-pounds using wrench 807586. Torque the remaining cap screws to 300 - 325 inch-pounds in a pattern that will ensure uniform seating of the cylinder on the flange. Final torque the .4375-20 cap screws to 500 - 525 inch-pounds, and the .500-20 cap screws to 625 - 650 inch-pounds.

i. Remove the two locating screws and replace with the cylinder cap screws. Torque to 500 - 525 inch-pounds.

7-169. CYLINDER HOLD-DOWN CAP SCREW SECUREMENT. Lockwire the cap screws in groups of five or six. If cylinder hold-down lock plates are used in place of lock wire, proceed as follows:

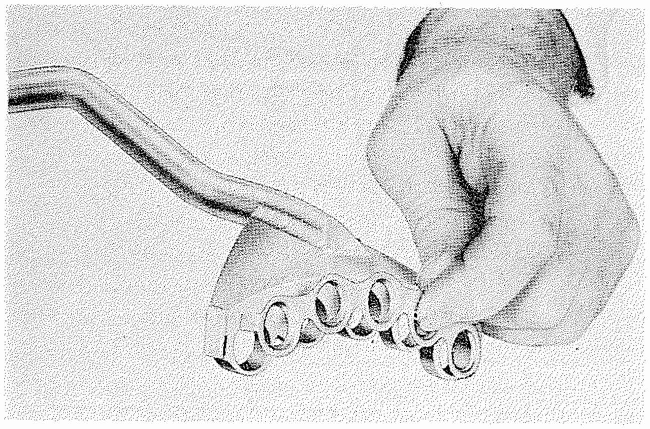


Figure 7-74. Attaching Lock Plate to Installing Tool

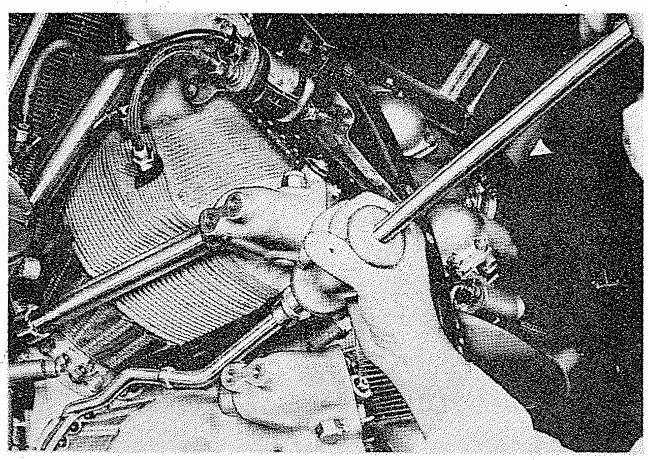


Figure 7-75. Installing Cylinder Hold-Down Cap Screw Lock Plate

a. Use new lock plates at each installation. Install the end tabs of the plate in the slots of installing tool 808124. See figure 7-74.
b. Position the tool over cap screws No. 1 through 5 and force the plate into position, using the impact weight on the tool. See figure 7-75.
c. Secure the lock plate by dimpling the rim of the lock plate into the hole in the head of the center cap screw. See figure 7-76.
d. Install three additional lock plates in the same manner, omitting cap screw No. 11 on front row cylinders and cap screw No. 21 on rear row cylinders.
e. Lockwire cap screw No. 11 on front row cylinders and cap screw No. 21 on rear row cylinders to the adjacent cap screw on either side.
f. An optional method of installing the lock plates, to entirely eliminate the use of lock wire, is accomplished by cutting two five hole lock plates into two three hole lock plates and installing them as shown in figure 7-77.

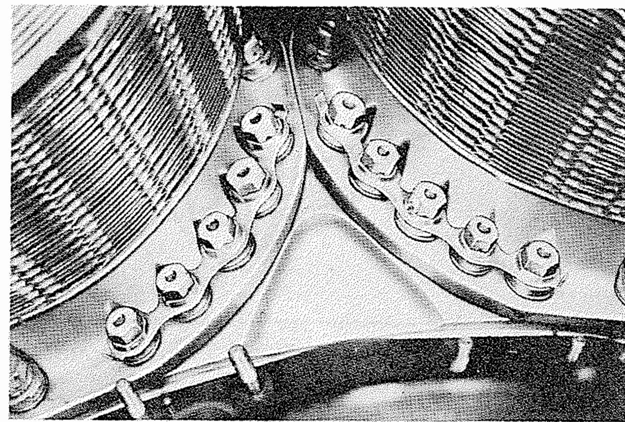


Figure 7-76. Lock Plates Secured to Cylinder Hold-Down Cap Screws

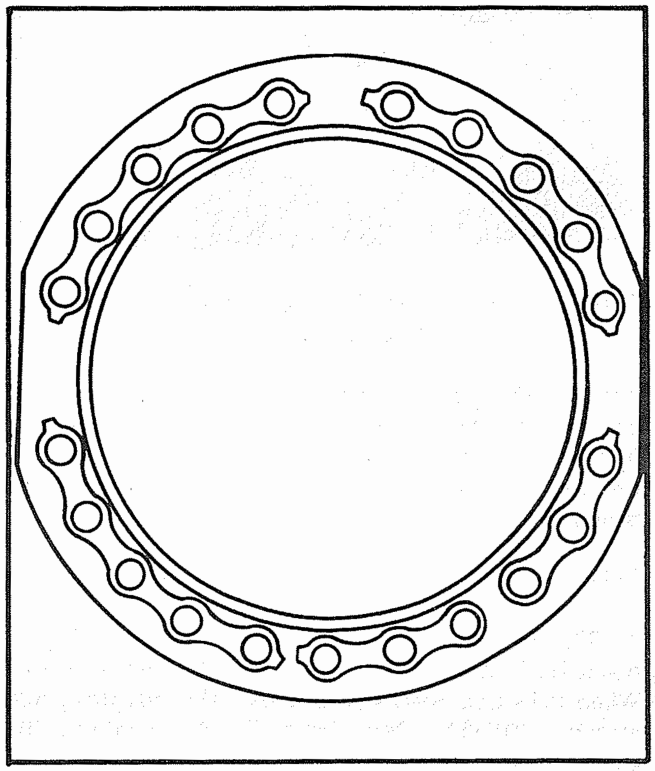


Figure 7-77. Optional Method of Installing Lock Plates

7-170. **FUEL INJECTION LINE TO CYLINDER HOLD-DOWN CAP SCREW CLIPS.** Install the single bend clips with a single attaching hole and the attaching screws to cylinder hold-down cap screw No. 8 of cylinders No. 2, 4, 6, 10, 12, 14, and 16. Install the double bend clips with a single attaching hole and the attaching screws to cap screws No. 2 and 5 of cylinders No. 2, 4, 6, 10, 12, 14, 16, and 18; cap screw No. 3 of cylinders No. 1, 3, 5, 7, 11, 13, 15, and 17; cap screw No. 18 of cylinders No. 1, 3, 5, 7, 9, 13, 15, and 17; and cap screw No. 2 of cylinder No. 8. Install the two hose type clips with

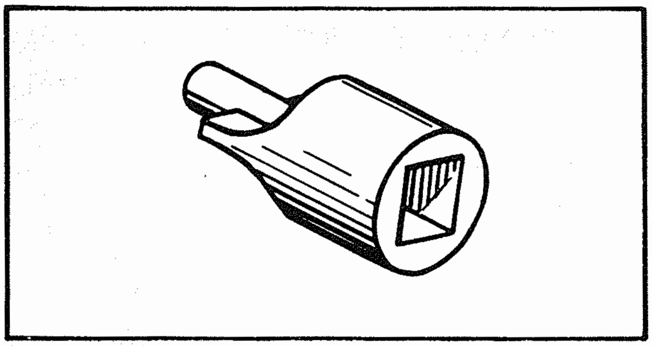


Figure 7-78. Cylinder Head Thermocouple Adapter Lug Wrench

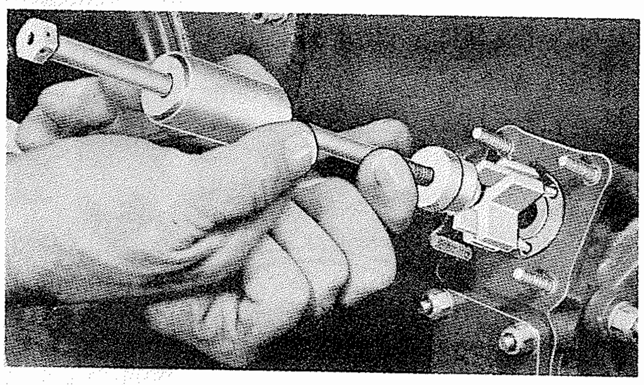


Figure 7-79. Removing Tachometer Drive Shaft Oil Seal and Retainer

two attaching holes, and the attaching screws to cap screws No. 14 and 15 of cylinders No. 1, 3, 5, 7, 9, 13, 15, and 17. Using a 3/8 inch wrench, tighten the clip attaching screws to 60 - 65 inch-pounds and lockwire.

7-171. CYLINDER HEAD THERMOCOUPLE.

7-172. Remove the thermocouple by turning it counterclockwise and pulling it out of the adapter. When it is necessary to remove the adapter, use wrench 806834. See figure 7-78. Replace the thermocouple adapter and tighten to 20 - 50 inch-pounds.

7-173. TACHOMETER DRIVE SHAFT OIL SEAL.

7-174. REMOVAL.

a. Remove the tachometer generator.

b. Remove the oil seal retainer attaching screws. Remove the oil seal and retainer assembly using puller 806147. See figure 7-79.

c. Remove the tachometer drive shaft oil seal retainer ring from the groove inside the housing.

7-175. REPLACEMENT.

a. When it is necessary to replace an oil seal ring in a retainer, use installing tool 805968. See figure 7-80.

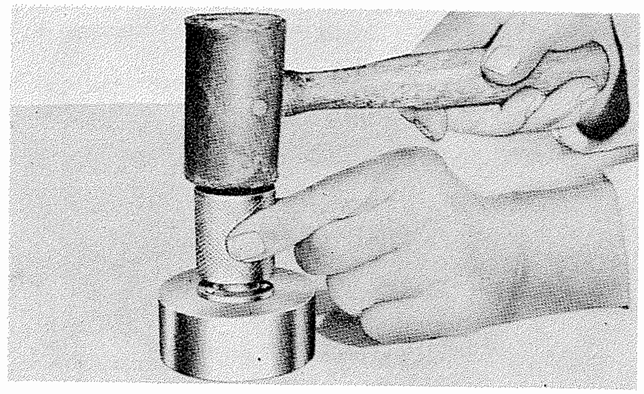


Figure 7-80. Installing Tachometer Drive Shaft Oil Seal in Retainer

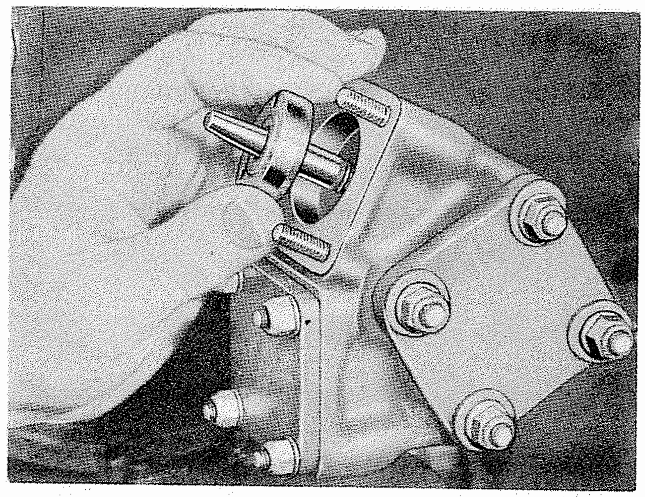


Figure 7-81. Installing Tachometer Drive Shaft Oil Seal and Retainer

b. Install a new rubber ring in the groove in the tachometer drive housing. Install the oil seal and retainer assembly using installing plug 806923. See figure 7-81.

c. Align the holes in the retainer, the drive shaft gear bushing, and the housing. Install the attaching screws, tighten to 18 - 20 inch-pounds and lockwire.

d. Install a new gasket and the tachometer generator. Install the washers and self-locking nuts. Tighten the nuts to 80 - 85 inch-pounds.

7-176. FUEL PUMP DRIVE SHAFT OIL SEAL.

7-177. REMOVAL.

a. Remove the fuel pump or substituting cover.

b. Remove the flat countersunk head screw from the fuel pump drive shaft support. Pull the support and drive shaft as a unit with puller 806887 (figure 7-82).

c. Remove the oil seal from the support using puller 801534. See figure 7-83.

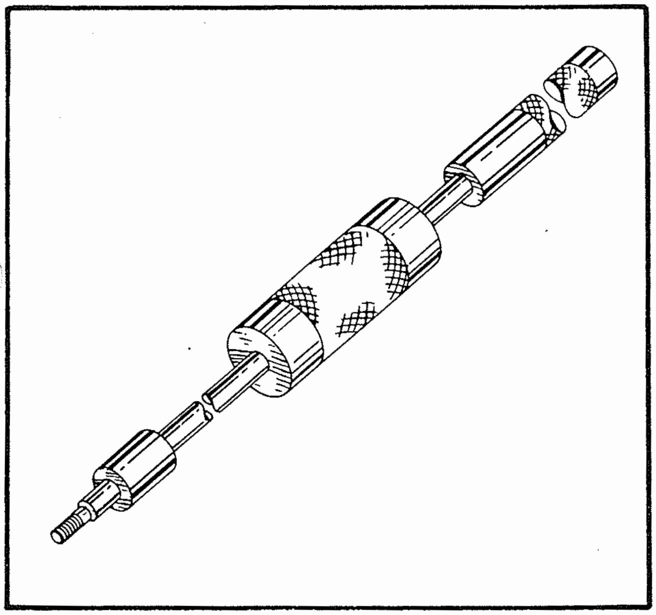


Figure 7-82. Fuel Pump Drive Shaft and Support Puller

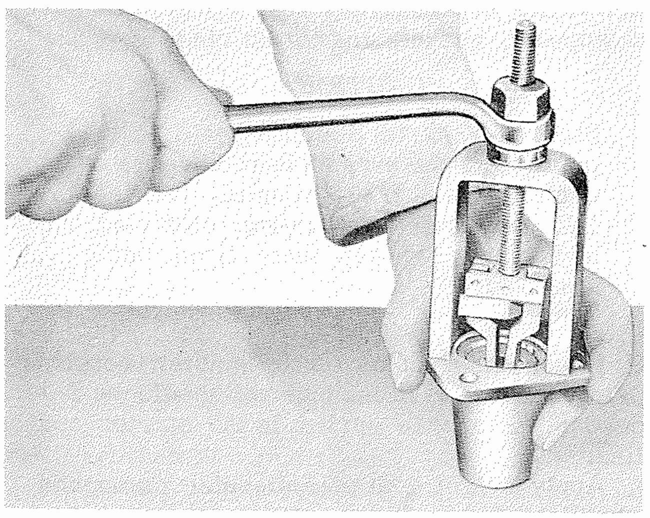


Figure 7-83. Pulling Fuel Pump Drive Shaft Oil Seal

7-178. REPLACEMENT.

a. Install a new oil seal in the support, using plug 805270 (figure 7-84). The seal should be a .001 - .006 inch tight fit in the support.

b. Install a new fuel pump drive shaft support gasket over the studs in the supercharger rear housing.

c. Lubricate the drive shaft and install it in the support. Install the shaft and support assembly in the rear housing. Install the flat countersunk head screw that secures the support to the housing. Tighten the screw to 22 - 25 inch-pounds.

d. Install a new gasket and the fuel pump or substituting cover. Install the washers and self-locking nuts. Tighten the nuts to 125 - 140 inch-pounds.

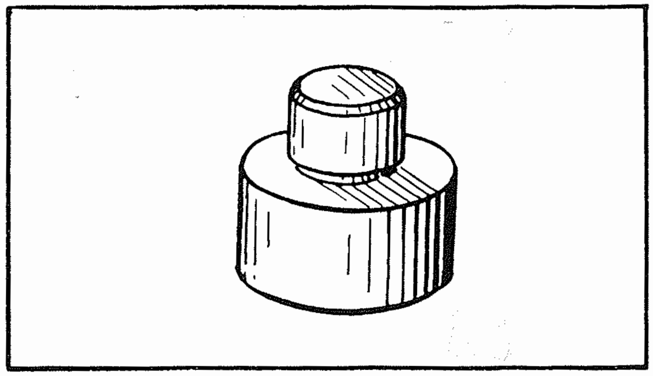


Figure 7-84. Fuel Pump Drive Shaft Oil Seal Installing Plug

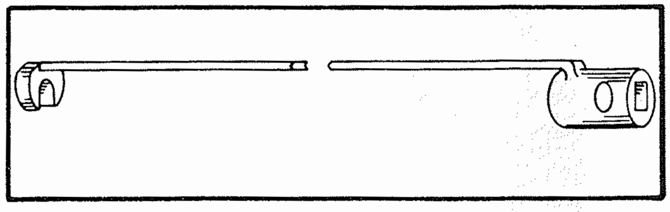


Figure 7-85. Generator Attaching Nut Wrench

7-179. SUPERCHARGER REAR HOUSING COVER ACCESSORY DRIVE OIL SEALS.

7-180. The magneto, upper left, upper right, and lower center accessory drive gear oil seals are interchangeable. A larger oil seal is used at the left and right generator drive shaft locations.

7-181. REMOVAL.

a. Remove the accessory. See paragraph 7-222 for instructions on magneto removal. Wrench 801080 (figure 7-85) may be used to remove a generator.

b. Remove the generator drive coupling. The generator drive coupling is secured to the generator drive shaft by means of a circlet fitting in a groove in the internal splines of the shaft and external splines of the coupling. The tool number, for the tool used in removing the coupling from the shaft, will be published when available.

c. Remove the oil seal collar attaching screws. The oil seal collars incorporate puller holes. Use two of the attaching screws to pull the seal assembly.

7-182. REPLACEMENT.

a. When it is necessary to replace the magneto, upper left, upper right, or lower center accessory drive gear oil seal in the collar, use plug and base 804854 to remove the oil seal and to install the new seal. See figure 7-86.

b. Apply anti-seize compound, Lubriplate 130A, to the oil seal gasket. Install the gasket

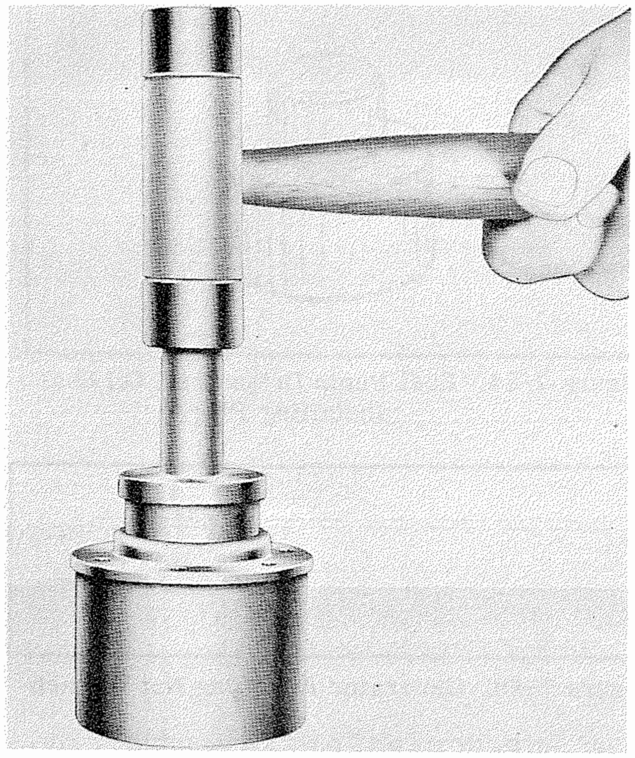


Figure 7-86. Removing Magneto Drive Gear Oil Seal from Collar

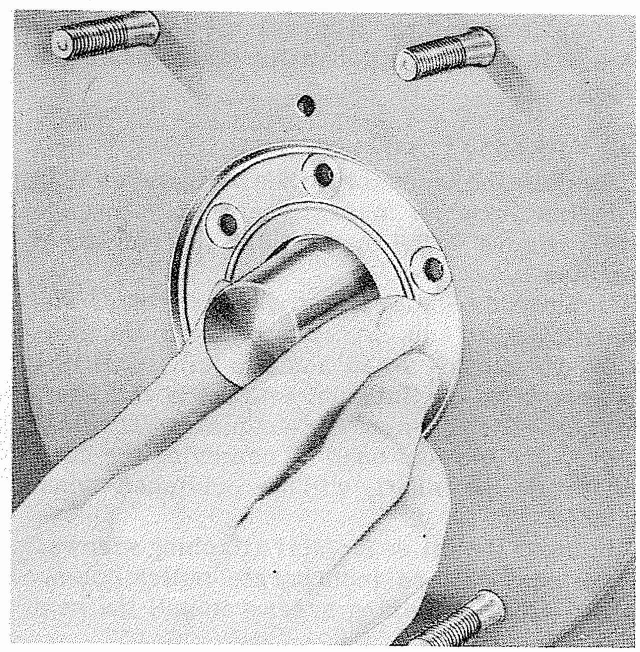


Figure 7-87. Installing Magneto Drive Gear Oil Seal Assembly

on the supercharger rear housing cover. Use installing tool 804855 when installing the magneto drive gear oil seal. See figure 7-87. No installing tool is needed for the upper left, upper right, lower center, or generator drive gear oil seal assemblies. Install the oil seal attaching screws, and tighten to 18 - 20 inch-pounds. Place a circlet in the groove in the external splines of the generator drive coupling and compress it sufficiently to allow the coupling to be inserted into the generator drive shaft. Push on the coupling until the circlet expands into the groove in the internal splines of the generator drive shaft.

c. Install the accessory. Refer to paragraph 7-223 for instructions on the installation of the magneto. Wrench 801080 may be used when a generator is installed. Torque generator attaching nuts to 275 - 300 inch-pounds.

7-183. STARTER COUPLING THRUST RING.

7-184. REMOVAL.

a. Remove the starter. Remove the starter adapter attaching nuts and washers, using a 1/2 inch wrench. Remove the adapter and gasket.

b. Remove the two flat countersunk head screws that secure the starter coupling thrust ring support to the supercharger rear cover. Remove the support, gasket, and thrust ring.

CAUTION

Since the starter coupling will move outward as the support is removed, exercise care that the coupling does not fall. Remove the coupling, stop ring, and spring to keep them from being damaged.

7-185. REPLACEMENT.

a. Check the tension of the starter coupling spring; load at 1.70 inch height should be 8-12 pounds. Install the spring in the starter coupling.

b. Apply a light coat of anti-seize compound, Lubriplate 130A, to the starter coupling stop ring and install it. Install the starter coupling and spring. Apply a light coat of anti-seize compound, Lubriplate 130A, on the thrust ring and install it on the coupling. See figure 7-88.

c. Install a new gasket and the thrust ring support to the supercharger rear housing cover. Secure with two flat countersunk head screws tightened to 22 - 25 inch-pounds.

d. Install a new gasket and the starter adapter. Secure the adapter with washers and fiber lock nuts. Torque the attaching nuts to 125 - 140 inch-pounds.

e. Measure the distance from the face of the starter mounting pad to the face of the starter coupling using gage 806222 (figure 7-89). If the distance is not within the limits of 1.657 - 1.683 inches, check for proper assembly of the starter coupling. Remove the gage and install the starter.

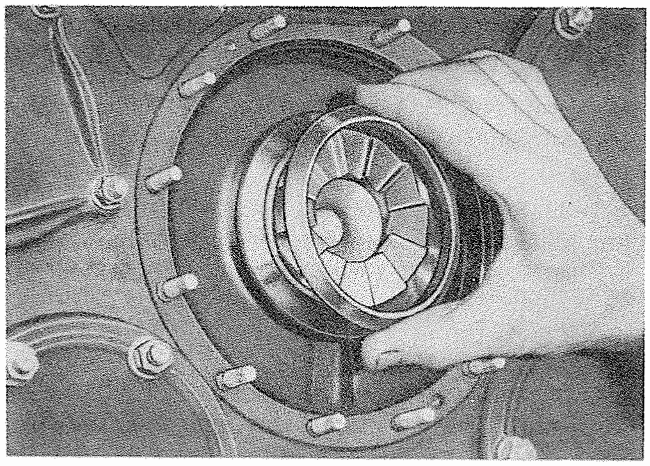


Figure 7-88. Installing Starter Coupling Thrust Ring

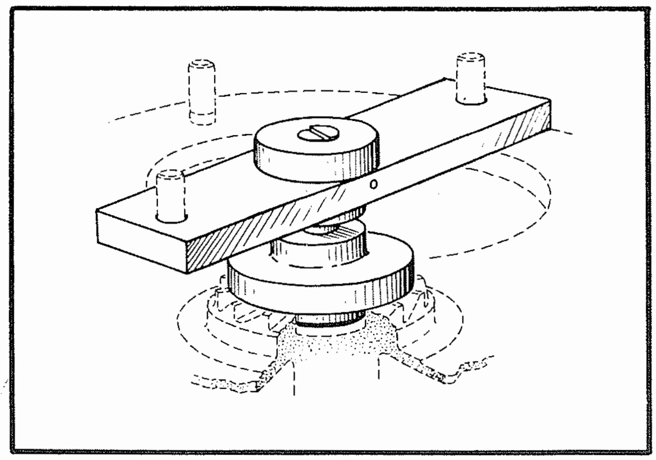


Figure 7-89. Starter Adapter to Starter Coupling Limit Flush Pin Gage

7-186. DISTRIBUTOR DRIVE OIL SEAL.

7-187. This operation requires removal and replacement of the following part:

	Paragraph
Distributor	7-224

7-188. REMOVAL.

a. Remove the distributor adapter to crankcase front section attaching screws and washers, including the two screws adjacent to the oil seal. Use a 7/16 inch wrench.

b. Tap the adapter with a fiber mallet to loosen it from the engine. Remove the adapter.

c. Remove the screws that secure the oil seal retaining plate to the distributor adapter. Remove the plate.

d. Remove the oil seal from the adapter using puller 806991 (figure 7-90).

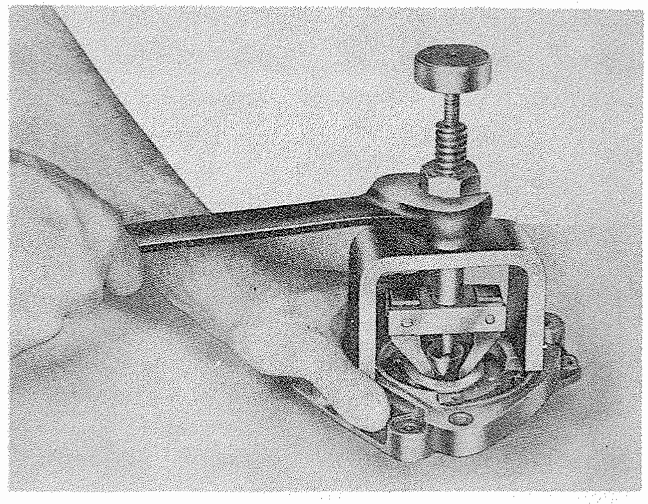


Figure 7-90. Distributor Drive Oil Seal Puller

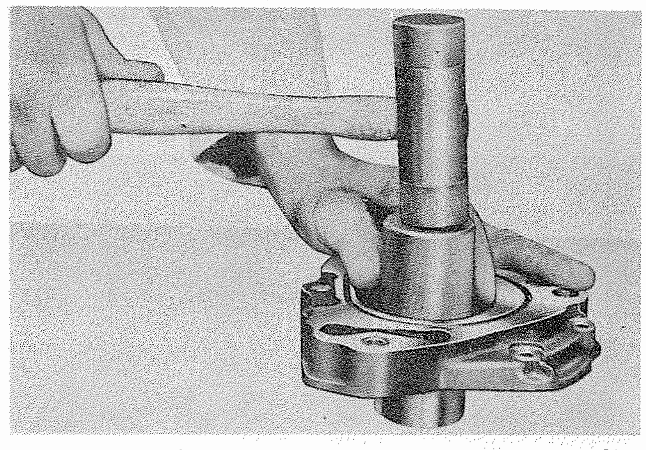


Figure 7-91. Installing Distributor Drive Oil Seal

7-189. REPLACEMENT.

a. Liberally coat a new oil seal with anti-seize compound, Lubriplate 130A, and install in the distributor adapter, using plug and base 807052. See figure 7-91.

b. Install the oil seal retaining plate. Install and tighten the retaining screws to 18 - 20 inch-pounds.

c. Place a new gasket on the crankcase front section mounting pad. Insert plug 807053 in the distributor drive intermediate gear and install the distributor adapter. See figure 7-92. Secure the adapter with washers and attaching screws, tightened to 80 - 85 inch-pounds. Lockwire the screws.

7-190. POWER RECOVERY TURBINE OIL PRESSURE CONTROL VALVE.

7-191. REMOVAL.

a. Remove the control valve cap, using a 5/8 inch wrench, and remove the gasket.

b. Insert wrench 806987 so the slots are over the valve spring seal locking pin and the lugs are

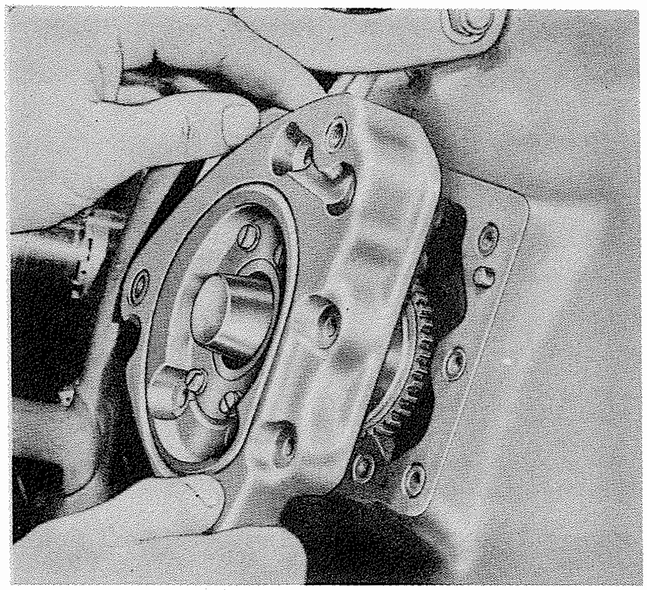


Figure 7-92. Installing Distributor Adapter

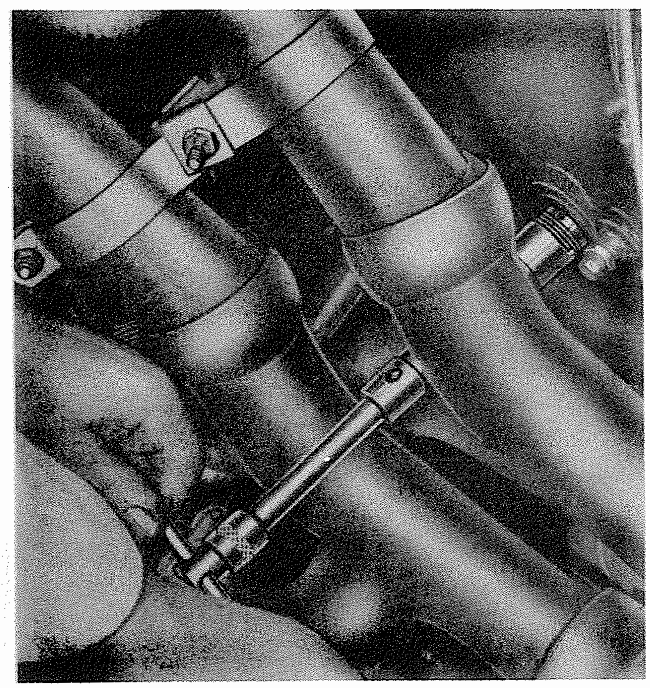


Figure 7-93. Loosening PRT Oil Pressure Control Valve Assembly

in the slots in the valve body. See figure 7-93. Remove the assembly from the supercharger front housing.

c. Push out the locking pin which passes through the holes in the valve body and the slots in the valve spring seat.

d. Unscrew the valve spring seat from the body using wrench 807005. Remove the spring and the valve.

7-192. REPAIR. If necessary, polish the control valve and the bore of the valve body with crocus cloth and clean engine oil. Wash the valve and body thoroughly in petroleum solvent and then coat the parts in clean engine oil.

7-193. REPLACEMENT.

a. Measure the tension of the control valve spring; load at 1.42 inch height should be 23 - 26 pounds.

b. Install the control valve body in the supercharger front housing using wrench 806987. Tighten to 350 - 400 inch-pounds.

c. Lubricate and install the control valve. Install the spring and the spring seat. Turn the seat in, using wrench 807005. Adjust the oil pressure as described in paragraph 7-21.

d. Insert the seat locking pin through the holes in the body and the slots in the seat.

e. Install a new gasket and the valve cap. Tighten to 75 - 100 inch-pounds. Lockwire.

7-194. POWER RECOVERY TURBINE COOLING AIR TUBE.

7-195. REMOVAL. Loosen the clamps on both connecting hoses using wrench 801122. See figure 7-94. Slide the hoses onto the tube, and remove the cooling air tube.

7-196. REPLACEMENT. Position the cooling air tube. Slide the connecting hose at the front onto the cooling air scoop and the hose at the rear onto the turbine cooling air inlet duct. Tighten the clamps using wrench 801122 until the hose shows a slight distortion. Lockwire the clamps.

7-197. POWER RECOVERY TURBINE.

7-198. This operation requires removal and replacement of the following parts:

	Paragraphs
PRT Cooling Air Tube	7-194
Exhaust Pipes	7-123

7-199. REMOVAL.

a. Remove the cotter pin, nut, bolt, and washers from the clamp. Use two 5/8 inch wrenches to loosen the nut. Spread the clamp.

b. Withdraw the turbine, maintaining alignment with the bore as closely as possible.

c. Cover the opening in the housing with plug 923474.

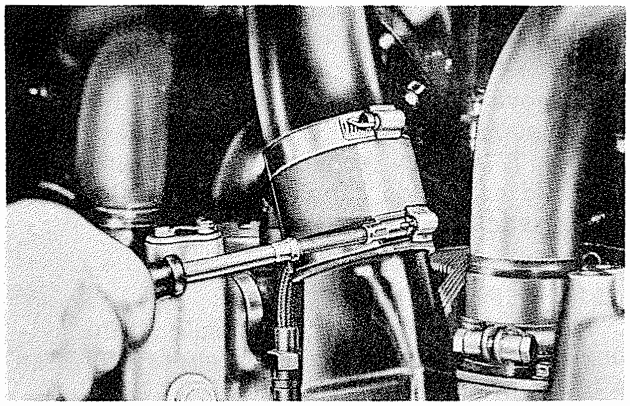


Figure 7-94. Loosening PRT Cooling Air Tube Hose Clamp

7-200. REPLACEMENT.

7-201. Invert the assembly and pre-oil by squirting castor oil into the passages in the turbine shaft support. Coat with Lubriplate 130A and install the two small and one large oil packing rings on the turbine shaft support. Place the attaching clamp on the supercharger front housing mounting boss. Install the turbine assembly, aligning the head of the locating pin in the shaft support with the deepest notch in the adapter. With the cooling air muff raised to avoid interference with the clamp, install the clamp. Place a washer under the head of the clamp bolt and install the bolt. Place a washer over the threaded end of the bolt and install the nut. Torque the nut to 400 - 475 inch-pounds and install a cotter pin.

7-202. IGNITION CABLE MANIFOLD AND LOW TENSION IGNITION COIL LEADS.

7-203. This operation requires removal and replacement of the following parts:

	Paragraph
Distributor	7-224

7-204. REMOVAL.

a. Disconnect the main primary lead at the manifold, using a 1 inch wrench. Place protective covers on the connections.

b. Disconnect the low tension ignition coil leads at the coils.

c. Remove the rear low tension ignition lead supporting clip screw at the intake air deflectors on the front cylinders, using a 7/16 inch wrench.

CAUTION

Do not loosen the "Y" lead connection to manifold connection nuts.

d. Remove the nuts that secure the ignition cable manifold brackets to the combination screws on the crankcase front section, using a 9/16 inch wrench.

e. Unfasten the distributor covers which were temporarily fastened to upper cylinder rocker boxes when the distributors were removed.

f. Remove the ignition cable manifold.

7-205. REPLACEMENT.

a. Place the ignition cable manifold in position on the crankcase front section. Secure the cable manifold brackets to the combination screws on the crankcase front section with washers and self-locking nuts, tightened to 275 - 300 inch-pounds.

b. Remove the protective covers from the distributors and distributor covers and uncover the openings in the crankcase front section. Install the distributors.

c. Remove the protective covers from the main primary lead and the main primary lead connection at the manifold. Apply Lubriplate 130A, sparingly, to the threads at the manifold and attach the main primary lead. Using a 1 inch wrench, tighten to 96 - 120 inch-pounds and lockwire.

CAUTION

Since the "Y" lead connections are adjusted at assembly to the angle enabling the leads to fit correctly on the engine, do not loosen the "Y" lead connection to manifold connection nuts, unless it is essential to eliminate an interference problem.

d. Attach the low tension leads to the ignition coils. Tighten to 95 - 105 inch-pounds and lockwire.

e. Attach the rear low tension lead supporting clip screw to the front cylinders at the intake air deflector location. Tighten to 80 - 85 inch-pounds and lockwire.

7-206. MAIN PRIMARY LEAD.

7-207. REMOVAL.

a. Disconnect the main primary lead at the magneto. Place protective covers on the connections.

b. Remove the primary lead clamp screws and clamp from the bracket on the supercharger rear housing cover. Disconnect the clamp at the upper flange bolt of the dual intake pipe for cylinders No. 3 and 4 on the supercharger front housing.

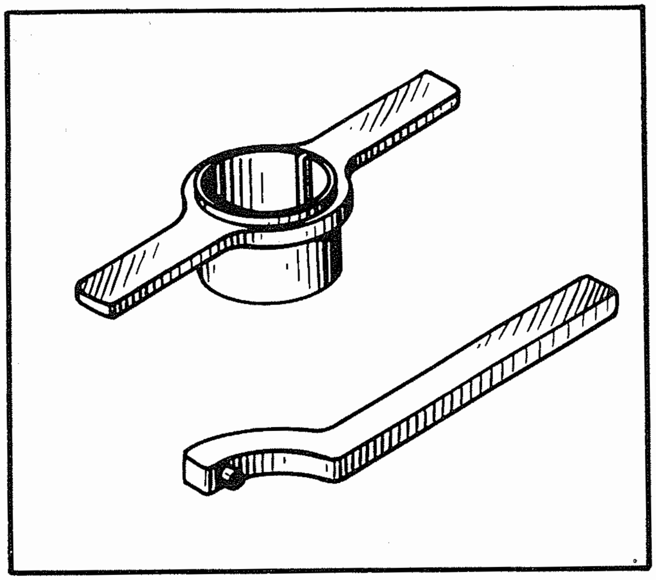


Figure 7-95. Ignition Cable Main Primary Lead Nut and Holder

c. Disconnect the main primary lead at the manifold, using a 1 inch wrench. Place protective covers on the connections. Remove the main primary lead from the engine.
d. In the event it is necessary to remove the smaller nut at the rear end of the main primary lead, use wrench and holder 806119. See figure 7-95.

7-208. REPLACEMENT.
a. Locate the main primary lead between cylinders No. 2 and 4 of the front row, and between cylinders No. 3 and 5 of the rear row.
b. Apply Lubriplate 130A, sparingly, to the connection threads of the magneto and attach the main primary lead. Tighten to 120 - 144 inch-pounds and lockwire.
c. Attach the main primary lead to the bracket at the supercharger rear housing cover, using a clamp and two screws tightened to 18 - 20 inch-pounds.
d. Attach the main primary lead clamp to the cylinders No. 3 and 4 dual intake pipe flange upper bolt on the supercharger front housing. Tighten the screw to 125 - 140 inch-pounds.
e. Connect the main primary lead to the ignition cable manifold. Using a 1 inch wrench, tighten the main primary lead nut to 96 - 120 inch-pounds and lockwire.

7-209. IGNITION COIL AND SUPPORTING SADDLE.

7-210. REMOVAL.
a. Disconnect the low tension ignition lead at the coil. Disconnect the spark plug leads at the coil.
b. Remove the self-locking nuts, using wrench 80449, and remove the coil strap. Remove the coil.
c. Remove the bolts and washers that secure the coil supporting saddle to the cylinder head, using a 7/16 inch socket wrench, universal joint, and extension handle. Remove the supporting saddle.

7-211. REPLACEMENT.
a. Install the coil supporting saddle on the cylinder head with bolts and lock washers. Tighten the bolts to 80 - 85 inch-pounds.
b. Insert the ignition coil in the saddle, ensuring that the ground button slides into the slot. Place the coil strap over the coil and secure with self-locking nuts. Torque the two nuts nearest the rocker box to 15 - 25 inch-pounds. Torque the remaining nut to the same value. Some clearance must exist between the strap and saddle at the single stud location. If there is no clearance, replace the coil strap with a new one.
c. Apply a .015 to .020 inch layer of DC-200 compound, viscosity of 60,000 centistokes at 25°C (77°F), to the coil end of the spark plug leads. DC-200 compound is manufactured by the Dow Corning Corporation of Midland, Michigan.

WARNING

Apply compound with care to avoid contamination of parts. Keep hands away from the face as this compound can cause severe irritation of the eyes.

d. Connect the spark plug leads to the ignition coil. Tighten to 165 - 175 inch-pounds. Connect the low tension ignition lead. Tighten to 95 - 105 inch-pounds and lockwire.

7-212. SPARK PLUG LEAD.

7-213. Disconnect the spark plug lead at the coil and spark plug. Use wrench 807311 at the spark plug end of the leads on the front spark plugs in cylinders No. 9 and No. 11. See figure 7-96. Use wrench 807580 at the spark plug end of the leads at all other spark plugs. See figure 7-97. Replace and torque the spark plug lead nuts at the coil and spark plug to 165 - 175 inch-pounds.

7-214. SPARK PLUGS.

7-215. REMOVAL.
a. Disconnect the spark plug lead at the spark plug. Use wrench 807311 at the front spark plugs in cylinders No. 9 and No. 11. Use wrench

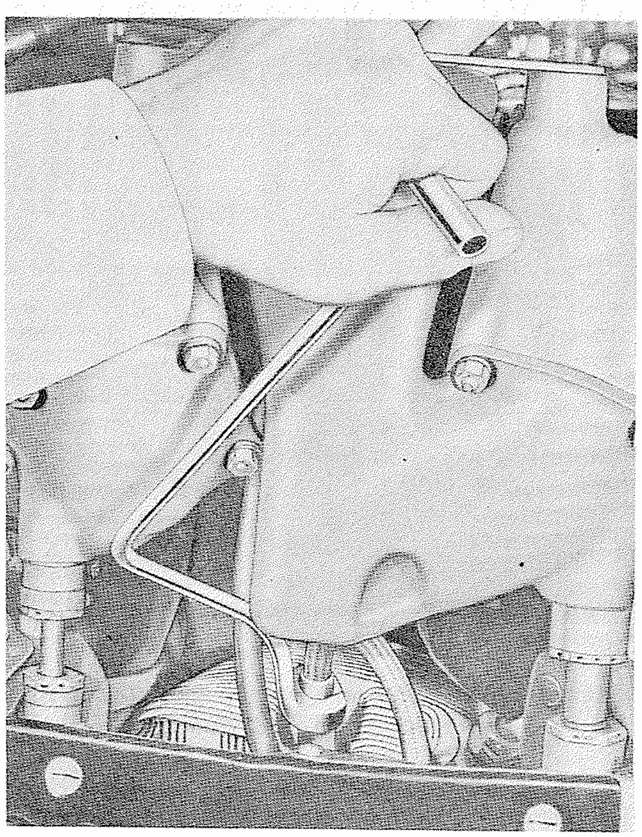


Figure 7-96. Disconnecting Front Spark Lead at Cylinder No. 9

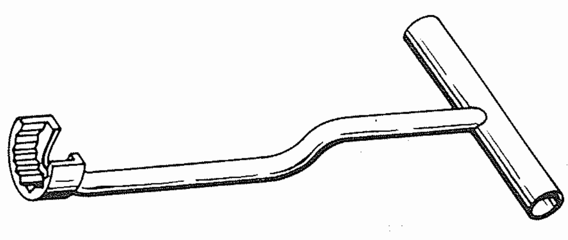


Figure 7-97. Spark Plug Lead to Spark Plug Nut Wrench

807580 on the leads at all other spark plugs. Install a protector on the spark plug lead.

b. Remove the spark plug. Use wrench 807265 on the front spark plugs in cylinders No. 9 and No. 11. Use wrench 808520 on all other spark plugs. See figure 7-98.

c. Install plug 802112 (figure 7-99) in the spark plug hole as soon as the spark plug is removed.

7-216. SPARK PLUG INSERTS - CLEANING. If hard carbon deposits have accumulated on the spark plug insert in the cylinder, clean the threads as follows:

a. Select a rejected spark plug that has good

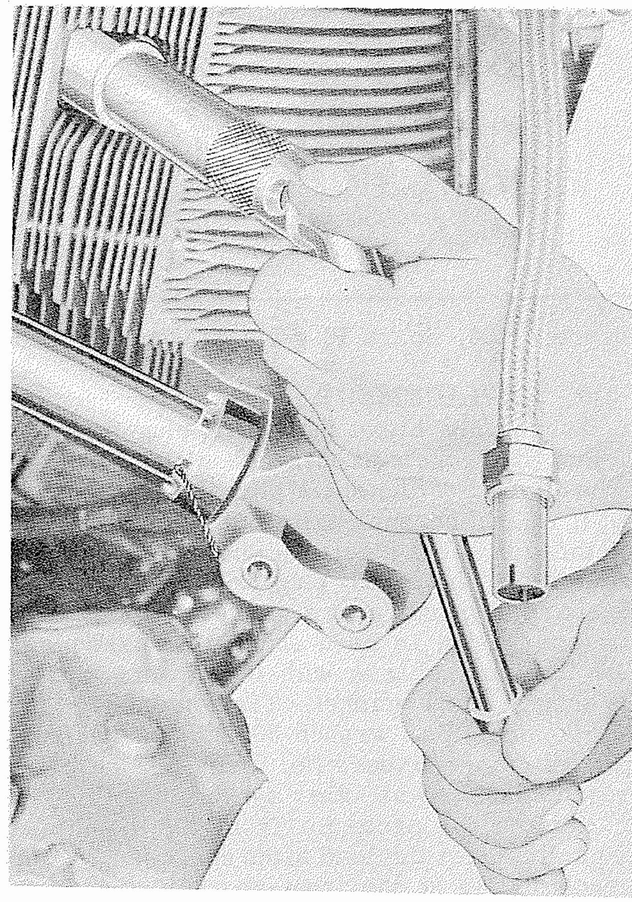


Figure 7-98. Removing Spark Plug

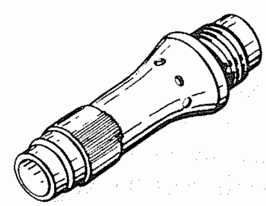


Figure 7-99. Spark Plug Hole Plug

threads. Mill four 1/16 inch slots in the threads as shown in figure 7-100. Mill the slots deep enough to provide clearance for any material that may accumulate when the plug is used as a tool. Dress the threads next to the slots with a fine, three cornered file.

b. Screw the plug, which is now similar to a tap, into the spark plug insert as far as it will go and then unscrew it.

NOTE

Do not use grease of any kind. Do not install a spark plug washer.

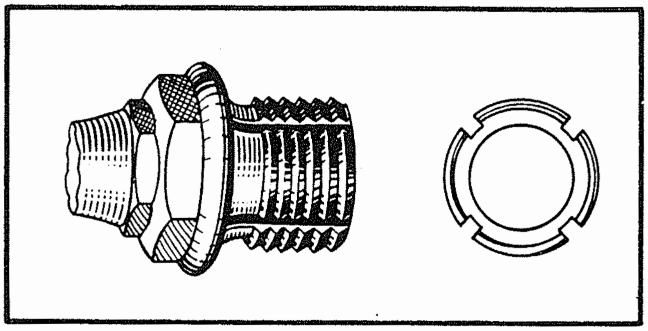


Figure 7-100. Spark Plug Insert Cleaning Tool

7-217. REPLACEMENT.

a. Thoroughly clean the spark plug threads. Ensure that the electrodes are clean. If compound is used on the spark plug threads, ensure that it is applied sparingly, but not to the first two threads at the electrode end.

b. Remove the spark plug hole plug. Install the spark plug and a new gasket. Ensure that only one gasket is used under the spark plug. Turn the spark plug in with the fingers until it fits snugly on the gasket. Tighten to 300 - 360 inch-pounds. Use wrench 807265 on the front spark plug in cylinders No. 9 and No. 11. Use wrench 808520 on all other spark plugs.

c. Remove the protector from the spark plug lead and connect the lead to the spark plug. Use wrench 807311 at the front spark plug lead in cylinders No. 9 and No. 11. Use wrench 807580 on all other spark plug leads. Torque the spark plug leads to 165 - 175 inch-pounds.

7-218. FINDING PISTON POSITION.

7-219. Remove the front spark plug from cylinder No. 1. Refer to paragraph 7-215. Turn the crankshaft until the piston in cylinder No. 1 is approximately 90 degrees before top center. Determine the stroke of the engine by the operation of the rocker arms and valves. When the piston is coming up on the compression stroke, the valves will be closed and the rocker arms will not have moved. Ensure that no spark plug gasket is present and install the cone of piston position indicator 805977 in the spark plug hole. Place pivot arm 805946 and scale 805942 on the indicator. Install the indicator so that the slot in the cone is parallel with the vertical axis of the cylinder and the scale is to the right of the slot.

7-220. Establish piston position in the following manner:

a. Move the slide pointer above the midway point in the slot. Turn the propeller shaft in the direction of rotation so the piston goes through top center position to about 90 degrees after top

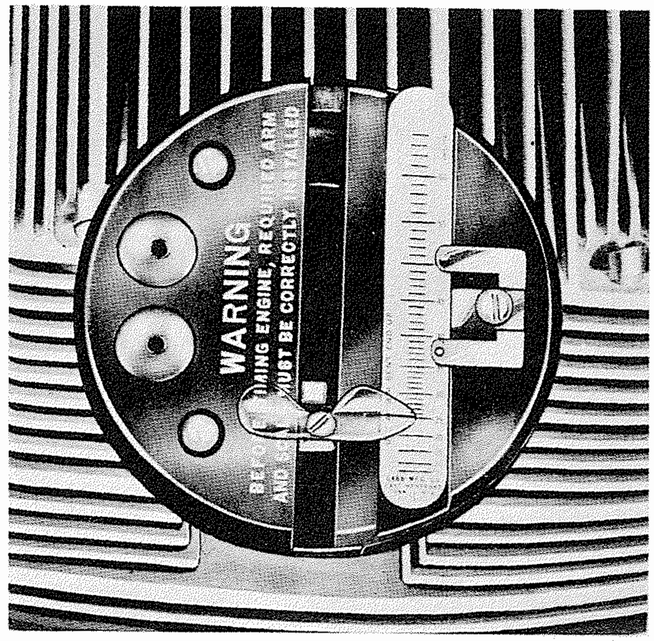


Figure 7-101. Piston Position Indicator with Piston at Timing Position

center. This will leave the slide pointer at the highest point of piston travel. Set the "O" on the scale opposite the reference mark on the slide pointer.

b. Turn the crankshaft until the piston in cylinder No. 1 is again coming up on the compression stroke. Adjust the pointer so that it is aligned at the desired number of degrees on the scale. Turn the propeller shaft slowly in the direction of rotation until the pivot arm just contacts the pointer. This will cause the light to go on, indicating that the piston is at the exact position desired. See figure 7-101.

7-221. MAGNETO.

7-222. REMOVAL.

a. Disconnect the ignition switch and booster cable, and the main primary lead at the magneto. Place protective covers over the connections.

b. Remove the four self-locking nuts at the magneto flange with a 1/2 inch wrench. Remove the washers and withdraw the magneto.

7-223. REPLACEMENT AND TIMING.

a. Be sure that the magneto has been inspected for correct assembly and operation and that the drive shaft nut is tight and a cotterpin is installed. Set the piston in No. 1 cylinder at 25 degrees before top center on the compression stroke. Refer to paragraph 7-218.

b. Remove the spring clip from the timing plunger on the junction box. Press down on the

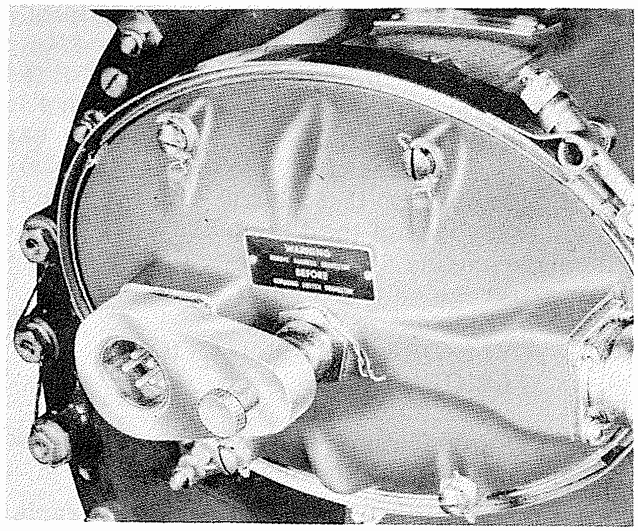


Figure 7-102. Magneto with Plunger Locking Clamp Installed

plunger and turn the magneto shaft until the plunger bottoms in one of the four notches in the magneto shaft. Hold the plunger in with clamp 808315. This ensures the correct "E" gap position for the magneto shaft. See figure 7-102.

c. Place the magneto on the mounting pad. If the drive splines do not mesh, remove the magneto. Back out the knurled clamp screw from the plunger and rotate the magneto shaft 90 degrees so the plunger will bottom in the next slot on the magneto shaft. Again hold the plunger in with the knurled clamp screw, and install the magneto. Continue this process of rotating the magneto shaft until the splines will engage and the studs are in the approximate center of the magneto flange slots. Remove the clamping tool. Hold the magneto in this exact position and secure with the self-locking nuts and washers.

d. Check to ensure the magneto is mounted properly. One man should turn the propeller shaft slowly in the direction of rotation until the piston in cylinder No. 1 is again at 25 degrees before top center on the compression stroke. Meanwhile, another man should push in on the timing plunger. If the installation is correct, the plunger will bottom in the slot just as the piston reaches 25 degrees before top center. Tighten the magneto attaching nuts to 125 - 140 inch-pounds.

e. Reinstall the spring clip on the timing plunger. Remove the protective covers from the magneto connections and connect the main primary lead and ignition switch and booster cable. Lockwire the connection.

7-224. DISTRIBUTOR.

7-225. REMOVAL.

a. Loosen and remove the distributor clamp cap screw. Expand the clamp and slide it back on the distributor cover.

b. Remove the distributor cover being careful not to damage the segments in the cover or the carbon brushes on the distributor. Install protective covers at once on both the distributor and the cover. Fasten the distributor cover to an upper cylinder rocker box temporarily with lock wire to avoid interference when removing and installing the distributor.

c. Remove the three cap screws and washers from the distributor mounting flange with a 9/16 inch wrench.

d. Remove the distributor.

7-226. REPLACEMENT AND TIMING.

a. Check the data plate on the distributor against the engine data plate to see that the distributor has the correct cams corresponding to the master rod location in the engine.

NOTE

When timing the distributor to the engine use the No. 1 retard breaker points, located to the right of the master rod designation plate, and closest to the collector ring plate.

b. Set the piston in cylinder No. 1 at 25 degrees before top center of the compression stroke. Refer to paragraph 7-218. Move the pointer down away from the pivot arm in the piston position indicator to disconnect the circuit through the arm and slide.

c. Ensure that all mating surfaces of the distributor flange and adapter are square and flat so that overstress of any mounting screw ear will not occur. Install a new oil seal ring on the pilot of the distributor flange. Ensure that it does not shift when the distributor is secured. Rotate the distributor shaft until the line marked "1R" on the finger is aligned with the line marked "TIME OPEN" on the collector plate. Maintain the shaft in this position and install the distributor on the engine so the centers of the elongated holes in the distributor flange are aligned over the centers of the screw holes in the mounting pad.

d. If the centers of the elongated holes are not aligned with the centers of the screw holes, remove the distributor. Remove the retaining nut and washer from the drive end of the distributor shaft and shift the drive gear coupling one tooth on its spline. Replace the washer and nut and again install the distributor on the engine as described above. Repeat this procedure until the distributor can be installed with the centers of the elongated holes on the distributor flange aligned with the centers of the screw holes.

e. When the correct mounting position has been found for the distributor, remove it from the mounting pad, tighten the nut on the drive shaft and install a new cotter pin to secure the castellated nut. Reinstall the distributor and install the attaching screws and washers. Do not final torque the attaching screws at this time.

f. Piston position indicator 805977 may be used as a timing light. Attach two wire leads to the pin jacks on the indicator face. A supplemental battery may be used with the piston position indicator so that the work will not be interrupted if the small battery fails. The supplemental battery may be used in parallel with the small battery by connecting the "plus" terminal to the screw on the scale friction spring and grounding the "minus" terminal to any convenient place on the engine.

g. Connect the lead or leads of the timing light (depending on the type of timing light used) across the No. 1 retard points, so that they will make and break the circuit of the timing light. Slowly rotate the distributor clockwise until the instant the points open. The light will either go on or off, depending upon the type of timing light used. With the distributor in this position tighten the distributor attaching screws snugly but not to their final torque value.

h. Turn the propeller shaft in the direction of normal rotation and slowly come up on the compression stroke of the piston in cylinder No.1. When the timing light indicates that the points are open, read the position indicator scale. It should read 25 degrees before top center. If it does not, loosen the distributor attaching screws and rotate the distributor until the points open at this instant, and then retighten the attaching screws.

i. Mount the second distributor, following the same procedure used for the first distributor. Check the timing of both distributors by turning the propeller shaft slowly in the direction of normal rotation. Both distributors should indicate that the points are opening at the same instant the piston in cylinder No. 1 is 25 degrees before top center. If the distributors are not timed properly, tap the second distributor lightly with a fiber mallet, turning it slightly on its pad until both sets of points open at the same instant relative to each other and simultaneously with the piston in cylinder No. 1 arriving at 25 degrees before top center of the compression stroke. If the No. 1 retard breaker points fail to open at the correct time, repeat the timing adjustment.

j. Torque the distributor attaching screws to 180 - 215 inch-pounds and lockwire.

k. Carefully install the distributor cover and place the clamping ring in piston. Torque the clamp screw to 30 - 40 inch-pounds. Do not exceed the specified torque as excessive torque will stretch the clamp. Lockwire the clamp screw to the holes provided in the clevis of the clamp bracket. There are four small plugs in the distributor, three are solid, the other has a drain hole. If necessary, interchange the position of these plugs so that the one with the hole is in the lowest boss of the distributor when mounted on the engine, to provide drainage for any oil or water which might enter the unit.

7-227. CYLINDER FUEL INJECTION FLEXIBLE HOSE.

7-228. This operation requires the removal and replacement of the following parts:

	Paragraph
Front Cylinder Intake and Exhaust Air Deflector	7-155

7-229. REMOVAL. Disengage the flexible hose from the connector assemblies at both ends using a 1/2 inch wrench on the connector nut and a 9/16 inch wrench on the hose fitting nut. Disengage the hose from the clips. Carefully remove the hose from between the cylinders.

7-230. REPLACEMENT.

NOTE

Ensure that the front and rear connectors are installed as described in paragraph 7-231.

a. Install the hose to the connector at the supercharger front housing using a 1/2 inch and a 9/16 inch wrench.

b. Route the hose through the cylinders as shown in figure 7-103, engaging the hose in the various clips.

c. Install the hose to the connector at the cylinder using a 1/2 inch and a 9/16 inch wrench.

7-231. FUEL INJECTION HOSE CONNECTORS.

7-232. REMOVAL.

a. Disconnect the hose from the connector assembly, using a 1/2 inch and a 9/16 inch wrench.

b. Remove the connector assembly from the nozzle, using a 9/16 inch wrench on the tube seal nut.

c. Remove the connector assembly at the supercharger front housing using wrench 807116.

7-233. REPLACEMENT.

a. Install the front connector assembly to the fuel injection nozzle. Tighten the tube seal nut to 175 - 200 inch-pounds and lockwire.

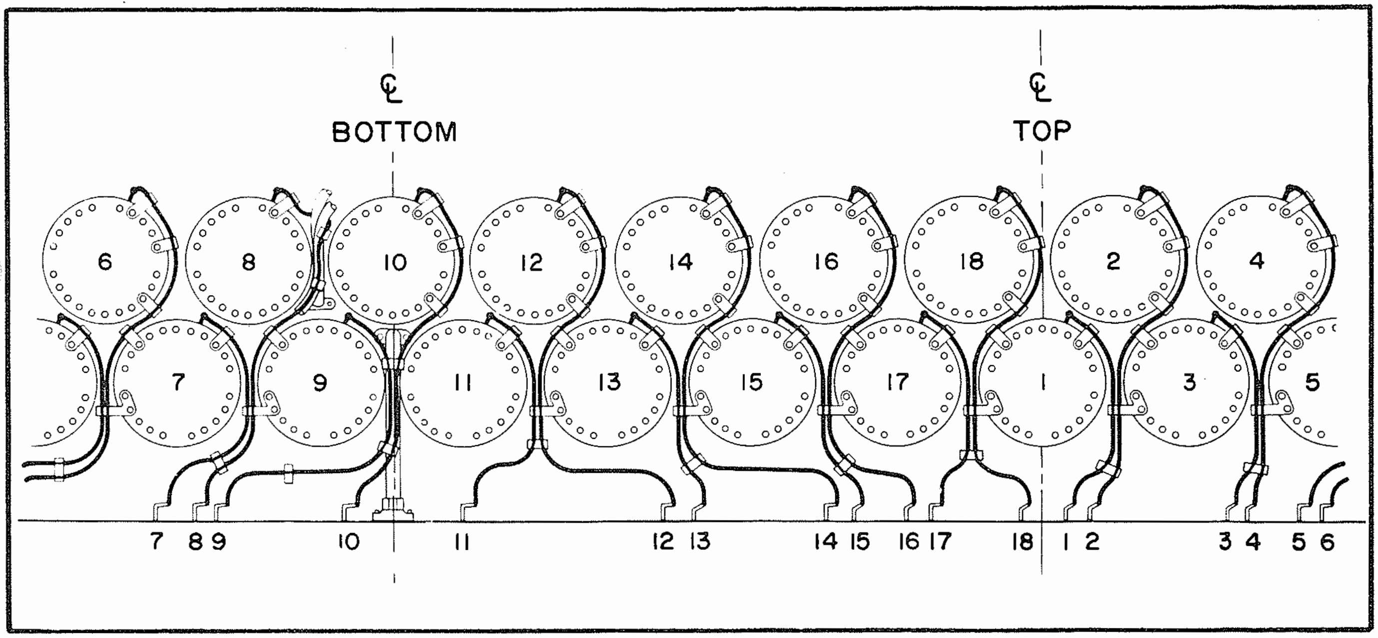


Figure 7-103. Schematic of Fuel Injection Hose and Clips Positioning

b. Engage the connector assembly to the hose, using a 1/2 inch wrench on the connector and a 9/16 inch wrench on the hose fitting. Tighten to 135 - 140 inch-pounds.

c. Install the connector assembly to the tube protruding from the supercharger front housing. Using wrench 807116 tighten the connector nut to 275 - 300 inch-pounds. The connectors used at the supercharger front housing for cylinders No. 1, 2, 3, 4, 13, 15, 16 and 18 have a 120 degree bend in the tube. The supercharger front housing connectors for the remaining cylinders have a 95 degree bend in the tube.

d. Install the supercharger front housing connector assembly to the flexible hose in the same manner as the connectors at the fuel injection nozzles. Tighten to 135 - 140 inch-pounds.

7-234. FUEL INJECTION TUBES (IN SUPERCHARGER FRONT HOUSING).

7-235. This operation requires removal and replacement of the following part:

	Paragraph
Fuel Injection Hose Connector at Supercharger Front Housing	7-231

7-236. REMOVAL. (Cylinders No. 5, 6, 14, and 15).

a. Remove the breather connection or substituting cover attaching screws and washers with a 1/2 inch wrench. Remove the breather or cover.

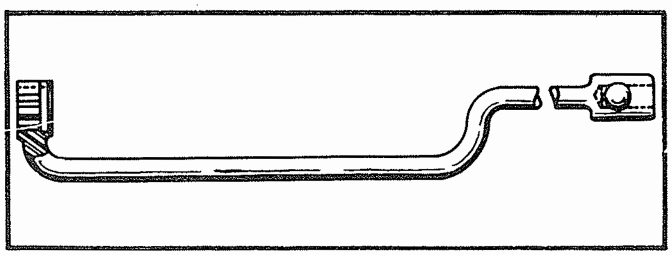


Figure 7-104. Fuel Injection Tube to Supercharger Rear Housing Connection Nut Wrench

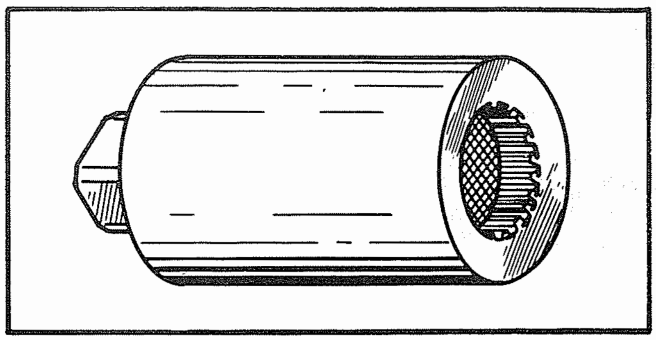


Figure 7-105. Fuel Injection Tube (in Supercharger Front Housing) Turning Wrench

b. Disconnect the fuel injection tube connection nut at the supercharger rear housing with wrench 807515 (figure 7-104).

c. Remove the cap screw and washer securing the fuel injection tube connector lock at the front of the supercharger front housing and remove the lock.

d. Use wrench 807241 (figure 7-105) to turn the tube so that the bent end will clear the supercharger rear housing.

e. Lightly tap the forward end of the tube with a rawhide mallet and withdraw the tube from the rear.

7-237. REMOVAL. (Cylinders No. 12 and 13). Remove the tubes as outiined in paragraph 7-236, steps b through e.

NOTE

The remainder of the tubes in the supercharger front housing cannot be withdrawn without removing major engine components.

7-238. REPLACEMENT (Cylinders No. 5, 6, 14 and 15).

a. Place two packing rings on the fuel injection tube front housing connector and two packing rings on the tube collar. Insert the tube into position in the supercharger front housing, turning the tube at the straight end splines with wrench 807241.

b. Install the splined lock over the tube connector at the front of the supercharger front housing. Install a washer on the cap screw and install and tighten the retaining cap screw to 125 - 140 inch-pounds. Lockwire the screw to the lock.

c. Tighten the tube nut at the supercharger rear housing with wrench 807515 and torque to 275 - 300 inch-pounds. Lockwire the nuts in pairs.

d. Install a gasket and the breather connection or substituting cover at the pad on the side of the supercharger rear housing, and secure with four cap screws and washers. Tighten to 125 - 140 inch-pounds and lockwire.

7-239. REPLACEMENT. (Cylinders No. 12 and 13). Install the tubes as outlined in paragraph 7-237, steps a through c.

7-240. FUEL INJECTION NOZZLES.

7-241. This operation requires removal and replacement of the following part:

	Paragraph
Fuel Injection Hose Connector at Cylinder Fuel Injection Nozzle	7-232

7-242. REMOVAL.

a. Using wrench 804801 remove the nozzle. Remove the nozzle washer and seal.

7-243. REPLACEMENT. Place a washer and seal over the fuel injection nozzle and insert the nozzle into the cylinder. Tighten the nozzle with wrench 804801 to 275 - 300 inch-pounds.

7-244. FUEL INJECTION PUMP SYNCHRONIZING ROD.

7-245. REMOVAL.

a. Disconnect the venturi suction tubes from the "T" located at the bottom of the master control and from the elbow at each fuel injection pump, using a 9/16 inch wrench.

b. Remove the five nuts and washers attaching the stabilizing bracket to the supercharger rear cover.

c. Remove the cotter pin and castellated nut from the control lever bolt at each pump location using a 1/2 inch wrench.

d. Remove the cupped washer from the left pump lever bolt and the shouldered washer from the right pump lever bolt. Remove the synchronizing rod and the remaining cupped washer and stepped washer from the left and right pump lever bolt, respectively.

e. Loosen the nut and remove the rod end bearing, washers, and nut from the anti-cam end of the rod. Slide the stabilizing bracket off the rod.

7-246. REPLACEMENT. When a synchronizing rod or fuel injection pump is replaced, the length of the synchronizing rod must be carefully adjusted in order to ensure perfect synchronization of both pumps.

7-247. Each fuel injection pump has a movable synchronizing block on the inside extension of the control lever bolt. This block can be moved to either of two positions, "Running" or "Synchronizing". When in the "Running" position, the flat surface of the block is downward. When in the "Synchronizing" position, the flat surface is toward the set-screw stop. There is a small indexing pin pressed into each pump control lever and there are two holes in each synchronizing block which fit over the indexing pin, thus firmly locating the block in either of its two positions.

CAUTION

Under no circumstances is the position of the set-screw stop to be altered in the field. This stop was located while the pump was being calibrated and if its position is changed in the field, the pump must be re-calibrated. The set-screw, nut, and synchronizing gage block plate are lockwired together and sealed to render the wiring tamper proof. If the lock wire or seal is broken, the pump must be re-calibrated by the manufacturer.

7-248. The following operations cover installation of the synchronizing rod and synchronization of the pumps on a cold engine:

a. Slide the stabilizing bracket assembly over the anti-cam end of the synchronizing rod.

b. Install, but do not tighten, the rod end bearing, nut, and washer on the anti-cam end of the rod.

c. Loosen the fiber lock nuts sufficiently to permit moving the blocks far enough out on the bolts to clear the locating pins. Use a 7/16 inch wrench. Rotate the blocks to the synchronizing position and then tighten the fiber lock nuts.

d. Loosen the clamp screw on the cam end of the rod, using wrench 806983, and remove the cotter pin. Rotate the knurled cam until the hole is centered vertically and tighten the cam clamp screw sufficiently to keep the cam from turning.

e. Place a shouldered washer on the right pump control lever bolt and install the cam end of the rod over the bolt.

f. Place a cupped washer on the left control lever bolt with the concave surface of the washer facing outward. Adjust the length of the synchronizing rod by turning the bearing at the left end in or out until the bearing will slide freely over the left pump lever bolt. Ensure that both rod bearings move in and out freely over the lever bolts with a minimum of drag.

g. To make a fine adjustment, rotate the knurled cam at the right end of the rod, thereby rotating the bearing. See figure 7-106. Install the cotter pin through holes which align in the knurled cam and the clamp. Torque the clamp screw to 10 - 15 inch-pounds using wrench 806983. See figure 7-107. Avoid overtightening the clamp screw which will cause binding in the bearing. Check the bearing for freedom of motion after tightening the clamp screw.

h. When the proper rod length has been established for pump synchronization, install a bearing alignment nut, Bendix Tool No. T-25522, finger tight on each pump lever bolt against the rod bearings. Tighten the lock nut on the left end of the synchronizing rod to 60 - 75 inch-pounds. Lockwire the nut to the hexagon head bushing in the rod end.

i. Remove the bearing alignment nuts. Place a cupped washer on the left pump lever bolt with the concave surface of the washer toward the synchronizing rod and place a shouldered washer on the right pump lever bolt. Install the castellated nuts and tighten with a 1/2 inch socket wrench and torque wrench to 100 - 125 inch-pounds.

CAUTION

When torquing the synchronizing rod attaching nuts, hold the external pump lever in a way to ensure that no force is transmitted to the internal lever which could slip on the shaft under such loads, thus upsetting the fuel injection pump calibration.

j. Do not exceed 125 inch-pounds torque when aligning the synchronizing rod attaching nut for the cotter pin. Install a cotter pin and check the rod to ensure that there is no binding. The rod must be free to rotate around its horizontal axis within the limitations of the washers.

k. Install the stabilizing bracket assembly on supercharger rear cover studs No. 1, 2, 3, 29, and 30. Install the bracket attaching nuts. Before final tightening of the nuts, ensure that the rod moves freely within the brackets. Tighten the bracket nuts to 125 - 140 inch-pounds and lockwire.

l. To check the setting of the synchronizing rod, move the synchronizing blocks and rod away

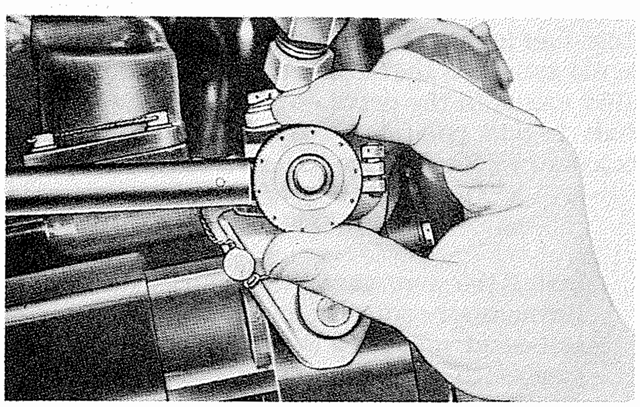


Figure 7-106. Rotating Knurled Cam

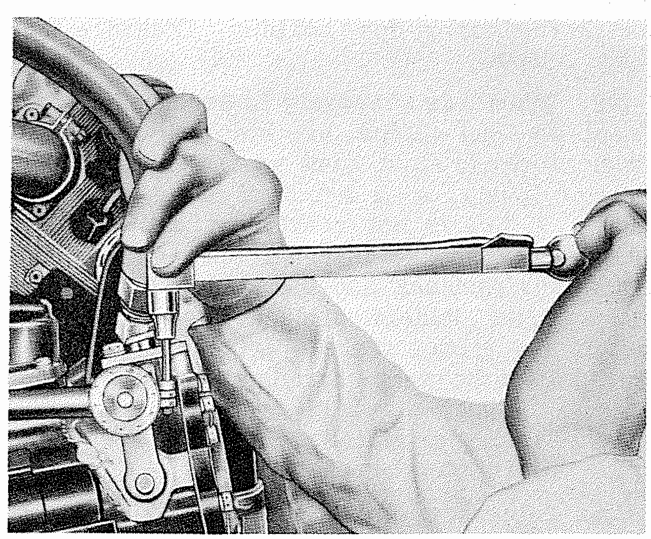


Figure 7-107. Tightening Clamp Screw at Cam End of Synchronizing Rod

from the set-screw stops far enough to insert a short length of .0010 - .0015 inch feeler gage stock, or paper of comparable thickness, between the blocks and the set-screw stops. Be sure to use the same thickness on both pumps. If the length of the rod is correct, both pieces of feeler gage stock or paper will be held firmly between the blocks and stops. If it is too long, the right hand feeler gage stock or paper will be loose between the block and the stop. If it is too short, the left hand feeler gage stock or paper will be loose between the block and the stop.

m. If necessary, the cam in the right end of the rod can again be adjusted by loosening the clamp screw, removing the cotter pin, and turning the knurled cam in the required direction to lengthen or shorten the rod. After making the adjustment, reinstall the cotter pin through holes which align in the knurled cam and the bearing clamp, and tighten the clamp screw to the proper torque before checking again to determine whether the adjustment is satisfactory.

NOTE

Whenever a change in adjustment is made on the knurled cam, the cotter pin must be installed and the clamp screw tightened to 10 - 15 inch-pounds before checking to determine if adjustment is correct.

n. After the synchronizing rod has been installed and adjusted, make the following checks: Make certain the clamp screw at the cam end of the rod has been properly torqued; ensure that the cotter pin located through the holes in the cam and bearing is installed with the ends spread to secure it permanently in position, and make certain the bearing does not bind. Lockwire the clamp screw.

7-249. When it is necessary to synchronize the pumps on a hot engine, use identical synchronizing blocks (a right hand synchronizing block on each pump, or a left hand block on each pump). If this is not convenient, a .008 inch feeler gage may be inserted between the left synchronizing block and the stop to obtain the same results. If identical blocks are used, make certain the proper right or left block is reinstalled after the pumps have been synchronized. Operate the engine until the cylinder head temperature is approximately 200°C (392°F) before synchronizing on a hot engine.

7-250. After the pumps have been properly synchronized, return the synchronizing blocks to the running position and then tighten the fiber lock nuts.

7-251. Connect the venturi suction tubes to the "T" located at the bottom of the master control and to the elbow at each fuel pump. Torque the nuts to 50 - 75 inch-pounds. Position the support brackets over studs No. 5 and No. 27 at the supercharger rear cover and secure with fiber lock nuts. Tighten to 125 - 140 inch-pounds.

7-252. FUEL INJECTION PUMP.

7-253. This operation requires removal and replacement of the following part:

	Paragraph
Synchronizing Rod	7-244

7-254. REMOVAL.

a. Disconnect the vapor tube from the fuel injection pump using a 9/16 inch wrench.

b. Disconnect the fuel tube from the pump using a 1 inch wrench.

c. Disconnect the venturi suction tube from the pump using a 9/16 inch wrench.

d. Remove the pump to adapter screws using wrench 807110 (figure 7-108).

e. To remove the pump, tap the pump lightly near its outer end with a fiber mallet to free it.

f. Remove the packing ring from the groove in the piloting shoulder on the pump flange. Remove all the packing rings from the ring grooves in the pump flange. Remove the packing ring from the hollow oil dowel projecting through the bottom of the pump flange.

g. Place protective covers over the fuel pump adapters.

7-255. REPLACEMENT.

a. Use fixture 807748, shown in figure 7-109, to align the fuel injection pump drive coupling with the drive gear. Loosen the knurled lock screw in the fixture. Place the fixture on the fuel injection pump adapter with the short locating pin in the dowel hole adjacent to the uppermost fuel hole in the adapter, and the blind external spline on the fixture shaft meshed with the blind spline in the drive gear. Lock the fixture shaft in this position by tightening the knurled lock screw. Remove the fixture from the adapter.

NOTE

Install the pump assembly having a parts list number ending in an odd digit on the left-hand mounting flange. Install the pump with a parts list number ending in an even digit on the right-hand mounting flange.

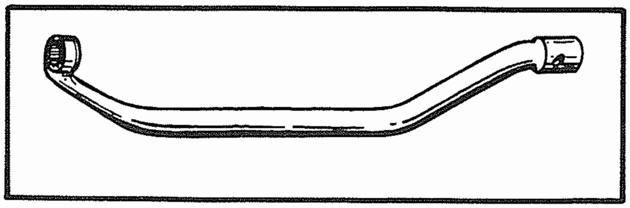


Figure 7-108. Fuel Injection Pump to Adapter Screw Wrench

Figure 7-109. Fuel Injection Pump and Pump Drive Gear Spline Aligning Fixture

b. Install the fixture on the pump with the blind internal spline in the fixture shaft meshed with the blind spline on the pump coupling. Rotate the splined coupling of the pump with the fixture until the long locating pin can be pushed into the hollow dowel in the pump flange. The engine drive gear splines and the pump coupling blind splines are now aligned for proper engagement when the pump is installed.

c. Coat nine new fuel injection tube to pump flange packing rings with anti-seize compound, Lubriplate 130A, and install one ring in each of the nine ring grooves in the fuel injection pump flange.

d. Install three locating studs, 807485 equally spaced at the 2, 6, and 10 o'clock positions, in the pump to adapter screw holes.

e. Coat a new fuel injection pump to adapter packing ring with anti-seize compound, Lubriplate 130A, and install the ring in the groove in the piloting shoulder of the pump flange. Coat a new hollow oil dowel packing ring with anti-seize compound, Lubriplate 130A, and install the ring in the counterbore around the dowel in the pump flange.

f. Install the pump. Install six of the nine pump to adapter screws. Torque the screws to 125 - 140 inch-pounds, using wrench 807110. Remove the three aligning studs and install the three remaining screws and tighten to the same torque value. Lockwire the nine screws.

g. After installing the synchronizing rod, install the venturi suction tube. Torque the nut on the tube to the elbow on the pump to 50 - 75 inch-pounds.

h. Install the fuel tube using a 1 inch wrench. Tighten to 200 - 350 inch-pounds.

i. Install the vapor tube using a 9/16 inch wrench. Torque the nut on the vapor tube at the pump end to 50 - 75 inch-pounds.

7-255A. FUEL INJECTION PUMP ADAPTER.

7-255B. This operation requires removal and replacement of the following parts:

	Paragraphs
Synchronizing Rod	7-244
Fuel Injection Pump	7-255

7-255C. REMOVAL

a. Remove the two screws and washers that secure the injection pump drive shaft gear retainer over the pump drive shaft gear and remove the retainer.

b. Withdraw the fuel injection pump drive shaft gear using puller 805298. See figure 7-109A.

c. Loosen the nine connector seal nuts in the pump adapter with a 9/16 inch wrench.

d. Remove the nine pump adapter to supercharger rear housing screws and washers with a 1/2 inch wrench.

e. Remove the pump adapter assembly and gasket from the supercharger rear housing.

f. Remove the nine fuel seal rings from the recesses in the pump adapter outer flange and the nine oil seal rings from the inner grooves in the fuel injection tube connectors.

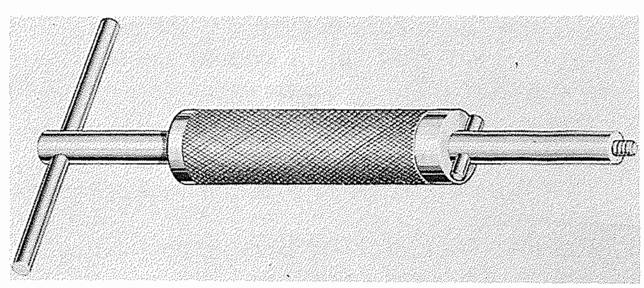


Figure 7-109A. Fuel Injection Pump Drive Shaft Gear Puller

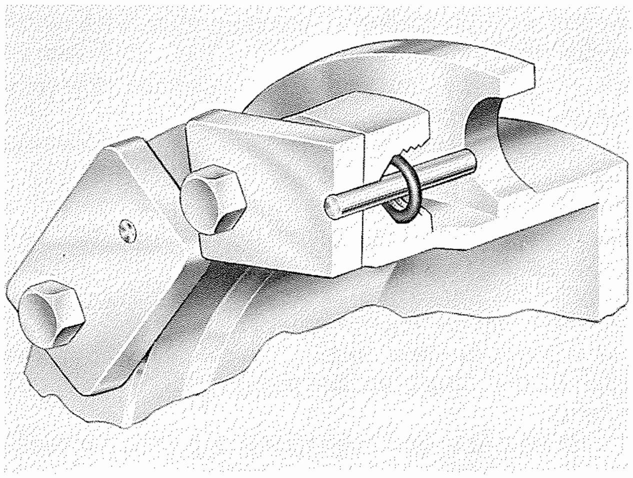


Figure 7-109B. Adapter with Locators and Seal Rings Installed

7-255D. REPLACEMENT.

a. Coat nine oil seal rings with Lubriplate 130A and install them on the inner grooves of the injection tube connectors.

b. Using the injection pump mounting bolts, mount nine locators 808699, on the outer flange of the pump adapter with the dowel pins protruding through the fuel holes.

c. Coat the nine protruding dowel pins and nine fuel seal rings with Lubriplate 130A, and install the seal rings over the locator dowel pins and into the recesses in the pump adapter outer flange, centered and in as far as possible around the locator dowels. See figure 7-109B.

d. Install a new pump adapter gasket on the inner flange of the pump adapter and locate the adapter assembly so that the ends of the dowel pins are in line with the holes in the tube connectors.

e. Slide the adapter on far enough so that the tube connectors are through the holes in the inner flange and will permit installation of three of the adapter mounting screws and washers 120 degrees apart.

CAUTION

Do not use a hammer or jar the parts in any way that might unseat the seal rings.

f. Install the three mounting screws and tighten them slowly and evenly, with a 1/2 inch wrench, to draw the adapter flush with the supercharger rear housing.

g. Remove the nine bolts holding the locator in place and remove the locators.

h. Install the remaining six mounting screws and washers and torque all nine screws to 125 - 140 inch-pounds.

i. Start the nine connector seal nuts into the threaded holes in the outer flange of the adapter and torque them to 175 - 200 inch-pounds.

j. Lockwire the connector seal nuts to the adapter mounting screws in pairs.

k. Pressure test the installed adapter as instructed in paragraph 6-53.

7-255E. TIMING FUEL INJECTION PUMP ADAPTER GEARS.

NOTE

This procedure is for the purpose of timing the injection pump drive shaft gear to the crankshaft.

a. Turn the crankshaft until the piston in cylinder No. 1 is 25 degrees before top center on the compression stroke. Refer to paragraph 7-218 for finding piston position.

b. Install fuel injection pump drive gear timing pointer 807326, in the fuel injection pump drive gear, so that the plunger of the tool is in the double spline. Tighten the thumb screw.

c. Turn the pump drive gear until the timing pointer scribe marks in the tool align on either side of the scribe marks on the adapter flange.

NOTE

The left pump adapter has two scribe marks. Align the 25 degree mark between the scribe marks on the pointer.

d. Hold the pump drive gear in this position and insert the fuel injection pump drive shaft gear so that its splines mesh at its inner end and the gear teeth mesh with the pump drive gear.

e. Check the position of the pump drive gear by turning the crankshaft in the direction of rotation until the piston in cylinder No. 1 is again at 25 degrees before top center on the compression stroke. The scribe mark on the adapter (25 degree mark on the left adapter; 15 degree mark on the right adapter) must be between the two scribe marks on the timing pointer. If it is not, remove the pump drive shaft gear and realign. Repeat this operation until the pointer aligns correctly with the adapter scribe mark.

f. Place the retainer over the end of the shaft and secure it with washers and screws. Torque to 30 - 35 inch-pounds and lockwire.

7-256. PRIMING SYSTEM.

7-257. REMOVAL.

a. Disconnect the priming hose to bracket clip from the bracket at the right hand side of the master control.

b. Disconnect the two priming hose to bracket clips from the bracket at the front of the master control mounting flange.
c. Using a 9/16 inch wrench, disconnect the upper priming hose from the elbow at the electric primer valve connection on the master control, and from the right hand priming nozzle in the supercharger rear housing.
d. Using a 9/16 inch wrench, disconnect the lower priming hose from the right and left hand priming nozzles in the supercharger rear housing.

7-258. REPLACEMENT.
a. Connect the lower priming hose to the right and left hand priming nozzles in the supercharger rear housing. Tighten the hose connection nuts to 50 - 75 inch-pounds.
b. Connect the upper priming hose to the elbow at the electric primer valve connection on the master control, and to the right hand priming nozzle in the supercharger rear housing. Tighten the hose connection nuts to 50 - 75 inch-pounds.
c. Connect the two priming hose to bracket clips to the bracket at the rear of the master control mounting flange. Tighten the bolts to 18 - 20 inch-pounds.
d. Connect the priming hose to bracket clip to the bracket at the right hand side of the master control. Tighten the bolt to 18 - 20 inch-pounds.

7-259. MASTER CONTROL FUEL STRAINER.

7-260. REMOVAL.
a. Cut the lock wire and loosen the bolt in the strainer cap with a 9/16 inch wrench. Remove the strainer assembly.
b. Remove the cotter pin from the strainer bolt and remove the strainer from the bolt for cleaning.

7-261. REPLACEMENT.
a. Install a washer on the strainer bolt and insert the bolt through the strainer cap. Install the spring over the bolt.
b. Install the strainer over the bolt and insert a new cotter pin through the hole in the bolt.
c. Install a new gasket under the strainer cap and install the strainer in the master control.
d. Tighten the bolt with a 9/16 inch wrench. Lockwire.

7-262. MASTER CONTROL.

7-263. This operation requires removal and replacement of the following parts:

	Paragraphs
Priming Hose to Master Control Bracket Clips	7-256
Fuel Injection Pump Synchronizing Rod	7-244

7-263A. REMOVAL.
a. Disconnect the vapor vent tubes at the master control using a 9/16 inch wrench. Disconnect the fuel tubes at the master control using a 1 inch wrench. Allow the vapor vent and fuel tubes to hang freely. If necessary, loosen the vapor vent to fuel tube clips.
b. Using a 9/16 inch wrench, loosen the cap screws retaining the master control to the supercharger rear housing. Remove the cap screws and washers. Remove the master control. Place a protective cover over the master control mounting deck of the supercharger rear housing.

7-264. REPLACEMENT. Prepare the master control unit for service in accordance with the manufacturer's instructions.
a. Remove the protective cover from the master control mounting deck on the supercharger rear housing and inspect the induction passage. Install a new gasket over the mounting deck.
b. Install the master control and install the washers and cap screws. Tighten the screws to 275 - 300 inch-pounds and lockwire.
c. Connect the fuel tubes at the master control. Tighten to 200 - 350 inch-pounds. Connect the vapor vent tubes to the fitting in the master control. Tighten to 50 - 75 inch-pounds. If the vapor vent tube clip was loosened, position and tighten it.

NOTE

The venturi suction tubes will be connected to the master control after the synchronizing rod is installed.

7-265. ACCESSORY DRIVE GEAR BOX.

7-266. REMOVAL.
a. Remove the supercharger clutch and housing assembly.
b. Loosen the two oil plugs in the accessory drive gear box rear housing, and disconnect the hose from the elbow on the front housing.

c. Remove the rear housing to front housing bolts and washers, and remove the gear box housing to rear cover retaining bolts, using a 5/8 inch wrench. Remove the two large retaining bolts using a 3/4 inch wrench. Remove the rear housing and gasket.

d. Remove the front housing to generator mounting pad attaching bolts using 3/4 inch wrench.

e. Tap the housing lightly with a fiber mallet to break the seal and remove it from the generator mounting pad. See figure 7-110.

f. Remove the coupling from the generator drive gear, or the front housing, whichever applies.

g. Remove the oil seal rings from the oil supply tube in the mounting flange of the front housing and from the groove on the boss.

7-267. REPLACEMENT.

NOTE

The accessory drive gear box is shipped separately from the engine. When a new installation is made on the right generator pad, the generator drive oil seal and coupling must be removed. Refer to paragraph 7-179. The plug in the pressure oil supply hole in the outer perimeter of the mounting flange must also be removed, using a 5/32 inch Allen wrench. See figure 7-111.

a. Install the oil seal ring in the boss on the propeller end of the front housing and in the counterbore provided around the oil supply tube. See figure 7-112.

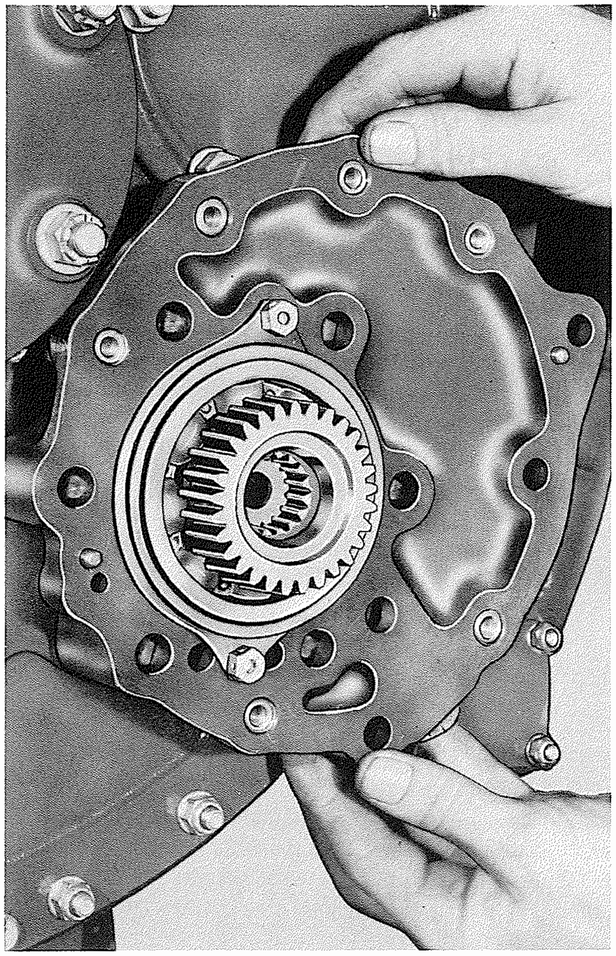


Figure 7-110. Removing Accessory Drive Gear Box Front Housing

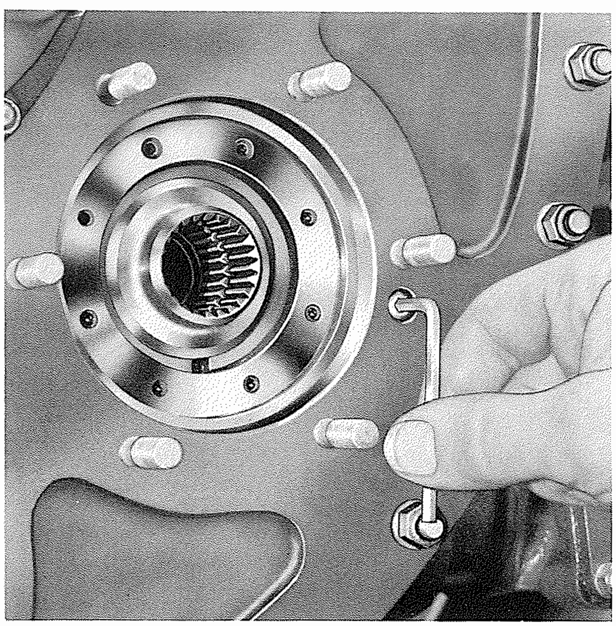


Figure 7-111. Removing Plug from Pressure Oil Supply Hole

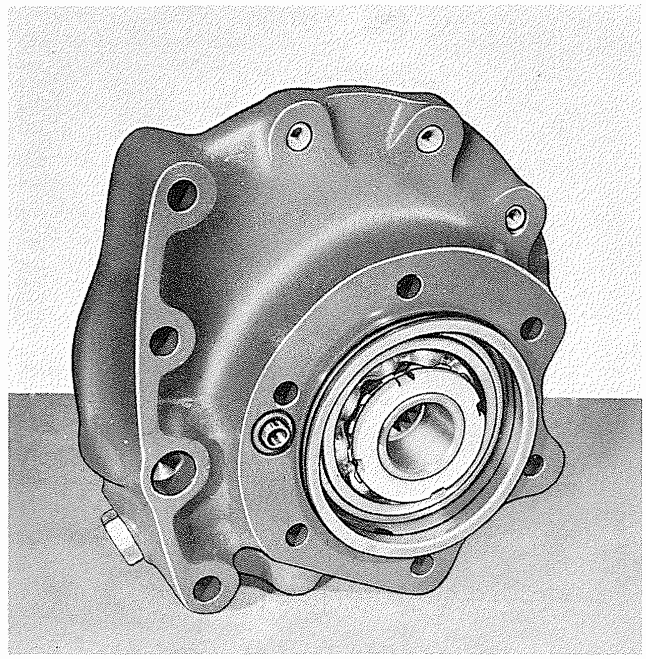


Figure 7-112. Front View of Gear Box Front Housing Showing Oil Seal Rings Installed

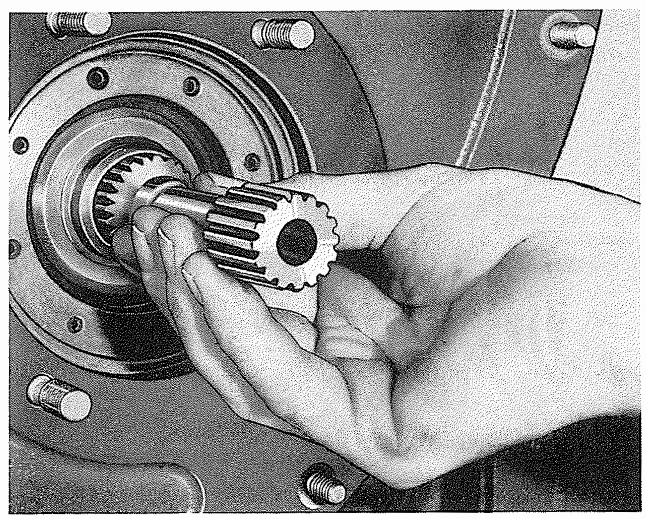


Figure 7-113. Installing Accessory Drive Gear Coupling

b. Install the accessory drive gear coupling in the generator drive gear, as shown in figure 7-113. Position the gear box front housing on the right generator mounting pad, engaging the splines of the coupling with the accessory drive gear pinion shaft. Install the four short internally threaded bolts and washers. Torque to 275 - 300 inch-pounds. Lockwire the outer bolts to the bearing retainer screws and lockwire the two inner bolts together. See figure 7-114.

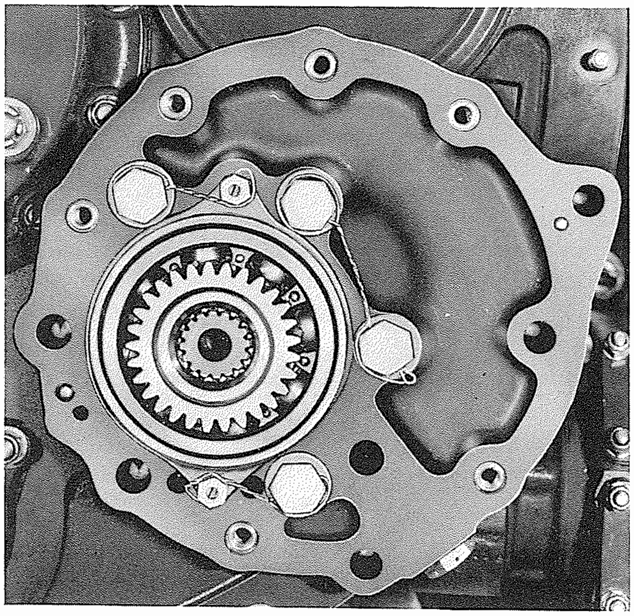


Figure 7-114. Accessory Drive Gear Box Front Housing Installed and Lockwired

c. Install the gasket on the rear face of the front housing, and position the rear housing. Attach the housing with the two long, internally threaded bolts having a 3/4 inch hex. head and the three long, internally threaded bolts having a 5/8 inch hex. head. Torque the 3/4 inch hex. head bolts to 275 - 300 inch-pounds. Lockwire. Torque the 5/8 inch hex. head bolts to 125 - 140 inch-pounds. Lockwire. Install the rear housing to front housing attaching bolts. Torque the bolts and lockwire in pairs. Figure 7-115 shows the rear housing installed and bolts lockwired.

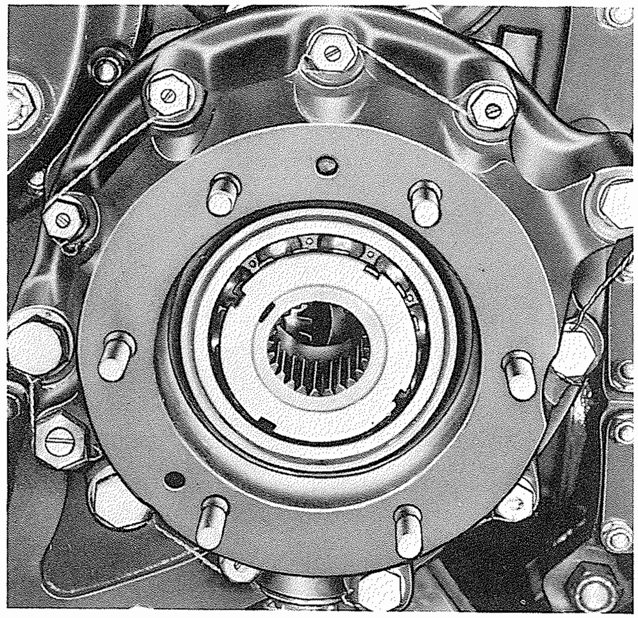


Figure 7-115. Accessory Drive Gear Box Rear Housing Installed and Lockwired

d. Couple the hose to the elbow on the front housing. Ensure that the two plugs on the rear housing are tightened.

Section VIII

SERVICE TOOLS

Tool Number	Nomenclature	Figure Number
80449	Wrench - Rocker box cover nut socket, 7/16 in. hex.	7-28, 7-49
81402	Handle - General use, 7/8 in. hex.	7-20
83130	Wrench - Cylinder hold-down screw speed, 1/2 in. hex.	7-65
83403	Wrench - Propeller shaft thrust bearing nut lug	7-17
83607	Wrench - Propeller shaft hydro oil connection cover nut plug, 2-5/8 in. hex.	7-20
84770	Removing Tool - Rocker box cover washer magnetic	7-49
801080	Wrench - Generator attaching nut, open end, 9/16 in.	7-85
801122	Wrench - Hose clamp socket 1/4 in. hex.	7-94
801332	Protector - Propeller shaft thread No. 60 spline	7-1
801534	Puller - Fuel pump drive oil seal	7-83
802139	Wrench - Oil pressure relief valve cap, 7/8 in. hex.	7-10, 7-30
802177	Screw - Cylinder to crankcase locating, 1/2 in. hex.	
803145	Clamp - Piston ring	
803763	Fixture - Cylinder compression leakage testing	6-1
803777	Installing Tool - Valve tappet circlet	7-55
804504	Installing Tool - Cylinder air deflector tube and clamp assembly	7-63
804801	Wrench - Fuel injection nozzle box, 3/4 in. hex.	
804849	Clip - Valve tappet to valve tappet guide, holding	
804854	Plug and Base - Magneto drive oil seal removing and installing, arbor press (804854D1 and 804854D2 are details of 804854)	7-86
804855	Plug - Magneto drive oil seal and collar to magneto coupling, installing	7-87
804885	Wrench - Clutch control valve housing to rear pump, box, 1/2 in. hex.	
805043	Wrench - Oil sump magnetic plug, flexible socket, 7/8 in. hex.	
805270	Plug - Fuel pump shaft support oil seal, installing	7-84
805298	Puller - Fuel injection pump drive shaft gear and plug removing	7-109A
805446	Holding Tools - Propeller shaft to crankcase front section	
805564	Adapter - Valve tappet guide impact puller (used with puller 806784)	7-53
805566	Wrench - Rear sump and pump to supercharger rear housing attaching screw, box, 1/2 in. hex.	7-40
805567	Wrench - Rear sump and pump to supercharger rear housing attaching screw, box, 1/2 in. hex.	7-39
805568	Puller - Propeller control oil supply tube and support assembly	7-22
805569	Wrench - Intake pipe connection nut, lug	7-45, 7-48
805925	Wrench - Oil pressure relief valve body, 1-5/8 in. socket	
805942	Scale - Piston position indicator, Gabb Mfg. Co. Catalog No. 1-209-14 (used with 805977)	
805946	Pivot Arm - Piston position indicator, Gabb Mfg. Co. Catalog No. 1-205M (used with 805977)	
805964	Wrench - Push rod housing outer connection nut	7-57
805965	Wrench - Push rod housing inner connection nut	7-50, 7-58
805968	Installing Tool - Tachometer drive housing oil seal	7-80

Tool Number	Nomenclature	Figure Number
805971	Screwdriver - Rocker arm adjusting screw, tightness checking, .109 in. blade thickness	7-14
805977	Indicator - Piston position, Gabb Mfg. Co. Model B (used with 805942 and 805946)	
806078	Jig - Cylinder head fins drill	7-71
806119	Wrench and Holder - Ignition cable main primary lead connection nut, disassembly and assembly	7-95
806147	Puller - Tachometer drive shaft oil seal	7-79
806222	Gage - Starter adapter to starter coupling limit flush pin (1.657 - 1.683 in. dia.)	7-89
806277	Wrench - Rocker arm shaft cap, box 1-1/16 in. hex.	
806474	Puller - Supercharger clutch oil control valve sleeve removing	7-32
806487	Wrench - Push rod housing connection nut lug (used with universal joint 806517 and extension 806518)	7-51
806517	Universal Joint - Push rod housing connection nut lug wrench to extension (used with wrench 806487 and extension 806518)	7-51
806518	Extension - Push rod housing connection nut lug wrench to extension (used with wrench 806487 and universal joint 806517)	7-51 7-68
806535	Wrench - External oil tube connection nut 1-3/8 in. open end	
806546	Protector - Rocker box drain manifold to cover and sump tube adapter, 1-1/16 in.	
806547	Protector - Rocker box to drain manifold tube adapter 13/16 inch	
806553	Pliers - Rocker arm shaft spacer, removing	7-59
806605	Installing Tool - Rocker arm shaft ring and spacer	7-62
806644	Wrench - Valve tappet guide attaching nuts socket, 7/16 in. hex.	7-52
806784	Puller - Valve tappet guide impact (used with adapter 805564)	7-53
806791	Puller - Cylinder hold-down screw lock wire	
806887	Puller - Fuel pump drive shaft and support (adapter 806887D1 is a replacement detail of puller 806887)	7-82
806888	Puller - Piston pin removing	7-67
806890	Feeler Gage - .010 in. and .055 in.	7-13
806915	Plate - Master rod guide	7-69
806916	Puller - Propeller control oil supply tube cover impact (adapter 806916D1 is a replacement detail of puller 806916)	7-21
806917	Turning Tool - Propeller shaft	7-2
806923	Plug - Tachometer drive shaft gear housing oil seals to shaft, installing	7-81
806956	Wrench - Propeller shaft thrust bearing nut, hydraulic torque	7-16
806957	Adapter - Propeller shaft thrust bearing nut, hydraulic torque wrench (detail of wrench 806956)	
806958	Housing - Propeller shaft thrust bearing nut, hydraulic torque wrench (detail of wrench 806956)	
806959	Adapter - Propeller shaft thrust bearing nut, hydraulic torque wrench (detail of wrench 806956)	
806960	Jack and Gage - Propeller shaft thrust bearing nut hydraulic torque wrench (detail of wrench 806956)	
806961	Puller - General purpose screw, 1/4 in. -20 thd.	
806962	Puller - General purpose screw, 5/16 in. -18 thd.	7-18
806963	Puller - General purpose screw, 5/16 in. -24 thd.	

Tool Number	Nomenclature	Figure Number
806983	Wrench - Fuel injection pump synchronizing rod cam clamp screw, 5/32 in. hex.	7-107
806987	Wrench - Oil pressure control valve body lug	7-93
806990	Pliers - Rear oil pump strainer discs assembling and disassembling	
806991	Puller - Ignition distributor adapter assembly oil seal	7-90
806993	Compressor - Valve spring	7-61
806996	Wrench - Cylinder hold-down screw reversible pneumatic speed, 1/2 in. hex. (shaft 806997, drive gear 806998, idler gear 806999, body 807000, socket 807001, and cover 807002 are details of 806996)	
806997	Shaft - Cylinder hold-down screw pneumatic speed wrench (detail of wrench 806996)	
806998	Gear - Cylinder hold-down screw, pneumatic speed wrench drive (detail of wrench 806996)	
806999	Gear - Cylinder hold-down screw, pneumatic speed wrench idler (detail of wrench 806996)	
807000	Body - Cylinder hold-down screw pneumatic speed wrench (detail of wrench 806996)	
807001	Socket - Cylinder hold-down screw pneumatic speed wrench (detail of wrench 806996)	
807002	Cover - Cylinder hold-down screw, pneumatic speed wrench (detail of wrench 806996)	
807004	Wrench - Valve clearnce adjusting screw lock screw, 1/2 in. hex.	7-12
807005	Wrench - Oil pressure control valve spring seat socket, 1/2 in. hex.	7-11
807012	Wrench - Rocker box oil drain tube nut, crowfoot, 7/8 in. hex.	7-24, 7-27
807013	Wrench - Rocker box drain manifold to cover and sump tube nut, crowfoot 1-1/8 in. hex.	
807019	Fixture - Internal torquemeter oil line pressure test 200 lbs. leakage checking	5-2
807052	Plug and Base - Ignition distributor adapter oil seal installing	7-91
807053	Plug - Distributor intermediate drive gear installing	7-92
807070	Fixture - Fuel injection lines leakage pressure, test	6-2
807071	Cap - Fuel injection lines leakage, pressure test	6-2
807110	Wrench - Fuel injection pump to adapter screw box 1/2 in. hex.	7-108
807116	Wrench - Fuel injection tube nut and injection nozzle screw, crowfoot, 13/16 in. hex.	
807210	Installing Tool - Push rod lower packing ring and washer (pilot 807210D1 and sleeve 807210D2 are details of 807210)	7-54
807237	Indicator - Cold cylinder "magic wand"	
807241	Wrench - Fuel injection tubes turning spline socket	7-105
807265	Wrench - Spark plug, , 7/8 in. double hex. (for front spark plugs in cylinders No. 9 and 11 only)	
807311	Wrench - Ignition lead spark plug terminal crowfoot 7/8 in. hex.	7-96
807319	Installing Tool - Supercharger clutch oil control valve sleeve	7-33
807326	Pointer - Fuel injection pump drive gear timing	
807485	Stud - Fuel injection pump to adapter aligning	
807514	Adapter - Hose connection to fuel injection line, pressure test	6-2
807515	Wrench - Fuel injection tube nut to supercharger rear housing 13/16 in. hex.	7-104
807580	Wrench - Ignition lead spark plug terminal, crowfoot 7/8 in. double hex.	7-97
807586	Wrench - Cylinder hold-down screws, box, 1/2 in. hex. (extension 807586D1, wrench 807586D2 and roll-pin 807586D3 are replacement details of wrench 807586)	

Tool Number	Nomenclature	Figure Number
807739	Wrench - Cylinder head thermocouple adapter, lug	7-78
807748	Fixture - Fuel injection pump and fuel injection pump drive gear spline aligning	7-109
807749	Wrench - Exhaust pipe clamp bolt 9/16 in. hex.	7-43
807813	Sealer - Engine shipping envelope	4-4
807890	Timing Disc - Tachometer and fuel pump drive housing location valve clearance checking	7-15
808080	Plug and Base - Crankcase front flange oil seal, assembly and disassembly (plug 808080D1 and base 808080D2 are details of 808080)	7-19
808124	Installing Tool - Cylinder hold-down screw lock plate	7-74
808171	Puller - Cylinder hold-down screw lock plate removing	7-64
808219	Barrel Assembly - Cylinder hold-down screw pneumatic reversible speed, 1/2 in. hex. wrench (detail of wrench 806996)	
808315	Clamp - Magneto timing plunger locking	
808400D5	Cover - Supercharger front housing intake pipe port	
808400D6	Cover - Front and rear cylinder exhaust port connection	
808400D7	Cover - PRT nozzle inlet pipe (ball joint)	
808400D8	Cover - Front and rear intake pipe connection	
808520	Wrench - Spark plug socket, 7/8 in. double hex. 1/2 in. square drive	
808576	Protector - Articulated rod, (Kelm No. 50E, SAE1 or 3 or equivalent)	7-68
808629	Adapter - Fuel injection line pressure test	6-2
808630	Plate - Fuel injection line pressure test	6-2
808709	Fixture - Rear oil pump and sump pressure strainer, disassembly and assembly	7-35
808699	Locator - Fuel injection pump adapter line connectors (9 required)	7-109B
923180	Pliers - Exhaust pipe clamp	7-41
923304	Sling - Engine hoist	4-2
923459	Wrench - Crankcase main section oil drain tube to supercharger front housing nut attaching, 1-3/4 in. open end	
923474	Cover - Supercharger front housing turbine mounting pad holes	
923479	Aligning Tool - Propeller control oil supply tube and support assembly installing	7-23
923483	Puller - Rocker arm floating shaft	7-60

Section IX

TABLE OF LIMITS AND REFERENCE CHARTS

9-1. TORQUE WRENCH INSTRUCTIONS.

9-2. Torque wrenches must be calibrated frequently by using weights and a measured lever arm. Do not check one wrench against another to indicate inaccuracies.

9-3. The torque wrench manufacturer's recommendations must be followed strictly. Apply force slowly and evenly until the specified tightening torque is reached. Then hold the wrench at this value until the nut, bolt, or screw has stopped turning.

9-4. Lubricate the threads and faces of parts to be assembled with engine oil, except when otherwise specified.

9-5. Torque wrench extensions may be used with any type or length of torque wrench, however, since such extensions change the length of the torque arm for which the scale is calibrated, the torque actually being applied at the end of the extension is not reflected in the torque wrench scale reading and must be calculated. When using torque wrench extensions the greatest accuracy will be achieved by applying the manual force at the calculated arm length which is the center of the handle. See figure 9-1.

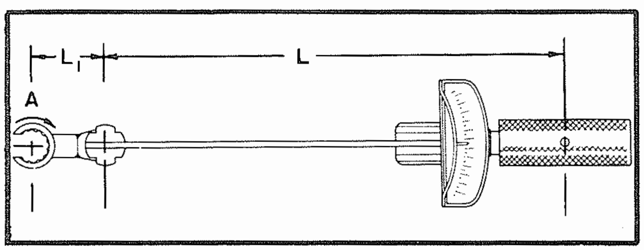


Figure 9-1

9-6. The applied torque is always greater than the observed scale reading when an extension is used. To determine applied torque from the observed scale reading, use the following formula:

$$\text{Applied Torque (A)} = \text{Scale Reading} \times \frac{(L \text{ plus } L_1)}{L}$$

9-7. Conversely, to determine correct scale reading for a desired torque at "A", for which the scale reading will always be less than the applied torque at "A", use the following formula:

$$\text{Scale Reading} = \frac{L}{(L \text{ plus } L_1)} \times \text{Desired Torque (A)}$$

NOTE

When substituting values in the above formulas use inch units throughout to obtain answer in inch-pounds or use foot units throughout to get answer in foot-pounds.

9-8. Wrench and extension centerlines must align as shown in figure 9-1.

9-9. To assist the user of these tools, all torque wrench extensions should have the L_1 length stamped on the tool itself. Then it will be necessary to determine the length of the torque wrench "L" and solve the above equations as applicable.

9-10. ALIGNMENT OF COTTER PIN OR LOCK WIRE HOLES.

9-11. Lubricate the threads and faces with engine oil to permit maximum angular turn of the nut within the torque limits specified.

9-12. Tighten the nut initially to the minimum torque value. If the holes do not align at the minimum torque value, continue to tighten the nut to obtain alignment, but in no case exceed the maximum torque value specified.

9-13. When the alignment is not reached within the specified torque limits, unscrew the nut and tighten again as outlined in paragraph 9-12. If the holes do not align after retightening the nut, select another nut and repeat the torque operations.

9-14. STUD INSTALLATION.

9-15. Unless otherwise specified, an anti-seize compound composed by weight of 75 per cent petrolatum which has a melting point of 49° - 60°C (120° - 140°F), and 20 per cent graphite (powdered flake) shall be applied in the tapped hole. Avoid using an excessive amount of the lubricant, especially in blind holes. Use only sufficient lubricant to cover the sides of the threads with a thin layer.

9-16. Select a tap which will produce a hole that permits the driving of the stud within the torque limits specified in Table I. When tapping stud holes in cast aluminum, forged aluminum, cast magnesium, and nodular cast iron, it is permissible to tap the hole a maximum of .0025 inch over drawing dimensions in order to meet torque requirements for installing the studs.

NOTE

It is extremely important that the accuracy and smoothness of the threads and the accuracy of the lead threads be maintained in order to retain the driving torque within specified requirements.

9-17. The amount of press fit required for driving a stud within the specified torque limits varies. In soft cast aluminum, maximum press fit is required, and the press fit decreases with increased hardness. Also, the press fit in magnesium is less than in aluminum for a given hardness of the material.

9-18. Table II is a guide for driving studs. The figures shown in the column for the pitch diameter of the tapped hole may vary to suit the condition of the assembly. The holes may be tapped larger or smaller than indicated in the table in order to obtain the torque required, but the hole should be maintained within drawing specifications, except as noted in paragraph 9-16.

9-19. SCREW BUSHING INSTALLATION.

9-20. Assemble screw bushings with a driving torque equal to, or greater, than the minimum torque value specified in Table III.

9-21. Unless otherwise specified, apply anti-seize compound composed by weight of 75 per cent petrolatum which has a melting point of 49° - 60°C (120° - 140°F), and 25 per cent graphite (powdered flake) in the tapped hole. Use only sufficient lubricant to cover the sides of the threads with a thin layer.

9-22. Select a tap to produce a hole which will permit driving the screw bushing at a driving torque equal to, or greater than, the minimum torque value specified in Table III. In order to facilitate installation, it is permissible to tap the hole a maximum of .002 inch over drawing dimensions. Do not tap the hole so large that the driving torque is reduced to a value less than that specified in Table III.

9-23. TAPER PIPE THREAD PLUG INSTALLATION.

9-24. Install taper pipe thread plugs with the torque value specified in Table IV.

9-25. Unless otherwise specified, apply anti-seize compound, to the male thread of the plug and, if desired, sparingly to the female thread. Wipe away any excess material.

9-26. TABLES OF TIGHTENING TORQUE VALUES.

9-27. There may be some instances arising which are not covered by, or are exceptions to, the limits and instructions given in the following tables. In all such cases good common sense and sound judgment should be exercised.

9-28. Tables I through X give torque values applied as standard practice. Special cases are covered in Tables XI through XIV and in the Table of Limits reference numbers beginning with 900.

9-29. TABLE OF LIMITS.

9-30. The Table of Limits on page 133 and Limits Charts on page 159 apply to 988TC18EA1 and 988TC18EA3 model engines only.

9-31. The Table of Limits in conjunction with the Limits Charts, gives comprehensive information about fits, clearances, ring gaps, backlash and special torque values. Reference numbers in the tables apply to the same numbers on the charts. Descriptions identify the fit locations. Minimum and maximum fits are the design measurements governing the installation of new parts. Maximum replacement fits, with the applicable minimum or maximum design measurements are the measurements governing the use of used engine parts. The abbreviations T and L used in the Table of Limits denote Tight and Loose respectively.

9-32. Fits under reference numbers through the 500 series are given in inches unless otherwise specified. Torque values are included in reference numbers beginning with 900 and are given in inch-pounds. Unless otherwise specified, they are established on the basis of parts lubricated with engine oil.

9-33. LIMITS CHARTS.

9-34. The Limits Charts at the end of this section show the particular location of the fits listed in the tables. The charts are colored to illustrate the engine lubrication system, although they do not show every oil passage.

Section IX - Continued

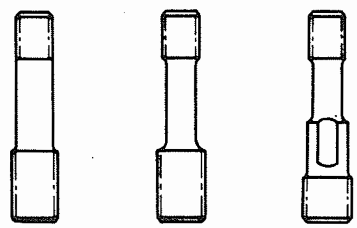
TABLES OF TIGHTENING TORQUE VALUES

TABLE I

STEPPED STUDS

Types X and Y are Driven From Nut End

Type Z is Driven from Flat on Stud End

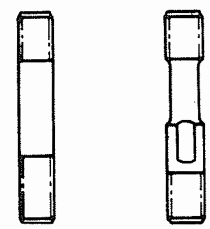


Type X Type Y Type Z

STRAIGHT STUDS

Type X is Driven from Nut End

Type Z is Driven from Flat on Stud End



Type X Type Z

Stepped Studs: Stud Size Stud End	Stepped Studs: Stud Size Nut End	Stepped Studs: Torque Value Inch-Pounds Type X	Type Y	Type Z	Straight Studs: Stud Size Stud End	Straight Studs: Stud Size Nut End	Straight Studs: Torque Value Inch-Pounds Type X	Type Z
Hand Driven								
-	-	-	-	-	.112-40	.112-48	3-7.5	-
-	-	-	-	-	.138-32	.138-40	8-14	-
-	-	-	-	-	.164-32	.164-36	18-25	-
.250-20	.190-32	25-50	-	-	.190-24	.190-32	25-35	-
.3125-18	.250-28	50-110	-	50-165	.250-20	.250-28	50-95	50-105
.375-16	.3125-24	100-240	-	100-350	.3125-18	.3125-24	100-225	100-250
.4375-14	.375-24	175-475	-	175-600	.375-16	.375-24	175-375	175-400
.500-13	.4375-20	250-725	250-525	250-1000	.4375-14	.4375-20	250-650	250-700
.5625-12	.500-20	400-1150	400-850	400-1500	.500-13	.500-20	400-1000	400-1100
.625-11	5625-18	600-1650	600-1150	600-2100	.5625-12	.5625-18	600-1450	600-1600
.6875-11	.625-18	900-2400	900-1700	900-3100	.625-11	.625-18	900-2000	900-2200
Machine Driven								
-	-	-	-	-	.112-40	.112-48	3-8	-
-	-	-	-	-	.138-32	.132-40	8-16	-
-	-	-	-	-	.164-32	.164-36	18-28	-
.250-20	.190-32	25-55	-	-	.190-24	.190-32	25-40	-
.3125-18	.250-28	50-125	-	50-165	.250-20	.250-28	50-105	50-105
.375-16	.3125-24	100-260	-	100-350	.3125-18	.3125-24	100-250	100-250
.4375-14	.375-24	175-525	175-350	175-600	.375-16	.375-24	175-400	175-400
.500-13	.4375-20	250-800	250-575	250-1000	.4375-14	.4375-20	250-700	250-700
.5625-12	.500-20	400-1300	400-925	400-1500	.500-13	.500-20	400-1100	400-1100
.625-11	.5625-18	600-1850	600-1300	600-2100	.5625-12	.5625-18	600-1600	600-1600
.6875-11	.625-18	900-2700	900-1900	900-3100	.625-11	.625-18	900-2200	900-2200

Section IX - Continued

TABLE II

STUDS

Size of Stud End	Material	Spec. No. (AMS)	Brinell Hardness 1000 KG Load	Approximate PD of Tapped Hole	PD of Stud	Approximate Press Fit
	Cast Alum.	4210	50-80	.0958-.0968	.1001-.1011	.0033-.0053
	Cast Alum.	4214, 4220, 4280	70-110	.0962-.0972	.1001-.1011	.0029-.0049
	Forg. Alum.	4142	60-90	.0960-.0970	.1001-.1011	.0031-.0051
.112-40	Forg. Alum.	4125, 4130	90-120	.0968-.0978	.1001-.1011	.0023-.0043
	Forg. Alum.	4121, 4135	120-160	.0978-.0988	.1001-.1011	.0013-.0033
	Cast Mag.	4424	60-95	.0968-.0978	.1001-.1011	.0023-.0043
	Cast Mag.	4434, 4484	80-110	.0978-.0988	.1001-.1011	.0013-.0033
	Cast Alum.	4210	50-80	.1177-.1187	.1221-.1231	.0034-.0054
	Cast Alum.	4214, 4220, 4280	70-110	.1181-.1191	.1221-.1231	.0030-.0050
	Forg. Alum.	4142	60-90	.1179-.1189	.1221-.1231	.0032-.0052
.138-32	Forg. Alum.	4125, 4130	90-120	.1187-.1197	.1221-.1231	.0024-.0044
	Forg. Alum.	4121, 4135	120-160	.1197-.1207	.1221-.1231	.0014-.0034
	Cast Mag.	4424	60-95	.1187-.1197	.1221-.1231	.0024-.0044
	Cast Mag.	4434, 4484	80-110	.1197-.1207	.1221-.1231	.0014-.0034
	Cast Alum.	4210	50-80	.1629-.1639	.1676-.1686	.0037-.0057
	Cast Alum.	4214, 4220, 4280	70-110	.1634-.1644	.1676-.1686	.0032-.0052
	Forg. Alum.	4142	60-90	.1631-.1641	.1676-.1686	.0035-.0055
.190-24	Forg. Alum.	4125, 4130	90-120	.1641-.1651	.1676-.1686	.0025-.0045
	Forg. Alum.	4121, 4135	120-160	.1651-.1661	.1676-.1686	.0015-.0035
	Cast Mag.	4424	60-95	.1641-.1651	.1676-.1686	.0025-.0045
	Cast Mag.	4434, 4484	80-110	.1651-.1661	.1676-.1686	.0015-.0035
	Cast Alum.	4210	50-80	.2175-.2185	.2218-.2233	.0033-.0058
	Cast Alum.	4214, 4220, 4280	70-110	.2180-.2190	.2218-.2233	.0028-.0053
	Forg. Alum.	4142	60-90	.2177-.2187	.2218-.2233	.0031-.0056
.250-20	Forg. Alum.	4125, 4130	90-120	.2188-.2198	.2218-.2233	.0020-.0045
	Forg. Alum.	4135	120-160	.2198-.2208	.2218-.2233	.0010-.0035
	Cast Mag.	4424	60-95	.2188-.2198	.2218-.2233	.0020-.0045
	Cast Mag.	4434, 4484	80-110	.2198-.2208	.2218-.2233	.0010-.0035
	Cast Alum.	4210	50-80	.2764-.2774	.2810-.2825	.0036-.0061
	Cast Alum.	4214, 4220, 4280	70-110	.2769-.2779	.2810-.2825	.0031-.0056
	Forg. Alum.	4142	60-90	.2766-.2776	.2810-.2825	.0034-.0059
.3125-18	Forg. Alum.	4125, 4130	90-120	.2778-.2788	.2810-.2825	.0022-.0047
	Forg. Alum.	4135	120-160	.2789-.2799	.2810-.2825	.0011-.0036
	Cast Mag.	4424	60-95	.2778-.2788	.2810-.2825	.0022-.0047
	Cast Mag.	4434, 4484	80-110	.2789-.2799	.2810-.2825	.0011-.0036

Section IX - Continued

TABLE II (CONT)

STUDS

Size of Stud End	Material	Spec. No. (AMS)	Brinell Hardness 1000 KG Load	Approximate PD of Tapped Hole	PD of Stud	Approximate Press Fit
.375-16	Cast Alum.	4210	50-80	.3344-.3354	.3392-.3407	.0038-.0063
	Cast Alum.	4214, 4220, 4280	70-110	.3350-.3360	.3392-.3407	.0032-.0057
	Forg. Alum.	4142	60-90	.3347-.3357	.3392-.3407	.0035-.0060
	Forg. Alum.	4125, 4130	90-120	.3357-.3367	.3392-.3407	.0025-.0050
	Forg. Alum.	4135	120-160	.3370-.3380	.3392-.3407	.0012-.0037
	Cast Mag.	4424	60-95	.3360-.3370	.3392-.3407	.0022-.0047
	Cast Mag.	4434, 4484	80-110	.3370-.3380	.3392-.3407	.0012-.0037
.4375-14	Cast Alum.	4210	50-80	.3911-.3921	.3962-.3977	.0041-.0066
	Cast Alum.	4214, 4220, 4280	70-110	.3917-.3927	.3962-.3977	.0035-.0060
	Forg. Alum.	4142	60-90	.3914-.3924	.3962-.3977	.0038-.0063
	Forg. Alum.	4125, 4130	90-120	.3925-.3935	.3962-.3977	.0027-.0052
	Forg. Alum.	4135	120-160	.3939-.3949	.3962-.3977	.0013-.0038
	Cast Mag.	4424	60-95	.3929-.3939	.3962-.3977	.0023-.0048
	Cast Mag.	4434, 4484	80-110	.3939-.3949	.3962-.3977	.0013-.0038
.500-13	Cast Alum.	4210	50-80	.4500-.4510	.4553-.4568	.0043-.0068
	Cast Alum.	4214, 4220, 4280	70-110	.4507-.4517	.4553-.4568	.0036-.0061
	Forg. Alum.	4142	60-90	.4503-.4513	.4553-.4568	.0040-.0065
	Forg. Alum.	4125, 4130	90-120	.4515-.4525	.4553-.4568	.0028-.0053
	Forg. Alum.	4135	120-160	.4529-.4539	.4553-.4568	.0014-.0039
	Cast Mag.	4424	60-95	.4519-.4529	.4553-.4568	.0024-.0049
	Cast Mag.	4434, 4484	80-110	.4529-.4539	.4553-.4568	.0014-.0039
.5625-12	Cast Alum.	4210	50-80	.5084-.5094	.5139-.5154	.0045-.0070
	Cast Alum.	4214, 4220, 4280	70-110	.5094-.5104	.5139-.5154	.0035-.0060
	Forg. Alum.	4142	60-90	.5089-.5099	.5139-.5154	.0040-.0065
	Forg. Alum.	4125, 4130	90-120	.5099-.5109	.5139-.5154	.0030-.0055
	Forg. Alum.	4135	120-160	.5114-.5124	.5139-.5154	.0015-.0040
	Cast Mag.	4424	60-95	.5104-.5114	.5139-.5154	.0025-.0050
	Cast Mag.	4434, 4484	80-110	.5114-.5124	.5139-.5154	.0015-.0040
.625-11	Cast Alum.	4210	50-80	.5660-.5670	.5717-.5732	.0047-.0072
	Cast Alum.	4214, 4220, 4280	70-110	.5670-.5680	.5717-.5732	.0037-.0062
	Forg. Alum.	4142	60-90	.5665-.5675	.5717-.5732	.0042-.0067
	Forg. Alum.	4125, 4130	90-120	.5675-.5685	.5717-.5732	.0032-.0057
	Forg. Alum.	4135	120-160	.5690-.5700	.5717-.5732	.0017-.0042
	Cast Mag.	4424	60-95	.5680-.5690	.5717-.5732	.0027-.0052
	Cast Mag.	4434, 4484	80-110	.5690-.5700	.5717-.5732	.0017-.0042

Note: Values have not been established for nodular cast iron.

Section IX - Continued

TABLE III

SCREW BUSHINGS

Size of Thread On Screw Bushing: Inside Thread	Outside Thread	Min Driving Torque Inch-Pounds
No. 10-32	.3125-24	40
.250-28	.4375-20	50
.3125-24	.500-20	100
.375-24	.5625-18	150
.4375-20	.625-18	250
.500-20	.6875-16	350
.5625-18	.750-16	500
.625-18	.8125-16	650

TABLE IV

TAPER PIPE THREAD PLUGS

Nominal Size	Torque Inch-Pounds
.0625-27	20-25
.125-27	35-50
.250-18	60-90
.375-18	100-140
.500-14	150-200
.750-14	200-250
1.000-11.5	250-300

TABLE V

STANDARD THREAD SCREWS SLOTTED HEAD - ALL TYPES

Thread Size	Min Dia Screw Thd Root Or Neck	Min Rockwell Hardness Of Screw	Torque Applied At Slot Inch-Pounds
.086-56	.0608	B75	2-3
.099-48	.0698	B75	3-4
.112-40	.0772	B75	5-6
.125-40	.0902	B75	6-7
.138-32	.0947	B75	7-9
.164-32	.1207	B75	10-12
.190-32	.1467	B75	18-20
.216-24	.1585	B75	22-25
.250-28	.180	C19	30-35
.3125-24	.229	C19	40-45
.375-24	.285	C19	55-60
.4375-20	.331	C19	80-90
.500-20	.387	C19	100-110
.5625-18	-	-	-
.625-18	-	-	-

TABLE VI

STANDARD THREAD SCREWS (HEX HEAD, ALL TYPES) STANDARD THREAD NUTS (PLAIN, SLOTTED, SELF-LOCKING)

Thread Size	Min Dia Screw Thd Root Or Neck	Min Rockwell Hardness Of Screw	Torque Plain, Self-Locking Nut Inch-Pounds	Torque Slotted Nut Inch-Pounds
.086-56	-	-	-	-
.099-48	-	-	-	-
.112-40	-	-	-	-
.125-40	-	-	-	-
.138-32	-	-	-	-
.164-32	-	-	-	—
.190-32	.1467	C26	45-50	-
.216-24	.1585	C26	60-65	-
.250-28	.180	C26	80-85	70-95
.3125-24	.229	C26	125-140	120-165
.375-24	.285	C26	275-300	250-325
.4375-20	.331	C26	425-450	400-475
.500-20	.387	C26	500-600	500-700
.5625-18	.436	C26	825-875	750-1000
.625-18	.493	C26	1125-1200	1000-1400

Section IX - Continued

TABLE VII

STRAIGHT THREAD PLUGS (GASKET SEAL)

Thread Size	Torque Slotted Head Inch-Pounds	Torque Hex Head Inch-Pounds	Thread Size	Torque Hex Head Inch-Pounds
.250-28	75-80	75-80	1.000-14	300-325
.3125-24	90-100	90-100	1.125-12	325-350
.375-24	110-125	110-125	1.250-12	350-400
.4375-20	125-140	125-140	1.375-12	400-450
.500-20	145-160	145-160	1.500-12	425-475
.5625-18	160-175	160-175	1.625-12	475-525
.625-18	-	175-200	1.750-12	500-550
.750-16	-	215-240	1.875-12	550-600
.875-14	-	250-275	2.000-12	600-650

TABLE VIII

FLUID FITTINGS (CONE TYPE)
TORQUE APPLIES WHEN
TIGHTENING NUT

Tube Size	Nut Size	Torque Inch-Pounds Min	Torque Inch-Pounds Max
.125	.3125-32	40	45
.250	.4375-20	80	85
.375	.625-18	150	175
.500	.750-16	275	300

TABLE IX

NUTS - RETAINING

Size	Torque Inch-Pounds Min	Torque Inch-Pounds Max
.250 to .500	15	*
.500 to 1.000	25	*
1.000 to 2.000	35	*
2.000 and up	50	*

* To first pinhole.
This is a group of nuts that are assembled against the shoulder of a shaft and primarily act as retainers with lightly loaded thrust faces.

TABLE X

NUTS - FLARED TUBE
STRAIGHT THREAD COUPLING

Tubing OD	Nut Size	Torque Inch-Pounds Aluminum Alloy Tubing	Torque Inch-Pounds Steel Tubing
.125	.3125-24	-	-
.188	.375-24	-	90-100
.250	.4375-20	40-65	135-150
.313	.500-20	60-80	180-200
.375	.5625-18	75-125	270-300
.500	.750-16	150-250	450-500
.625	.875-14	200-350	650-700
.750	1.0625-12	300-500	900-1000
1.000	1.3125-12	500-700	1200-1400
1.250	1.625-12	600-900	-
1.500	1.875-12	600-900	-

Section IX - Continued

TABLE XI

STANDARD PRACTICES FOR SPECIAL APPLICATIONS

Name	Thread Size Nut End	Min Dia Of Thd Root Or Neck	Minimum Rockwell Hardness	Torque Inch-Pounds Min	Max
Spark Plug	18mm-1.5mm	-	-	300	360
Water Injection Discharge Valve	.750-16	-	-	130	170
Water Injection Tube Gland Nut	.5625-18	-	-	140	180

TABLE XII

INSERTS

Name	Thread Size	Torque Value
Spark Plug Insert	1.000-14	Seat by applying 1200-1800 in.-lb plus driving torque
Fuel Injection Nozzle Insert	.625-18	Seat by applying 400-600 in.-lb plus driving torque

Select inserts to obtain .0005-.0015 drive fit. Apply sealing compound, Irvington Varnish No. 5 to threads. Drive inserts at room temperature.

TABLE XIII

NUTS - IGNITION CONNECTIONS

Name	Torque Inch-Pounds Min	Max
High Tension Spark Plug Lead	165	175
Low Tension Manifold to Coil Lead	95	105

TABLE XIV

CYLINDER HOLD-DOWN SCREW

Thread Size	Minimum Dia of Neck	Minimum Rockwell Hardness	Torque Inch-Pounds Min	Max
.4375-20	.338	C26	500	525
.500-20	.398	C26	625	650

The heads of cylinder hold-down screws and the spherical washers shall be free from oil or other lubricant. Apply Goodrich A75B rubber cement to screw threads.

Section IX - Continued

TABLE OF LIMITS 201

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
1	2	Propeller Shaft - SKF Bearing - MRC Bearing	End End	.0092 .0146	.0214 .0258	.0266 .0310
2	2	Propeller Hub and Propeller Shaft Spline Measured at 15 inch radius from center of propeller shaft.	Movement	---	---	.040
3	2	Propeller Shaft Measured from thrust nut to center of hole.	Length	10.485	10.515	10.515
4	2	Propeller Shaft Measured 1 inch from thrust nut with engine hot. Full indicator reading.	Radial Looseness	---	.010	.015
5	2	Propeller Shaft Thrust Bearing and Propeller Shaft	Dia.	.0001L	.0015L	.0015L
6	2	Propeller Shaft Roller Bearing and Propeller Shaft	Dia.	.0005T	.0019T	.0005T
7	2	Crankcase Front Section Flange and Bearing Liner	Dia.	.0026T	.0016L	.0020L
8	2	Propeller Shaft Thrust Bearing and Liner	Dia.	.0104L	.0137L	.0137L
9	2	Propeller Shaft Bearing Liner and Crankcase Front Section	Dia.	.006T	.010T	.006T
10	2	Propeller Shaft Roller Bearing and Liner	Dia.	.0004L	.0032L	.0032L
11	2	Propeller Shaft Thrust Bearing - SKF - MRC	End End	.0066 .0120	.0106 .0150	.0156 .0200
12	2	Propeller Shaft Bearings and Liner	Side	.0026L	.0108L	.0110L
13	2	Propeller Shaft Between threads and spline at forward end when in position in engine. Full indicator reading.	Runout	---	---	.012
14	2	Propeller Shaft Thrust Bearing Oil Seal and Crankcase Front Section Flange	Dia.	.0046T	.0110T	.0046T
15	2	Propeller Shaft Oil Seal Sleeve Ring Set gaps 180 degrees apart.	Gap	.002	.005	.005

Section IX - Continued

Ref. No.	Chart No.	Location			Minimum Fit	Maximum Fit	Maximum Replace.
16	2	Propeller Shaft Oil Seal Sleeve and Ring		Side	.001L	.006L	.006L
17	2	Propeller Shaft Oil Seal Sleeve and Propeller Shaft		Dia.	.001L	.003L	.004L
18	2	Propeller Shaft Bearing and Crankcase Front Section		Dia.	.006T	.008T	.004T
19	2	Propeller Shaft Bearing and Propeller Shaft		Dia.	.0040L	.0066L	.0085L
20	2	Propeller Control Oil Supply Adapter Rear Half and Propeller Shaft		Dia.	.003T	.005T	.003T
21	2	Propeller Control Oil Supply Adapter Rear Half and Bearing (plain)		Dia.	.002T	.004T	.002T
22	2	Crankshaft Front End and Propeller Control Oil Supply Adapter Bearing		Dia.	.0055L	.0101L	.0120L
23	2	Propeller Control Oil Supply Adapter Front Half and Oil Return Sleeve		Dia.	.0015T	.0040T	.0015T
24	2	Torque Indicator Piston Oil Seal Rings (Set gaps 180 degrees apart)		Gap	.003	.005	.005
25	2	Torque Indicator Piston and Oil Seal Rings		Side	.0015L	.0055L	.0055L
26	2	Stationary Reduction Gear					
		Torque Indicator Support	Cast Iron	Gap	.003	.005	.005
		Oil Seal Ring	Bronze	Gap	.018	.021	.024
27	2	Stationary Reduction Gear Torque Indicator Support and Oil Seal Ring		Side	.002L	.005L	.005L
28	2	Stationary Reduction Gear Torque Indicator Support and Crankcase Front Housing		Dia.	.001L	.006L	.006L
29	2	Reduction Gear Pinion and Bushing		End	.007L	.014L	.020L
30	2	Reduction Gear Pinion Carrier and Bushing		Dia.	.002L	.004L	.006L
31	2	Reduction Gear Pinion and Bushing		Dia.	.001L	.003L	.005L
32	2	Reduction Gear Pinion and Stationary Reduction Gear		Backlash	.008	---	---
33	2	Reduction Gear Pinion and Driving Gear		Backlash	.008	---	---
34	2	Governor Drive and Torque Indicator Booster Pump Adapter and Drive Gear Bushing		Dia.	.002T	.004T	.002T

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
35	2	Governor Coupling and Torque Indicator Booster Pump Drive Gear and Bushing	Dia.	.001L	.003L	.005L
36	2	Governor Coupling and Torque Indicator Booster Pump Drive Gear and Housing	Dia.	.001L	.003L	.005L
37	2	Governor Coupling and Torque Indicator Booster Pump Drive Gear (Shaft) and Housing	Dia.	.001L	.003L	.005L
38	2	Torque Indicator Booster Pump Gear and Housing - Small Gear	End	.0020L	.0035L	.0040L
		- Large Gear	*End	.0010L	.0020L	.0030L
		*Select large gear to obtain this clearance with pump attaching nuts tightened per Table VI in Tables of Tightening Torque Values				
39	2	Governor Coupling and Torque Indicator Booster Pump Drive and Driven Gears	Backlash	.006	---	---
40	2	Torque Indicator Booster Pump Housing and Driven Gear Shaft	Dia.	.001L	.003L	.005L
41	2	Torque Indicator Booster Pump Driven Gear and Housing	Dia.	.0008L	.0028L	.0060L
42	2	Front Oil Pump Intermediate Gear	End	.002L	.010L	.020L
43	2	Front Oil Pump Intermediate Gear and Bushing	Dia.	.001L	.003L	.005L
44	2	Front Oil Pump End Plate and Intermediate Gear Bushing	Dia.	.002T	.004T	.002T
45	2	Front Oil Pump Drive Gear and Intermediate Gear	Backlash	.008	---	---
46	2	Front Oil Pump Drive Gear Bushing and Support	Dia.	.002T	.004T	.002T
47	2	Front Oil Pump Drive Gear Bushing and End Plate	Dia.	.002T	.004T	.002T
48	2	Front Oil Pump Drive Gear and Bushings	Dia.	.001L	.003L	.005L
49	2	Front Oil Pump Drive Gear	End	.003L	.010L	.020L
50	2	Front Oil Pump and Suction Pump Gear Bushings and End Plate	Dia.	.0019T	.0039T	.0019T

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
51	2	Front Oil Pump and Suction Pump Gear Bushings and Body	Dia.	.0019T	.0039T	.0019T
52	2	Front Oil Pump Drive Shaft Gears and Bushings	Dia.	.0015L	.0025L	.0050L
53	2	Front Oil Suction Pump Driven Gear and Bushings	Dia.	.0015L	.0025L	.0050L
54	2	Front Oil Pump Drive Shaft Gear and Suction Pump Driven Gear	End	.004L	.008L	.010L
55	2	Front Oil Pump Drive Shaft Gear and Oil Suction Pump Driven Gear	Backlash	.008	---	---
56	2	Front Oil Pump Drive Shaft Gear and Suction Pump Driven Gear and Body	Dia.	.004L	.007L	.008L
57	2	Front Oil Pump Rocker Box Scavenge Drive Gear Bushing and Housing	Dia.	.0019T	.0039T	.0019T
58	2	Front Oil Pump Rocker Box Scavenge Drive Gear and Bushing	Dia.	.001L	.003L	.005L
59	2	Front Oil Pump Rocker Box Scavenge Drive Gear and Housing	Dia.	.004L	.007L	.009L
60	2	Front Oil Pump Rocker Box Scavenge Drive Gear	End	.004L	.007L	.008L
61	2	Front Oil Pump Rocker Box Scavenge Drive Gear and Driven Gear	Backlash	.008	---	---
62	2	Front Oil Pump Rocker Box Scavenge Driven Gear and Housing	Dia.	.004L	.007L	.009L
63	2	Front Oil Pump Rocker Box Scavenge Driven Gear and Bushings	Dia.	.001L	.003L	.005L
64	2	Front Oil Pump Rocker Box Scavenge Driven Gear Bushing and Housing	Dia.	.0019T	.0039T	.0019T
65	2	Front Oil Pump Rocker Box Scavenge Driven Gear Bushing and Front Oil Pump and Sump Body	Dia.	.0019T	.0039T	.0019T
66	2	Front Oil Pump Rocker Box Scavenge Driven Gear	End	.004L	.007L	.008L
67	2	Crankcase Front Section Accessory Drive Pinion Bushing and Bracket	Dia.	.0015T	.0035T	.0015T

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
68	2	Crankcase Front Section Accessory Drive Pinion and Bushing	Dia.	.001L	.003L	.005L
69	2	Crankcase Front Section Accessory Drive Pinion and Cam	Backlash	.004	---	---
70	2	Distributor Drive Shaft Gear Bushing and Crankcase Front Section	Dia.	.002T	.004T	.002T
71	2	Distributor Drive Shaft Gear and Bushing	Dia.	.002L	.005L	.007L
72	2	Distributor Drive Shaft Gear and Intermediate Gear	Backlash	.002	---	---
73	2	Distributor Drive Intermediate Gear	End	.011L	.023L	.030L
74	2	Distributor Drive Intermediate Gear Bushing and Crankcase Front Section	Dia.	.002T	.004T	.002T
75	2	Distributor Drive Intermediate Gear and Bushing	Dia.	.001L	.003L	.005L
76	2	Front Section Oil Pressure Control Valve and Body	Dia.	.001L	.003L	.005L
77	2	Front Oil Pump Body and Front Section Oil Pressure Control Valve Body	Dia.	.0003L	.0023L	.0023L
78	2	Front Section Oil Pressure Control Valve Spring Wire Dia. .071	Load at 1.55 Height	14.00 lb	15.00 lb	13.00 lb
79	2	Front Oil Pump Check Valve Spring Wire Dia. .026	Load at .88 Height	.36 lb	.44 lb	.33 lb
200	3	Front Balanceweight	End	.0083L	.0169L	.0250L
201	3	Front Balanceweight Bearing and Drive Gear	Dia.	.0072L	.0098L	.0150L
202	3	Front and Rear Balanceweight Bearing and Balanceweight	Dia.	.004T	.006T	.004T
203	3	Front and Rear Balanceweight Oil End Seal and Balanceweight	Dia.	.0015L	.0035L	.0050L
204	3	Front and Rear Balanceweight Drive Intermediate Gear and Balanceweight	Backlash	.006	---	---
205	3	Front and Rear Balanceweight Drive Gear and Intermediate Gear	Backlash	.005	---	---

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
206	3	Front and Rear Balanceweight Drive Intermediate Gear	End	.010L	.030L	.035L
207	3	Front and Rear Balanceweight Drive Intermediate Gears and Bushings	Dia.	.001L	.003L	.005L
208	3	Front and Rear Balanceweight Drive Intermediate Gear Bushings and Pinion Bearing	Dia.	.001L	.003L	.005L
209	3	Front and Rear Balanceweight Drive Pinion Bearing and Cam Support	Dia.	.0005L	.0020L	.0020L
210	3	Front and Rear Cam Support and Intake and Exhaust Cam	Dia.	.007L	.012L	.015L
211	3	Front and Rear Cam Retainer and Intake and Exhaust Cam	Side	.002L	.007L	.010L
212	3	Front Cam Drive Intermediate Gear Tilt Inward - .016 Outward - .010 When referenced to a parallel bar placed across the parting flange of the crankcase main front section. Measurements must be taken in a plane perpendicular to the center line of the engine. Parts may be selected to obtain the requirement specified.				
213	3	Crankcase Main Section and Front and Rear Bearing Rings	Dia.	.001T	.003T	.001T
214	3	Crankshaft Front and Rear Main Bearings and Rings	Dia.	.0005T	.0017L	.0025L
215	3	Crankshaft and Front and Rear Main Bearings	Dia.	.0006T	.0020T	.0006T
216	3	Crankshaft At front and rear main bearings when supported at propeller shaft journal and center main bearing. Full indicator reading.	Runout	---	.004	.006
217	3	Crankcheek and Front and Rear Counterweight Bushings	Dia.	.0020T	.0035T	.0020T
218	3	Front and Rear Counterweights and Bushings	Dia.	.002T	.000	.001L

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
219	3	Front Counterweight and Stop	Clearance	.024	.032	.048
220	3	Master Rod Oil Seal Disc and Plain Knuckle Pin Locking Plate	Dia.	.0005L	.0045L	.0060L
221	3	Master Rod and Knuckle Pin	Dia.	.0005L	.0018L	.0030L
222	3	Knuckle Pin and Bushing	Dia.	.0027L	.0041L	.0060L
223	3	Articulated Rod and Master Rod	Side	.007L	.021L	.035L
224	3	Master Rod Bearing and Master Rod	Dia.	.0010L	.0025L	.0035L
225	3	Master Rod Bearing and Crankshaft	Dia.	.0045L	.0060L	.0080L
226	3	Master Rod Oil Seal Disc and Splined Knuckle Pin Locking Plate	Dia.	.0005L	.0045L	.0060L
227	3	Master Rod and Crankpin	End	.015L	.044L	.050L
228	3	Crankpin	Length	3.659	3.661 (3.660 desired)	3.663
229	3	Crankshaft	End	.029L	.062L	.065L
230	3	Crankcheek Clamp Screw	Stretch	.010	.011	---
231	3	Piston Pin and Bushing	Dia.	.0020L	.0035L	.0080L
232	3	Piston Pin and Piston - At end of pin	Dia.	.000	.002L	.004L
233	3	Piston and Cylinder Barrel - Center of skirt	Dia.	.023L	.027L	.041L
		Piston Wear - Center of skirt	Dia.	---	---	.004
234	3	Piston Pin Plug and Cylinder Wall	End	.040L	.064L	.075L
235	3	Piston and No. 1 (Top) Piston Ring (Wedge) (Refer to Paragraph 7-168)	Side	.000	.022	Close
236	3	Piston and No. 2 Piston Ring (Wedge) (Refer to Paragraph 7-168)	Side	.013	.037	Close
237	3	Piston and No. 3 Piston Ring	Side	.011L	.013L	.013L
238	3	Piston and No. 4 Piston Ring	Side	.011L	.013L	.013L
239	3	Piston and No. 5 Piston Ring	Side	.006L	.008L	.008L
240	3	All Piston Rings	Gap	.044	.058	---
241	3	Cylinder Barrel Bore	Out-of-Round	---	---	.005
			Wear	---	---	.010

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
242	3	Crankshaft Center Main Bearing and Support When assembled on shaft.	Dia.	.0020T	.0039T	.0020T
243	3	Crankshaft and Center Main Bearing Support When assembled on shaft.	Dia.	.0020T	.0039T	.0020T
244	3	Crankshaft Center Main Bearing	Side	.0018L	.0058L	.0058L
245	3	Crankshaft Center Main Bearing and Front and Rear Rings	Dia.	.0005T	.0018L	.0030L
246	3	Crankcase Main Center Section and Front and Rear Bearing Rings	Dia.	.006T	.010T	.006T
247	3	Front and Rear Crankshaft Crankpin Plug and Crankshaft	Dia.	.0000	.0015T	.0000
248	3	Crankpin Sludge Retaining Plug Installation of plug below end of crankshaft center section.	Depth	.115	.125	---
249	3	Rear Counterweight and Stop	Clearance	.016	.025	.045
250	3	Rear Balanceweight Sleeve and Crankshaft Rear Main Bearing (Use shims if necessary to obtain this fit.)	End	.001T	.003T	.001T
251	3	Rear Balanceweight Bearing and Sleeve	Dia.	.0072L	.0098L	.0150L
252	3	Rear Balanceweight	End	.0083L	.0189L	.0250L
253	3	Front Cam Drive Gear and Rear Cam and Balanceweight Drive Gear and Cam Drive Intermediate Gear (Backlash computed at minimum center distance)	Backlash	.0015	---	---
254	3	Rear Cam Drive Intermediate Gear Tilt Inward - .016 Outward - .010 When referenced to a parallel bar placed across the parting flange of the rear cam and tappet housing. Measurements must be taken in a plane perpendicular to the center line of the engine. Parts may be selected to obtain the requirements specified.				
255	3	Front and Rear Cam Drive Pinion and Cam (Serial numbers of each intermediate cam drive gear and pinion must correspond. All intermediate cam drive gear and pinion assemblies that drive any one cam must bear the same "N" number)	Backlash	.002	---	---

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
256	3	Intermediate Cam Drive Gear and Pinion Bearing (This fit obtained when unit is assembled and retaining bolt torqued per fit No. 913)	End	.0033L	.0087L	.0120L
257	3	Cam Drive Pinion and Bearing	Dia.	.001L	.003L	.006L
258	3	Valve Tappet Roller Pin and Bushing	Dia.	.0025L	.0045L	.0060L
259	3	Valve Tappet Roller and Bushing	Dia.	.001L	.002L	.005L
260	3	Valve Tappet Roller Pin and Tappet	Dia.	.0025L	.0045L	.0080L
261	3	Valve Tappet Guide and Housing	Dia.	.0000	.0015L	.0020L
262	3	Valve Tappet and Guide	Dia.	.00175L	.00350L	.00430L
263	3	Valve Tappet Spring Wire Dia. .063	Load at 2.14 Height	10.00 lb	12.00 lb	9.00 lb
264	3	Valve Tappet and Ball Socket	Dia.	.00120L	.00245L	.00300L
265	3	Rocker Arm and Push Rod Ball Upper Socket	Dia.	.0005T	.0020T	.0005T
266	3	Rocker Arm Shaft Bushings and Cylinder Head	Dia.	.0020T	.0035T	.0020T
267	3	Rocker Arm Shaft and Bushings	Dia.	.002L	.003L	.006L
268	3	Rocker Arm Bushing and Shaft	Dia.	.002L	.003L	.006L
269	3	Rocker Arm and Bushing	Dia.	.001T	.003T	.001T
270	3	Valve Rocker Arm and Shaft Bushing	Side	.010L	.028L	.035L
271	3	Valve Clearance .010				
272	3	Valve Outer Spring Wire Dia. .3065	Load at 1.838 Height Load at 2.400 Height	250.00 lb 106.00 lb	276.00 lb 130.00 lb	244.00 lb ---
273	3	Valve Inner Spring Wire Dia. .2365	Load at 1.688 Height Load at 2.250 Height	211.00 lb 106.00 lb	233.00 lb 130.00 lb	205.00 lb ---
274	3	Exhaust Valve Guide and Valve	Center Dia. End Dia.	.0045L .0045L	.0060L .0060L	.0080L .0100L
275	3	Exhaust Valve Guide and Cylinder Head	Dia.	.0035T	.0050T	.0035T
276	3	Exhaust Valve Seat and Cylinder Head	Dia.	.009T	.013T	.009T
277	3	Valve Face Angle Valve Seat Face Angle		44°00' 44°45'	44°15' 45°00'	
278	3	Intake Valve Seat and Cylinder Head	Dia.	.0065T	.0105T	.0065T
279	3	Intake Valve Guide and Cylinder Head	Dia.	.001T	.003T	.001T
280	3	Intake Valve Guide and Valve	Center Dia. End Dia.	.0020L .0020L	.0035L .0035L	.0080L .0100L

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
281	3	Crankcase Front Oil Distributing Ring Check Valve Valve must open at 16 psi pressure. Leakage must not exceed 50 cc/min between 16 and 60 psi pressure. Valve must close at 5-16 psi pressure. (When tested with mating parts, or a testing rig, using engine oil at engine operating temperature, or equivalent)				
282	3	Crankcase Front Oil Distributing Ring Check Valve Spring Wire Dia. .033	Load at .86 Height	.17 lb	.22 lb	.15 lb
283	3	Crankcase Rear Oil Distributing Ring Check Valve Valve Must open at 16 psi pressure. Leakage must not exceed 50 cc/min between 16 and 60 psi pressure. Valve must close at 5-16 psi pressure. (When tested with mating parts, or a testing rig, using engine oil at engine operating temperature, or equivalent)				
284	3	Crankcase Rear Oil Distributing Ring Check Valve Spring Wire Dia. .033	Load at .86 Height	.17 lb	.22 lb	.15 lb
400	3	Rear Face of Cam and Tappet Housing to End of Spacer Select Spacer "Y" to obtain this dimension with crankshaft in extreme rear position.		.630	.650	.650
401	3	Power Recovery Turbine Crankshaft Drive Gear Coupling (With crankshaft in extreme rear position)	End	.032	.068	.073
402	5	Power Recovery Turbine Crankshaft Drive Gear Bushing and Supercharger Front Housing	Dia.	.005T	.007T	.005T
403	5	Power Recovery Turbine Crankshaft Drive Gear and Bushing	Dia.	.003L	.005L	.008L

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
404	5	Impeller Shroud Plate and Diffuser Plate (Measure pinch before diffuser is assembled on supercharger rear housing by placing diffuser plate in place on shroud plate in supercharger front housing. Measure, at several points, the relative height of the supercharger front housing parting surface and the diffuser plate inner bolt circle parting surface. Measure the relative height of the corresponding parting surfaces on the supercharger rear housing. Select shims to make the latter measurement exceed the former measurement by the amount of pinch required)	Pinch	.010	.014	.010
405	5	Impeller and Shroud Plate	Side	.050L	---	---
406	5	Impeller and Diffuser Plate (Set with impeller shaft in extreme rear position)	Side	.045L	.055L	---
407	5	Supercharger Impeller Inducer and Impeller At outside diameter of inducer.	Pinch	.004	.008	.004
408	5	Impeller Shaft Front Oil Seal Sleeve Rings (Set gaps 180 degrees apart)	Gap	.010	.012	.012
409	5	Impeller Shaft Front Oil Seal Sleeve and Ring	Side	.0042L	.0086L	.0086L
410	5	Impeller Shroud Plate and Sleeve	Dia.	.001L	.003L	.005L
411	5	Impeller Outer Shaft and Front Bushing	Dia.	.002T	.004T	.002T
412	5	Impeller Outer Shaft Front Bushing and Accessory Drive and Starter Shaft	Dia.	.003L	.005L	.007L
413	5	Impeller must be tight fit on splines (.022 inch maximum wobble allowable at rear end of outer impeller shaft with impeller in approximate running position)				
414	5	Impeller Shaft Oil Seal Rear Sleeve and Ring	Side	.0042L	.0086L	.0086L
415	5	Impeller Shaft Oil Seal Rear Sleeve Rings - Three front rings	Gap	.016	.018	.018
		- Three rear rings (gaps to be set 180 degrees apart)	Gap	.012	.014	.014

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
416	5	Impeller Shaft	End	.0137	.0271	.0350
417	5	Impeller Drive Multi-Plate Clutch Piston Ring Gaps See Fits No. 417a, 417b and 417c.				
417a	5	Impeller Drive Multi-Plate Clutch Piston Ring	Gap	.006	.025	.028
417b	5	Impeller Drive Multi-Plate Clutch Piston Ring	Gap	.020	.039	.042
417c	5	Impeller Drive Multi-Plate Piston Ring	Gap	---	.005	---
418	5	Impeller Drive Multi-Plate Clutch Piston and Ring	Side	.001L	.006L	.006L
419	5	Impeller Drive Multi-Plate Clutch Support Ring Gaps See Fits No. 419a, 419b and 419c.				
419a	5	Impeller Drive Multi-Plate Clutch Support Ring	Gap	.006	.023	.026
419b	5	Impeller Drive Multi-Plate Clutch Support Ring	Gap	.020	.037	.040
419c	5	Impeller Drive Multi-Plate Clutch Support Ring	Gap	---	.005	---
420	5	Impeller Drive Multi-Plate Clutch Support and Ring	Side	.001L	.006L	.006L
421	5	Impeller Outer Shaft and Bushing	Dia.	.0030L	.0065L	.0080L
422	5	Impeller Outer Shaft Rear Bushing and Thrust Ring Support	Dia.	.0015T	.0030T	.0015T
423	5	Impeller Drive Secondary Pinion Front Carrier Bushing and Impeller Shaft Thrust Ring Support	Dia.	.0015L	.0035L	.0050L
424	5	Impeller Drive Secondary Pinion Front Carrier Bushing and Carrier	Dia.	.001L	.003L	.004L
425	5	Impeller High Ratio Clutch Drive Gear Pinion Large Shaft and Bushing	Dia.	.0020L	.0035L	.0050L
426	5	Impeller Drive Outer Secondary Pinion and Bushing	Dia.	.0015T	.0031T	.0015T

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
427	5	Impeller Drive Outer Secondary Pinion Bushing Flange and Outer Pinion	Dia.	.001L	.003L	.005L
428	5	Impeller Drive Inner and Outer Secondary Pinion and Carrier	End	.008L	.016L	.020L
429	5	Impeller Drive Inner Secondary Pinion Bushing Flange and Inner Pinion	Dia.	.001L	.003L	.005L
430	5	Impeller Drive Inner Secondary Pinion and Bushing	Dia.	.0015T	.0031T	.0015T
431	5	Impeller High Ratio Clutch Drive Gear Pinion Small Shaft and Bushing	Dia.	.0020L	.0035L	.0050L
432	5	Impeller Inner Shaft Rear Bushing and Rear Half of Secondary Pinion Carrier	Dia.	.0015T	.0035T	.0015T
433	5	Impeller Inner Shaft and Rear Bushing	Dia.	.0050L	.0070L	.0085L
434	5	Impeller Drive Secondary Pinion Rear Half Carrier and Intermediate Gear Bushings	Dia.	.0028L	.0052L	.0070L
435	5	Impeller Drive Intermediate Gear and Bushings	Dia.	.003L	.005L	.007L
436	5	Impeller Primary Pinion Bushing and Carrier	Dia.	.002L	.004L	.005L
437	5	Impeller Drive Primary Pinion and Bushing	Dia.	.0015T	.0031T	.0015T
438	5	Impeller Drive Primary Pinion Bushing and Carrier	End	.004L	.016L	.022L
439	5	Roller Clutch Cage and Impeller Drive Primary Pinion Carrier Support	Side	.004L	.011L	.015L
440	5	Roller Clutch Cage and Cam	Dia.	.010L	.016L	.020L
441	5	Impeller Drive Secondary Pinion Rear Half Carrier and Bushing	Dia.	.0035L	.0075L	.0090L
442	5	Impeller Drive Primary Pinion Carrier and Accessory Drive Gear Support and Front Bushing	Dia.	.002T	.004T	.002T
443	5	Impeller Drive Primary Pinion Carrier and Accessory Drive Gear Support and Rear Bushing	Dia.	.0015T	.0040T	.0015T
444	5	Accessory Drive and Starter Shaft and Rear Bushing	Dia.	.001L	.005L	.007L

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
445	6	Accessory Drive Gear Support and Thrust Ring (Select thrust ring to obtain this dimension with accessory drive gear support in extreme forward position)	Side	.020L	.030L	---
446	6	Impeller Clutch Drive and Accessory Drive Coupling Bearing and Supercharger Rear Cover	Dia.	.005T	.007T	.005T
447	6	Impeller Drive Primary Pinion Carrier and Accessory Drive Gear Support and Bearing	Dia.	.003L	.005L	.007L
448	6	Starter Coupling and Stop Ring	Side	.018L	.045L	.045L
449	6	Starter Coupling Oil Seal Spring Wire Dia. .078	Load at 1.70 Height	9.00 lb	12.00 lb	8.00 lb
450	6	Starter Pad to Face of Coupling (Coupling in rearmost position)		1.657	1.683	---
451	5	Supercharger Clutch Piston Retracting Spring Wire Dia. .048	Load at .54 Height	7.50 lb	8.50 lb	6.75 lb
452	6	Center Accessory Drive Shaft and Bearing	Side	.010L	.018L	.025L
453	6	Center Accessory Drive Shaft and Bearing	Dia.	.002L	.004L	.006L
454	6	Center Accessory Drive Shaft Gear Bearing and Supercharger Rear Cover	Dia.	.0035T	.0055T	.0035T
455	6	Oil Pump Drive Gear and Center Accessory Drive Shaft	Dia.	.001L	.003L	.003L
456	6	Oil Pump Drive Gear and Coupling Gear	Backlash	.002	---	---
457	6	Oil Pump Drive Intermediate Shaft Gear and Coupling Gear	Dia.	.001L	.003L	.004L
458	6	Oil Pump Drive Intermediate Shaft Gear and Upper Bushing	Dia.	.001L	.003L	.005L
459	6	Oil Pump Drive Intermediate Shaft Gear Upper Bushing and Support	Dia.	.002T	.004T	.002T
460	6	Oil Pump Drive Intermediate Shaft Gear and Lower Bushing	Dia.	.001L	.003L	.005L

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
461	6	Oil Pump Drive Intermediate Shaft Gear Lower Bushing and Support	Dia.	.002T	.004T	.002T
462	6	Oil Pump Drive Intermediate Shaft Gear and Coupling Gear	End	.018L	.032L	.045L
463	6	Oil Pump Drive Intermediate Shaft Gear and Drive Gear	Backlash	.002	---	---
464	6	Oil Pump Drive Gear and Shaft	Dia.	.002L	.004L	.005L
465	6	Oil Pump Drive Shaft and Bushing	Dia.	.001L	.003L	.005L
466	6	Oil Pump Drive Gear Bushing and Gear Housing End Plate	Dia.	.002T	.004T	.002T
467	6	Oil Pump Gear Housing Cover and Drive Gear Shaft	Dia.	.001L	.003L	.005L
468	6	Suction Pump Drive Gear Shaft and Drive Gear	Dia.	.0010L	.0025L	.0060L
469	6	Suction Oil Pump Gears	End	.003L	.006L	.008L
470	6	Oil Pump Gears	Backlash	.008	---	---
471	6	Oil Pump Gears and Housing	Dia.	.005L	.007L	.012L
472	6	Oil Pump Gear Housing End Plate and Driven Gear Shaft	Dia.	.0010L	.0025L	.0030L
473	6	Suction Oil Pump Driven Gear and Shaft	Dia.	.0010L	.0025L	.0060L
474	6	Oil Pump Gear Housing Cover and Driven Gear Shaft	Dia.	.0005T	.0020T	.0005T
475	6	Oil Check Valve Spring Wire Dia. .0485	Load at 1.34 Height	3.00 lb	3.50 lb	2.70 lb
476	6	Oil Pump and Sump Body and Oil Check Valve Body	Dia.	.001T	.003T	.001T
477	6	Oil Check Valve and Oil Check Valve Spring Seat	Dia.	.0106L	.0226L	.0250L
478	6	Oil Check Valve Body and Oil Check Valve Spring Seat	Dia.	.001L	.003L	.005L
479	6	Oil Check Valve and Body	Dia.	.004L	.006L	.008L
480	6	Oil Pump Strainer *(Refer to Paragraph 7-113)	Axial Load	*	700 lb	---

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
481	6	Oil Pump Strainer By-pass Valve Spring Wire Dia. .080	Load at .90 Height	18.00 lb	20.00 lb	16.00 lb
482	6	Oil Pressure Relief Valve Inner Spring Wire Dia. .0635	Load at 2.24 Height	11.80 lb	13.00 lb	10.60 lb
483	6	Oil Pressure Relief Valve Outer Spring Wire Dia. .078	Load at 2.08 Height	19.90 lb	21.90 lb	18.00 lb
484	6	Oil Pressure Relief Valve and Body	Dia.	.0015L	.0030L	.0050L
485	5	Supercharger Front Housing Oil Pressure Control Valve Body and Valve	Dia.	.001L	.003L	.005L
486	5	Supercharger Front Housing Oil Pressure Control Valve Body and Housing	Dia.	.0003L	.0023L	.0023L
487	5	Supercharger Front Housing Oil Pressure Control Valve Spring Wire Dia. .080	Load at 1.42 Height	25.00 lb	26.00 lb	23.00 lb
488	6	Supercharger Clutch Oil Control Valve Sleeve and Oil Pump and Sump Body	Dia.	.0005T	.0010L	.0020L
489	6	Supercharger Clutch Oil Control Valve and Sleeve	Dia.	.0005L	.0020L	.0030L
490	6	Supercharger Clutch Oil Control Valve Spring Wire Dia. .0555	Load at 2.12 Height	17.70 lb	19.70 lb	16.00 lb
491	5	Tachometer Drive Gear Shaft Oil Seal Retainer and Oil Seal	Dia.	.002T	.008T	.002T
492	5	Tachometer Drive Gear Shaft Bushing and Housing	Dia.	.0005L	.0020L	.0020L
493	5	Tachometer Drive Gear Shaft Bushing and Shaft	Dia.	.0035L	.0050L	.0095L
494	5	Tachometer Drive Gear Shaft Bearing and Housing	Dia.	.0005T	.0025T	.0005T
495	5	Tachometer Drive Gear Shaft	End	.030L	.052L	.060L
496	5	Tachometer and Fuel Pump Drive Shaft and Tachometer Drive Shaft Gear	Backlash	.004	---	---
497	5	Fuel Pump and Tachometer Drive Housing and Bushing	Dia.	.001T	.004T	.001T
498	5	Tachometer and Fuel Pump Drive Shaft and Outer Bushing	Dia.	.0015L	.0035L	.0060L

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
499	5	Tachometer and Fuel Pump Drive Shaft Support and Housing	Dia.	.000	.004L	.004L
500	5	Tachometer and Fuel Pump Drive Shaft Support Bushing and Shaft	Dia.	.001L	.003L	.005L
501	5	Tachometer and Fuel Pump Drive Shaft Support and Bushing	Dia.	.003T	.005T	.003T
502	5	Tachometer and Fuel Pump Drive Shaft Support and Supercharger Rear Housing	Dia.	.001L	.003L	.004L
503	5	Tachometer and Fuel Pump Drive Shaft	End	.006L	.017L	.017L
504	5	Tachometer and Fuel Pump Drive Shaft and Driven Gear	Dia.	.0010L	.0025L	.0030L
505	5	Tachometer and Fuel Pump Driven Gear and Bushing	Dia.	.001L	.003L	.005L
506	5	Tachometer and Fuel Pump Driven Gear Support and Bushing	Dia.	.002T	.004T	.002T
507	5	Tachometer and Fuel Pump Drive Gear and Driven Gear	Backlash	.002	---	---
508	5	Tachometer and Fuel Pump Driven Gear Support and Bushing	Dia.	.002T	.004T	.002T
509	5	Fuel Pump Driven Gear and Bushing	Dia.	.001L	.003L	.005L
510	5	Fuel Pump Drive Shaft and Driven Gear	Dia.	.0010L	.0025L	.0030L
511	5	Fuel Pump Drive Shaft (When bevel gear is in contact with face of bushing)	End	.003L	.025L	.040L
512	5	Fuel Pump Drive Shaft and Bushing	Dia.	.001L	.003L	.005L
513	5	Fuel Pump Gear Shaft Support and Bushing	Dia.	.003T	.005T	.003T
514	5	Fuel Pump Gear Shaft Support and Supercharger Rear Housing	Dia.	.0005L	.0030L	.0035L
515	5	Fuel Pump Gear Shaft Support and Oil Seal	Dia.	.001T	.006T	.001T
516	5	Fuel Injection Pump Adapter and Drive Gear Bushing	Dia.	.001T	.003T	.001T
517	5	Fuel Injection Pump Drive Gear and Bushing	Dia.	.001L	.003L	.005L

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
518	5	Fuel Injection Pump Drive Gear	End	.004L	.012L	.020L
519	5	Fuel Injection Pump Drive Shaft Gear and Drive Gear	Backlash	.004	---	---
520	5	Fuel Injection Pump Drive Shaft Gear (When fuel injection pump drive pinion is held against flange of bushing.)	End	.005	.057	.065
521	5	Fuel Injection Pump Drive Shaft Gear and Bushing	Dia.	.001L	.003L	.005L
522	5	Fuel Injection Pump Drive Shaft Gear Bushing and Adapter	Dia.	.001T	.003T	.001T
523	6	Fuel Injection Pump Drive Bevel Pinion and Drive Shaft Gear	Dia.	.0010L	.0025L	.0030L
524	6	Fuel Injection Pump Drive Bevel Pinion and Bushing	Dia.	.0015L	.0035L	.0055L
525	6	Fuel Injection Pump Drive Bevel Pinion Bracket and Bushing	Dia.	.002T	.004T	.002T
526	6	Fuel Injection Pump Drive Gear and Drive Bevel Pinion	Backlash	.002	---	---
527	6	Magneto Drive Shaft Gear	End	.010	.020	.025
528	6	Magneto Drive Shaft Gear Bearing and Supercharger Rear Cover	Dia.	.0035T	.0055T	.0035T
529	6	Magneto Drive Shaft Gear and Bearing	Dia.	.002L	.004L	.006L
530	6	Magneto and Accessory Drive Oil Seal Collar and Oil Seal	Dia.	.002T	.008T	.002T
531	6	Magneto Drive Shaft Gear and Idler Gear	Backlash	.004	---	---
532	6	Magneto Drive Idler Gear Bushing and Support	Dia.	.0015L	.0035L	.0050L
533	6	Magneto Drive Idler Gear and Bushing	Dia.	.001T	.003T	.001T
534	6	Magneto Drive Idler Gear	End	.004L	.008L	.015L
535	6	Magneto Drive Idler Gear Support and Supercharger Rear Cover	Dia.	.0005L	.0025L	.0040L
536	6	Left Hand and Right Hand Accessory Drive Oil Seal and Collar	Dia.	.002T	.008T	.002T

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
537	6	Left Hand and Right Hand Accessory Drive Shaft Gear Bearing and Supercharger Rear Cover	Dia.	.0035T	.0055T	.0035T
538	6	Left Hand and Right Hand Accessory Drive Shaft Gear and Bearing	Dia.	.002L	.004L	.006L
539	6	Left Hand and Right Hand Accessory Drive Shaft Gear	End	.010L	.018L	.025L
540	6	Left Hand and Right Hand Generator Drive Idler Gear Bushing and Supercharger Rear Cover	Dia.	.001T	.001L	.001L
541	6	Left Hand and Right Hand Generator Drive Idler Gear and Bushing	Dia.	.0035L	.0055L	.0070L
542	6	Left Hand and Right Hand Generator Drive Idler Gear and Bushing	End	.011L	.017L	.023L
543	6	Left Hand and Right Hand Generator Drive Gear and Idler Gear	Backlash	.004	---	---
544	6	Left Hand and Right Hand Generator Drive Gear and Bushing	End	.011L	.017L	.023L
545	6	Left Hand and Right Hand Generator Drive Gear and Bushing	Dia.	.0035L	.0055L	.0070L
546	6	Left Hand and Right Hand Generator Drive Gear Bushing and Supercharger Rear Cover	Dia.	.001T	.001L	.001L
547	6	Left Hand and Right Hand Generator Drive Gear and Shaft	Dia.	.0005L	.0025L	.0030L
548	4	Power Recovery Turbine Fluid Coupling Drive Shaft Bushing and Fluid Coupling Support	Dia.	.0035T	.0055T	.0035T
549	4	Power Recovery Turbine Fluid Coupling Impeller and Bushing	Dia.	.003L	.005L	.008L
550	4	Power Recovery Turbine Fluid Coupling Drive Shaft	Total End	.008	.022	.030
		With fluid coupling expanded	End	.004	.016	.024
551	4	Power Recovery Turbine Fluid Coupling Runner (Select spacer "X" to obtain this dimension)	End	.004	.006	---

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
552	4	Power Recovery Turbine Fluid Coupling Runner and Cover (Provide additional gaskets, if necessary, to obtain this dimension between runner and cover. This is to be minimum clearance with impeller moved toward shaft nut and runner moved toward shaft flange)	Side	.015	.030	---
553	4	Power Recovery Turbine Fluid Coupling Runner and Bearing	Dia.	.0010T	.0025T	.0010T
554	4	Power Recovery Turbine Fluid Coupling Runner Bearing and Drive Shaft	Dia.	.001L	.005L	.008L
555	4	Power Recovery Turbine Crankshaft Drive Gear and Pinion	Backlash	.006	---	---
556	4	Power Recovery Turbine Crankshaft Drive Gear Pinion and Bearing	Dia.	.0010T	.0025T	.0010T
557	4	Power Recovery Turbine Crankshaft Drive Gear Pinion Bearings and Fluid Coupling Drive Shaft	Dia.	.003L	.005L	.007L
558	4	Power Recovery Turbine Fluid Coupling Drive Shaft and Bushing	Dia.	.003L	.005L	.007L
559	4	Power Recovery Turbine Fluid Coupling Drive Shaft Bushing and Bushing Support	Dia.	.0015T	.0035T	.0015T
560	4	Power Recovery Turbine Fluid Coupling Drive Shaft and Gear	Dia.	.0005L	.0025L	.0030L
561	4	Power Recovery Turbine Shaft Gear and Fluid Coupling Drive Gear	Backlash	.005	---	---
562	4	Power Recovery Turbine Shaft Gear and Bushings	Dia.	.004L	.006L	.008L
563	4	Power Recovery Turbine Shaft Gear Bushings and Supercharger Front Housing	Dia.	.0030T	.0045T	.0030T
564	4	Power Recovery Turbine Shaft Gear and Bushing	End	.010L	.016L	.022L
566	4	Power Recovery Turbine Shaft Support and Spherical Bushing	Dia.	.001T	.003T	.001T

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
567	4	Power Recovery Turbine Shaft and Spherical Bushing	Dia.	.0017L	.0057L	.0080L
568	4	Power Recovery Turbine Adapter and Supercharger Front Housing	Dia.	.001L	.006L	.006L
569	4	Power Recovery Turbine Shaft and Outer Bushing	Dia.	.0040L	.0072L	.0082L
570	4	Power Recovery Turbine Shaft Support and Outer Bushing	Dia.	.001T	.003T	.001T
571	4	Power Recovery Turbine Vibration Damper Outer Discs and Damper Support	Dia.	.000	.002L	.005L
572	4	Power Recovery Turbine Vibration Damper Spring				
		Wire Dia. .105	Load at 1.60 Height	37.00 lb	40.00 lb	33.00 lb
		Assembled Damper	Total Spring Load	270.00 lb	330.00 lb	270.00 lb
573	4	Power Recovery Turbine Shaft (Select thrust washer "R" to obtain)	End	.0120	.0175	.0175
574	4	Power Recovery Turbine Vibration Damper Inner Discs and Shaft Support	Dia.	.0015L	.0035L	.0060L
575	4	Power Recovery Turbine Wheel Cooling Air Impeller and Labyrinth Seal (Select shim "P" to obtain this clearance with turbine wheel in inner position. Do not use more than three shims)	Axial Clearance	.025	.035	---
576	4	Power Recovery Turbine Wheel Assembly on Shaft (Wash splines and threads with carbon tetrachloride and air dry. Apply molybdenum disulphide mixed with engine oil to a thin paste, or colloidal copper to the threads. Apply a thin coating of engine oil to shaft and wheel splines and impeller splines and between mating surfaces of nut and wheel. Remove any excess oil. Extreme care must be taken that no lubricant is present on any of the wheel, impeller or spacer mating surfaces)	Shaft Stretch	.003 (at torque not exceeding 4000 in-lb)	.004	---

Section IX - Continued

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
577	4	Bottom of Groove in Outer Flange of Nozzle to Top of Upper Lip on Power Recovery Turbine Wheel				
		New parts		1.465	1.485	---
		Used parts		1.460	1.495	---
		The average wheel height must be within 1.470 - 1.480 in. (Select spacer "T" to obtain this dimension with wheel in outermost position)				
578	4	Power Recovery Turbine Wheel and Cooling Shield				
		New parts	Axial Clearance	.030	.050	---
		Used parts	Axial Clearance	.030	.065	---
		(Axial clearance between upper lip on turbine wheel and bottom of outer cooling shield with wheel in outermost position. Check this clearance after setting wheel height per Reference No. 577)				
579	7	Exhaust Pipe Bracket and Clamp Ring (Insert .010 - .020 wire stock at "Z". Adjust brackets to clamp pipe centrally between rocker boxes. Tighten bracket bolts and remove wire stock)	Side	.010	.020	---
580	4	Power Recovery Turbine Wheel and Cooling Air Impeller	Pinch	.000	.004T	.000
581	4	Power Recovery Turbine Wheel Hub Cooling Shield Outer Flange and Flange Ring		---	---	.034L
900	2	Propeller Shaft Hydro Oil Connection Cover Nut (Use Lubriplate 130A on threads)		4000	4200	
901	2	Propeller Shaft Thrust Bearing Nut		26400	28800	
902	2	Stationary Reduction Gear Adapter Torquemeter Piston and Support Attaching Nuts		400	475	
903	2	Carrier Ring to Propeller Shaft Attaching Bolt Nut		1400	1450	
904	2	Front Oil Pump and Sump Locating Screw		40	45	
905	2	Crankcase Front Section Accessory Drive Retaining Cap		5	25	
906	2	Distributor Attaching Cap Screw		180	215	

Section IX - Continued

Ref. No.	Chart No.	Location	Minimum Fit	Maximum Fit	Maximum Replace.
907	2	Distributor Shield Assembly Attaching Clamp Nut	30	40	
908	2	Front Section Oil Pressure Control Valve Body	350	400	
909	2	Front Section Oil Pressure Control Valve Cap	75	100	
910	2	Reduction Driving Gear Retaining Nut	6000	7200	
911	2	Reduction Gear Pinion Bolt Nut	120	170	
912	2	Reduction Gear Pinion Bolt	200	250	
913	3	Cam Drive Pinion and Intermediate Gear Front and Rear Retaining Bolt	700	800	
914	2	Crankcase Front to Main Section Top and Bottom Hollow Bolt Nuts	325	450	
915	3	Crankcase Attaching Bolt Nut	500	550	
916	3	Crankcase Main Center Section Front to Crankcase Main Center Section Rear Attaching Bolt	350	375	
917	3	Counterweight Attaching Bolt Nut Tighten to 850 - 950 inch-pounds torque, then apply impact (shock) load to gain an additional 20 degrees angular rotation of the counterweight attaching bolt nut in a tightening direction.			
918	3	Crankcase Main Section Oil Drain Tube Nut	900	1000	
919	3	Knuckle Pin Retaining Bolt Nut	225	250	
920	3	Oil Distributing Ring Nozzle	175	200	
921	3	Push Rod Housing Inner Connection Nut (Use Lubriplate 130A on threads and on rubber asbestos washers)	100	125	
922	3	Push Rod Housing Outer Connection. Seat by Applying 1200 - 1400 Inch-Pounds Plus Driving Torque (Use Gasoila on Threads)			
923	3	Push Rod Housing Outer Connection Nut (Use Lubriplate 130A on threads)	400	450	
924	3	Valve Clearance Adjusting Screw Lock Screw Check adjusting screw tightness by applying 350 inch-pounds break-away torque. (See Section VII, Paragraph 7-22)	275	325	

Section IX - Continued

Ref. No.	Chart No.	Location	Minimum Fit	Maximum Fit	Maximum Replace.
925	7	Packing Gland Nuts on Rocker Box to Drain Manifold Tube, Drain Manifold to Cover and Sump Tube, and Drain Manifold to Scavenge Pump Tube	40	45	
926	7	Intake Pipe Connection Nut (Use Lubriplate 130A on threads)	570	600	
927	7	Intake Pipe Drain Plug	60	90	
928	7	Exhaust Pipe Clamp Bolt Nut			
		Castellated Nut	100	125	
		Fiber Lock Nut	125	150	
929	5	Impeller Shaft Oil Seal Front Sleeve Nut (Use Lubriplate 130A on threads)	3750	4250	
930	5	Fuel Injection Tube Connection Nut	275	300	
931	5	Fuel Injection Tube to Rear Supercharger Housing Sealing Nut	300	350	
932	5	Fuel Injection Pump Drive Gear Retaining Washer Attaching Nut	50	250	
933	5	Injection Pump to Adapter Screw	125	140	
934	3	Fuel Injection Tube Seal Nut	175	200	
935	3	Fuel Injection Nozzle	275	300	
936	6	Oil Pressure Relief Valve Body	350	400	
937	6	Oil Pressure Relief Valve Cap	75	100	
938	6	Generator Drive Idler Gear Retaining Bolt Nut	125	175	
939	6	Generator Drive Shaft Nut	125	175	
940	5	Supercharger Front Housing Oil Pressure Control Valve Body	350	400	
941	5	Supercharger Front Housing Oil Pressure Control Valve Cap	75	100	
942	4	Power Recovery Turbine Fluid Coupling Impeller to Cover Attaching Screw	45	55	
943	5	Impeller Drive Primary Pinion Bolt Nut	70	110	
944	7	Rocker Box Drain Right Hand and Left Hand Manifold to Center Manifold Attaching Nut (Threads must be lubricated with oil)	250	275	
945	2	External Oil Tube to Supercharger Front Housing Connection Nut	550	575	

Section IX - Continued

Ref. No.	Chart No.	Location	Minimum Fit	Maximum Fit	Maximum Replace.
946	6	Oil Sump Accessory Drive Drain Hole Plug	100	140	
947	3	Ignition Coil Strap Retaining Nuts (Tighten the two nuts on side of coil saddle closest to the rocker box. Torque the remaining nut. A gap must remain between the saddle and strap on the single stud side)	15	40	
948	3	Rocker Arm Shaft Cap (Threads must be lubricated with oil)	350	400	
949	7	Exhaust Pipe Anti-Chafe Clamp Ring Bolt Nut	30	40	
950	4	Power Recovery Turbine Shaft Oil Seal Support to Nozzle Support Screw	30	35	
951	4	Power Recovery Turbine Vibration Damper Support to Nozzle Support Screw	30	35	
952	3	Crankcase Main Section Oil Drain Tube to Supercharger Front Housing Attaching Nut	600	650	
954	7	Exhaust Pipe Clamp "Figure 8" Through Guide Attaching Bolt Nut	50	70	

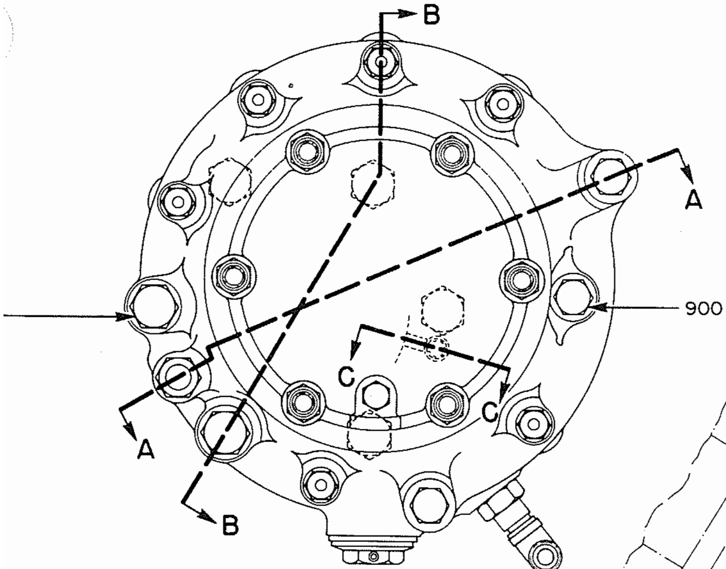
Section IX - Continued

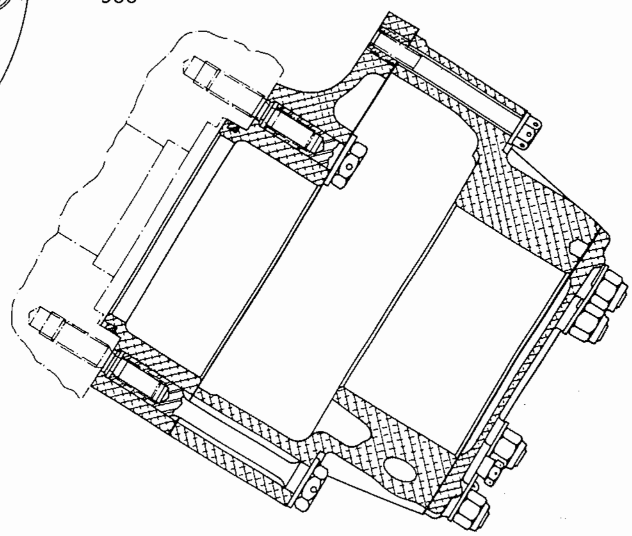
TABLE OF LIMITS - 184
979 GBA1 ACCESSORY DRIVE GEAR BOX

Ref. No.	Chart No.	Location		Minimum Fit	Maximum Fit	Maximum Replace.
1	1	Accessory Drive Gear Pinion and Gear	Backlash	.004	---	.004
2	1	Accessory Drive Gear Pinion	End Play	.001	.045	.050
3	1	Accessory Drive Gear Pinion and Pinion Front Bearing	Dia.	.0009T	.0002L	.0002L
4	1	Accessory Drive Gear Pinion and Pinion Bearing Spacer	Dia.	.0008L	.0034L	.0034L
5	1	Accessory Drive Gear Pinion Bearing Support and Pinion Front Bearing	Dia.	.0000	.0012L	.0020L
6	1	Accessory Drive Gear Pinion and Pinion Rear Bearing	Dia.	.0009T	.0002L	.0002L
7	1	Accessory Drive Gear Front Housing and Pinion Bearing Support	Dia.	.0020T	.0040T	.0020T
8	1	Accessory Drive Gear Pinion Bearing Support and Pinion Rear Bearing	Dia.	.0000	.0015L	.0020L
9	1	Accessory Drive Gear Bearing Support and Gear Front Bearing	Dia.	.0000	.0015L	.0020L
10	1	Accessory Drive Gear Rear Housing and Gear Bearing Support	Dia.	.0020T	.0040T	.0020T
11	1	Accessory Drive Gear and Gear Front Bearing	Dia.	.0009T	.0002L	.0002L
12	1	Accessory Drive Gear Bearing Support and Gear Rear Bearing	Dia.	.0000	.0015L	.0020L
13	1	Accessory Drive Gear and Gear Rear Bearing	Dia.	.0009T	.0002L	.0002L
14	1	Accessory Drive Gear and Gear Bearing Spacer	Dia.	.0009L	.0035L	.0035L
15	1	Accessory Drive Gear	End Play	.001	.045	.050
16	1	Accessory Drive Gear Front Housing and Oil Tube	Dia.	.000	.002T	.000
900	1	Accessory Drive Gear Box to Supercharger Rear Cover Stud Attaching Nut		125	140	
901	1	Accessory Drive Gear Box to Accessory Pad Stud Attaching Nut		275	300	

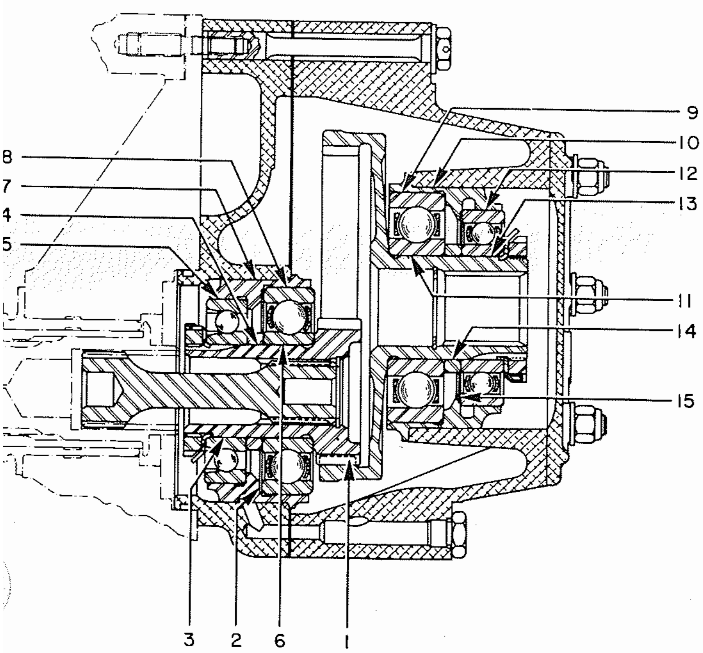
CHART 1 OF 1

979 GBA1 ACCESSORY DRIVE
GEAR BOX

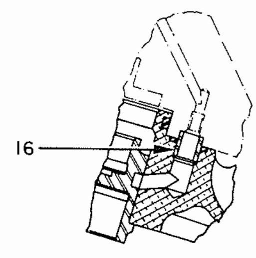




SECTION B-B



SECTION A-A



SECTION C-C

WRIGHT AIRCRAFT ENGINES

DIRECT INJECTION TURBO COMPOUND MODELS

972TC18DA-1,-2,-3,-4
981TC18EA-1
988TC18EA-1,-2,-3,-4,-5,-6
R3350-34,-38,-91

OPERATING INSTRUCTIONS

THIS INFORMATION IS ISSUED FOR REFERENCE PURPOSES ONLY. IT IS SUBJECT TO CHANGE AND WILL NOT BE KEPT UP TO DATE.

OCTOBER 1957

SUPERSEDES APRIL 1957 ISSUE

THE PROCEDURES CONTAINED IN THESE INSTRUCTIONS ARE NOT INTENDED TO SUPERSEDE OR CANCEL THE PROCEDURES OF THE APPLICABLE CAA APPROVED AIRPLANE OPERATING MANUAL OR MILITARY TECHNICAL ORDER.

FIELD ENGINEERING DEPARTMENT

CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION
WOOD-RIDGE, NEW JERSEY, U. S. A.

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A DIVISION OF

CURTISS-WRIGHT

TABLE OF CONTENTS

SECTION I

INTRODUCTION

These instructions cover the recommended operating procedures and limits of the Wright Direct Injection Turbo Compound Aircraft engines without regard to the type or model of aircraft in which the engine may be installed. Compliance with these recommendations is required to maintain Wright Aeronautical Division engine warranty in effect. The procedures and limits have been established from engine design characteristics and experience with a view toward satisfactory parts life and long periods of reliable operation between overhauls.

The engine models covered by this instruction and the WAD Engine Specifications on which their characteristics and specific operating data are based are:

Engine	Spec.
972TC18DA-1, -2, -3, -4	972G
981TC18EA-1	981C
988TC18EA-1, -2, -3, -4, -5, -6	988F
R3350-34	N872B
R3350-38	N932
R3350-91	923

These instructions are intended to cover all the routine ground and flight conditions as well as certain abnormal conditions. The Wright Aeronautical Division recognizes the following normal engine operating conditions and the instructions given herein should be applied accordingly: Starting, Warm-Up, Ground Operation, Take-Off, Climb, Level Flight, Normal Descent, Landing, and Engine Stopping.

Instructions for operating under the following abnormal conditions are also given in this manual: Feathering, Unfeathering, One Engine Out, Operation Under Icing Conditions, Emergency Descent, and Emergency Go-Around.

In cases of a Declared Emergency, engine operation is recommended at the discretion of the pilot, but within or as close to the limits and procedures of this publication as is practicable.

Overhaul and Maintenance Instructions for these engines are published in separate manuals. Information regarding accessory drive limits is provided in the applicable, current WAD Engine Specifications.

SECTION II

GENERAL OPERATING PROCEDURES

POWER CHANGES

Any increase in power should be made by increasing the RPM first and then increasing the manifold pressure. Any decrease in power should be made by decreasing the manifold pressure first and then decreasing the RPM.

SUPERCHARGER SHIFTS IN FLIGHT

Make all shifts as smoothly and rapidly as possible. Reduce the manifold pressure to 20 inches Hg or less, and engine speed to approximately 1600 RPM before shifting from "LOW" ratio to "HIGH" ratio. Shifting from "HIGH" to "LOW" ratio may be done without decreasing RPM or manifold pressure. Do not shift into the high ratio at less than five-minute intervals.

Shift from "LOW" to "HIGH" ratio when power available in "LOW" ratio is less than that available in "HIGH" ratio.

Shift from "HIGH" to "LOW" at maximum practical altitude.

MIXTURE CONTROL DURING INDUCTION AIR CHANGES

Air flow changes caused by a change in induction air system configuration may result in engine instability when operating with lean mixtures. Always place mixture in "AUTO-RICH" before the addition of carburetor heat. If engine instability is encountered when changing to or from alternate air or from preheat, place mixture in "AUTO-RICH" momentarily until engine stability is obtained.

Recheck manual lean mixture setting when operating at cruise power after changing induction air scoop configuration.

ACCESSORY POWER ACCOUNTABILITY

Cabin superchargers absorb power which is not measured by the engine torquemeter. Disregarding this unmeasured power absorption can result in exceeding BMEP limits with possible adverse effects on engine durability. It is therefore recommended that BMEP maximum limits at any RPM for any CLIMB or CRUISE power setting be reduced by 5 BMEP on engines driving the cabin superchargers.

This reduction does not apply for "TAKE-OFF" or "METO" operation.

ENGINE OVERSPEED

Operation up to 3050 RPM (105% of "TAKE-OFF" RPM) is recognized as normal.

Operation in excess of 3120 RPM or at the maximum calibrated reading of the tachometer if less than 3120 RPM, requires removal of the engine from service for disassembly inspection to reinstate the WAD engine warranty.

Operation between 3050 RPM and 3120 RPM requires the following special inspection to reinstate the WAD engine warranty.

a. Check oil sumps and magnetic plugs for indications of parts failure.

b. Check cylinder compression for indication of cracked heads and valves bent from piston-valve interference.

c. Check piston domes and internal cylinder domes visually for indications of twisted connecting rods and/or piston valve interference.

d. Check power recovery turbines for freedom of rotation and loss or damage of turbine blades.

e. Check propeller low pitch stop to ensure proper setting.

f. Check or replace governor or other suspected malfunctioning items which may be responsible for the overspeed.

If adverse findings occur during the above inspections, remove the engine for overhaul. If above checks are satisfactory, conduct a thorough ground run and reinspect oil sumps and magnetic plugs for condition. If satisfactory, release the engine for flight.

Conduct a post flight inspection of oil sumps and magnetic plugs following the first flight. (All sump checks to be made by draining the oil through a clean cloth.)

If the inspections reveal no indication of failure or overspeed damage and the condition of the propeller and governing system is normal, the WAD engine warranty is reinstated.

ALTERNATE GRADE FUEL

Both 100/130 and 108/135 fuels are approved for "AUTO-RICH" LOW supercharger ratio operation only. For either of these fuels, the 100/130 power ratings and "RECOMMENDED OPERATING SCHEDULE - 100/130 FUEL" are to be observed.

Fuel flow curves for 115/145 are equally applicable to 100/130 and 108/135 operation.

When changing operation from either of these fuels to 115/145 fuel, with the intent of using the 115/145 power ratings, the fuel system must be drained prior to refueling with 115/145 fuel. The engines should then be given a normal preflight ground run to ensure that the residual alternate grade fuel is consumed. The maximum permissible mixture of either lower grade fuel with 115/145 fuel with which the 115/145 ratings may be used is 2 gallons per 100 gallons of 115/145 fuel.

FUEL BOOST PUMP OPERATION

Fuel boost pumps are recommended for use:

1. As required to maintain fuel pressure within recommended limits during any stage of flight.

2. To overcome unstable engine operation due to entrained vapor or air particularly during climb and early stages of cruise.

3. To prevent sudden power loss or engine damage due to failure of engine driven fuel pump during take-off and during final approach in the event a "go-around" is necessary. It is recommended the boost pumps be operated on "HIGH" for take-off and landing.

4. To facilitate starting.

MAP PERFORMANCE COMPARISON

The manifold pressure required to produce a given BMEP at any RPM and fuel flow should be used as a general check of engine condition. On multi-engine aircraft, a comparison of engine manifold pressures provides a check of the relative condition of the engines without reference to manifold pressure-power charts. Under normal conditions with either "AUTO-RICH" or 10% BMEP drop mixture, all engines should be within two inches of manifold pressure to obtain a given BMEP. Variations of two inches or greater between engines in any given airplane should be investigated and maintenance action taken to correct the discrepancy.

When operating at or near full throttle, with manifold pressures adjusted to equal values, a limit of 15 BMEP spread between engines should be observed in place of the two inch Hg MAP limit.

Where large variations of accessory power requirements exist between engine positions, such as cabin supercharger vs. no cabin supercharger, suitable allowance should be made in the manifold pressure or BMEP spread recommended above.

CHT COMPARISON - F/A DISTRIBUTION

Improper F/A distribution between the front and rear row cylinders can adversely affect combustion chamber component service life and contribute to combustion chamber failures. The cylinder head temperature differential between the front and rear row of cylinders is the best indication of the distribution characteristics of the direct injection engine.

The following constitutes the limit of allowable CHT spread for both low and high blower operation.

Low Blower

An excessive REAR ROW RICH condition exists when the rear row CHT is more than 20°C hotter than the front row CHT when operated at 10% lean mixture accompanied by a shift of the hot head to the front row when the engine is operated in "AUTO-RICH".

An excessive FRONT ROW RICH condition exists when the front CHT is more than 15°C hotter than the rear row CHT when operated at 10% lean mixture accompanied by a shift of the hot head to the rear row when its engine is operated in "AUTO-RICH".

High Blower

An excessive REAR ROW RICH condition exists when the rear row CHT is more than 25°C hotter than the front row CHT when operated at 10% lean mixture accompanied by a shift of the hot head to the front row when the engine is operated in "AUTO-RICH".

An excessive FRONT ROW RICH condition exists when the front row CHT is more than 10°C hotter than the rear row CHT when operated at 10% lean mixture accompanied by a shift of the hot head to the rear row when the engine is operated in "AUTO-RICH".

NOTE

When improper distribution is suspected, the above checks should be made above 1800 BHP in low blower or above 1700 BHP in high blower.

Care should be exercised to obtain stabilized CHT readings at a stabilized indicated airspeed and altitude. The spark should be advanced on manual spark equipped engines throughout the check.

Cylinder head temperature spreads in excess of the above limits should be investigated and maintenance action taken to correct the discrepancy. The following checks are suggested:

1. Determine that the cylinder head temperature instrumentation is providing correct indication.

2. Check the fuel injection synchronizer bar setting and reset if necessary. WAD permits a latitude of synchronizer bar adjustment from standard to a maximum of .010" long depending upon the particular operator's decision on all installations.

   WAD recommends a .010" long synchronizer bar adjustment as a standard for all operators generally using cruise powers of 1700 BHP or above.

   Resetting the synchronizer bar from standard to .010" long will reduce a rear row hot cylinder head temperature spread by 5° - 8°C.

3. Eliminate ignition system trouble as the cause by use of the analyzer.

4. Make the following checks on the two cylinders to which thermocouples are connected:

   a. Check for fuel injection leaks.

   b. Check intake pipes for leaks or looseness.

   c. Check injection nozzle for opening pressure and spray pattern. Check spark plugs and ignition coils (if not checked with analyzer).

   d. Make borescope inspection of valves and piston dome.

5. Check magneto generator timing.

6. Change both fuel injection pumps and readjust synchronizer bar.

OIL DILUTION

When oil dilution is mandatory, dilute the oil before stopping as follows:

1. Idle until the oil temperature falls to 40°C (104°F).

2. Dilute at 1000 to 1200 RPM.

3. Maintain the oil temperature below 50°C (122°F) and the oil pressure above 15 lb. per sq. inch during this procedure.

4. Hold the dilution switches "ON" in accordance with the airplane manual.

NOTE

If a hydromatic propeller which uses engine oil is used, the propeller governor control and feathering system should be operated several times during the dilution process to ensure that properly diluted oil is left in the propeller dome, governing system, and feathering lines. When operating the governor control, make sure that the engine RPM is above the minimum governing speed. When operating the feathering system pull out the feathering switch after a 300 to 400 RPM drop has been obtained, wait for recovery of RPM, and then repeat this procedure.

PRECAUTION

The oil supply of an engine in which the oil has been diluted should be checked after a thorough warm-up, prior to repeating the dilution cycle or proceeding to take-off on the next flight.

REVERSE PITCH OPERATION

Reverse operation should be accomplished as early as possible during the landing roll to achieve maximum braking at normal power with minimum effect on engine cooling.

Reverse operation for taxi purposes is to be avoided if possible. If such operation is required, it must be limited to a maximum period of 30 seconds.

SECTION III

GROUND OPERATING PROCEDURES

PRE-STARTING

1. See that no tools or equipment are lying loose on or about the engine or airplane and that all fastenings are properly secured.

2. Check the fuel and oil supply for proper grade and quantity*. Check water-alcohol injection supply for quantity, if so equipped.

3. Check the engine controls for smooth movement and full travel.

4. Set the following controls as indicated:

Cowl Flaps	"OPEN"
Oil Cooler Flaps	"AUTO" or "CLOSED" if manually operated
Carburetor Air	"DIRECT"
Ignition Switch	"OFF"
Spark	"RETARD" (if manual)
Mixture	"IDLE CUT-OFF"
Propeller	"INCREASE RPM" (low pitch)
Supercharger	"LOW"
Alternate Fuel Metering	"OFF"

5. Note MAP reading before starting for use during ground checks. Compare to field barometer reading.

STARTING

1. Throttle . . . . Set for 1200 RPM.

NOTE

In temperatures below freezing starting is improved by setting throttle near closed position.

2. Fuel Boost Pump . . . . "ON" (low)

3. Starter . . . . "ENGAGE"

NOTE

Turn the propeller through at least two revolutions with the engine starter. If there is unusually high compression, remove the spark plugs from the lower cylinders and drain all liquid as the presence of any quantity of liquid in a combustion chamber is likely to cause serious damage. Never turn the propeller opposite to engine rotation as this may force liquid into an intake pipe from where it is apt to be drawn into the cylinder when the engine is started.

4. Ignition Switch . . "BOTH" after propeller has turned two revolutions

5. Ignition Booster . . ."ON" if independently operated

6. Mixture Control . . . Position on basis of engine temperature

Cold Engine — "AUTO-RICH" prior to engaging starter. If engine does not fire within a short period after the ignition switch is activated, place mixture in "IDLE-CUT-OFF" momentarily to prevent afterburning.

Cold weather starts should be made with closed throttle using either mixture control or primer. If primer starts are made, the mixture control should remain in "IDLE-CUT-OFF" until a positive start with smooth operation is obtained.

Simultaneous use of both primer and mixture control during starting often results in exhaust system fires.

Following initial firing, and disengagement of the starter, the engine will often "motor" at low speed, rather than accelerate to normal idle speed. Allow the engine to run at this condition until speed increases to normal idle speed. Premature application of throttle or attempts to vary the mixture will stop the engine. Such a false start results in "iced" spark plugs, preventing successful starting on following attempts.

Warm Engine — "AUTO-RICH" prior to activating ignition. (Optimum point depends on engine temperature). If engine does not fire within two revolutions after ignition, or if engine loads up, move mixture control to "IDLE-CUT-OFF" momentarily.

Hot Engine — "IDLE-CUT-OFF" until engine fires or two revolutions after ignition, then advance mixture control to "AUTO-RICH". If engine does not fire within a short period in "AUTO-RICH", return to "IDLE-CUT-OFF"

NOTE

If engine fails to start within 30 seconds, discontinue starting attempt and allow starter to cool before repeating starting procedure.

7. Throttle . . . Reset for 1200 RPM (do not allow engine to exceed 1400 RPM on start).

Observe the oil pressure gages. Stop the engine if the oil pressure does not register within 10 seconds or reach 40 lb. per sq. inch within 20 seconds.

8. Head the airplane into the wind when ground operation for an extended period of time is anticipated.

9. Fuel Boost Pump . . . . "OFF"

WARM-UP

Operate the engine at 1000-1400 RPM until the oil inlet temperature reaches 40°C, or if above 40°C, until a definite rise over the pre-starting temperature is indicated, and the oil pressure is stable.

NOTE

The minimum torque pressure with the reverse flow torquemeter is dependent on front section (nose) oil pressure. This pressure in turn is affected by main and nose oil pressure settings as well as oil inlet temperature. Therefore oil pressures should be set as recommended and oil inlet temperature be above 40°C to complete a satisfactory auto-feathering system check prior to take-off.

GROUND OPERATION

Unless otherwise specified to accomplish ground run-up checks, all warm-up and ground operation of the engine should be accomplished with the controls set as follows:

1. Ignition Switch . . . . "ON - BOTH"
2. Mixture . . . . "AUTO-RICH"
3. Alternate Fuel Metering Source. . . "OFF"
4. Water Injection . . . . "OFF"
5. Spark . . . . "RETARD" (if manual)
6. Propeller . . "INCREASE RPM" (low pitch)
7. Supercharger . . . . "LOW"
8. Cowl Flaps . . . . "OPEN"
9. Oil Cooler Flaps. . . "AUTO", or to maintain within limits if "Manual"
10. Fuel Boost Pump . . . . "OFF"
11. Carburetor Air . . . . "DIRECT"

NOTE

Prolonged ground operation under severe icing conditions may require use of "ALTERNATE-AIR" and or "HEAT". Shift to "DIRECT", prior to take-off.

GROUND CHECKS

1. Oil Pressure - At 1500-1800 RPM with 80-85°C oil inlet temperature, main oil pressure should be 65-75 psi.

2. Fuel Pressure - At 1500-1800 RPM, fuel pressure should be 24-26 psi.

3. Propeller

   a. Set 1600 RPM with the propeller in "FULL INCREASE RPM" (low pitch).

   b. Place propeller control in "FULL DECREASE RPM" (high pitch) and note RPM reaction.

   c. Return the control to "FULL INCREASE RPM" (low pitch).

   d. Check for reduction and full recovery of RPM.

   e. Conduct additional propeller system checks as recommended by the applicable airplane manual.

4. Supercharger

   a. Set 1600 RPM with throttle and shift to "HIGH" ratio.

   b. Advance throttle to approximately 30" MAP, stabilize and shift to "LOW" ratio. A sudden decrease of MAP indicates proper operation.

5. Power Performance

   a. Set MAP equal to field barometric pressure with the throttle, and note the RPM, BMEP and fuel flow obtained to cross-check engines of a multi-engine airplane.

   b. In a multi-engine airplane, a variation greater than 100 RPM between engines should be investigated and corrective action taken.

6. Magneto

   a. Set MAP equal to field barometric pressure with the throttle and note RPM and BMEP obtained.

b. Switch ignition to "LEFT" and note RPM and BMEP change.

c. Return ignition switch to "BOTH" and allow RPM to stabilize.

d. Repeat the procedure for the "RIGHT" ignition switch position.

e. Atmospheric conditions and spark timing will influence the readings obtained.

Check as follows:

Manual Spark Advance System -- A drop of 75 RPM or less when operating on one magneto is satisfactory providing no engine roughness is encountered.

Automatic Spark Advance System -- A drop of 30 RPM or less or an increase of 10 RPM when operating on one magneto is considered satisfactory providing no engine roughness is encountered. If RPM exceeds 2350 when operating at MAP equal to field barometric pressure, a drop of 75 RPM is permitted when checking magnetos.

NOTE

The use of BMEP as a measure of power loss during the magneto check is recommended to substantiate the RPM variation observed. A drop of 7-8 BMEP is considered equivalent to a 75 RPM drop.

f. In cases of known richer than normal carburetion and/or the presence of high atmospheric absolute humidity which effectively richens the fuel-air ratio, the following procedure is recommended, if the above limits are exceeded.

1. Set MAP equal to field barometric pressure with the throttle.
2. Lean mixture manually to best power setting (maximum BMEP).
3. Richen mixture to obtain approximately 2 BMEP drop.
4. Conduct magneto check as before. If the above limits continue to be exceeded, the conditions should be investigated and corrective action taken.

7. Manual Spark Advance -

a. Set throttle to obtain 2000 RPM and lock.

b. Manually lean mixture to obtain 1900 RPM.

c. With ignition switch on "LEFT", select "ADVANCE" spark and note change in RPM and BMEP. Return spark to "RETARD" and ignition switch to "BOTH".

d. Repeat the above procedure with the ignition switch on "RIGHT".

e. Check for a definite rise of 2-4 BMEP or approximately 25 RPM. If no rise occurs, the mechanism may be locked in either "RETARD" or "ADVANCE" and the discrepancy should be corrected prior to the use of any power above 2400 RPM.

NOTE

In lieu of the above procedure the spark advance system may be checked with an ignition analyzer by noting pattern shift when switching from "ADVANCE" to "RETARD".

If established by the analyzer that a distributor is locked in "RETARD", but not "ADVANCE", the aircraft may continue to schedule termination at which time the distributor should be corrected.

8. Alternate Fuel Metering Source -

a. Set 2000 RPM with the throttle.

b. Switch AFMS "ON" momentarily.

c. Check for a definite increase in fuel flow.

9. Water Injection -

a. Set 2000 RPM with the throttle.

b. Place water switch "ON".

c. Advance throttle to approximately 50" MAP.

d. Place water switch "OFF". Check for fuel flow increase and power decrease.

10. Idle Mixture -

a. Check at closed throttle and above 150°C CHT.

b. Check for stable idle speed of 500 - 800 RPM.

c. Momentarily energize the primer and check for:

1. Increase in MAP and decrease in RPM,

or

2. Slight MAP decrease and RPM increase (0-100 RPM).

NOTE

Since the Automatic Mixture Control unit does not provide altitude compensation at "IDLE", the amount of RPM increase when applying prime will vary with field elevation. It is therefore recommended that operators set the idle mixture to obtain lean best power (0-25 RPM increase on prime) at the majority of air ports served. At no station should more than 100 RPM increase be obtained when applying prime.

At extremely high altitudes or under hot day conditions when no increase is obtained on prime, it may be necessary to manually lean to 25 RPM drop in order to prevent spark plug fouling.

d. Slowly move mixture control toward "IDLE-CUT-OFF" and check for MAP increase and RPM decrease.

11. Ignition Switch Circuit -

a. At idle speed, place ignition switch in "OFF" momentarily and return switch to "BOTH".

b. Check to see the engine ceases to fire with switch "OFF".

NOTE

This check is made to assure that the magneto ground has not been broken, for without this ground connection, the ignition system cannot be made inoperative and the engine would be dangerous for ground handling. The check is normally not necessary when a drop in RPM is experienced during the magneto check for if either the "LEFT" or "RIGHT" magneto is not grounded, no drop will occur when checking the opposite magneto.

SPARK PLUG ANTI-FOULING METHODS

In the event of prolonged ground operation, the following procedures are recommended to prevent spark plug fouling:

1. Low Power Operation

   RPM . . . . 800-1200 RPM

   Mixture . . Lean until RPM drops slightly (25 RPM). There is no time limit for this operation; however, it is recommended that the cylinder head temperature not exceed 200°C.

2. 1340 BHP Operation (R-103 spark plugs only)

   Mixture . . . . "RICH"

   After each 15 minutes of ground operation, operate at this power for one minute. If RPM, when operating on propeller low pitch stop, violates propeller ground running restrictions, select another suitable RPM-BMEP setting to obtain 1340 BHP. It is recommended that the cylinder head temperature not exceed 200°C.

PRE-TAKE-OFF CHECKS

Prior to each take-off, compliance with the following check list is recommended:

1. Complete the functional checks as indicated:

   a. Oil Pressure . . . . "CHECKED"

   b. Oil-Inlet Temperature . . "MINIMUM 40°C AND RISING"

   c. Fuel Pressure . . . . . . "CHECKED"

   d. Propeller . . . . "CHECKED"

   e. Power Performance. . . . "CHECKED"

   f. Magneto . . . . "CHECKED"

   g. Manual Spark Advance. . . "CHECKED and NOTED AS REQUIRED"

   h. Water Injection . . . . . . "CHECKED"

2. Set the following controls as indicated:

   a. Ignition Switch . . . . "BOTH"

   b. Mixture . . . . "AUTO-RICH"

   c. Alternate Fuel Metering Source. . "OFF"

   d. Water Injection . . . . "ON"

   e. Manual Spark Advance. . . . "RETARD"

   f. Propeller. . . . . . "INCREASE RPM"

   g. Supercharger . . . . "LOW"

   h. Carburetor Air . . . . "DIRECT"

   i. Fuel Boost Pump . . . . . . "ON" (high)

   j. Oil Cooler Flap . . . . "AUTO" or "TAKE-OFF" if manual

   k. Cowl Flaps. . . . . "TAKE-OFF"

SECTION IV

FLIGHT OPERATING PROCEDURES
NORMAL CONDITIONS

GENERAL FLIGHT OPERATION

Engine temperatures and pressures during flight are to be controlled as recommended in the Table of Specific Operating Data.

TAKE-OFF

1. Advance throttle to "TAKE-OFF" MAP or BMEP, whichever occurs first. Do not operate in excess of either of these limits and do not use take-off power in excess of five minutes. If vapor pressure is above standard day value, a correction equal to twice the difference between actual vapor pressure and standard (.4" Hg. at sea level) may be added to the allowable "TAKE-OFF" MAP up to a maximum of 1".

2. After becoming airborne, establish desired climb power and set the following controls as indicated:

a. Fuel Boost Pump. . . . . As Required

b. Water Injection (if applicable) . . "OFF"

METO

1. METO power may be used as the first power reduction after take-off in transition from TAKE-OFF to CLIMB power. Otherwise its use is reserved for operation as required under emergency conditions.

2. Set the following controls as indicated:

Mixture . . . . "AUTO-RICH"

Spark . . . . "RETARD" (if manual)

3. Observe both METO MAP and BMEP limits.

CRUISE POWER CLIMB

1. Set the following controls as indicated:

Mixture . . . . "AUTO-RICH"

Spark . . . . "RETARD" (if manual)

RPM 2400

2. Observe the following limits:

MAP. . . . . 38.0" (LOW ratio) Maximum
38.0" (HIGH ratio) Maximum

BMEP . . . . Per Recommended Operating Schedules

ALTERNATE POWER CLIMB

1. Set the following controls as indicated:

Mixture . . . . "AUTO-RICH"

Spark . . . . "RETARD" (if manual)

RPM . . . . 2500 (Manual Spark Advance)
2600 (Automatic Spark Advance)

2. Observe the following limits:

MAP . . . . 40.0" (LOW ratio) Maximum
43.0" (HIGH ratio) Maximum

BMEP. . . . . Per Recommended Operating Schedules

NOTE

Powers up to Alternate Climb Power settings may be extended into the early phase of level flight when high dispatch altitudes are required for high gross weight aircraft to prevent operation at cruise airspeeds below airplane minimum recommended speeds. Operation at these powers is restricted to "RICH" mixture, 2500 RPM, and to engines equipped with manual spark advance.

CLIMB POWER FUEL FLOW

1. Fuel flow metering at climb power is in the lower range of the master control power enrichment valve opening, where small variations of induction airflow may result in appreciable changes of fuel flow. Consequently, differences in fuel flow between engines and the fuel flow charts may exist.

2. The minimum fuel flow permitted is mean chart value minus 40 pounds per hour. If the fuel flow is below this value, reduce power to 170 BMEP. Take the necessary corrective action at the first landing where suitable facilities exist.

3. If fuel flows in "AUTO-RICH" mixture position are in excess of chart values, manual leaning is permitted to the chart values in accordance with the following conditions:

a. The maximum manifold pressure spread between engines must not exceed 1" Hg.

b. The outboard engines must be operated 5 BMEP below the inboard engines to account for cabin supercharger horsepower.

c. The fuel boost pump must be "ON".

d. Fuel flowmeters must be calibrated and calibration cards posted next to each flowmeter indicator.

NOTE

If flowmeter calibration cards are not used, the maximum instrument shop calibration error limit must be added to the chart fuel flow value to establish the climb fuel flow minimum value for manual control.

e. If any unusual engine operation, such as engine instability is experienced during the climb, the mixture must be placed in "AUTO-RICH".

CRUISE POWER-LEVEL FLIGHT

1. Select cruise power required from the "RECOMMENDED OPERATING SCHEDULE" and set the following controls as indicated:

   Mixture . . . . "AUTO-RICH"

   RPM . . . As selected for desired power

   Throttle . . . . To obtain BMEP for desired power

   Spark . . . . . . "ADVANCE" (if manual)

2. Observe the following limits for all cruise power operation.

   a. All engines except 988TC18EA-4, -5, and -6.

   RPM . . . . 2400 (Maximum)

   BMEP . . Per Recommended Operating Schedule

   MAP . . 41.0" (LOW ratio) Maximum
   41.0" (HIGH ratio) Maximum

   b. 988TC18EA-4, -5, and -6.

   RPM . . . . 2500 (Maximum)

   BMEP . . Per Recommended Operating Schedule

   MAP . . 42.0" (LOW ratio) Maximum
   43.0" (HIGH ratio) Maximum

3. Select manual lean mixture as follows:

   a. Move mixture control from "AUTO-RICH" toward "AUTO-LEAN" to obtain "best power". The normal BMEP increase from "AUTO-RICH" is 1-5 BMEP.

   b. Reset desired cruise BMEP with the throttle.

   c. Continue manual leaning until the BMEP drops 10% from the desired value.

   If the cruise power is above 1550 BHP in low ratio or above 1450 BHP in high ratio and the position of the mixture control, after manual leaning, is richer than the "AUTO-LEAN" detent, place the mixture control in "AUTO-LEAN". This condition should be investigated as it may indicate an engine discrepancy requiring maintenance correction.

   If investigation discloses that this condition is encountered only in low blower and the power drop is not greater than 15%, operation may be continued in "AUTO-LEAN" without further maintenance providing the specified CHT spread limits are not exceeded.

   At powers below those stated above, the power enrichment valve is closed and the position of the mixture control is of no consequence.

   d. Advance throttle to obtain desired cruise BMEP.

   Manual leaning to a 10% BMEP drop from "Best Power" is recommended for all cruise operation at maximum cruise power and below. This procedure will place the mixture in the Best Economy range and is desirable since it results in a direct saving in fuel. It has the additional advantage of cooling the engine by means of lower combustion and exhaust temperature due to the excess air which absorbs some of the heat of combustion resulting in optimum cylinder, turbine, nozzle box and exhaust system durability.

   An occasional need is recognized to maintain cruise power at altitudes above the 10% BMEP drop. On such occasions, it is permissible, at the discretion of the operator, to use the same procedure, leaning to 7% BMEP drop.

   The critical altitude increase is approximately 700 feet. The use of mixtures richer than 7% BMEP drop at cruise power in level flight should be avoided since this results in temperatures which may have an adverse effect on engine durability.

   The use of mixtures leaner than 10% BMEP drop should be avoided also since any abnormal distribution of fuel or air to the cylinders can result in serious cylinder to cylinder power differences which are aggravated by extremely lean operation.

   If "engine condition" does not permit stable operation when leaned to 10% BMEP drop, it is recommended that "AUTO-RICH" be used until the "engine condition" can be corrected.

DESCENT

Operating techniques are identical to cruise power level flight. Normal choice for routine descent operation is to have the mixture control handle at the 10% lean condition. If excessive leaning is encountered during descent, it will be evidenced on individual engines by those engines exceeding the 2" MAP spread limit. In these cases, it is permissible to enrichen the mixture as required to align MAP or obtain engine stability. If engine instability persists, use "AUTO-RICH". Under abnormal descent conditions or where traffic control requires frequent altitude changes use of "AUTO-LEAN" or "AUTO-RICH" mixture is authorized.

In the event level cruise flight is re-established, reset 10% lean mixture point.

During descent, use of low manifold pressure and BMEP, especially in conjunction with high RPM, could result in piston ring flutter. To reduce this possibility, high RPM - low BMEP combinations should be avoided. It is recommended not less than one inch MAP be used for each 100 RPM during descent.

This recommendation is not applicable during final approach for landing.

PRE-LANDING CHECKS

On, or before final approach, set the following controls as indicated:

1. Mixture . . . . "AUTO-RICH"
2. Spark . . . . "RETARD" (if manual)
3. RPM 2400

NOTE

2400 RPM normally permits adequate power flexibility required to maintain glide path on approach. The RPM usually overruns to approximately 2600 on a go-around permitting flight crew to reset governor at METO RPM.

4. Fuel Boost Pump . . . . "ON" (high)

LANDING

1. Use reverse operation as required. Do not exceed 2600 RPM.
2. After landing run-out is completed, set the following controls as indicated:
   a. Cowl Flaps . . . . "OPEN"
   b. Propeller . . . . . "INCREASE RPM"
   c. Fuel Boost Pump . . . . "OFF"

STOPPING

If the engine has been warmed by taxiing, idle until the cylinder head temperatures drop to at least 150°C (300°F) or to a value consistent with existing ambient temperature. Operate engine below 1000 RPM for a minimum of 30 seconds to ensure optimum crankcase scavenging and reduce the possibility of hydraulic lock on subsequent start. Taxiing the airplane below this RPM will further improve oil system scavenging.

1. Throttle . . . . "CLOSED"
2. Mixture Control . . . . "IDLE CUT-OFF"
3. Ignition Switch . "OFF" (after engine stops)

CAUTION

There is some tendency for a hot fuel injection engine to fire when being pulled through with the ignition switch "OFF". Therefore, it is recommended that manually positioning the propeller after shutdown be prohibited to avoid possible injury to ground crew. If positioning of the propeller is required, it is recommended that it be accomplished with the engine starter.

NOTE

Do not close cowl flaps, regardless of weather until engine has cooled. Closing cowl flaps immediately after shutdown may cause damage from excessive soak temperatures. If the engine is to be idle for an extended period of time or if dusty conditions exist, cover all openings after the engine has cooled.

SECTION V

FLIGHT OPERATING PROCEDURES
ABNORMAL CONDITIONS

ENGINE MALFUNCTION

Continued flight operation when serious engine malfunctioning exists may cause severe damage to the engine and possibly to the aircraft. Experience indicates the longer the delay between detection of a malfunction and the actual feathering, the more severe is the damage. All operators are cautioned of the risks after malfunction has become evident and to require the following:

Feather or stop the engine when:

1. An extreme or abnormal engine vibration occurs.
2. An excessive or uncontrollable power loss occurs.
3. A sudden or uncontrollable rise in oil temperature occurs.
4. A sudden or uncontrollable drop in oil pressure occurs.
5. A sudden and uncontrollable rise of cylinder head temperature occurs.
6. Two or more cylinders are inoperative/or when symptoms of impending mechanical failure exist in any one cylinder.
7. A heavy discharge of oil is seen to emit from the engine breather or exhaust system and/or a sudden decrease in oil quantity indication.
8. The oil temperature or cylinder head temperature cannot be maintained within the published limits.
9. An engine fire is experienced.
10. In the event of turbine malfunction. Malfunction of a blowdown turbine is usually evidenced by one or more of the following symptoms:
    a. Unusual discharge of smoke from or around the exhaust flight hood.
    b. Heavy orange colored flame or heavy discharge or sparks.
    c. Loss of BMEP (varies depending on the type of malfunction).

Where continued operation of any engine evidencing any of the foregoing conditions of malfunction is considered imperative in the interest of the safety of the aircraft and passengers and crew, such operation shall be at the discretion of the responsible crew member. If these conditions exist, it is recommended that operation of the engine be conducted with caution and at the minimum power consistent with requirements.

FEATHERING

The following procedure is recommended for feathering the propeller in flight. The sequence or order of execution may vary to suit specific installation requirements.

1. Feathering Switch . . . . "CLOSED"
2. Mixture Control . . . . "IDLE CUT-OFF"
3. Throttle . . . . "CLOSED"
4. Fuel Boost Pump . . . . "OFF"
5. Ignition Switch. . "OFF" (after engine stops)
6. Spark . . . . "RETARD" (if manual)
7. Cowl Flaps . . "CLOSED". In case of fire, operate with procedures outlined in Airplane Operation Manual; when fire extinguished, "CLOSED".

UNFEATHERING

The following procedure is recommended for unfeathering the propeller in flight, but the sequence may be altered to suit specific installation requirements. Steps 1-7 must precede Step 8.

1. Operate the starter switch until the propeller has turned two revolutions. This procedure will indicate the presence of liquid lock. Do not attempt to restart engine if liquid lock is present.
2. Propeller Control ."FULL DECREASE RPM" (High Pitch)
3. Supercharger . . . . "LOW"
4. Fuel Supply . . . . "ON"
5. Oil Shut-off Valve . . . "OPEN" (if installed)
6. Throttle . . . . "CLOSED"
7. Spark . . . . "RETARD"

8. Feathering Switch . . Operate in accordance with applicable instructions.

9. Ignition Switch. . . . . "ON"

10. Mixture Control . . . "AUTO-RICH" when engine speed exceeds 600 RPM. The control must be shifted from "IDLE CUT-OFF" to "AUTO-RICH" as quickly and smoothly as possible.

NOTE

Operate the engine below 1800 RPM until a definite rise of oil inlet temperature above the pre-starting value is obtained and oil pressure is stable.

ONE-ENGINE-OUT OPERATION

One-engine-out operation is considered abnormal operation and as such the area of permissible operation may be extended into the "Abnormal Operation" shaded area of the Recommended Operating Schedule. "AUTO-RICH" mixture is required for all such operations.

Temperature and pressure limits as shown on the Table of Specific Operating Data for climb and cruise shall not be exceeded except for "METO" power where permissible limits are listed.

EMERGENCY DESCENT

1. Set the following controls as indicated:

   Mixture . . . . "AUTO-RICH"

   Supercharger . . . . "LOW"

2. The use of high RPM (do not exceed take-off RPM) and low MAP is permitted for emergency descent only.

EMERGENCY "GO-AROUND"

Increase the RPM to 2600 and open the throttle to obtain METO power and then, if necessary, advance the propeller control to "TAKE-OFF" RPM, and the throttle to give "TAKE-OFF" power.

FLIGHT MAGNETO CHECK

In-flight magneto checks are permitted, however, these checks should not be considered a substitute for the normal ground magneto check prior to "TAKE-OFF". The following procedure should be followed in making this check.

1. Mixture . . . . "AUTO-RICH"
2. RPM . . . . Cruise Range
3. Supercharger . . . . "LOW" ratio
4. BMEP . . . . Do not exceed 130
5. Propeller . . . . . Fixed Pitch on Curtiss
6. Magneto Switch

   a. Left . . . . . Hold only long enough to observe BMEP change.

   b. Both . . . . . Allow engine to stabilize.

   c. Right . . . . . Hold only long enough to observe BMEP change.

   d. Return to both.

NOTE

In the event of abnormal power loss, throttle should be retarded prior to switching back to "BOTH", to avoid exhaust system afterfiring due to unburned fuel discharge, and to prevent engine overspeed.

No limits on in-flight magneto checks have been established, however, if the BMEP on either "LEFT" or "RIGHT" is less steady than on "BOTH" and/or there is engine roughness, the engine should be given a ground check at the next station.

INDUCTION SYSTEM ICING

Atmospheric moisture, which may result in fuel flow disturbance, is encountered in the form of water, snow and ice. The problem of separating this moisture prior to its entering the carburetor has been met by the aircraft manufacturer primarily by the design and use of various types of protected air scoop inlets (inertia separating). These inlets do not always accomplish 100 per cent separation because the effectiveness of the inlet depends on both the particle size and the velocity of the air flowing past the inlet.

Operational experience indicates that when there is visible moisture in the air such as rain, snow, sleet, clouds or supercooled precipitation, the flight crew should alert themselves for any sign of carburetor icing. This condition can be detected by close attention to the fuel flow and BMEP. Experience indicates that carburetor impact system icing is most likely to occur when the indicated outside air temperature is below +10°C. Any instability or loss of either Fuel Flow or BMEP is fair warning of impending impact system icing, and corrective measures should be immediately taken.

A. Power Loss Due to Incorrect Fuel Metering -

Usually sudden and radical if due to leanness, and gradual, if due to richness.

Cause: Moisture in the carburetor air system.

Discussion: Moisture particles enter the carburetor air metering system through the impact tubes with the following possible results:

1. Leanness due to impact tube restriction, primarily caused by icing.

2. Leanness due to automatic mixture control (AMC) needle (variable orifice) restriction caused by water, snow or ice. This is generally a high altitude problem since the AMC orifice is smallest there.

3. Richness due to mixture control bleed restriction. This is a rarer occurrence than either of the above.

4. Leanness or richness due to head of water in air passages.

Prevention: The most important part of preventing a fuel metering disturbance is that of anticipating a moisture condition and taking the following action:

1. Set mixture to "AUTO-RICH".

2. Use protected carburetor air inlet system, if available.

3. Apply carburetor preheat to the minimum value required to prevent icing for any given installation. This will reduce critical altitude; however, there is no practical substitute under severe conditions. DO NOT EXCEED 38°C CAT. Experience indicates that 25°-30°C CAT is usually adequate.

4. Reset cruising mixture.

5. Observe fuel flow and BMEP while in icing condition to detect first evidence of any malfunction. Intermittent fluctuation indicates impending loss of power.

NOTE

Good results can often be obtained by use of alcohol with no carburetor heat. When any instability of fuel flow or BMEP is noted use intermittent application of carburetor alcohol until smooth operation is again apparent. Close observation of fuel flow and BMEP to insure early detection of instability is of utmost importance.

When alcohol is used, it should be applied for a period of 3-5 seconds, then released and an observation made as to whether or not stable power has been regained.

It is recommended, however, that whenever engine critical altitude is not adversely affected that carburetor preheat be used as a preventive measure, since the use of alcohol requires considerable skill acquired only through experience.

Correction: In event of BMEP or fuel flow loss during icing conditions, take the following action:

1. Follow procedures 1, 2, 3 under "Prevention" if not already accomplished. DO NOT EXCEED 38°C CAT.

2. Apply alcohol as required until power is regained and stabilized.

NOTE

If extreme richness is experienced, it may be necessary to manually control mixture to retain power while applying the above corrective measures.

3. After smooth operation has been re-established, reset mixture using preventative CAT.

4. Leave preheat on until after leaving moisture conditions and power is stable.

CAUTION

The removal of preheat should be done slowly and to one engine at a time. It is possible for snow and ice to accumulate in the air inlet system in such a manner that it will break loose when the preheat door position is changed. This accumulation may move to a position where it can seriously restrict air flow or disturb metering characteristics.

B. Power Loss Due to Manifold Pressure Loss -

Usually gradual.

Cause: Airflow loss due to screen and surface icing either in air scoop or carburetor.

Discussion: This condition may be encountered in freezing rain, heavy snow, or ice.

Prevention: Same as before.

Correction: Same as before. Alcohol injection usually very effective in removing the accumulation of ice, if it is on the screen.

C. Alternate Fuel Metering Source -

The alternate fuel metering source is a standby provision for use in the event the procedures recommended above are employed too late to be effective. If a power loss is experienced to an extent that adequate preheat cannot be obtained and stable engine operation thereby regained, take the following action on one engine at a time:

1. Mixture . . . . "AUTO-RICH"
2. Throttle . . . . Set 25" MAP
3. AFMS . . . . "ON"
4. Throttle . . . . Reset desired power
5. Mixture . . . Manual lean to "best power"

NOTE

Fuel flow when operating with AFMS is not dependent on air flow. Fuel flow is controlled only by use of the manual mixture control. The fuel flow and power indications should be carefully monitored as any change of air flow altitude or power may require mixture control readjustment.

The AFMS will provide sufficient fuel flow to operate at maximum cruise power, or below, with zero carburetor air metering differential pressure, if the mixture control is in "AUTO-RICH" position.

6. Maintain CAT at value required to de-ice. DO NOT EXCEED 38°C

7. If heat is immediately effective, monitor mixture control to maintain stable engine operation.

8. Resume normal metering operation as soon as it is determined the icing disturbance has been eliminated.

a. Mixture . . . . "AUTO-LEAN"

b. AFMS . . . . "OFF"

c. Reset cruise power and mixture as recommended for normal cruise operation.

9. If found necessary to continue operation in level flight with AFMS "ON", lean mixture and simultaneously open the throttle until MAP is three inches above the value noted at best power mixture. The normal manual lean procedure cannot be used with AFMS energized.

CAUTION

a. The AFMS will not alleviate icing of the top deck screen or any icing affecting induction airflow. Therefore the AFMS should not be used without adequate preheat.

b. The AFMS should not be used during take-off or landing.

c. The AFMS should not be energized below 1600 RPM for excessive richness and exhaust flaming will result.

d. The AFMS should not be used during starting as it has no effect on cranking speed fuel flow.

SECTION VI

ENGINE CHARACTERISTICS AND SPECIFIC OPERATING DATA

TABLE OF ENGINE CHARACTERISTICS

Series . . . . Turbo Compound

Models . . . . . . 972TC18DA1, -2, -3, -4; 981TC18EA1; 988TC18EA1, -2, -3, -4, -5, -6; R3350-34, -38, -91

Type . . . . Double row radial, air cooled with exhaust driven turbines geared to crankshaft.

Number of Cylinders 18

Bore . . . . 6.125 in.

Stroke . . . . 6.312 in.

Piston Displacement . . . . 3350 cu. in.

Compression Ratio 6.70:1

Supercharger Ratio . . . . 6.46 and 8.67:1

Impeller Diameter . . . . 13.5 in.

Turbine Drive Ratio 6.52:1

Turbine Wheel Diameter 11.45

Rotation of Crankshaft (from rear) . . . Clockwise

Rotation of Propeller Shaft (from rear) . . Clockwise

Propeller Reduction Gear Ratio . . . .

988TC18EA-2, -5	0.355:1
All others	0.4375:1

Propeller Shaft Spline Size 60A

Fuel . . . Grade 115/145 A. M. S. Spec. No. 3036A

Oil . . . . Grade 120 Second, WAD Spec. No. 5815
Grade 100 Second, WAD Spec. No. 5818

Water Injection Fluid . . . . 50/50 MIX AMS 3006A Type I (above -45°C)

60/40 MIX AMS 3006A Type IV (below -45°C)

1% Corrosion Resistant Oil Allowable

NOTE

Oils such as Dromus "B" and Donax "C" or their equivalent are acceptable.

These oils are only soluble in water and therefore must be added and mixed prior to the addition of the Methyl alcohol.

Master Control . . . . Bendix PR-58-S-2

Master Control Assembly Drawing

WAD No. 136723N2	TC18DA1, 2;	R3350-34, 91
WAD No. 136723N5	TC18DA3, 4	
WAD No. 136723N6	TC18EA1, 2, 3, 4, 5, 6;	R3350-38
WAD No. 136723N4	TC18EA1	

Magneto . . . . Scintilla DLN-9

Ignition System . . . . Low Tension with manual or automatic Spark Advance

Torque Cell Press. Constant = K_{TC}	988TC18EA2, 5	201
	All Others	142
BMEP Constant = K_E		236
Gage Pressure Ratio = H	988TC18EA2, 5	1.174
	All Others	1.662

$$BHP = \frac{BMEP \times RPM}{K_E} = \frac{\text{Torque Cell Press.} \times RPM}{K_{TC}}$$

TABLE I OF SPECIFIC OPERATING DATA

LOW RATIO

Operating Condition	RPM	BHP	Altitude Feet	Mixture Position
Take-Off (5 minutes)				
972TC18DA-1, -2, -3, -4;R3350-34, -91	2900	3250	S.L. - Full Throttle	"Auto-Rich"
988TC18EA-1, -2, -3, -4, -5, -6;R3350-38	2900	3400	S.L. - Full Throttle	"Auto-Rich"
981TC18EA1	2900	3700	S.L. - Full Throttle	"Auto-Rich (Wet)"
Alternate Take-Off (30 minutes)				
981TC18EA1	2900	3400	S.L. - Full Throttle	"Auto-Rich"
Normal Rated Power (METO)				
972TC18DA1, 2;R3350-34, -91	2600	2600	Sea Level	"Auto-Rich"
	2600	2650	6,500	"Auto-Rich"
972TC18DA3, 4	2600	2700	Sea Level	"Auto-Rich"
	2600	2750	5,800	"Auto-Rich"
988TC18EA1, 2, 3, 4, 5, 6;R3350-38;981TC18EA1	2600	2800	Sea Level	"Auto-Rich"
	2600	2850	4,700	"Auto-Rich"
Alternate Rated Power (METO)				
988TC18EA1, 2, 3, 4, 5, 6;R3350-38;981TC18EA1	2650	2860	Sea Level	"Auto-Rich"
	2650	2920	4,800	"Auto-Rich"
Cruise Power Climb				
All Models	2400	1840	Sea Level	"Auto-Rich"
	2400	1910	12,600	"Auto-Rich"
Alternate Climb				
All Models	2500	2080	Sea Level	"Auto-Rich"
	2500	2150	11,300	"Auto-Rich"
Cruise Power Level Flight and Descent				
972TC18DA1, 2;R3350-34, -91	2400	1840	Sea Level	"Manual Lean"
	2400	1910	11,300	"Manual Lean"
972TC18DA3, 4;988TC18EA1, -2, -3; R3350-38;981TC18EA1	2400	1840	Sea Level	"Manual Lean"
	2400	1910	11,600	"Manual Lean"
988TC18EA4, 5, 6	2500	1900	Sea Level	"Manual Lean"
	2500	1975	12,500	"Manual Lean"
Ground Operation				"Auto-Rich"

HIGH RATIO

Operating Condition	RPM	BHP	Altitude Feet	Mixture Position
Take-Off				
All Models	2600	2515	10,000	"Auto-Rich"
	2600	2550	15,200	"Auto-Rich"
Rated Power (METO)				
All Models	2600	2410	10,000	"Auto-Rich"
	2600	2450	16,400	"Auto-Rich"
Cruise Power Climb				
All Models	2400	1750	10,000	"Auto-Rich"
	2400	1800	22,100	"Auto-Rich"
Alternate Power Climb				
All Models	2500	2080	10,000	"Auto-Rich"
	2500	2140	19,200	"Auto-Rich"
Cruise Power Level Flight and Descent				
All Models except 988TC18EA4, 5, 6	2400	1750	10,000	"Manual Lean"
	2400	1800	20,000	"Manual Lean"
988TC18EA4, 5, 6	2500	1900	10,000	"Manual Lean"
	2500	1950	20,000	"Manual Lean"

NOTES:
1. The powers shown for the altitudes listed define limits of power. Operation above altitudes listed for either supercharger ratio must be limited to the maximum power shown.
2. With Automatic Spark Advance System on the 972TC18DA1, 2; R3350-34, 2600 RPM, must be used for Alternate Power Climb.

TABLE II OF SPECIFIC OPERATING DATA

Operating Condition	Clutch Position	Maximum Cyl. Head Temp. °C	Oil-In Temp. °C			Fuel Pressure		Oil Pressure		
			Min.	Desired	Max.	Min.	Max.	Min.	Desired	Max.
Take-Off	Low	260	40	80-85	104	23	27	65	65-75	100
	High	260	40	80-85	104	23	27	65	65-75	100
Normal Rated Power (METO)	Low	246	70	80-85	104	23	27	65	65-75	90
	High	246	70	80-85	104	23	27	65	65-75	90
Climb, Level Flight, and Descent	Low	232	70	80-85	104	23	27	65	65-75	90
	High	232	70	80-85	104	23	27	65	65-75	90
Ground Operation	Low	260	40	80-85	104	23	27	65	65-75	90

NOTES:

1. Minimum allowable oil pressure at idle speed - 15 psi.
2. Maximum permissible fuel pressure for limited operation when "HIGH" boost pump is required - 35 psi.
3. Maximum recommended cylinder head temperature for normal flight conditions - 215°C.
4. Maximum permissible CAT during use of "HEAT" - 38°C.
5. Water injection control inlet pressure - 25 - 27 psi. (Pressure referenced to carburetor lower deck)

EXAMPLES ON USE OF BEST POWER PERFORMANCE CURVES

Refer to 972TC18DA1, DA2 Performance Curve VI-20

1. Sea Level Performance - Low Blower
   10,000 Foot Performance - Hi Blower

On the low blower sea level calibration curve, find MAP necessary to obtain 1620 BHP at 2300 RPM at sea level with 10% BMEP drop lean mixture and 22°C CAT (7°C above standard).

a. Follow a line parallel to 1600 BHP power drop correction line to 10% power drop.

b. Move horizontally to standard CAT line, then move up slope line to left (CAT variation above standard) to +7°C.

c. Move horizontally to 2300 RPM line and read down to 36.8" Hg. MAP.

NOTE

Auto-Rich mixtures vary from zero to 2% rich power drop in the cruise range. Normally 2% power drop should be used for Auto-Rich when mixture strength is not known.

In determining a similar problem for 10,000 foot high blower, follow the same steps on the 10,000 foot calibration curve.

2. Part Throttle BHP Determination

On the low blower curve, find BHP for 28" MAP/2000 RPM, 9000 ft. pressure altitude, +3°C CAT (6°C above standard), 10% BMEP drop.

a. Construct constant 28" MAP - 2000 RPM line from full throttle through 9000 ft. altitude.

b. Read intersection horsepower - 1200 BHP. This is standard day best power BHP.

c. Correct for CAT. Follow 1200 BHP to +6°C CAT variation intersection. Follow nearest slope to standard. Power corrected for CAT is 1190 BHP.

d. Correct for % power drop. 10% power drop corrects to 1070 BHP.

In developing a constant MAP-RPM slope on the high blower curve the MAP-RPM point obtained from the 10,000 foot calibration curve must be transferred to the 10,000 ft. line on the altitude portion. Except for this difference, the procedure for solution when using the high blower curve is the same as in low blower.

3. Part Throttle MAP Determination

On the low blower curve find MAP necessary to produce 1500 BHP at 7000 ft. using 2200 RPM, 10% BMEP drop with CAT -10°C (11°C below standard).

a. Spot power/altitude/combination on altitude curve

b. Move horizontally to zero power drop and correct for 10% BMEP drop by paralleling nearest correction slope line.

c. Proceed horizontally to standard CAT line. Since the CAT is below standard, parallel right side of the slope line to -11°C.

d. Read the adjusted BHP, and spot this value (1630 BHP) on the altitude performance curve (7000 ft).

e. Draw a constant MAP/RPM line near the adjusted power point. (Draw in 33"/2200 RPM line.)

f. Draw line from 7000 ft/1630 BHP point parallel to 33"/2200 RPM line to sea level or 2200 Full throttle line. Read MAP directly at full throttle or move horizontally to left at sea level to 2200 RPM and read down to 33.2" MAP.

In addition to using the 10,000 foot line in developing the constant MAP-RPM slope for high blower, the last step is from the 10,000 foot altitude rather than the sea level point noted, otherwise, proceed as above.

4. Full Throttle BHP Determination

When full throttle power performance is experienced at higher altitudes than chart values due to the variations in carburetor air temperature from standard altitude conditions and/or ram recovery for installed conditions, the expected BHP may be determined by extending the constant MAP-RPM line for the observed MAP and RPM values beyond the chart limits to the actual pressure altitude.

On the low blower curve find the full throttle BHP for 28" MAP/2400 RPM which is being obtained at 18,500 feet at -20°C CAT (2°C above standard), 10% BMEP drop.

a. Construct constant 28" MAP -2400 RPM line beyond full throttle line to 18,500 feet.

b. Best power indicated BHP is 1625.

c. Move horizontally to 10% power drop and follow closest slope to zero drop, 1460 BHP.

d. Move horizontally to + 2°C CAT and follow temperature correction slope to standard CAT. Expected BHP at observed conditions should be 1455 BHP.

Only values for observed conditions can be determined because variation in CAT at full throttle results in a double correction; the normal change of 2% power per 10°C at constant MAP, and also a change in MAP and power due to change in supercharger rise with temperature variations.

High blower solutions are the same as low blower.

5. Full Throttle MAP and Critical Altitude Determination

On the low blower curve find full throttle MAP and critical altitude at 7% BMEP drop and 1910 BHP/2400 RPM.

a. Follow MAP correction slope from desired lean horsepower (1910 BHP) at right edge of MAP correction curve to 7% power drop. Equivalent best power BHP is 2060 BHP for same MAP at 1910 BHP at 7% power drop.

b. Follow the 2060 BHP line to 2400 RPM intersection on the altitude portion of the curve. MAP = 36.0", critical altitude = 10,600 ft.

NOTE

This results in critical altitude for no-ram; standard CAT condition. Variation in CAT, airspeed and degree of ram recovery will determine change in critical altitude obtainable. As in the Full Throttle BHP determination, the CAT correction is a double effect and the correction scale shown on the curve cannot be used.

High blower solutions are the same as low blower.

CURTISS—WRIGHT CORPORATION

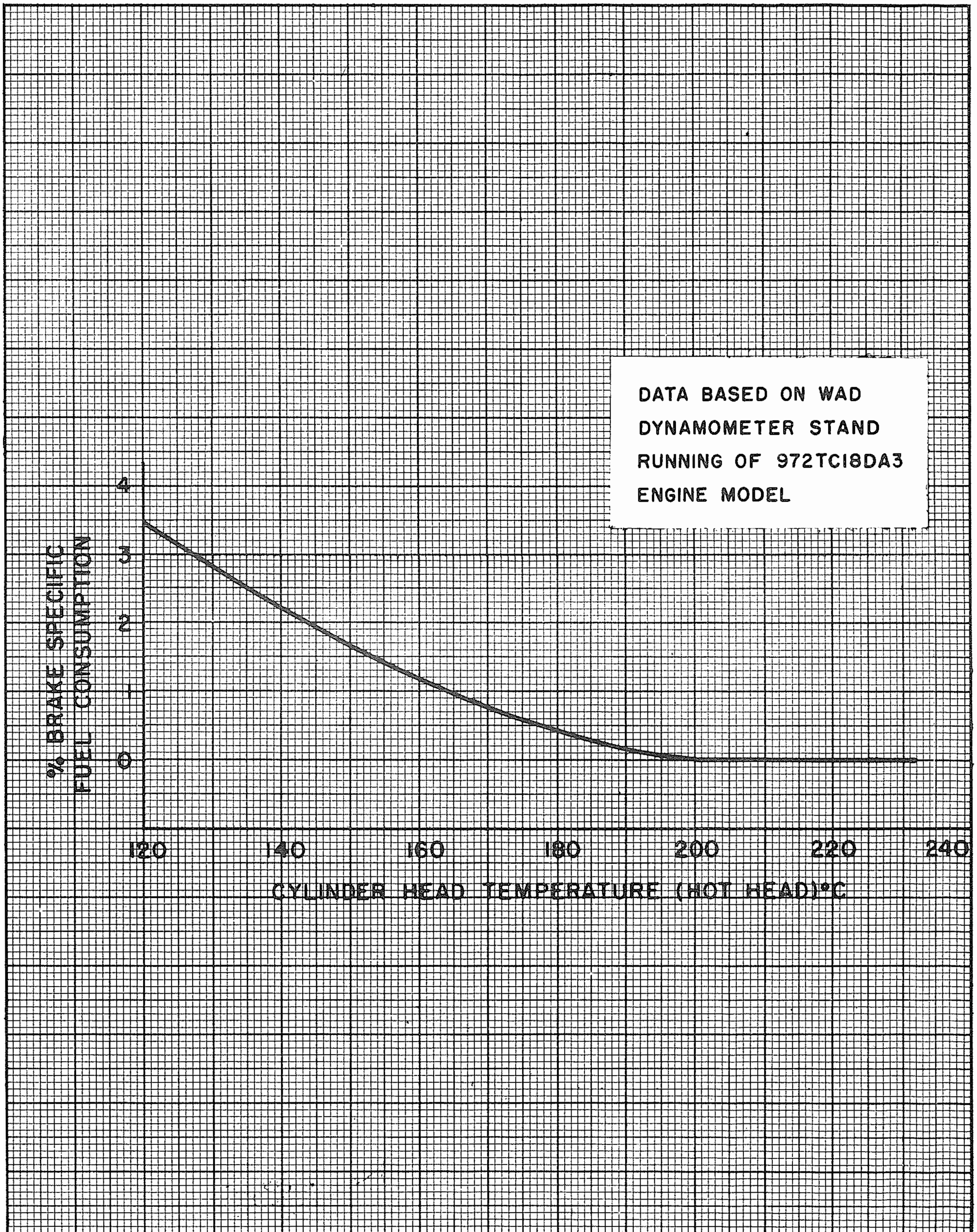
WRIGHT AERONAUTICAL DIVISION

CYLINDER HEAD TEMPERATURE EFFECT ON BRAKE SPECIFIC FUEL CONSUMPTION

DIRECT INJECTION

TURBO COMPOUND ENGINES

APRIL, 1957

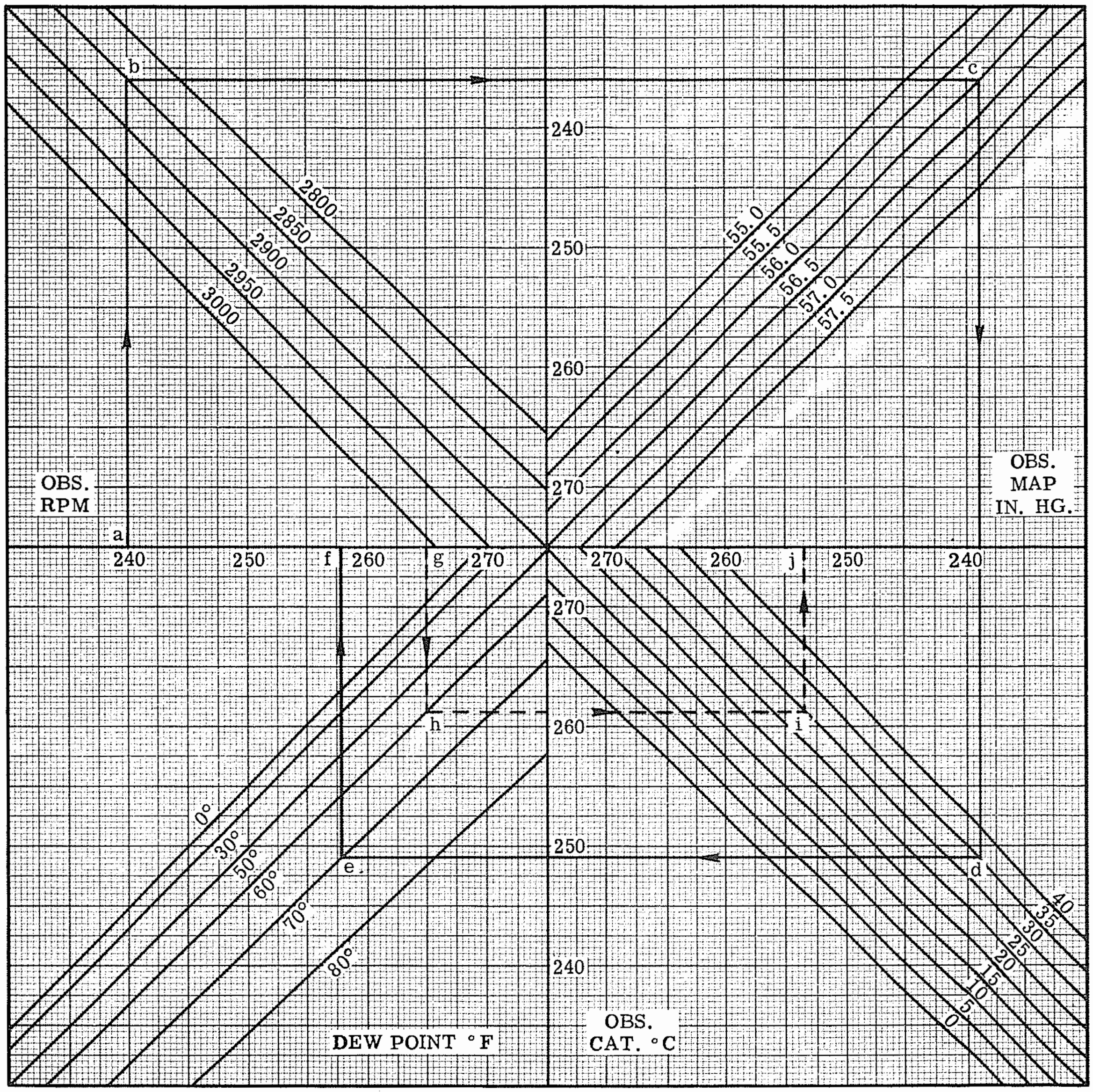


CURTISS-WRIGHT CORPORATION

WRIGHT AERONAUTICAL DIVISION

TAKE-OFF BMEP ACCOUNTABILITY CHART

DIRECT INJECTION TURBO COMPOUND ENGINE 3250 BHP



Example (1)

If the following readings are obtained:

BMEP	240
RPM	2850
MAP	56.0"
CAT	35°C
Dew Point	70°F

Find the corrected BMEP by starting at (a) and correct for RPM, MAP, CAT, and Dew Point ending at (f).

The corrected BMEP is 259, which is the BMEP the engine should produce under standard conditions. Standard conditions are 2900 RPM, 56.5" MAP, 15° CAT, and 50°F Dew Point.

Example (2)

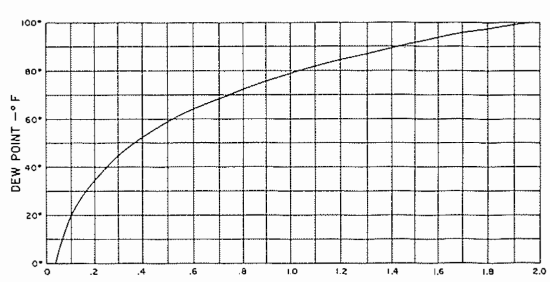
Specification BMEP under standard conditions is 265 BMEP.

Assume Dew Point and CAT are known prior to take-off. If Dew Point is 60°F and CAT is 30°C, the Spec. 265 BMEP can be corrected by starting at (g) and correcting for Dew Point and CAT ending at (j).

The expected BMEP is 253.5 if both 2900 RPM and 56.5" MAP are obtained. With a Dew Point of 60°F, the allowable take-off MAP is 56.7" at sea level. (See "Take-off" Page IV-1)

CONVERSION CHART

VAPOR PRESSURE TO DEW POINT



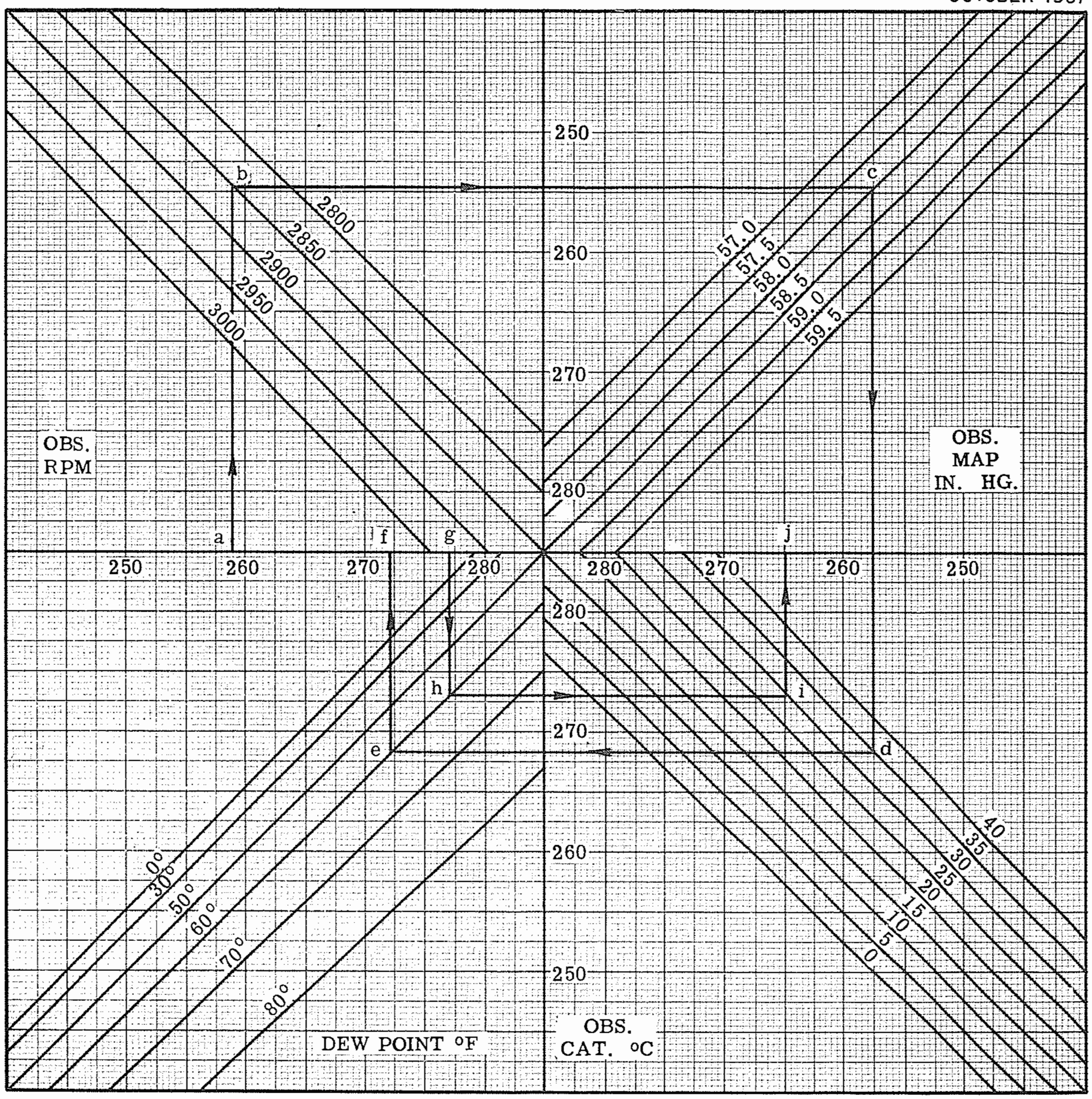
CURTISS-WRIGHT CORPORATION

WRIGHT AERONAUTICAL DIVISION

TAKE-OFF BMEP ACCOUNTABILITY CHART

DIRECT INJECTION
TURBO COMPOUND ENGINE
3400 BHP

OCTOBER 1957



Example (1)

If the following readings are obtained:

BMEP	259
RPM	2850
MAP	58.0"
CAT	35°
Dew Point	60°F

Find the corrected BMEP by starting at (a) and correct for RPM, MAP, CAT, and Dew Point ending at (f).

The corrected BMEP is 272, which is the BMEP the engine should produce under standard conditions. Standard conditions are 2900 RPM, 58.5" MAP, 15° CAT, and 50°F Dew Point.

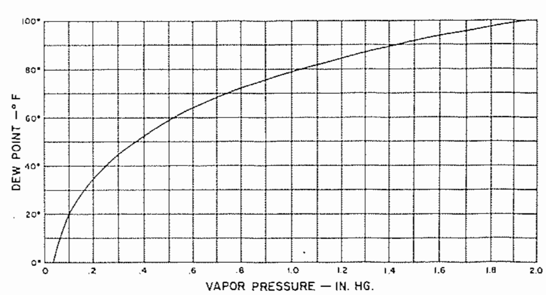
Example (2)

Specification BMEP under standard conditions is 277 BMEP.

Assume Dew Point and CAT are known prior to take-off. If Dew Point is 60°F and CAT is 30°, the Spec. 277 BMEP can be corrected by starting at (g) and correcting for Dew Point and CAT ending at (j).

The expected BMEP is 265 if both 2900 RPM and 58.5" MAP are obtained. With a Dew Point of 60°F, the allowable take-off MAP is 58.7" at sea level. (See "Take-off" Page IV-1)

CONVERSION CHART
VAPOR PRESSURE TO DEW POINT

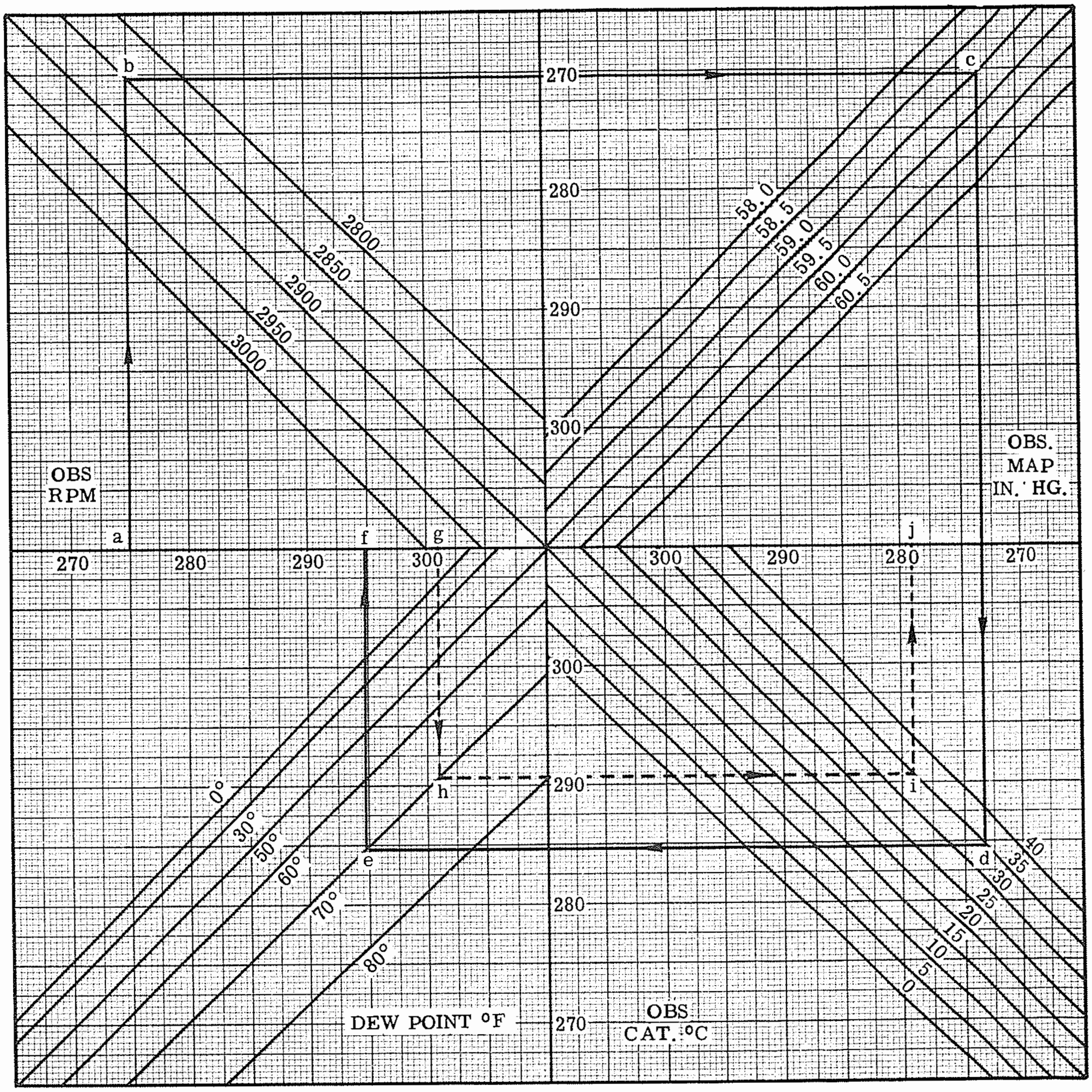


CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

TAKE-OFF BMEP ACCOUNTABILITY CHART

DIRECT INJECTION
TURBO COMPOUND ENGINE
3700 BHP

OCTOBER 1957



Example (1)

If the following readings are obtained:

BMEP	275
RPM	2850
MAP	59.0"
CAT	35°
Dew Point	70°F

Find the corrected BMEP by starting at (a) and correct for RPM, MAP, CAT, and Dew Point ending at (f).

The corrected BMEP is 295, which is the BMEP the engine should produce under standard conditions. Standard conditions are 2900 RPM, 59.5" MAP, 15° CAT, and 50°F Dew Point.

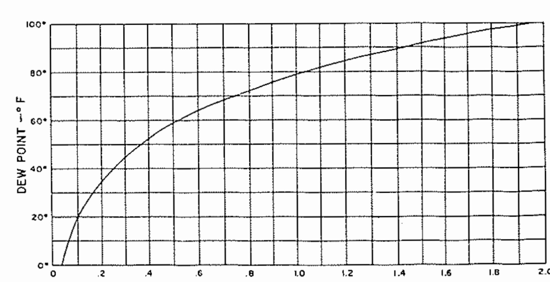
Example (2)

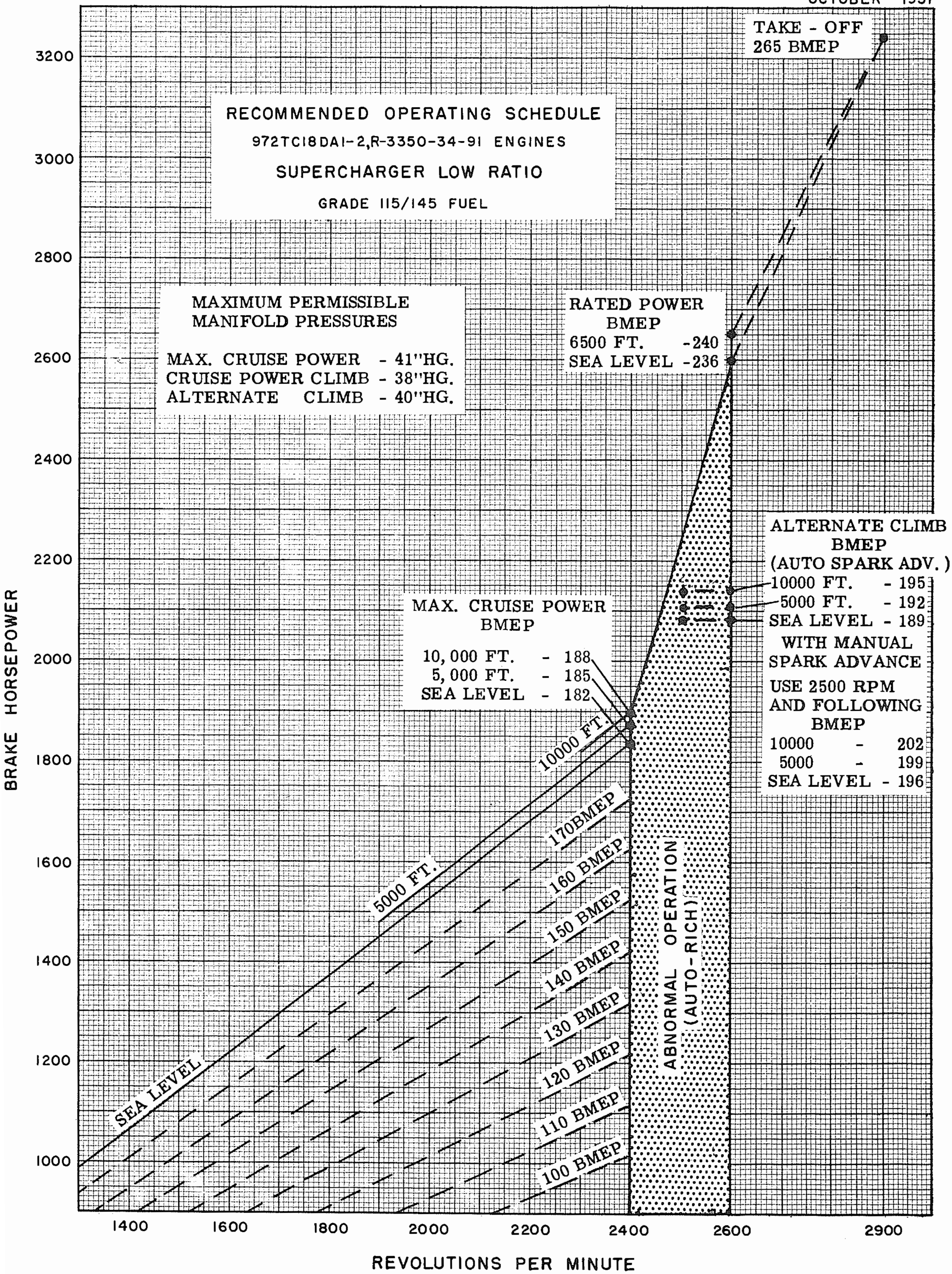
Specification BMEP under standard conditions is 301 BMEP.

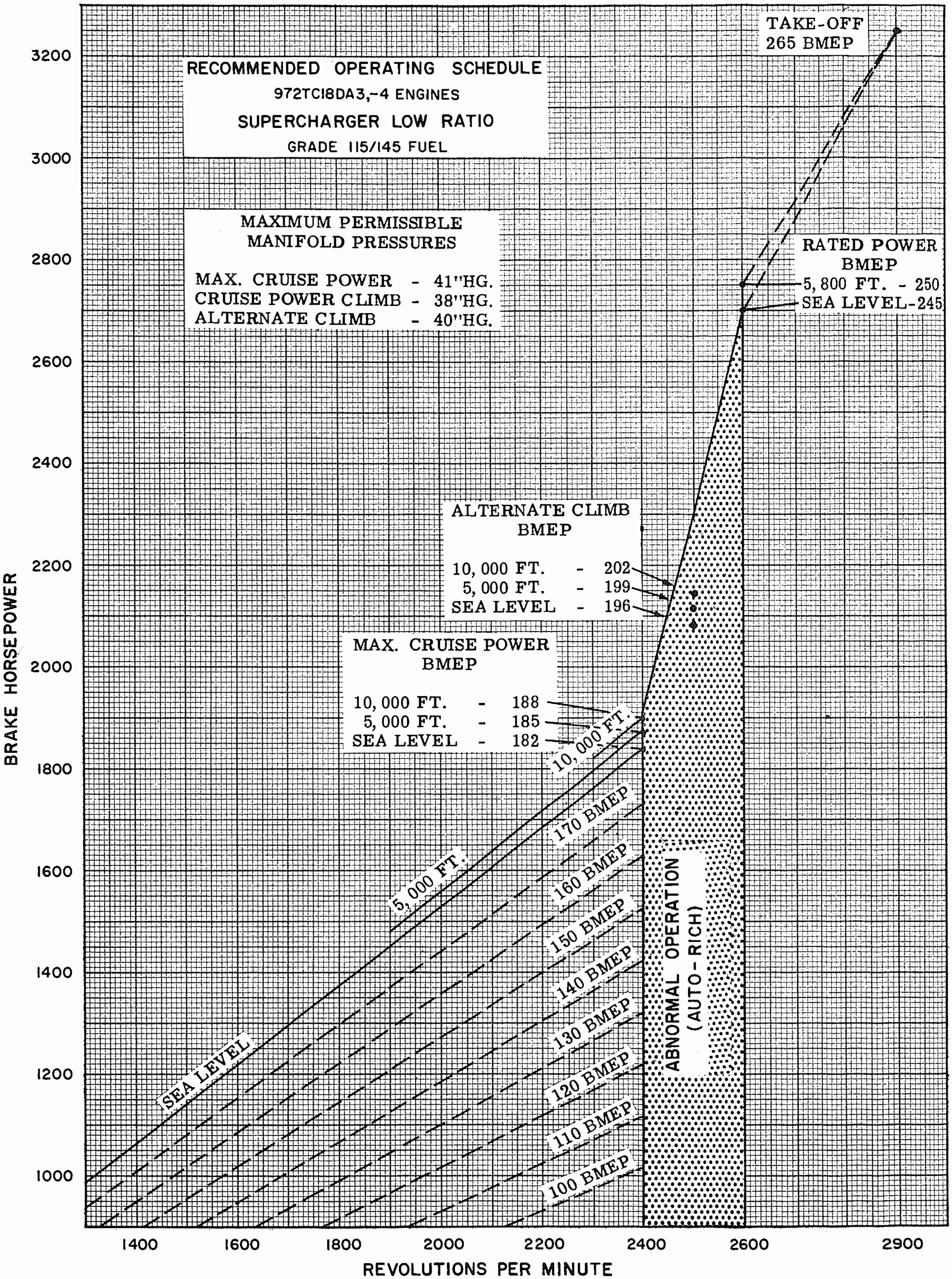
Assume Dew Point and CAT are known prior to take-off. If Dew Point is 70°F and CAT is 35°, the Spec. 301 BMEP can be corrected by starting at (g) and correcting for Dew Point and CAT ending at (j).

The expected BMEP is 279 if both 2900 RPM and 59.5" MAP are obtained. With a Dew Point of 70°F, the allowable take-off MAP is 60.2" Hg. at sea level. (See "Take-off" Page IV-1)

CONVERSION CHART
VAPOR PRESSURE TO DEW POINT

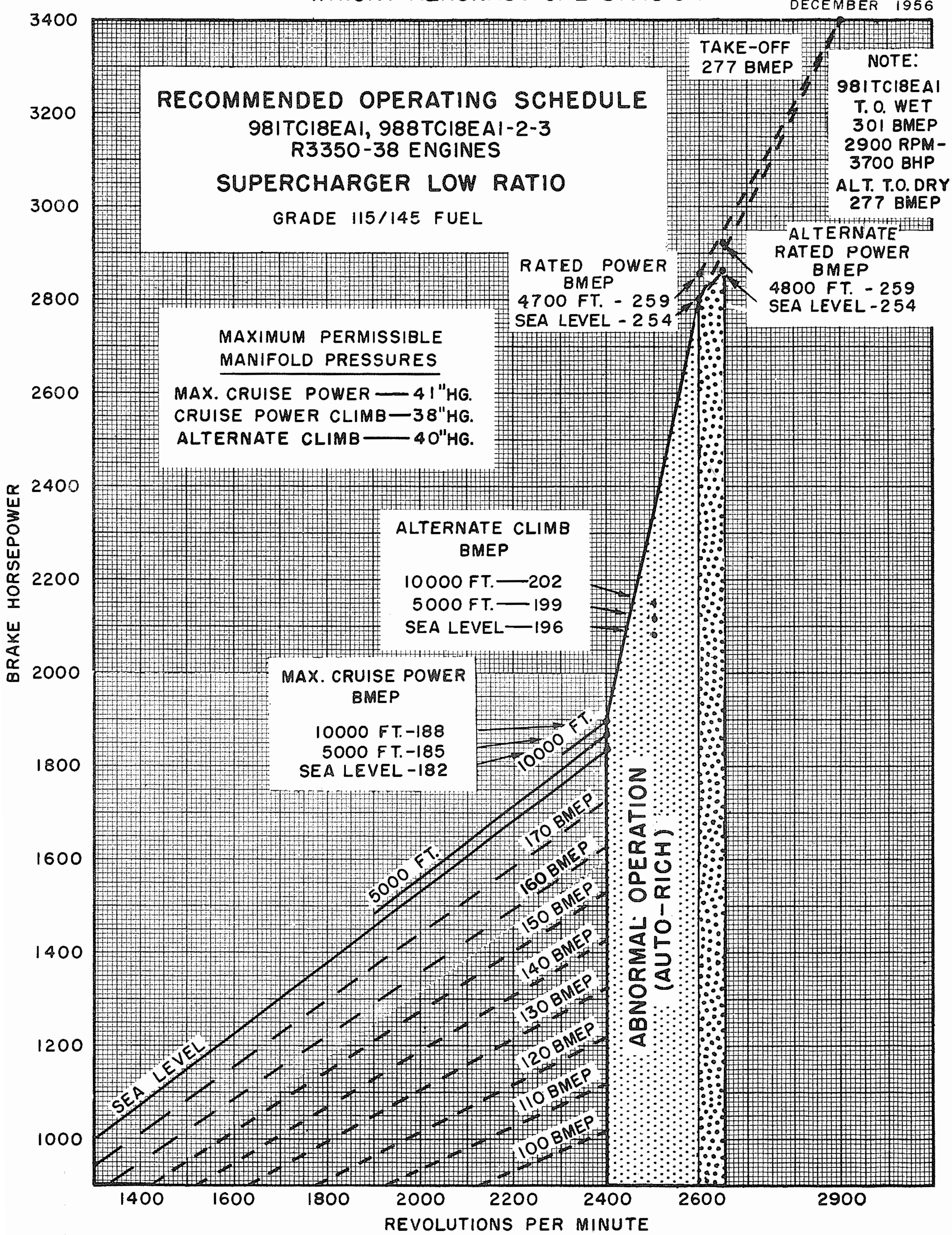


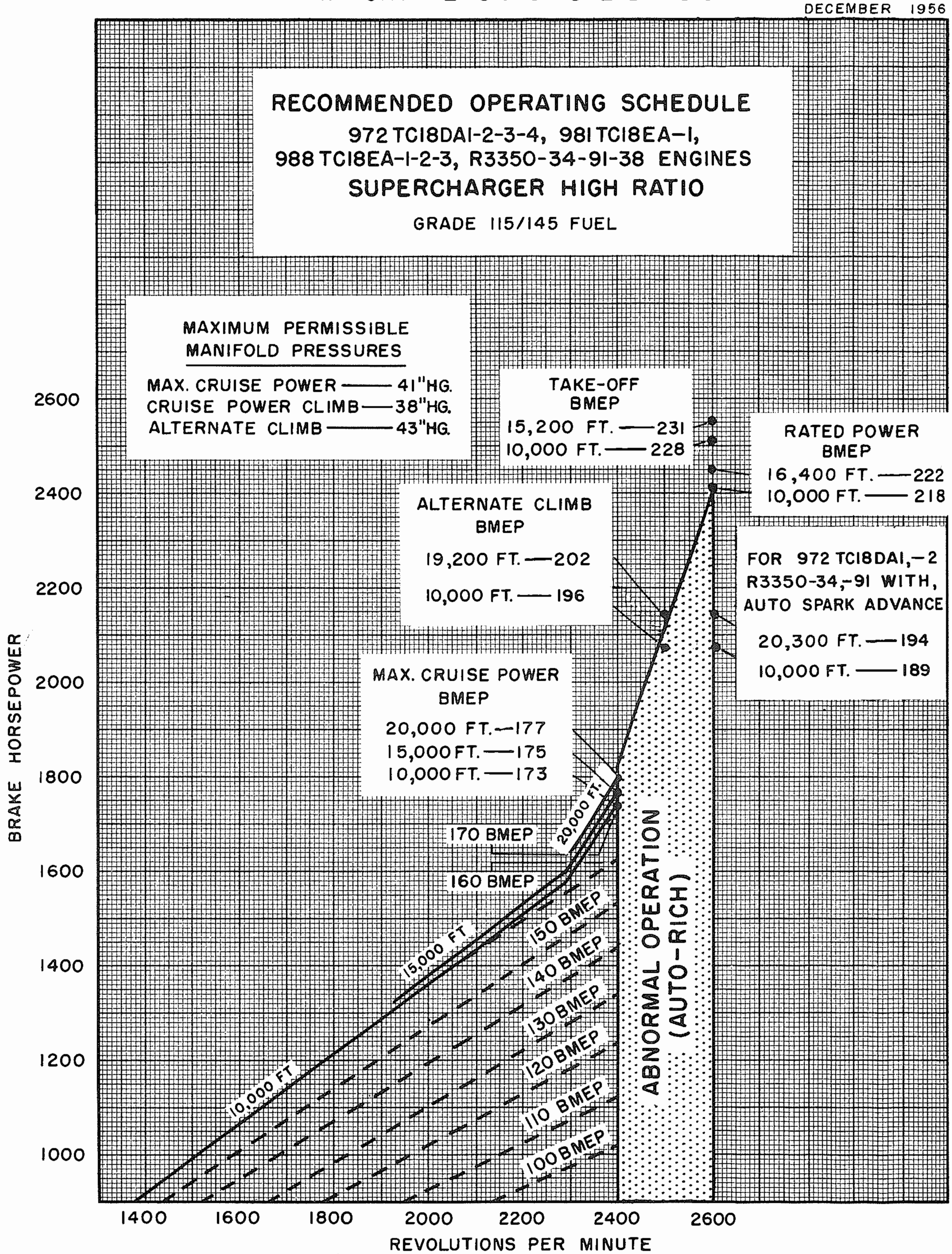

RECOMMENDED OPERATING SCHEDULE
972TC18DA1-2,R-3350-34-91 ENGINES
SUPERCHARGER LOW RATIO
GRADE 115/145 FUEL
TAKE - OFF
265 BMEP
MAXIMUM PERMISSIBLE
MANIFOLD PRESSURES
MAX. CRUISE POWER - 41"HG.
CRUISE POWER CLIMB - 38"HG.
ALTERNATE CLIMB - 40"HG.
RATED POWER
BMEP
6500 FT. -240
SEA LEVEL -236
ALTERNATE CLIMB
BMEP
(AUTO SPARK ADV.)
10000 FT. - 195
5000 FT. - 192
SEA LEVEL - 189
WITH MANUAL
SPARK ADVANCE
USE 2500 RPM
AND FOLLOWING
BMEP
10000 - 202
5000 - 199
SEA LEVEL - 196
MAX. CRUISE POWER
BMEP
10,000 FT. - 188
5,000 FT. - 185
SEA LEVEL - 182
10000 FT.
5000 FT.
SEA LEVEL
170BMEP
160 BMEP
150 BMEP
140 BMEP
130 BMEP
120 BMEP
110 BMEP
100 BMEP
ABNORMAL OPERATION
(AUTO-RICH)
BRAKE HORSEPOWER
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
1400
1600
1800
2000
2200
2400
2600
2900
REVOLUTIONS PER MINUTE


RECOMMENDED OPERATING SCHEDULE
972TC18DA3,-4 ENGINES
SUPERCHARGER LOW RATIO
GRADE 115/145 FUEL
MAXIMUM PERMISSIBLE MANIFOLD PRESSURES
MAX. CRUISE POWER - 41"HG.
CRUISE POWER CLIMB - 38"HG.
ALTERNATE CLIMB - 40"HG.
TAKE-OFF 265 BMEP
RATED POWER BMEP
5,800 FT. - 250
SEA LEVEL-245
ALTERNATE CLIMB BMEP
10,000 FT. - 202
5,000 FT. - 199
SEA LEVEL - 196
MAX. CRUISE POWER BMEP
10,000 FT. - 188
5,000 FT. - 185
SEA LEVEL - 182
10,000 FT.
5,000 FT.
SEA LEVEL
170 BMEP
160 BMEP
150 BMEP
140 BMEP
130 BMEP
120 BMEP
110 BMEP
100 BMEP
ABNORMAL OPERATION (AUTO-RICH)
BRAKE HORSEPOWER
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
1400
1600
1800
2000
2200
2400
2600
2900
REVOLUTIONS PER MINUTE

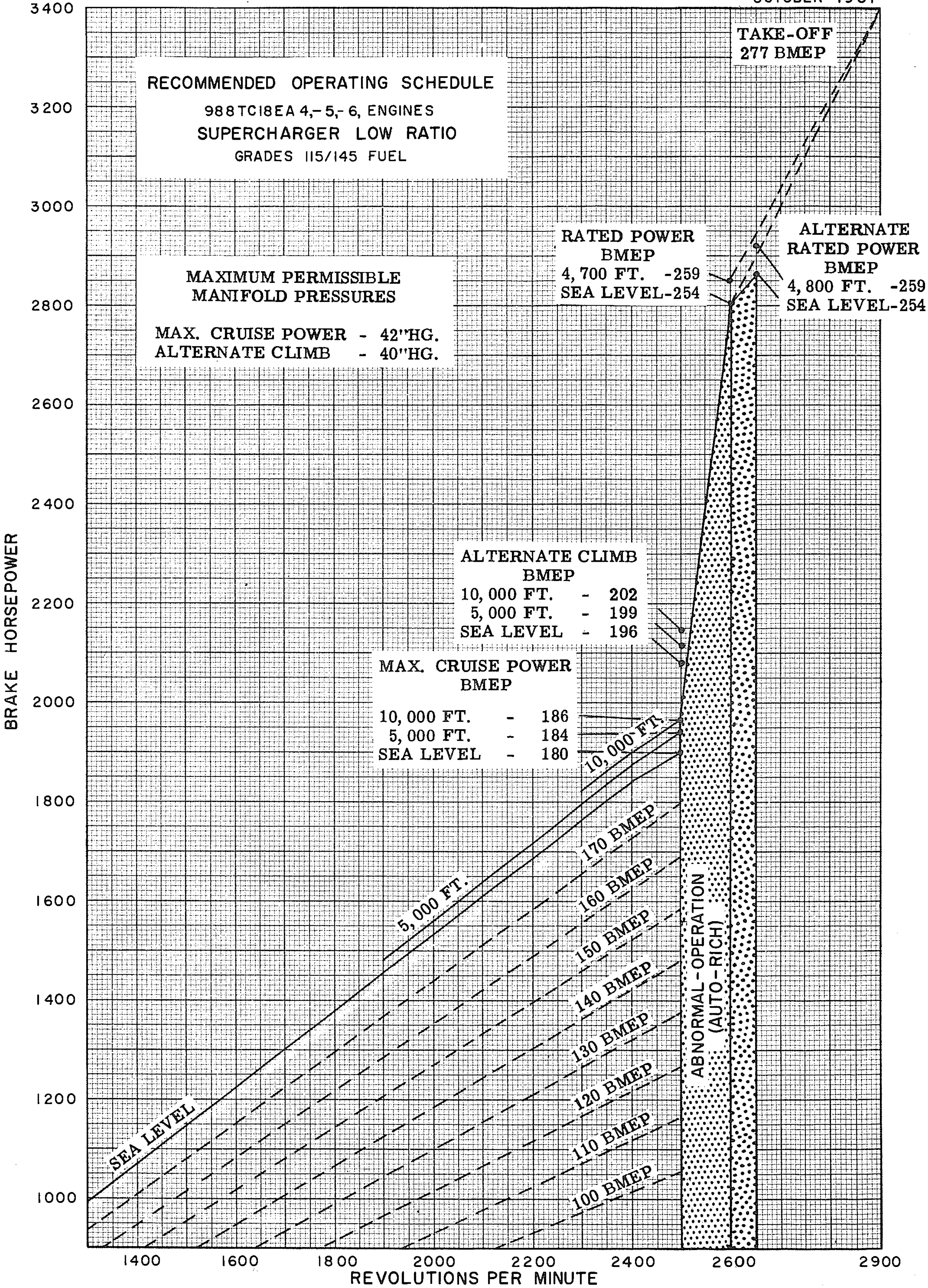
CURTISS-WRIGHT CORPORATION

WRIGHT AERONAUTICAL DIVISION




RECOMMENDED OPERATING SCHEDULE
972 TC18DA1-2-3-4, 981 TC18EA-1,
988 TC18EA-1-2-3, R3350-34-91-38 ENGINES
SUPERCHARGER HIGH RATIO
GRADE 115/145 FUEL
MAXIMUM PERMISSIBLE MANIFOLD PRESSURES
MAX. CRUISE POWER —— 41"HG.
CRUISE POWER CLIMB —— 38"HG.
ALTERNATE CLIMB —— 43"HG.
TAKE-OFF BMEP
15,200 FT. —— 231
10,000 FT. —— 228
RATED POWER BMEP
16,400 FT. —— 222
10,000 FT. —— 218
ALTERNATE CLIMB BMEP
19,200 FT. —— 202
10,000 FT. —— 196
FOR 972 TC18DA1,-2 R3350-34,-91 WITH, AUTO SPARK ADVANCE
20,300 FT. —— 194
10,000 FT. —— 189
MAX. CRUISE POWER BMEP
20,000 FT. —— 177
15,000 FT. —— 175
10,000 FT. —— 173
170 BMEP
160 BMEP
150 BMEP
140 BMEP
130 BMEP
120 BMEP
110 BMEP
100 BMEP
20,000 FT.
15,000 FT.
10,000 FT.
ABNORMAL OPERATION (AUTO-RICH)
BRAKE HORSEPOWER
2600
2400
2200
2000
1800
1600
1400
1200
1000
1400
1600
1800
2000
2200
2400
2600
REVOLUTIONS PER MINUTE

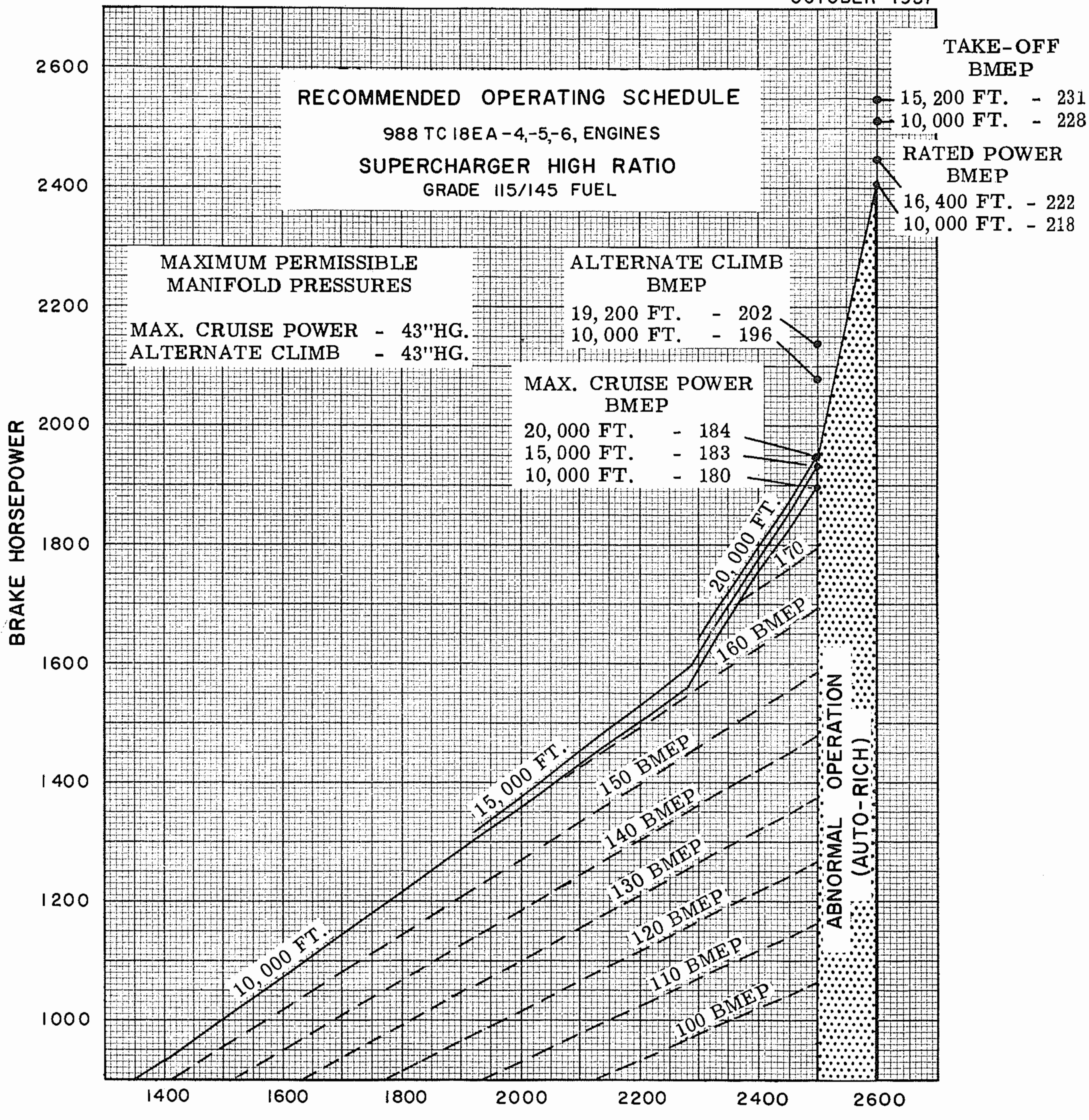
OCTOBER 1957

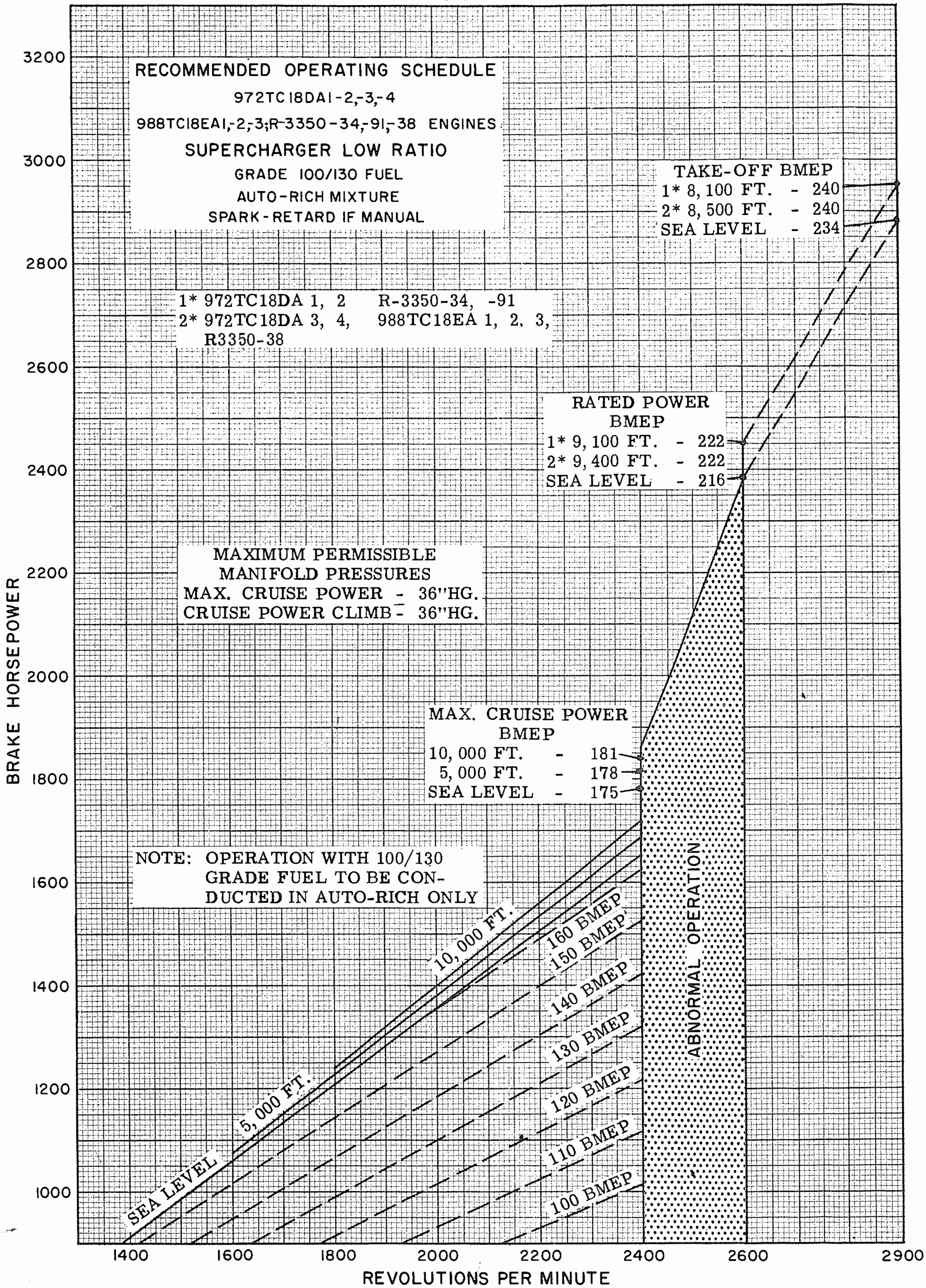


CURTISS-WRIGHT CORPORATION

WRIGHT AERONAUTICAL DIVISION

OCTOBER 1957



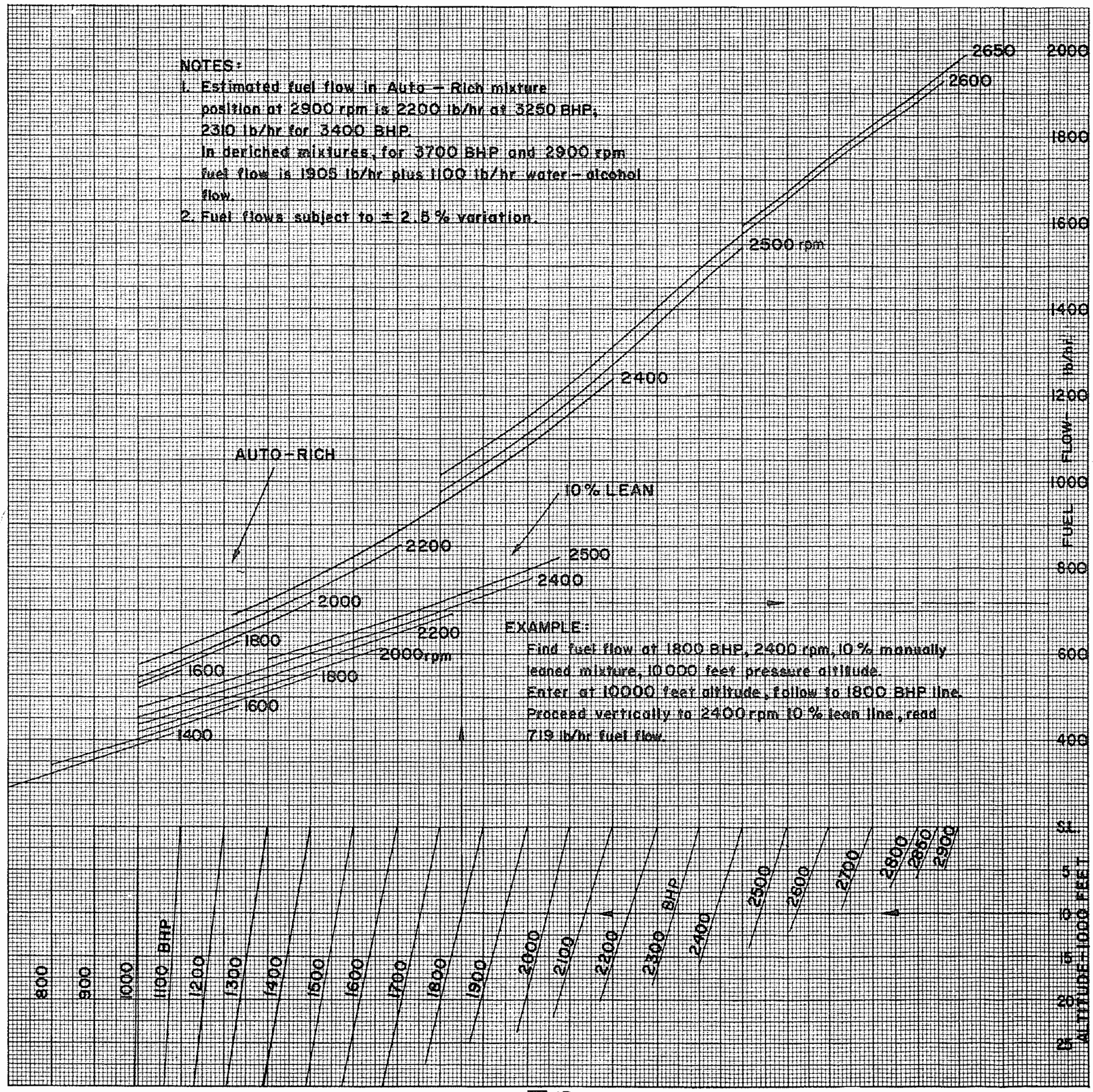

RECOMMENDED OPERATING SCHEDULE
972TC18DA1-2,-3,-4
988TC18EA1,-2,-3;R-3350-34,-91,-38 ENGINES
SUPERCHARGER LOW RATIO
GRADE 100/130 FUEL
AUTO-RICH MIXTURE
SPARK-RETARD IF MANUAL
1* 972TC18DA 1, 2 R-3350-34, -91
2* 972TC18DA 3, 4, 988TC18EA 1, 2, 3, R3350-38
TAKE-OFF BMEP
1* 8,100 FT. - 240
2* 8,500 FT. - 240
SEA LEVEL - 234
RATED POWER BMEP
1* 9,100 FT. - 222
2* 9,400 FT. - 222
SEA LEVEL - 216
MAXIMUM PERMISSIBLE MANIFOLD PRESSURES
MAX. CRUISE POWER - 36"HG.
CRUISE POWER CLIMB - 36"HG.
MAX. CRUISE POWER BMEP
10,000 FT. - 181
5,000 FT. - 178
SEA LEVEL - 175
NOTE: OPERATION WITH 100/130 GRADE FUEL TO BE CONDUCTED IN AUTO-RICH ONLY
10,000 FT.
5,000 FT.
SEA LEVEL
160 BMEP
150 BMEP
140 BMEP
130 BMEP
120 BMEP
110 BMEP
100 BMEP
ABNORMAL OPERATION
BRAKE HORSEPOWER
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
REVOLUTIONS PER MINUTE
1400
1600
1800
2000
2200
2400
2600
2900

CURTISS – WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

ESTIMATED FUEL FLOWS
972TC18DA1, -2, -3, -4; 981TC18EA1; 988TC18EA1, -2, -3, -4, -5, -6
R-3350-34, -38, -91

SEA LEVEL – LOW RATIO

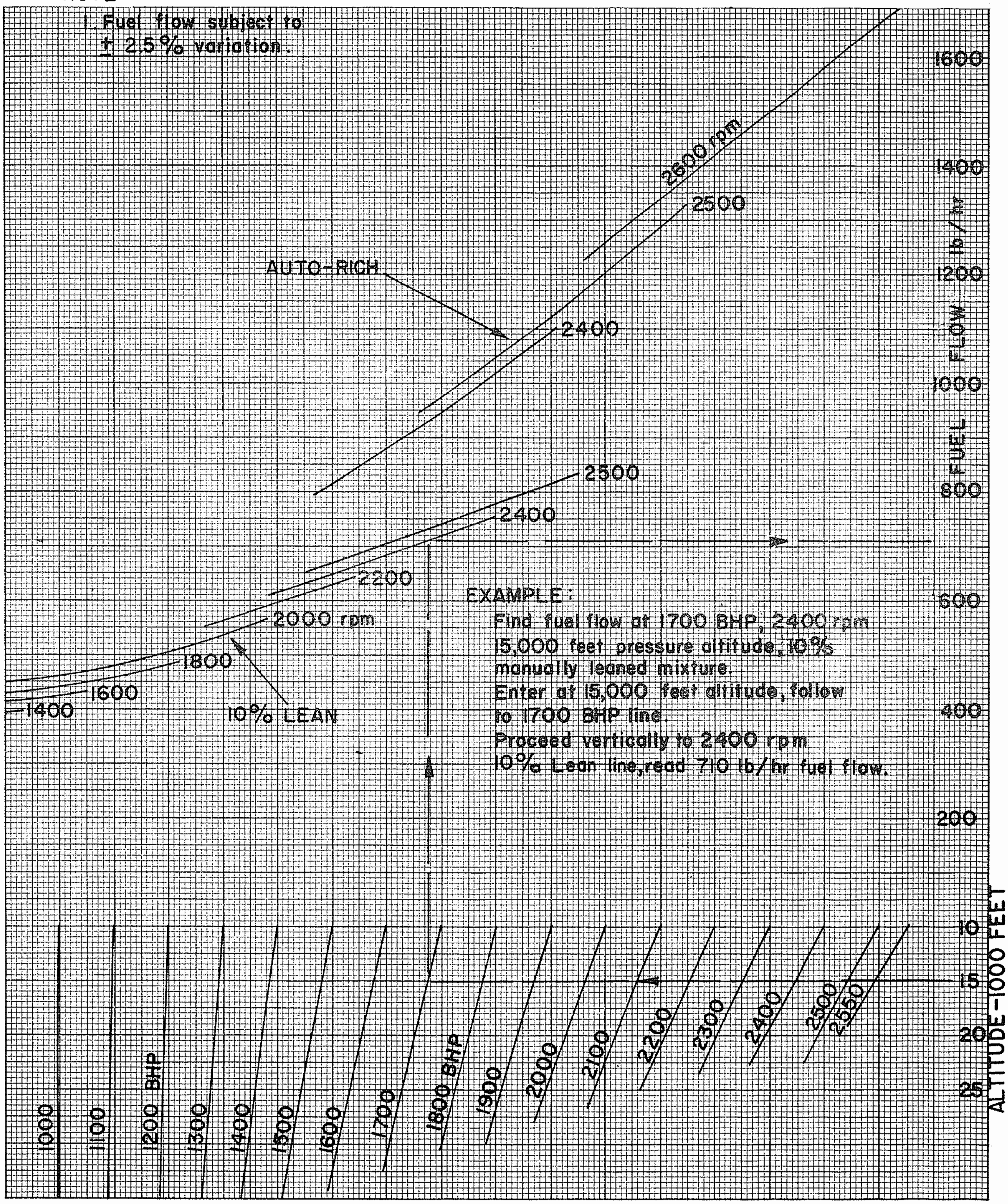
OCTOBER 1957
SP 2046-E



CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION
ESTIMATED FUEL FLOWS
972TC18DA1,-2,-3,-4; 981TC18EA1; 988TC18EA1,-2,-3,-4,-5,-6
R-3350-34,-91,-38
10,000 FEET — HIGH RATIO

OCTOBER 1957
SP-2047-E

NOTE:



GT-56-342a

FIELD ENGINEERING DIVISION REPORT

No. TCI-4 (A)

August 20, 1954
Revised
February 14, 1955

Subject: Alternate Fuel Source

Written By: H. George Jonas

H. George Jonas
Reciprocating Engine Section

H. E. Moerman

H. E. Moerman
Assistant Chief Field Engineer

This report is for information only and does not supersede, cancel, or change applicable engine specification or operating instructions. Inquiries regarding this report should be forwarded to the address shown below.

Field Engineering Division
CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

Wood-Ridge, N. J.

Field Engineering Division Report
No. TCI-4 (A)

FOREWORD:

Under certain weather conditions, icing of the boost hanger, in the throttle body of Master Controls has been experienced. This icing condition can bec severe enough so as to completely close-up the impact tubes which will result in the metering suction differential approaching zero, and fuel flow being drastically redu

The phenomenon at which the Alternate Fuel Source system is directe was first observed and recognized during early operation of the C18BD engine (R3350- in the Constellation 749 (C121) on Eastern Air Lines during the summer of 1947. It manifested by sudden power loss simultaneously on three (3) engines during a rain storm at 19,000 feet with temperature approximately 0°C. Since that time it has bee rather widely observed by operating personnel and has been the subject of a large amount of study, observation and testing, the first of which was conducted in a coor ated effort by Lockheed and Wright immediately after the above incident.

It has been established that application of precautionary procedure prior to entering areas of certain atmospheric conditions will prevent occurence of this trouble. These procedures are outlined in WAD Operation Bulletin No. 18A. It also been found that these precautions, which include application of preheat, simply will not be followed in practice by operating personnel regardless of the emphasis placed thereon. This, it is believed, is because of the consequent loss of critical altitude (preheat plus ram loss) and the necessity for readjustment of power control balanced against the hope that trouble will not be encountered (it frequently is not The problem appears to occur oftener on later engines because, for reasons not fully understood, the engine gives less warning of an impending cutout, and presumably mor operation is conducted in bad weather.

Despite the efforts described herein the exact cause of this phenom enon has never been isolated to WAD satisfaction largely because of the difficulty in reproducing conditions on a flight test basis suitable to its occurence. It is believed to be the result of ice or possibly water in the master control air meterin system which by collecting in critical locations, disrupts the relatively low air fl through the master control metering passages. This causes an immediate and drastic reduction of fuel flow. Since cruise operation is conducted at minimum engine opera mixtures the engine cuts out immediately. Conditions have been observed by Field Engineering Personnel where less than best economy fuel flow was obtained in the Aut Rich mixture position and continuous primer application plus de-icing alcohol (for i fuel value) were required temporarily to obtain minimum operating mixtures. It ordinarily occurs at higher altitudes (circa 15000-20000 feet) possibly because the Automatic Mixture control orifice size varies inversely with altitude. Therefore, t problem does not ordinarily appear on aircraft where operation is normally below 10,000 feet.

Field Engineering Division Report
No. TCI-4 (A)

FOREWORD: (CONTINUED)

This phenomenon should not be confused with impact or refrigerated ice accretion in the induction air passages (airscoop, master control venturii, top deck screen, etc.) which causes a gradual loss of manifold pressure. Either phenomenon can occur with or without the other. Several attempts have been made to develop corrections or compensating features without signal success. Among the things tried are a heating coil in the vicinity of the AMC needle, the NACA undercowl air scoop, several methods of electrically heating the boost hanger plus various other attempts in addition to development of improved alcohol de-icing and carburetor preheat systems. Some of these, such as the undercowl scoop and the shrouded impact tubes have improved the problem by reducing the amount of moisture ingested. However, the changes accomplished as of this date have not eliminated the problem and requests for further improvement have been widespread particularly among operators who must fly at altitude in bad weather.

DESCRIPTION:

Because of the above experience it was considered necessary to develop an auxiliary means of recovering engine power pending relief by application of alcohol and preheat. The Alternate Fuel Source was thus developed and built for the Bendix-Stromberg PR58 series Master Control. Fuel inlet pressure, taken from a "T" at the fuel pressure connection, is applied to the "D" chamber balance diaphragm as shown in the attached schematic diagram. The resulting line is used not for flow but merely to apply rearward pressure to the regulator stem assembly thus artificially opening the poppet valve and compensating for the loss of Metering Suction Differential. A solenoid valve identical to the primer solenoid is incorporated in this line for use in actuating the system. The actual pressure established in the "D" chamber balance system is determined by the pressure release, or flow, across the two bleeds located in the regulator section, i.e., the amount of enrichment obtained is an inverse function of the bleed size. The attached curve shows the amount of enrichment obtained. This enrichment is considered to be optimum. The fuel flow is shown for both Auto-Rich and Auto-Lean with and without the Alternate Fuel Source energized. A fuel flow of 850 lbs. in Auto-Rich position with a zero MSD reading, which is adequate to obtain maximum cruise power, is obtainable. The fuel flow is increased in proportion to any MSD remaining. Having obtained this fuel flow the manual mixture control can be used to lean to the desired fuel flow in the event that the flow is more than required. The attached photographs show the actual installation. The solenoid valve is mounted on a new accelerating pump cover.

In the event that the operator prefers not to use the Alternate Fuel Source, the solenoid and supply lines may be easily removed, and the bleeds in the regulator section may remain without effecting the normal metering characteristic of the master control.

The system is standard equipment on 972TC18DA3 and DA4 engines, and will also be incorporated as standard equipment on the 981 and 988TC18EA1 engines.

Field Engineering Division Report
No. TCI-4 (A)

OPERATION:

It is anticipated that Alternate Fuel Source will be actuated upon encountering the loss of power mentioned above, which ordinarily will occur only when alcohol and/or preheat have not been applied per Operation Bulletin No. 18A and left on only until immediate application of these procedures permits restoration of normal operation. Operation Bulletin No. 35 containing detailed operational information will be published in the near future.

DISCUSSION:

In discussing this system certain comments have been obtained, the answers to which may help to achieve a better understanding of the Alternate Fuel Source. These comments and answers appear in the following paragraphs.

Comment:

In its present form the proposed Alternate Fuel Source duplicates the primer and unnecessarily complicates the metering system.

Answer:

The three-point primer supplies approximately 240#/hr fuel. Assuming Zero MSD (at which the fuel flow is approximately 380#/hr) this would permit a maximum of 620#/hr fuel which is enough to obtain in the vicinity of 1500 BHP at cruise mixtures. At this horsepower level flight could not be maintained at high gross weights. At climb mixture 620#/hr fuel flow would permit about 1200 BHP where, of course, the airplane cannot maintain level flight, much less climb. In determining the minimum fuel requirement for this system WAD believes the airplane should be able to climb using the Alternate Fuel Source after taking some external ice. This means the minimum acceptable fuel flow is that required for approximately 1800 BHP, or 800-900#/hr. Since it is believed that the MSD seldom if ever actually reaches Zero somewhat more fuel will be available, probably enough to operate at alternate climb power. The primer could not possibly fulfill this requirement. Furthermore, only one engine can be primed at a time, and the assistance is often needed on two or more engines at the same time.

To evaluate the possibility of using the Alternate Fuel Source as a primer WAD operated a test rig (involving suitable portions of the metering system) at cranking speed with 25 PSI fuel inlet pressure, and measured fuel flow and injection pump inlet pressure versus throttle angle.

Field Engineering Division Report
No. TCI-4 (A)

Answer (Continued):

Without the Alternate Fuel Source the fuel flow reached 23#/hr at 2^{o} throttle opening and remained constant above that angle. (Idle stop normally set at about 4^{o}). The injection pump inlet pressure was equal to fuel pressure, or 25 PSI. This fuel flow represents the capacity of the injection pump plungers at cranking speed. Application of Alternate Fuel Source would not increase the fuel flow since the pressure into the pumps would not be affected and the plungers were already operating at capacity. Although engine starts have been made without the primer the above fuel flow is not sufficient to permit satisfactory starting especially under low temperature conditions. Also a full scale engine was run through the idle speed range with the Alternate Fuel Source on. Excessively rich mixtures were encountered at all speeds with rich rough engine operation and some torching. At 800 RPM, for example, the airflow was nearly twice its normal value of approximately 1000#/hr, and the F/A ratio was .264. From these tests WAD has concluded that the Alternate Fuel Source cannot be used as a primer because of insufficient fuel flow at cranking speed and excessive fuel flow at idle speeds.

The complication is minor compared to the benefits offered. A standard primer solenoid is mounted on the accelerating pump pad cover and two short flexible lines lead from it to the master control regulator. No installation interferences occur.

Comment:

The proposed system lends itself to complacency on the part of the crew who, having recovered power by its application may overlook the tendency to continued ice build up thus precipitating more serious trouble.

Answer:

This is true both with and without the Alternate Fuel Source. Ice build up can occur with or without causing the instantaneous power failure that this system is designed to correct. We offer here an instrument to recover fuel flow (immediate recovery is usually imperative to avoid loss of altitude) while applying the procedures required to reduce or avoid the more serious trouble. During this period the pilot or flight engineer who has the Alternate Fuel Source is assured of having sufficient fuel flow available to permit manual control of fuel flow and maintain at least maximum cruise power. Proper de-icing procedures can then be carried out without fear of power loss. Complacency that leads to continued ice build up of any kind can be disastrous regardless of any and all facilities provided for ice prevention and in the interests of safety cannot be tolerated. In practical operation the sudden need for application of this system constitutes a sharp warning that all is not well and full protective

Field Engineering Division Report
No. TCI-4 (A)

Answer (Continued):

measures must be taken at once. As pointed out above no such system is necessary if the precautions of Operations Bulletin No. 18A are observed. They are not observed for the reasons indicated and this creates the problem herein discussed. The failure thus can be considered as much human as mechanical.

Comment:

The Alternate Fuel Source supplies a high enough fixed fuel flow so that pilots would be adjusting the throttle to obtain maximum BMEP and could obtain lean mixtures unintentionally. Detonation might be encountered.

Answer:

This is true any time icing is encountered and flight crews must be trained to avoid it. If interruption of fuel flow occurs at alternate power climb, for example, the mixture could become lean to the point of detonation without an Alternate Fuel Source. Application of Alternate Fuel Source under these conditions would permit recovery of the lost fuel flow. Insofar as cruise operation is concerned we already operate at best economy mixtures below which the engine will not run and detonation is not a problem. There is no alternative to reliance upon flight crews to set proper power and mixtures.

During operation should the alternate fuel system be used inadvertently the engine will not drown out although leaning might be necessary to maintain stable operation. This situation can best be detected by sudden enrichment of individual engine fuel flows.

Ground checking of the alternate fuel system may be accomplished by energizing the cockpit solenoid switches and noting rate of enrichment of individual fuel flows.

Conversion kits will be available for 972TC18DA1, DA2, and R3350-34 engines. For complete rework instructions refer to Bendix Aircraft Carburetor Service Bulletin No. 784.

RECOMMENDATIONS:

Although fuel flow can be maintained if normal metering is destroyed due to icing conditions, every effort must be excercised to restore normal metering (MSD) at all times that the Alternate Fuel Source is in operation, in accordance with recommendations described in Operation Bulletin No. 18A.

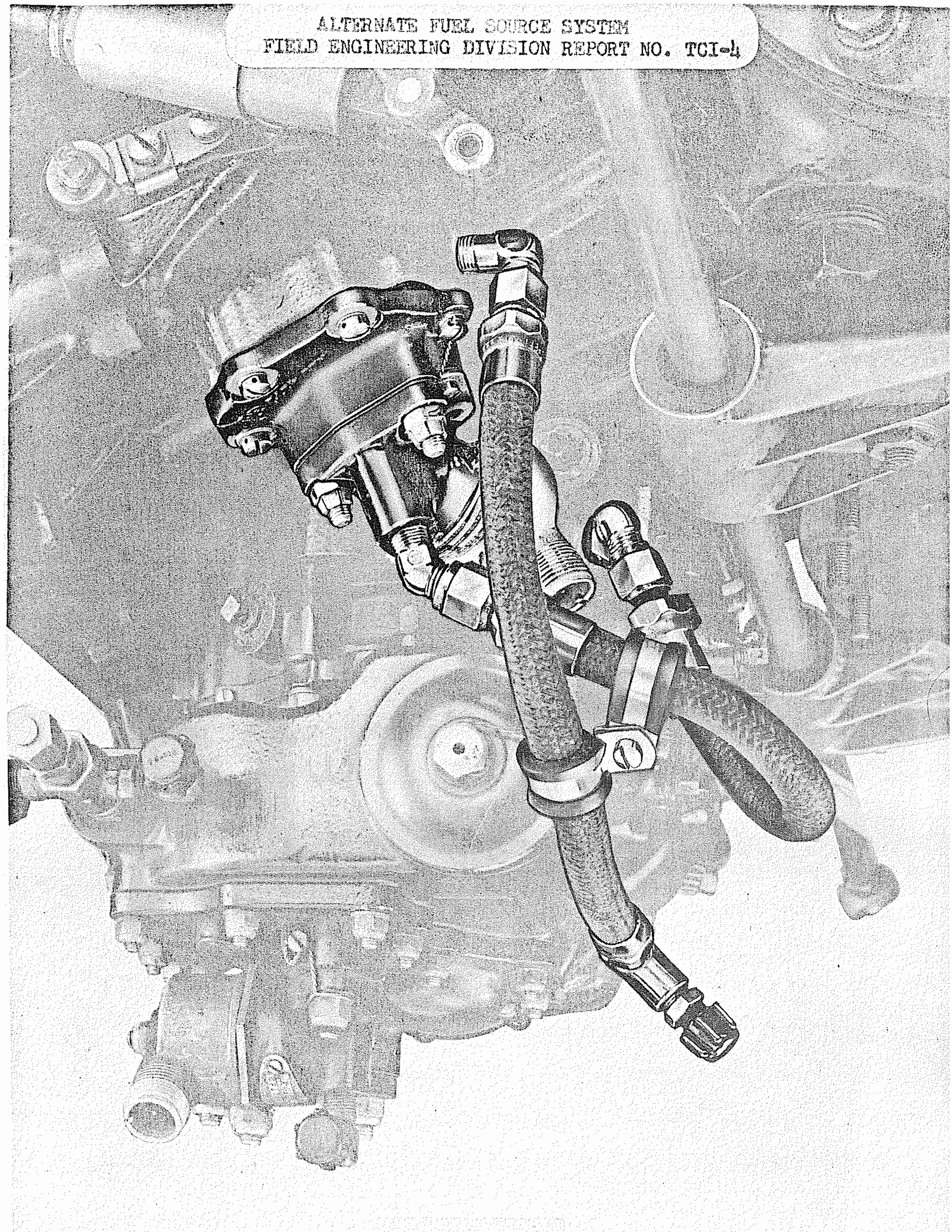
Field Engineering Division Report
No. TCI-4 (A)

)NCLUSIONS:

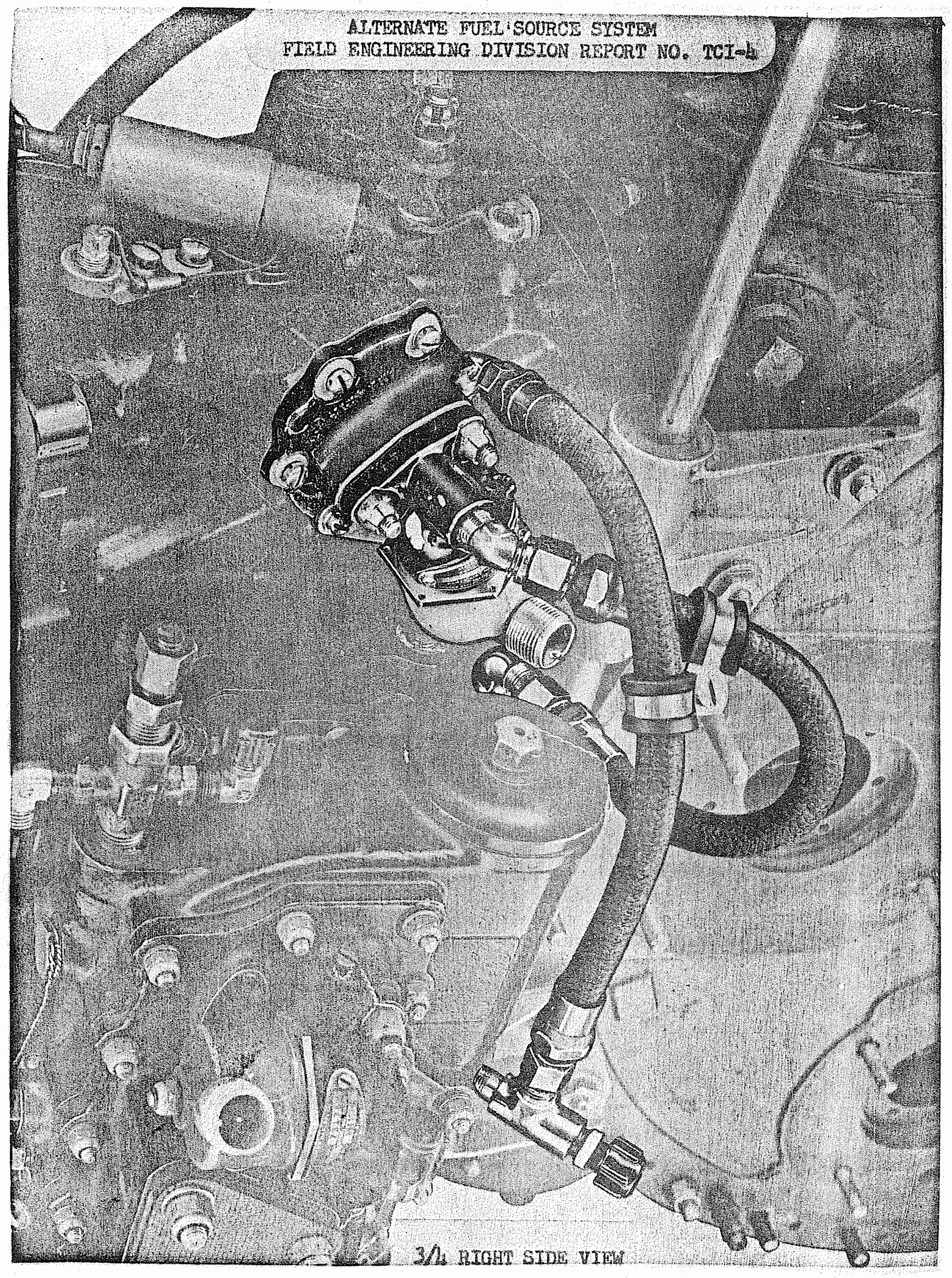
1. The Alternate Fuel Source satisfactorily supplies fuel flow necessary to operate at maximum cruise powers.

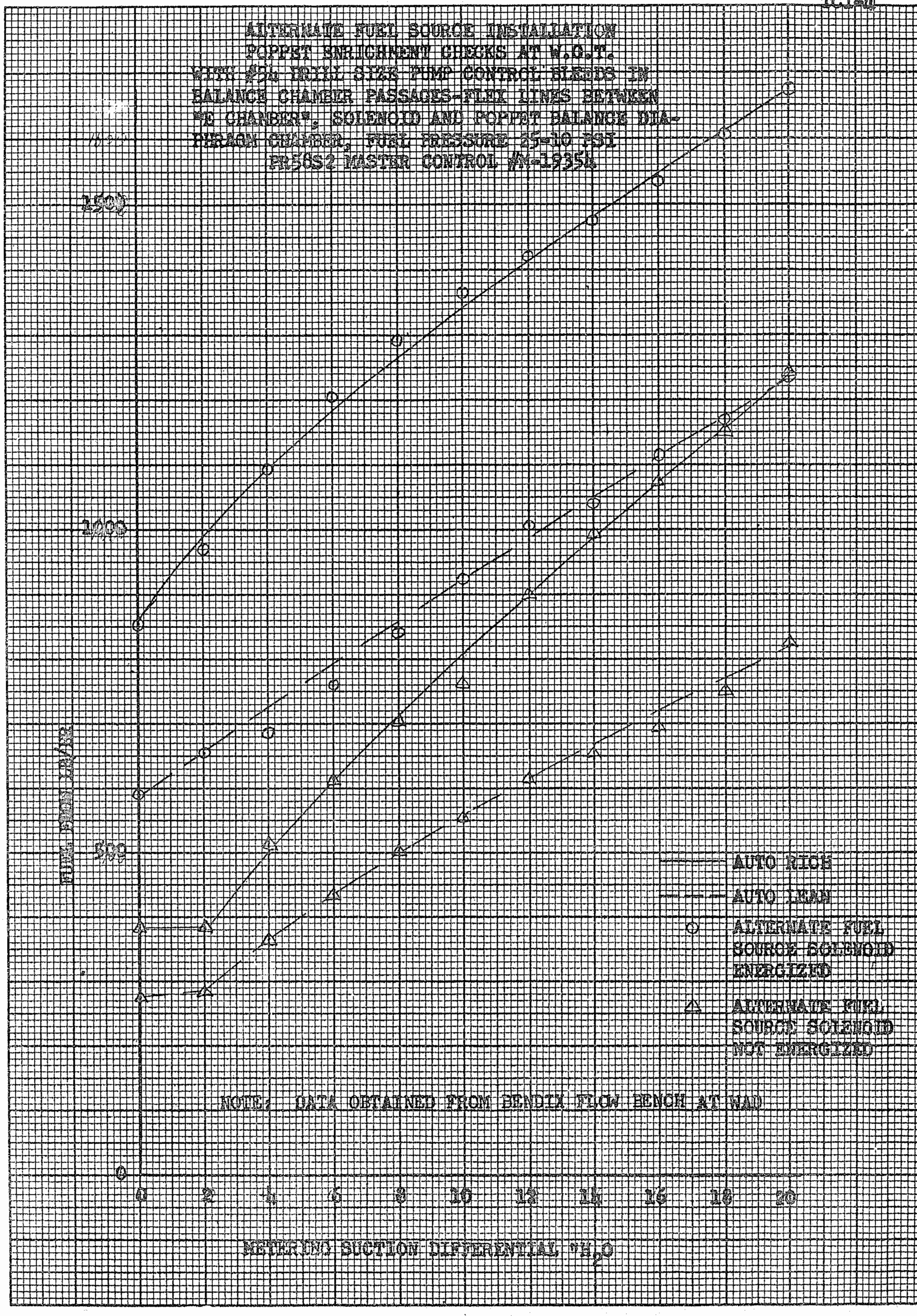
2. Alternate fuel systems may be installed on all Wright engines employing Bendix-Stromberg PR58 series Master Controls.

GJ/HEM/eor
ttachments



RIGHT SIDE VIEW


ALTERNATE FUEL SOURCE SYSTEM
FIELD ENGINEERING DIVISION REPORT NO. TCI-4
3/4 RIGHT SIDE VIEW


ALTERNATE FUEL SOURCE INSTALLATION
POPPET ENRICHMENT CHECKS AT W.O.T.
WITH #34 DRILL SIZE PUMP CONTROL BLEEDS IN
BALANCE CHAMBER PASSAGES-FLEX LINES BETWEEN
"E CHAMBER", SOLENOID AND POPPET BALANCE DIA-
PHRAGM CHAMBER, FUEL PRESSURE 25-10 PSI
PR58S2 MASTER CONTROL #N-19354
1500
1000
500
0
FUEL FLOW LB/HR
AUTO RICH
AUTO LEAN
ALTERNATE FUEL SOURCE SOLENOID ENERGIZED
ALTERNATE FUEL SOURCE SOLENOID NOT ENERGIZED
NOTE: DATA OBTAINED FROM BENDIX FLOW BENCH AT WAD
0
2
4
6
8
10
12
14
16
18
20
METERING SUCTION DIFFERENTIAL "H2O

GT-56-339a

FIELD ENGINEERING DIVISION REPORT

No. TCI-2

July 19, 1954

Subject: The Effect of Fuel Air Distribution on 972TC18DA1, 972TC18DA2, and R3350-34 Engine Operation

Written By George Ripley
George Ripley
Operations Section

Field Engineering Division
CURTISS WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

Wood-Ridge, N. J.

Field Engineering Division Report
No. TCI-2

FOREWORD:

A recent analysis conducted at WAD has indicated that an improvement in combustion chamber service life can be expected if strict control is maintained as to fuel-air distribution between the front and rear row of cylinders on DA and TC18-34 engines. A survey of a number of combustion chamber failures experienced in DA engine operation indicated row to row distribution to be a contributing factor as to the cause of several types of such failures. Improper distribution can be determined by a close check of the front and rear row cylinder head temperature spread relationship between auto-rich and 10% BMEP drop mixture settings at a constant RPM and BHP. When dual cylinder head indicators are not available a relationship of the cylinder head temperature change characteristics between auto-rich and 10% BMEP drop mixture settings may be used as a basis on which to trouble shoot an engine for unequal distribution. The thermocouples on the Douglas DC-7 aircraft are installed on No. ~~17~~ 3 and 18 cylinders while on the Lockheed L1049 resistance bulbs are installed on No. 1 and 2 cylinders. The information in this report applies to both installations.

CONCLUSIONS:

1. The use of any leaning procedure which results in greater than a 10% power drop below best power can cause substantial power differential between the two rows of cylinders when any distribution tolerances are present. The leaner the engine the greater this differential. When a differential exists, the rich row of cylinders may be overloaded substantially by use of a "super lean" procedure, and this has been confirmed by service experience.

2. When a "super lean" procedure is used, the magnitude of the overload of the rich row of cylinders can be equivalent to an overboost condition of the engine by as much as 150 - 200 BHP without noticeable change in observed MAP - fuel flow or BMEP. By the same token the lean row is underboosted by a like amount since a constant BHP is being taken out of the propeller shaft of the engine.

3. The substantial overloading of either one row of cylinders or the other can be determined by observation of the cylinder head temperature gage during level cruise operation.

a. With equal distribution the rear row CHT as measured should read 10-15°C higher than the front row CHT when the engine is operated at 10% manual lean. The rear row auto-rich temperature should approximately equal the 10% power drop rear row temperature.

b. If an excessive rear row rich condition exists, the rear row temperature will be more than 25°C in excess of the front row temperature when the engine is operated at 10% power drop accompanied by a shift of the hot head temperature to the front row when the engine is operated in auto-rich. The rear row CHT when operated at 10% power drop should be no more than 15°C higher than the auto-rich rear row CHT.

c. If an excessive front row rich condition exists, the front row CHT will be higher than the rear row temperature when the engine is operated at a 10% power drop accompanied by a shift of the hot head to the rear row when operated in auto-rich. The rear row CHT when operated at 10% power drop should be no more than 15°C lower than the auto-rich rear row CHT.

Field Engineering Division Report
No. TCI-2

CONCLUSIONS: (CONT'D)

Note: a, b, and c are illustrated on Curve 1 of this report.

RECOMMENDATIONS:

1. That the practice of leaning in excess of a 10% power drop during cruise operation be discontinued and all mixture operation be in accordance with WAD operations bulletins.

2. That engines which show signs of unequal distribution be investigated and corrected if necessary.

3. That the flight logs and operational history of engines which show predominant damage (piston strut cracking or valve and piston burning) in one row of cylinders be checked for any signs of unequal or improper fuel air distribution by each operator.

George Ripley

GR:rvp
Encls.

Field Engineering Division Report
No. TCI-2

DETAILED REPORT

1. Cylinder head temperature patterns obtained from various DA engines by running constant horsepower mixture control curves have indicated that uneven row to row fuel air distribution can cause an unequal power loading between the front and rear row of cylinders. As can be seen from Curve 1, when unequal distribution is present, the lean row of cylinders quickly peaks at best power and attains its maximum temperature at too rich an overall engine fuel air mixture. Further leaning of the mixture causes the lean row to drop power quickly even though the rich row may not yet have even reached its best power peak. This can easily be seen by the temperature characteristics on Curve 1. The more the mixture is leaned on an engine with marginal or poor distribution, the more the rich row becomes overloaded. This becomes more critical on compound engines than on non-compound engines, due to increasing turbine power recovered as the engine is leaned; it is possible to operate the engine at much greater percents of power drop (leaner fuel air mixtures) than before.

Realizing that uneven row to row fuel air distribution can cause an unequal power loading between the front and rear row of cylinders; a study has been made to determine the magnitude of overload imposed on the rich row of cylinders on the DA engine at various mixture strengths.

A curve of manifold pressure rise vs. fuel air ratio for a standard DA engine was obtained from WAD test stand data (Sea Level - 1840 BHP @ 2400 RPM). This was plotted (Curve 2) along with dotted lines to represent calculated fuel air ratios which would be obtained at varying degrees of unequal fuel injection pump synchronization, at various values of MAP rise above best power. Since a mixture spread between rows also means a power spread between rows, we can proceed to determine from this curve, the extent of such power spread at any given combination of mixture spread and MAP rise, by merely noting the total differences in MAP requirement to obtain max. cruise power with the mixtures in question and then converting this MAP difference to horsepower, as indicated. In other words, the rich bank of cylinders is being overboosted in power by an amount equivalent to the MAP increment between the actual operating MAP rise and F/A combination and the mean curve for the corresponding mean F/A and MAP rise combination. Conversely the lean bank is being underboosted the amount represented by the MAP increment from the lean bank F/A and actual MAP rises to the corresponding mean F/A and MAP rise combination. Since an increase of 1 inch of MAP represents 66 BHP on the overall engine the BHP difference between the lean row and rich row can be calculated by multiplying the effective row to row MAP spread by 66/2. See example on Curve 2. The rich and lean row BHP can therefore be calculated for any operating mixture strength.

Since the row BHP obtained above included both turbine horsepower and the effect of supercharger horsepower increase it is necessary to add supercharger BHP increase and remove the total turbine BHP in order to arrive at the basic BHP of the engine and thus the individual bank BHP. Information was obtained from test stand data on supercharger and turbine BHP. With this information it was possible to determine the basic engine BHP and individual

DETAILED REPORT (CONT'D)

bank cylinder BHP's for any operating mixture condition. From this information and Curve 3 a plot of rich row cylinder overload was prepared. This plot appears in this report as Curve 4, and the extent of cylinder overload or equivalent total cylinder BHP overboost can be determined for any degree of uneven fuel injection pump distribution and operating percent of power drop or mixture strength.

2. Recently the operational history of a number of engines whose primary causes for premature removal had been due to either piston or valve burning was checked. The flight logs of these engines were surveyed to see whether any operational discrepancies could be noted prior to the actual failure with particular emphasis on row to row power spread as indicated by cylinder head temperature indication.

Of the engines reviewed, in all cases where it was possible to predict that one row of cylinders was rich, the failure always occurred in the rich row whether it was front or rear. This indicates that the power differential between banks present with marginal distribution coupled with a practice of leaning the mixtures to BMEP drops in excess of 10% is sufficient to cause a heat failure in the rich row during max cruise operation.

To further bear out these findings, a check was made on these same engines on the pistons which were replaced at overhaul after the failure. It was noted that piston strut cracking was most predominant in the rich row and very little or no cracking ever occurred in the lean row. On some engines whose operational histories were not available, it was found that the failure always had occurred in the same row in which this strut cracking was predominant further correlating the power differential.

3. Unequal distribution can be detected by a check of cylinder head temperature characteristics and spreads between rows by a check in the rich range versus a check in the lean range as is illustrated on Curve 1. This is true because if exact distribution is present, both rows of cylinders achieve both their best power and peak temperature points at the same overall engine fuel air ratios. As can be seen from Curve 1, if this relationship does not hold true then it is an indication of poor distribution and the discrepancy should be corrected.

Since most of the engines involved in the survey were from aircraft equipped with a single thermocouple on the rear row of cylinders, the method used in determining the rich row of cylinders was as follows. If an engine during lean cruise operation consistently required noticeably less cowl flap opening to maintain the same CHT as the other engines and more cowl flap opening during rich climb, then that engine was classified front row rich. Conversely if more cowl flap was required in cruise and less in climb then that engine was classified rear row rich. When engines with dual gages were involved the method used was checking for excessive CHT spread in the low range accompanied by the characteristic switch over of the hot head during rich climb operation.

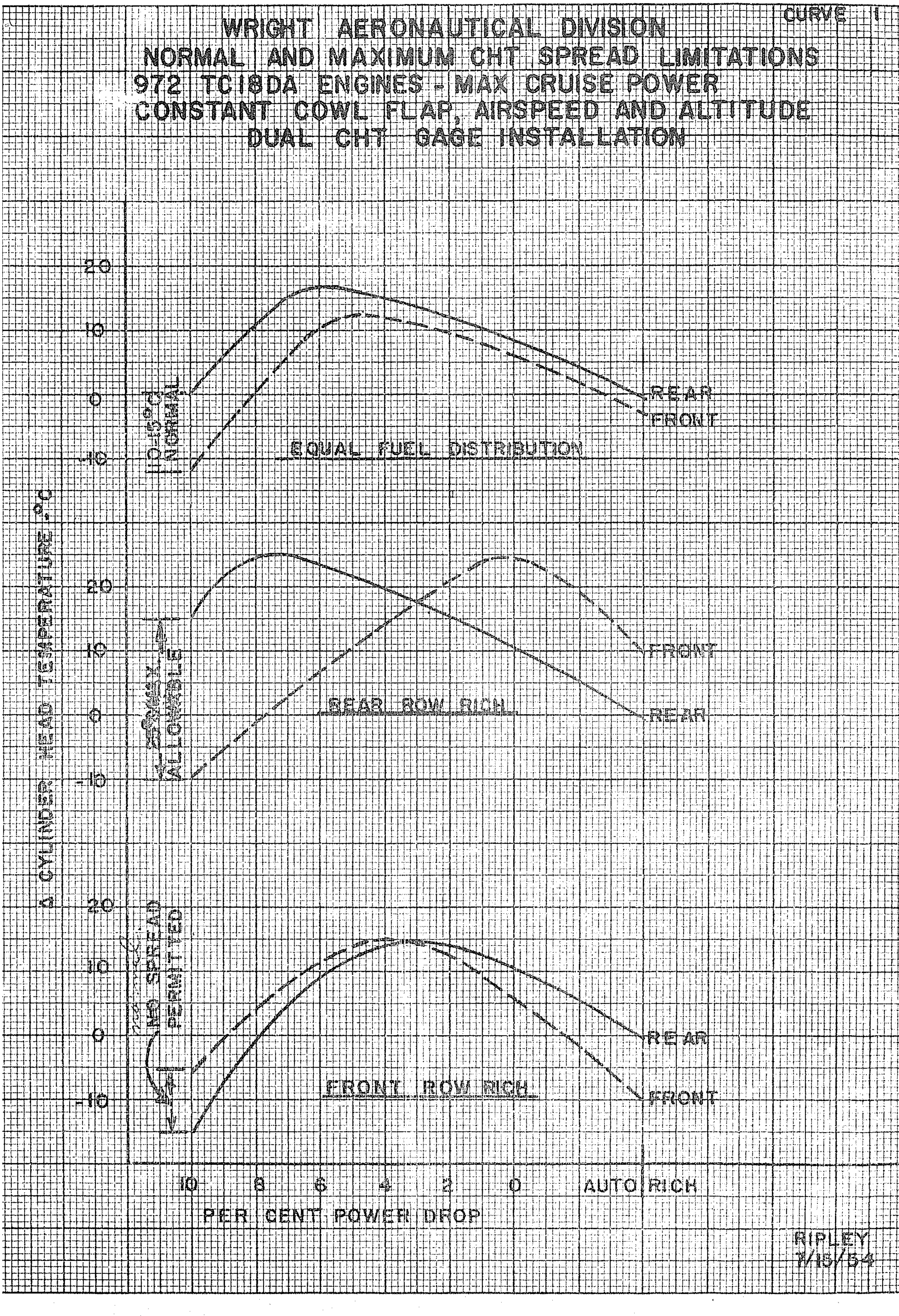
Field Engineering Division Report

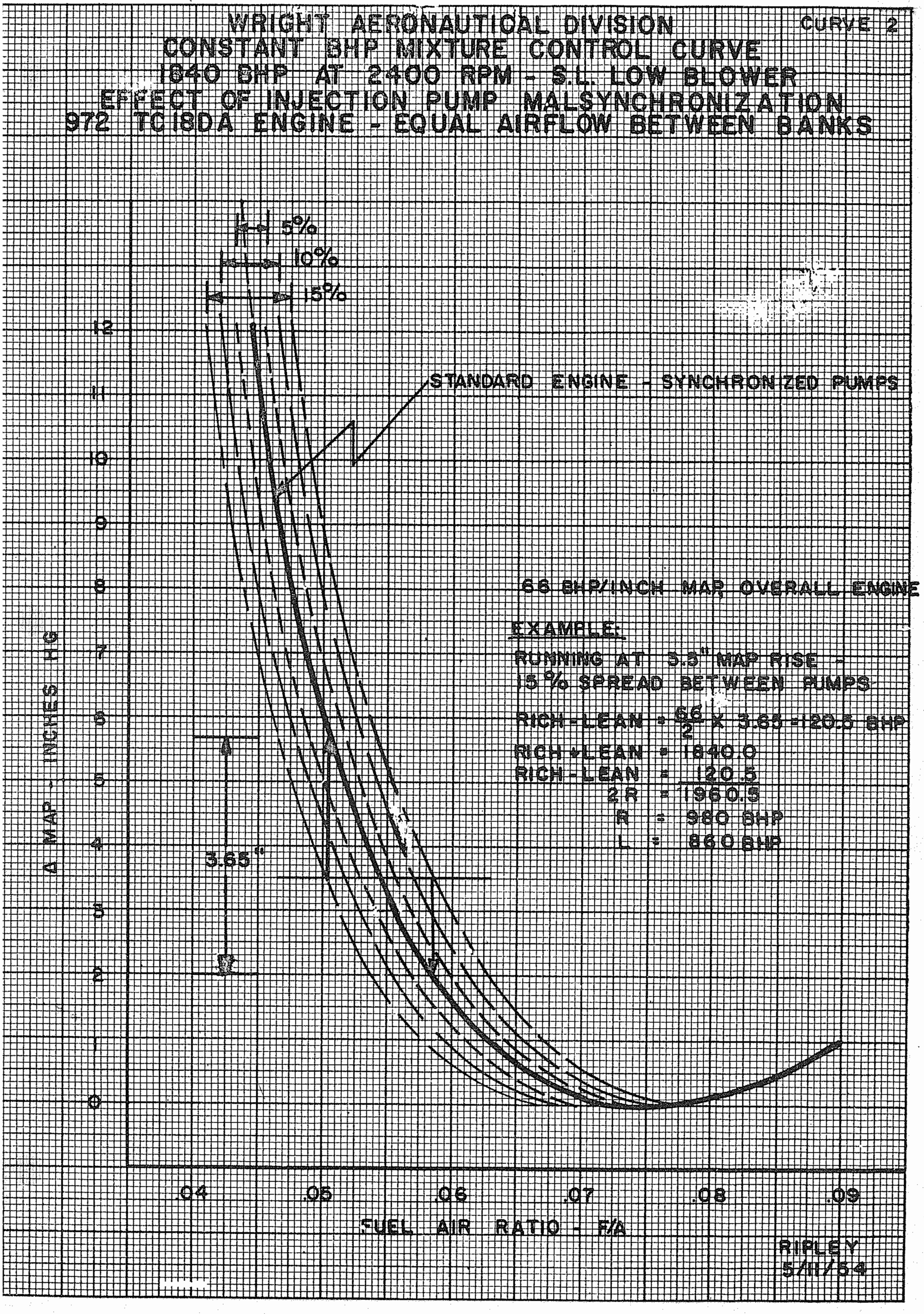
No. TCI-2

The magnitude of the CHT spreads experienced operationally on these engines which encountered combustion chamber distress have indicated that if distribution is controlled adequately to compare to the limits set in this report, and if "super leaning" is not utilized that a substantial improvement in combustion chamber service life can be expected.

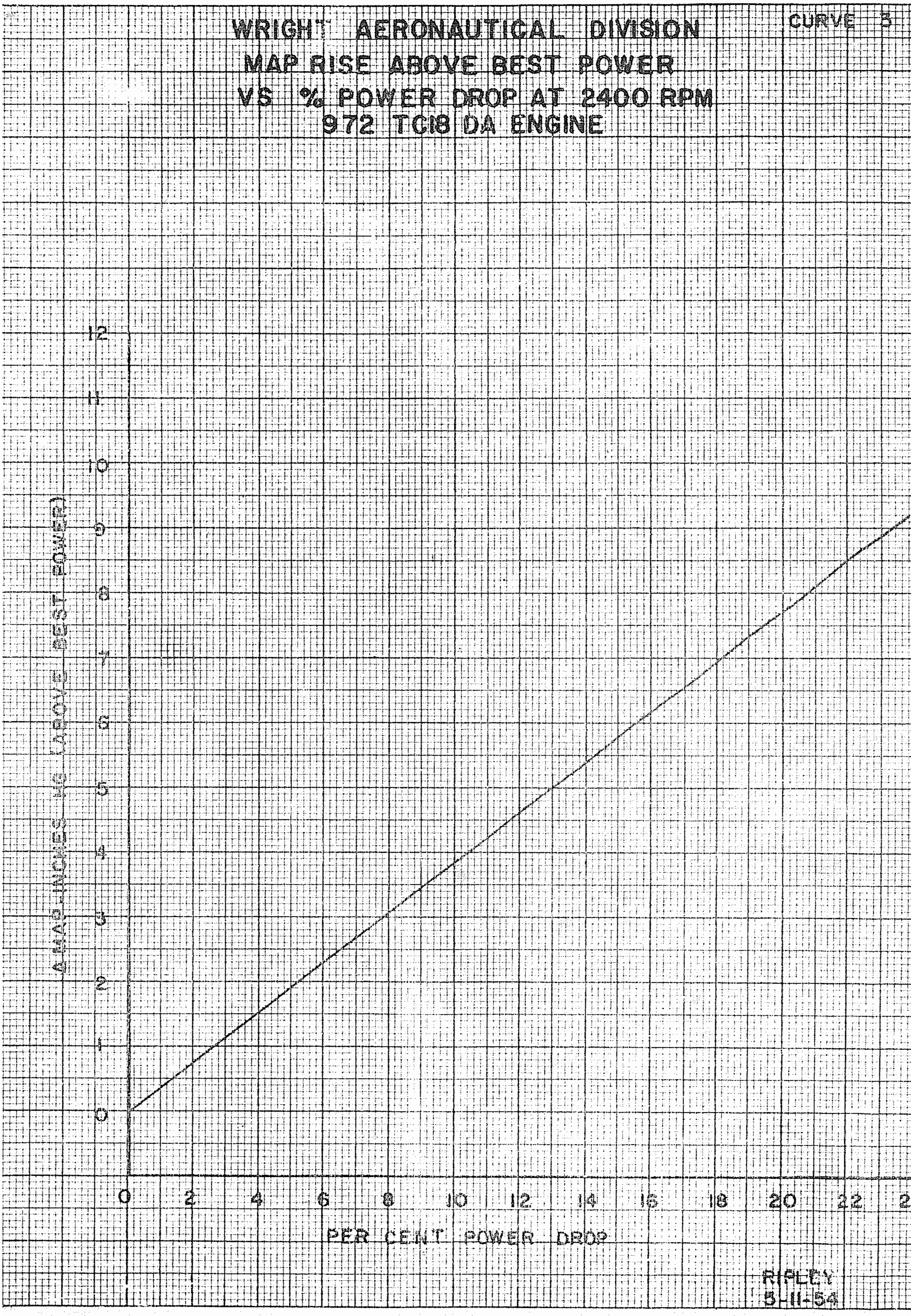
George Ripley

GR:rvp


CURVE 1
WRIGHT AERONAUTICAL DIVISION
NORMAL AND MAXIMUM CHT SPREAD LIMITATIONS
972 TC18DA ENGINES - MAX CRUISE POWER
CONSTANT COWL FLAP, AIRSPEED AND ALTITUDE
DUAL CHT GAGE INSTALLATION
Δ CYLINDER HEAD TEMPERATURE °C
10-15°C NORMAL
EQUAL FUEL DISTRIBUTION
REAR
FRONT
ALLOWABLE
REAR ROW RICH
FRONT
REAR
NO SPREAD PERMITTED
FRONT ROW RICH
REAR
FRONT
20
10
0
-10
10
8
6
4
2
0
AUTO RICH
PER CENT POWER DROP
RIPLEY
7/15/54


WRIGHT AERONAUTICAL DIVISION
CURVE 2
CONSTANT BHP MIXTURE CONTROL CURVE
1840 BHP AT 2400 RPM - S.L. LOW BLOWER
EFFECT OF INJECTION PUMP MALSYNCHRONIZATION
972 TC18DA ENGINE - EQUAL AIRFLOW BETWEEN BANKS
5%
10%
15%
STANDARD ENGINE - SYNCHRONIZED PUMPS
66 BHP/INCH MAP OVERALL ENGINE
EXAMPLE:
RUNNING AT 3.5" MAP RISE -
15 % SPREAD BETWEEN PUMPS
RICH - LEAN = 66/2 X 3.65 = 120.5 BHP
RICH + LEAN = 1840.0
RICH - LEAN = 120.5
2R = 1960.5
R = 980 BHP
L = 860 BHP
3.65"
Δ MAP - INCHES HG
0
1
2
3
4
5
6
7
8
9
10
11
12
.04
.05
.06
.07
.08
.09
FUEL AIR RATIO - F/A
RIPLEY
5/11/54

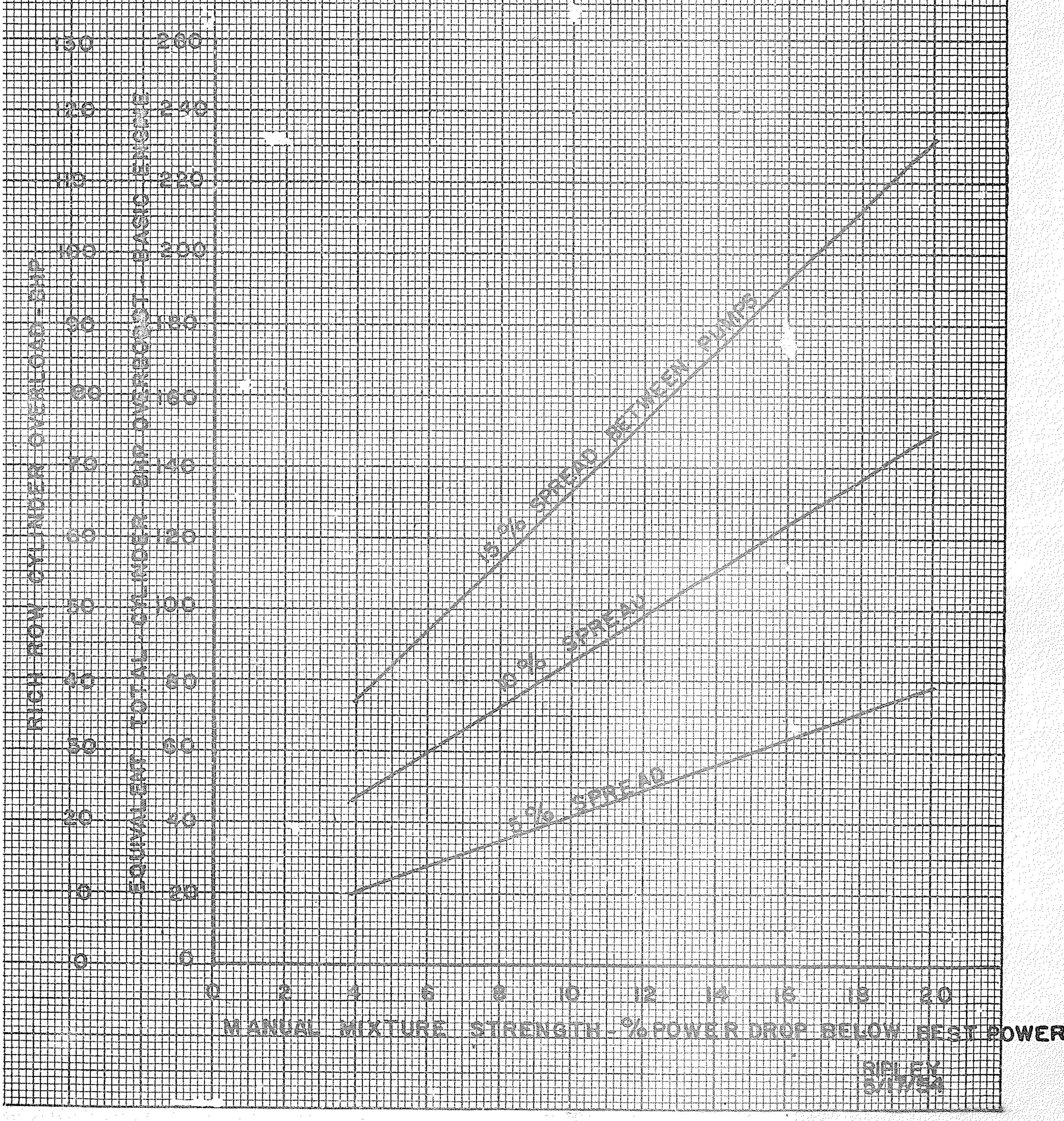
GT-56-339i


WRIGHT AERONAUTICAL DIVISION
MAP RISE ABOVE BEST POWER
VS % POWER DROP AT 2400 RPM
972 TC18 DA ENGINE
CURVE 5
Δ MAP INCHES HG (ABOVE BEST POWER)
0
1
2
3
4
5
6
7
8
9
10
11
12
0
2
4
6
8
10
12
14
16
18
20
22
24
PER CENT POWER DROP
RIPLEY
5-11-54

GT-56-339j

WRIGHT AERONAUTICAL DIVISION — CURVE 4

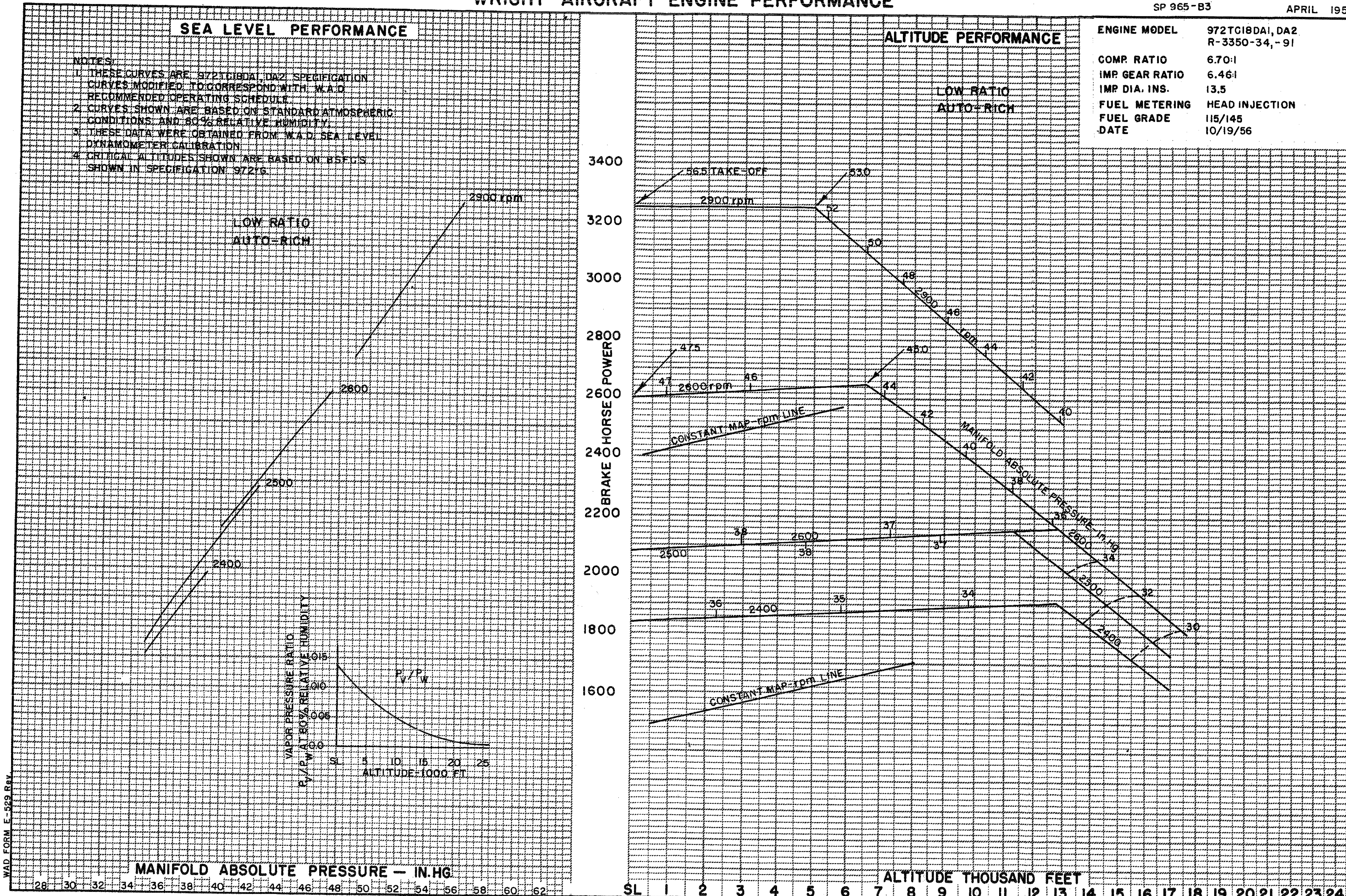
EFFECT OF FUEL INJECTION PUMP SYNCHRONIZATION
MIXTURE STRENGTH VS EQUIVALENT TOTAL CYLINDER
BHP OVERBOOST - 1840 BHP AT 2400 RPM
972 TC18DA ENGINES - SEA LEVEL - LOW BLOWER



WRIGHT AIRCRAFT ENGINE PERFORMANCE

ENGINE MODEL	972TC18DA1, DA2 R-3350-34, -91
COMP. RATIO	6.70:1
IMP. GEAR RATIO	6.46:1
IMP. DIA. INS.	13.5
FUEL METERING	HEAD INJECTION
FUEL GRADE	115/145
DATE	10/19/56

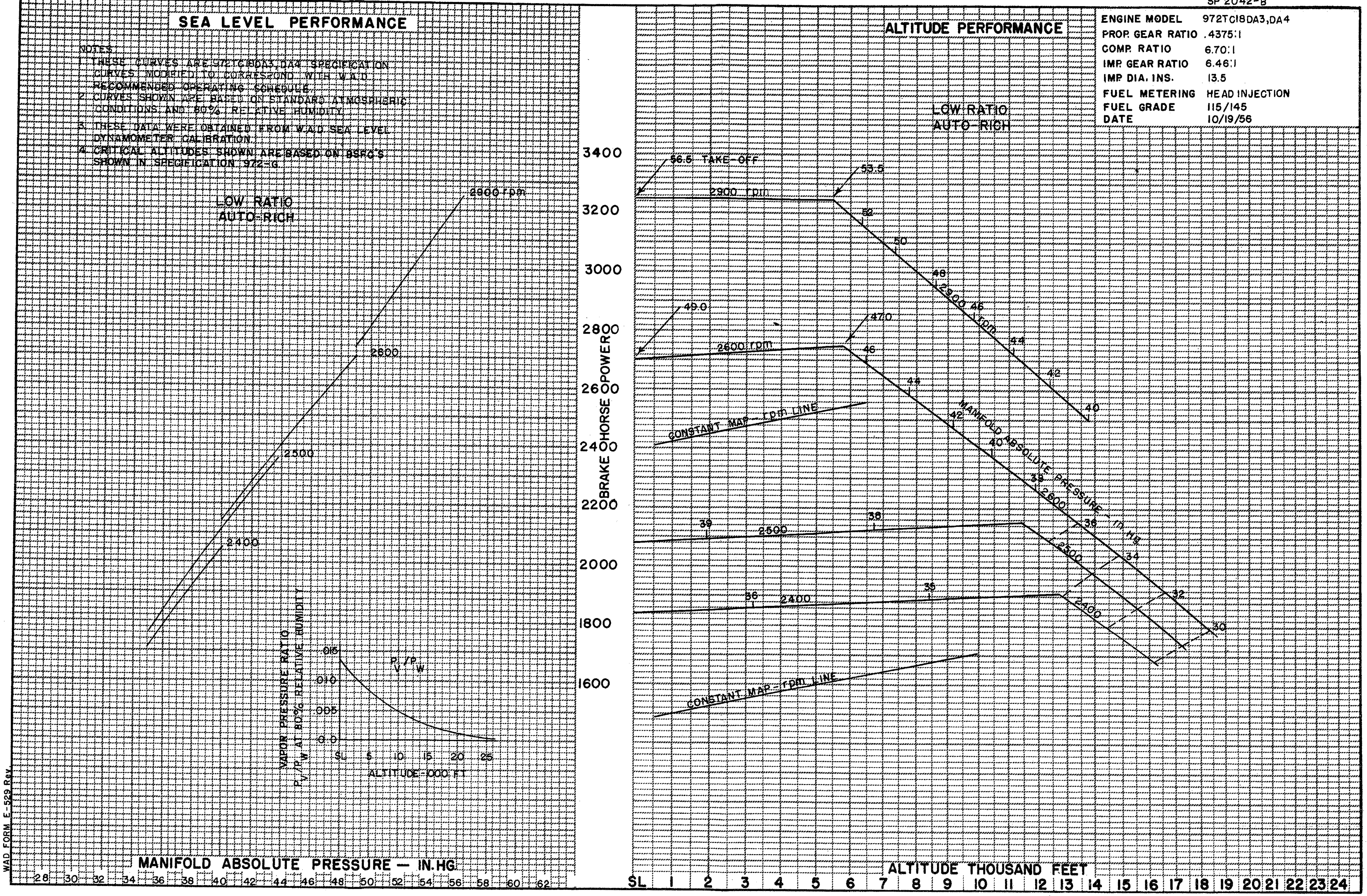
NOTES:
1. THESE CURVES ARE 972TC18DA1, DA2 SPECIFICATION CURVES MODIFIED TO CORRESPOND WITH W.A.D. RECOMMENDED OPERATING SCHEDULE.
2. CURVES SHOWN ARE BASED ON STANDARD ATMOSPHERIC CONDITIONS AND 80% RELATIVE HUMIDITY.
3. THESE DATA WERE OBTAINED FROM W.A.D. SEA LEVEL DYNAMOMETER CALIBRATION.
4. CRITICAL ALTITUDES SHOWN ARE BASED ON BSFC'S SHOWN IN SPECIFICATION 972-G.



WAD FORM E-529 Rev.

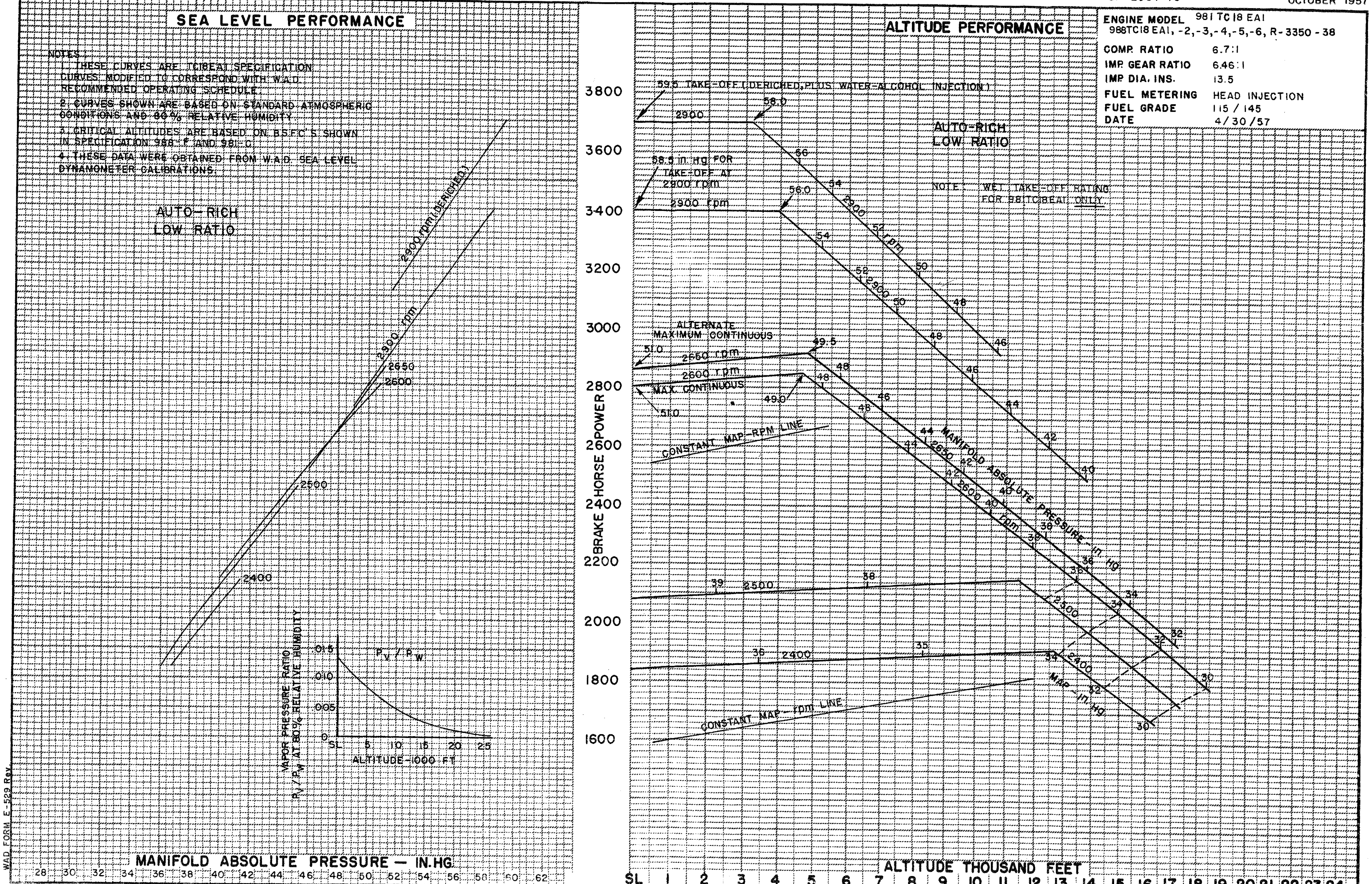
WRIGHT AIRCRAFT ENGINE PERFORMANCE

SP 2042-B DECEMBER 1956



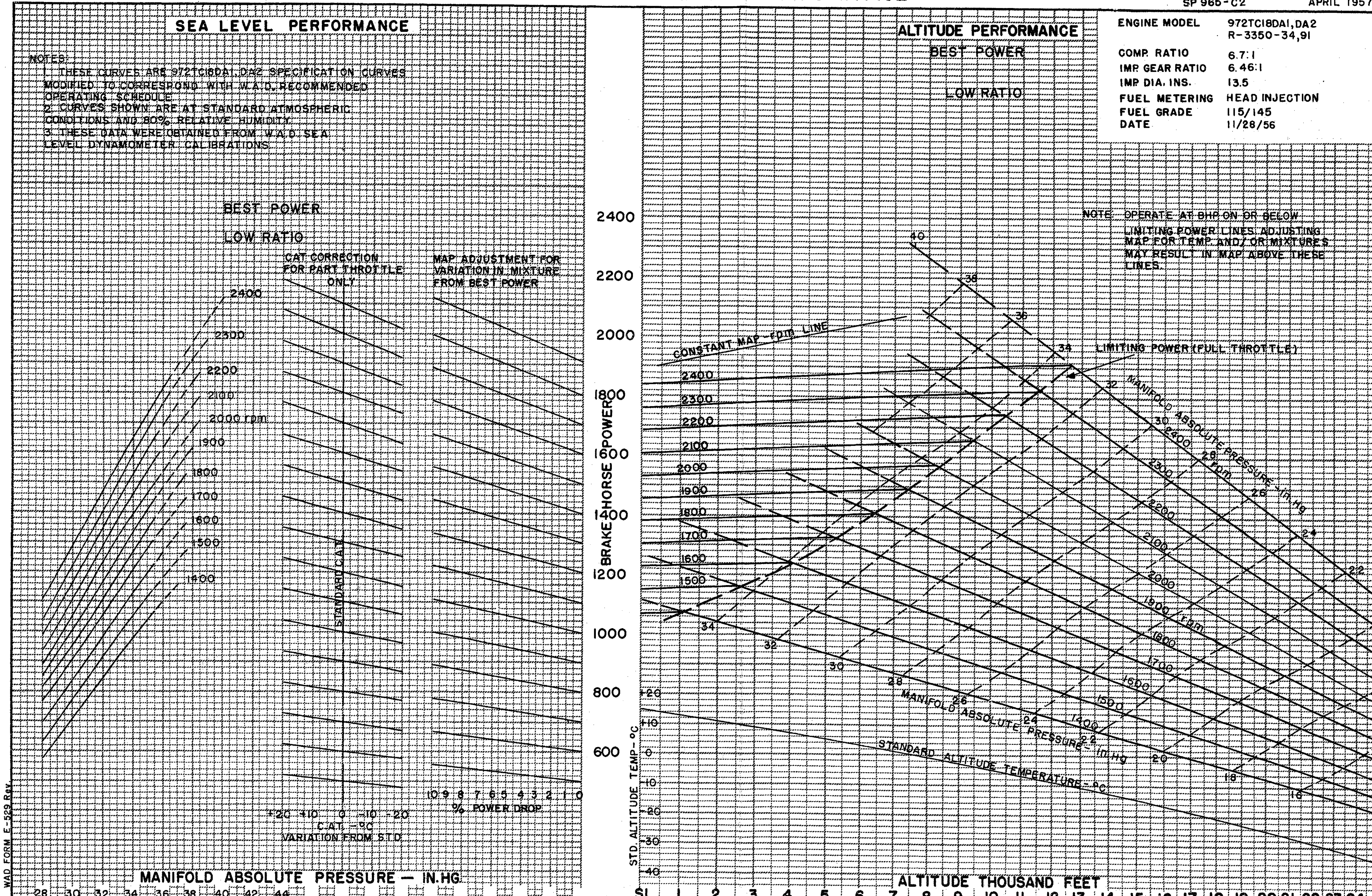
WRIGHT AIRCRAFT ENGINE PERFORMANCE

SP-2064-1C OCTOBER 1957



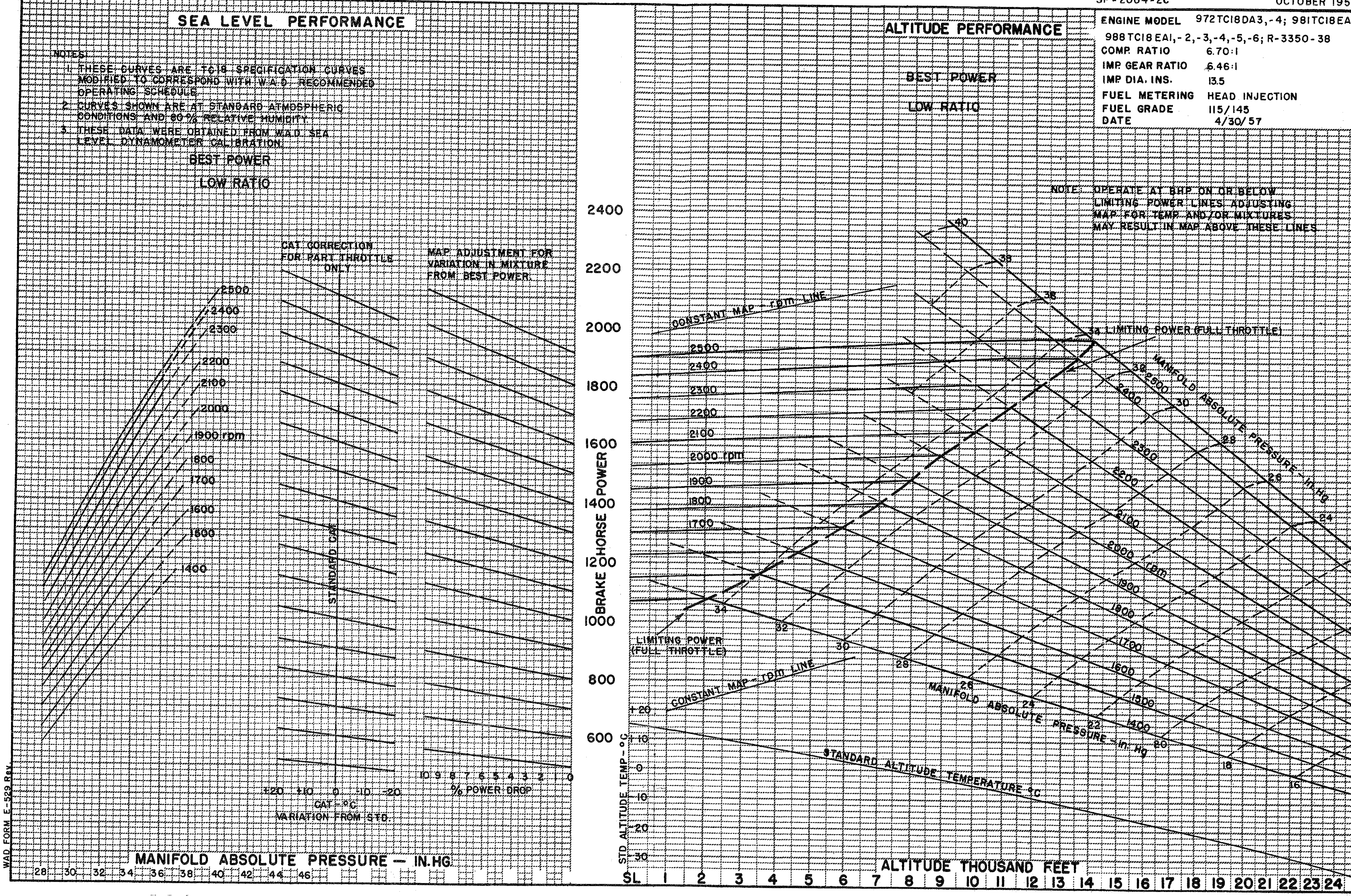
WRIGHT AIRCRAFT ENGINE PERFORMANCE

SP 965-C2 APRIL 1957



WRIGHT AIRCRAFT ENGINE PERFORMANCE

SP-2064-2C OCTOBER 1957



WRIGHT AIRCRAFT ENGINE PERFORMANCE

SP-2065-IC

OCTOBER 1957

ENGINE MODEL	972TC18DA1,-2,-3,-4; 981TC18EA1 988TC18EA1,-2,-3,-4,-5,-6; R-3350-34,38,91
COMP. RATIO	6.7:1
IMP. GEAR RATIO	8.67:1
IMP. DIA. INS.	13.5
FUEL METERING	HEAD INJECTION
FUEL GRADE	115/145
DATE	4/30/57

SEA LEVEL PERFORMANCE

NOTES:

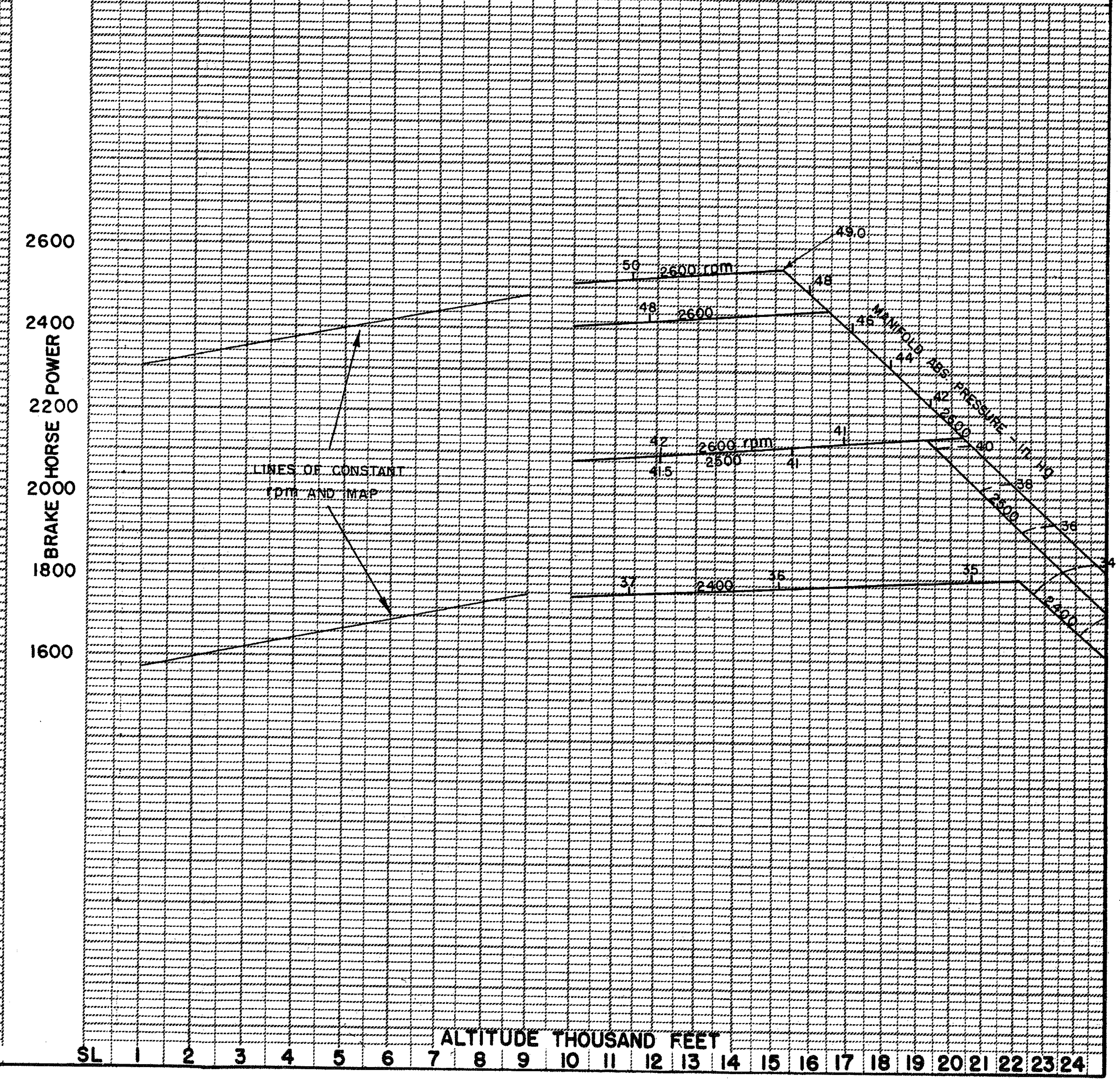
1. THESE CURVES ARE TC18 SPECIFICATION CURVES MODIFIED TO CORRESPOND WITH W.A.D. RECOMMENDED OPERATING SCHEDULE.
2. CURVES SHOWN ARE BASED ON STANDARD ATMOSPHERIC CONDITIONS AND 80% RELATIVE HUMIDITY.
3. NO SEA LEVEL PERFORMANCE IS SHOWN FOR HIGH GEAR RATIO.
4. THESE DATA WERE OBTAINED FROM W.A.D. SEA LEVEL DYNAMOMETER CALIBRATIONS.
5. CRITICAL ALTITUDES SHOWN ARE BASED ON BSFC'S SHOWN IN SPECIFICATIONS 988-F, 981-C & 972-G.

MANIFOLD ABSOLUTE PRESSURE — IN.HG

ALTITUDE PERFORMANCE

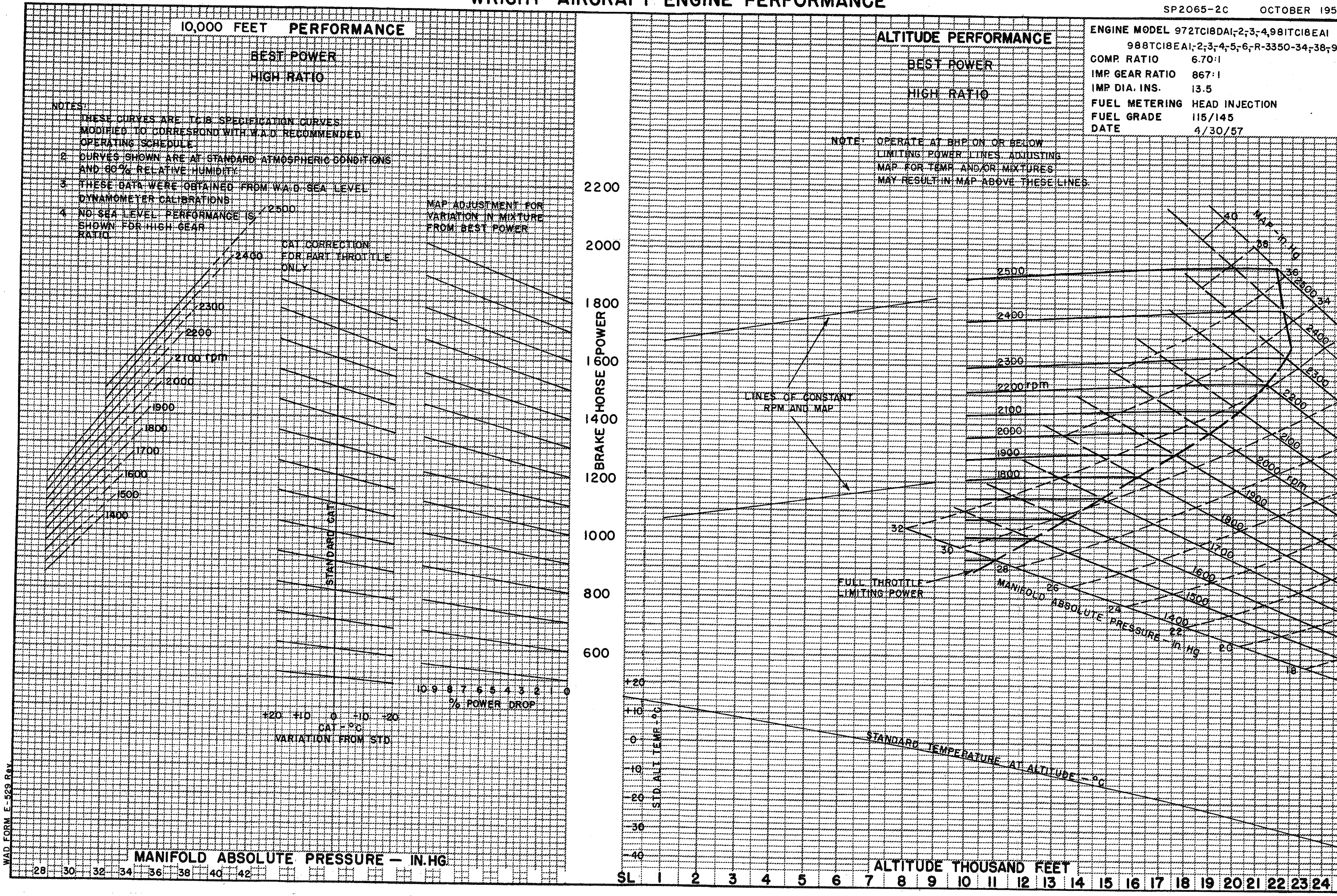
AUTO-RICH

HIGH RATIO



WAD FORM E-529 Rev.

WRIGHT AIRCRAFT ENGINE PERFORMANCE



WRIGHT AIRCRAFT ENGINE PERFORMANCE

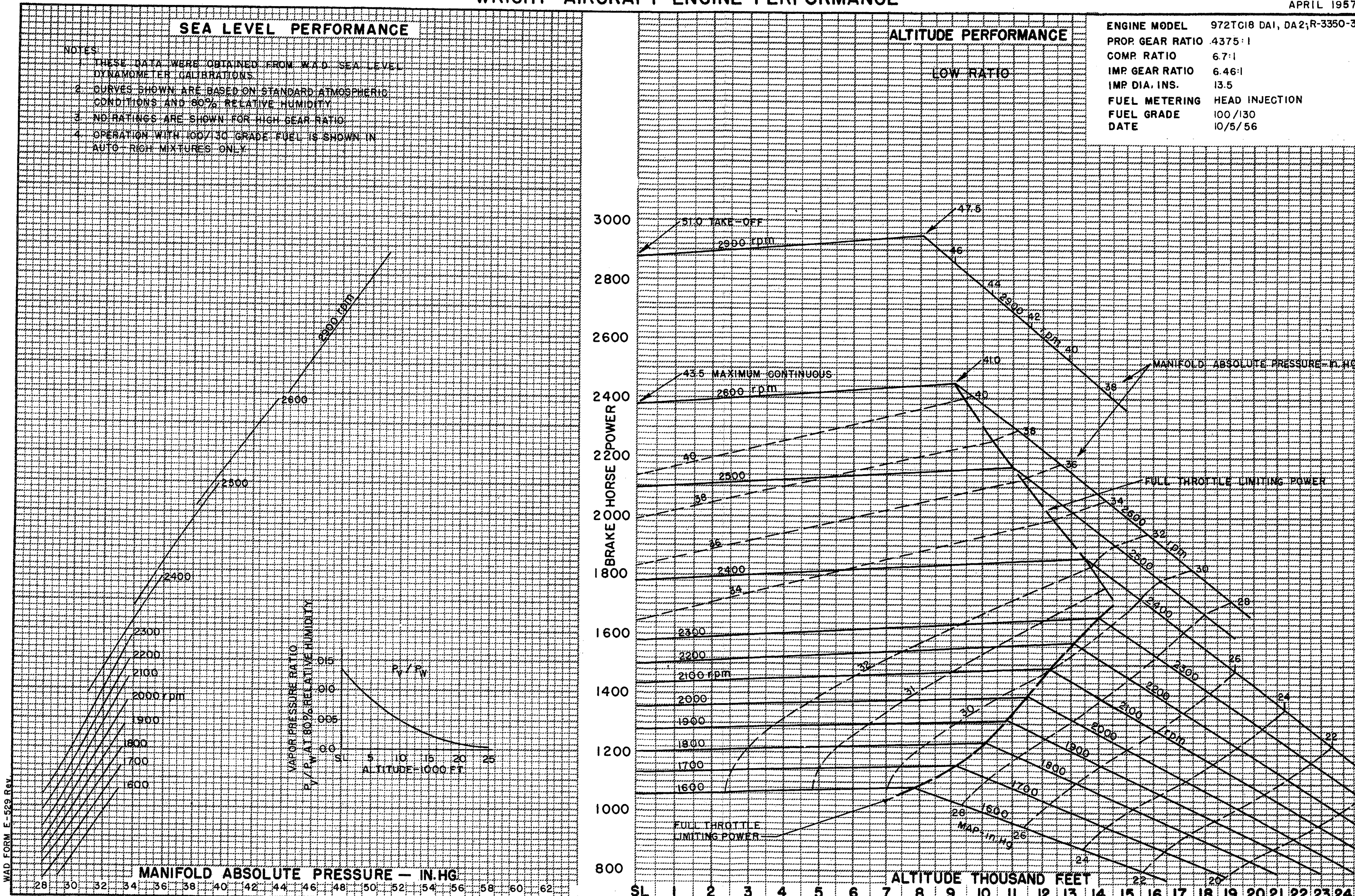
APRIL 1957

ENGINE MODEL	972TC18 DA1, DA2; R-3350-34
PROP. GEAR RATIO	.4375:1
COMP. RATIO	6.7:1
IMP. GEAR RATIO	6.46:1
IMP. DIA. INS.	13.5
FUEL METERING	HEAD INJECTION
FUEL GRADE	100/130
DATE	10/5/56

SEA LEVEL PERFORMANCE

NOTES:

1. THESE DATA WERE OBTAINED FROM W.A.D. SEA LEVEL DYNAMOMETER CALIBRATIONS.
2. CURVES SHOWN ARE BASED ON STANDARD ATMOSPHERIC CONDITIONS AND 80% RELATIVE HUMIDITY.
3. NO RATINGS ARE SHOWN FOR HIGH GEAR RATIO.
4. OPERATION WITH 100/130 GRADE FUEL IS SHOWN IN AUTO-RICH MIXTURES ONLY.



WAD FORM E-529 Rev.

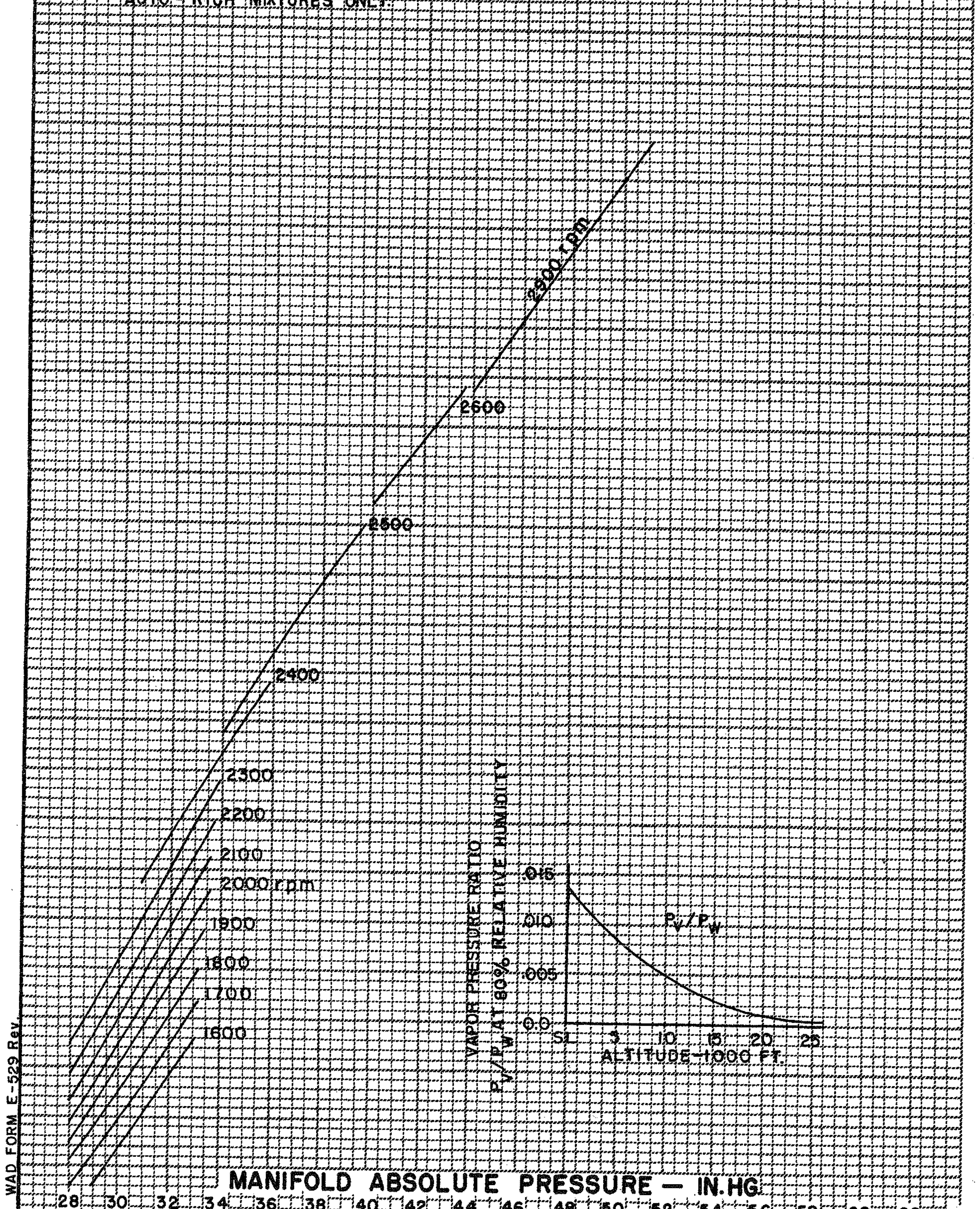
WRIGHT AIRCRAFT ENGINE PERFORMANCE

OCTOBER 1957

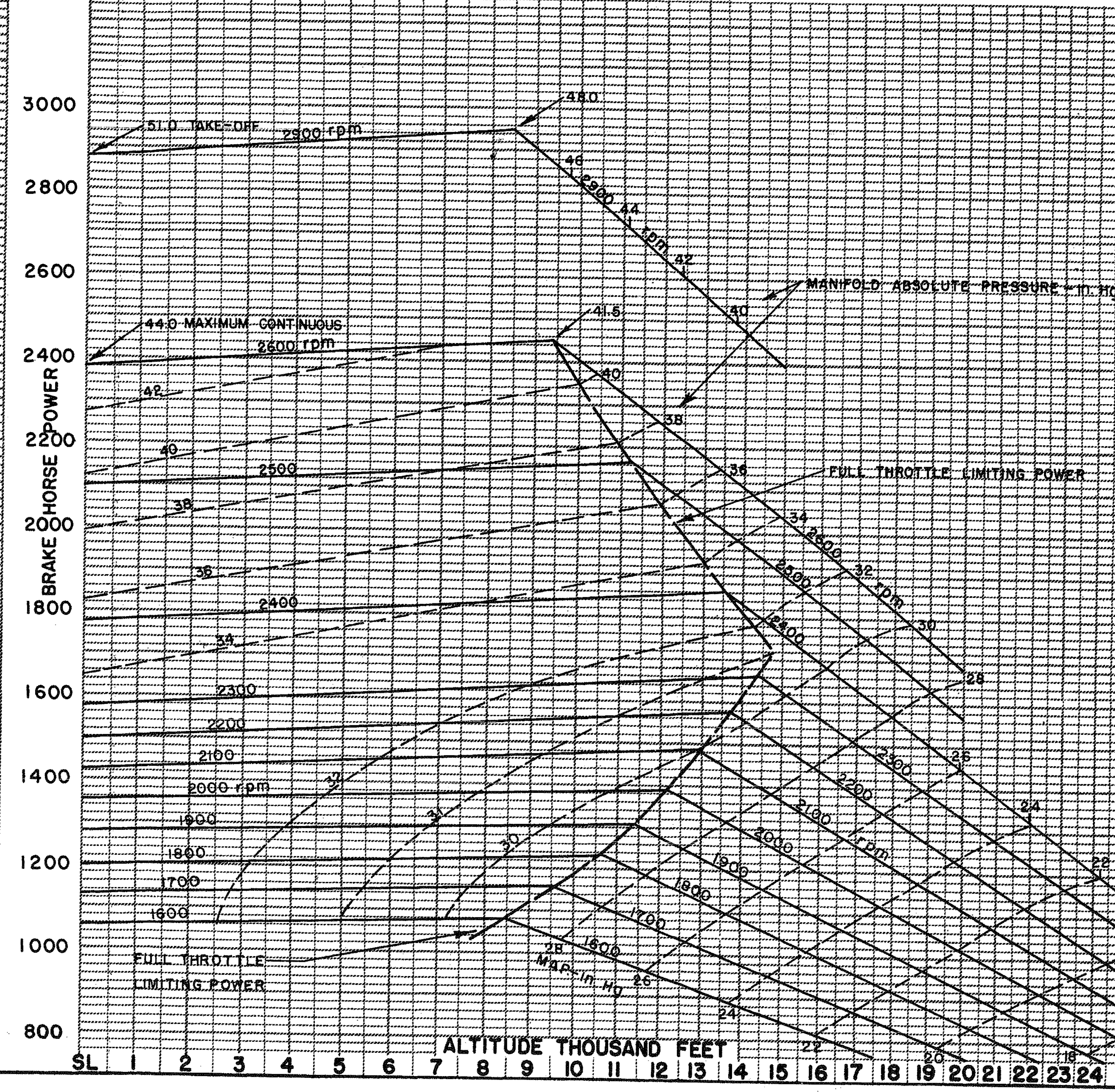
ENGINE MODEL	972TC18DA3,-4; 988TC18EA1,-2,-3,-4,-5,-6; R-3350-38
COMP. RATIO	6.7:1
IMP. GEAR RATIO	6.46:1
IMP. DIA. INS.	13.5
FUEL METERING	HEAD INJECTION
FUEL GRADE	100/130
DATE	10/5/56

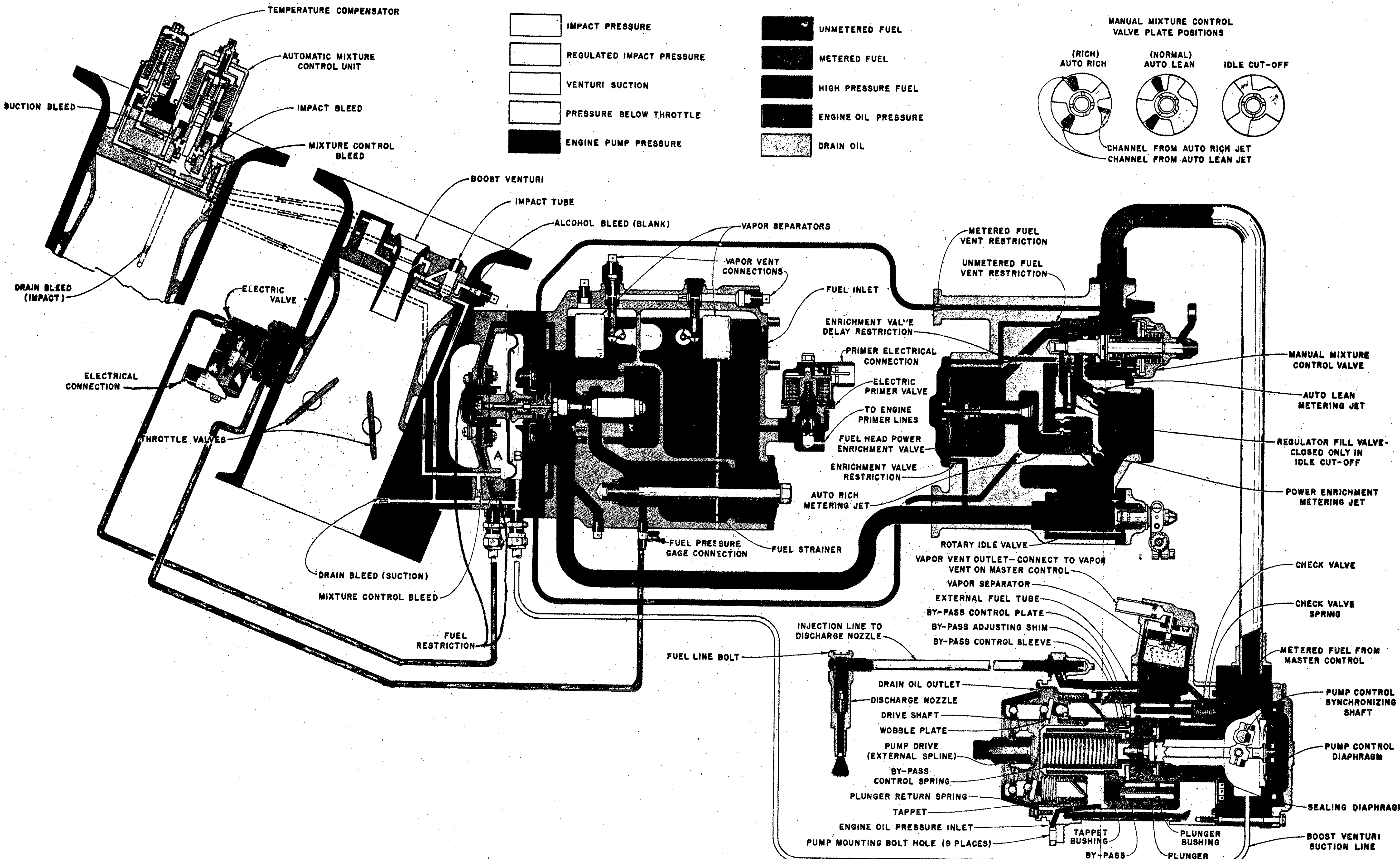
SEA LEVEL PERFORMANCE

NOTES:
1. THESE CURVES WERE OBTAINED FROM W.A.D SEA LEVEL DYNAMOMETER CALIBRATIONS.
2. CURVES SHOWN ARE BASED ON STANDARD ATMOSPHERIC CONDITIONS AND 80% RELATIVE HUMIDITY.
3. NO RATINGS ARE SHOWN FOR HIGH GEAR RATIO.
4. OPERATION WITH 100/130 GRADE FUEL IS SHOWN IN AUTO-RICH MIXTURES ONLY.



ALTITUDE PERFORMANCE

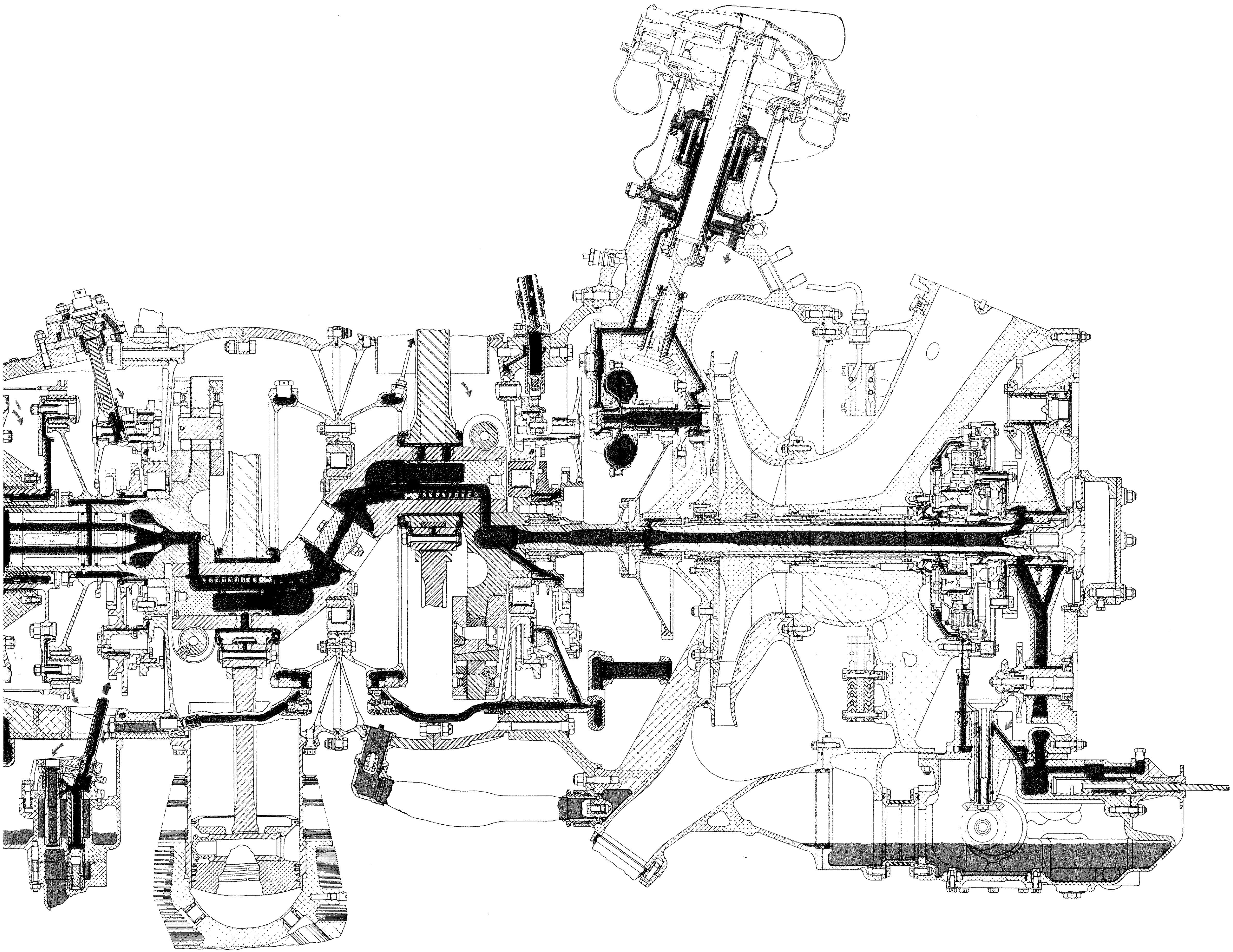




Schematic Diagram of Direct Fuel Injection System

'HART FOR MODEL 981TC18EA1 & 988TC18EA1 ENGINES

FULL ENGINE VIEW

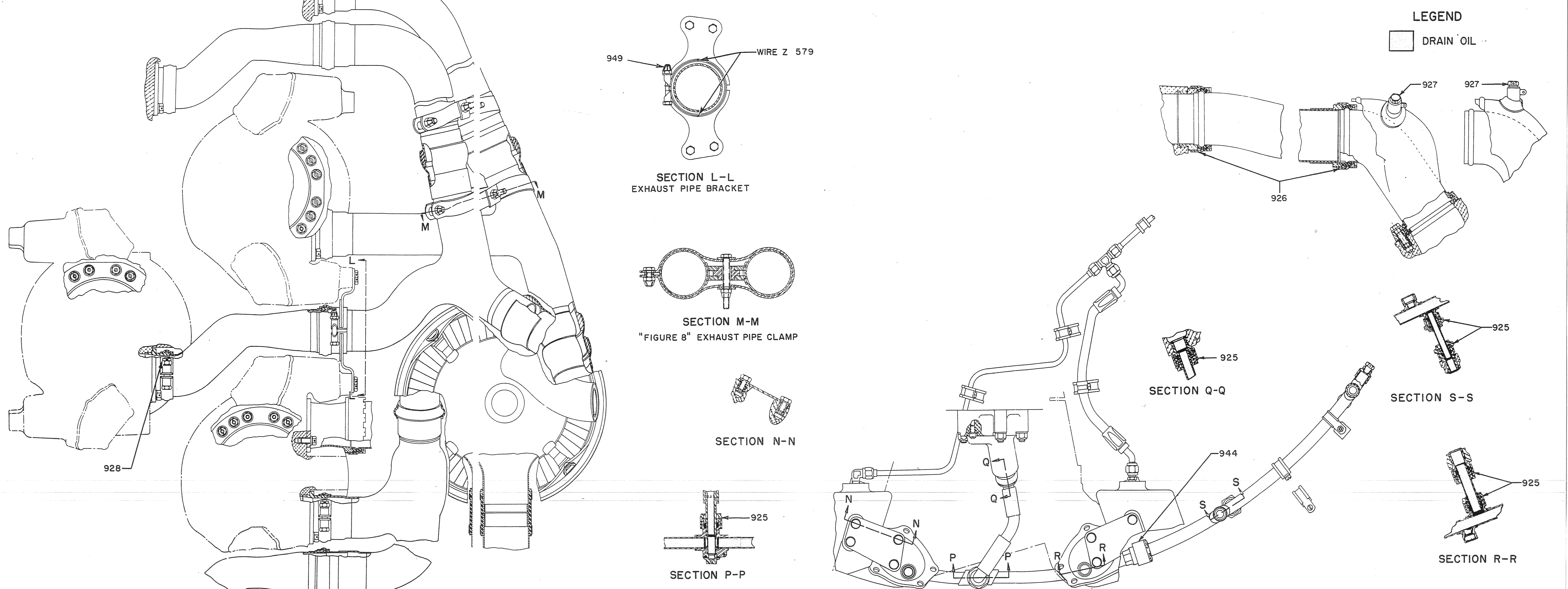


INDEX FOR TABLE OF LIMITS AND LUBRICATION CHARTS

CHART	TITLE
2	CRANKCASE FRONT SECTION. FRONT OIL PUMP AND SUMP.
3	POWER SECTION. CYLINDER AND PISTON. INTERNAL TORQUEMETER OIL TUBE.
4	PRT ASSEMBLY. CRANKSHAFT FLUID DRIVE.
5	SUPERCHARGER FRONT AND REAR HOUSING. IMPELLER AND IMPELLER DRIVE.
6	SUPERCHARGER REAR COVER. REAR OIL PUMP AND SUMP.
7	EXHAUST PIPES. INTAKE PIPES. ROCKER BOX DRAIN MANIFOLD.

LIMITS AND LUBRICATION CHART FOR MODEL 981TC18EA1 & 988TC18EA1 ENGINES

EXHAUST PIPES
INTAKE PIPES
ROCKER BOX DRAIN MANIFOLD

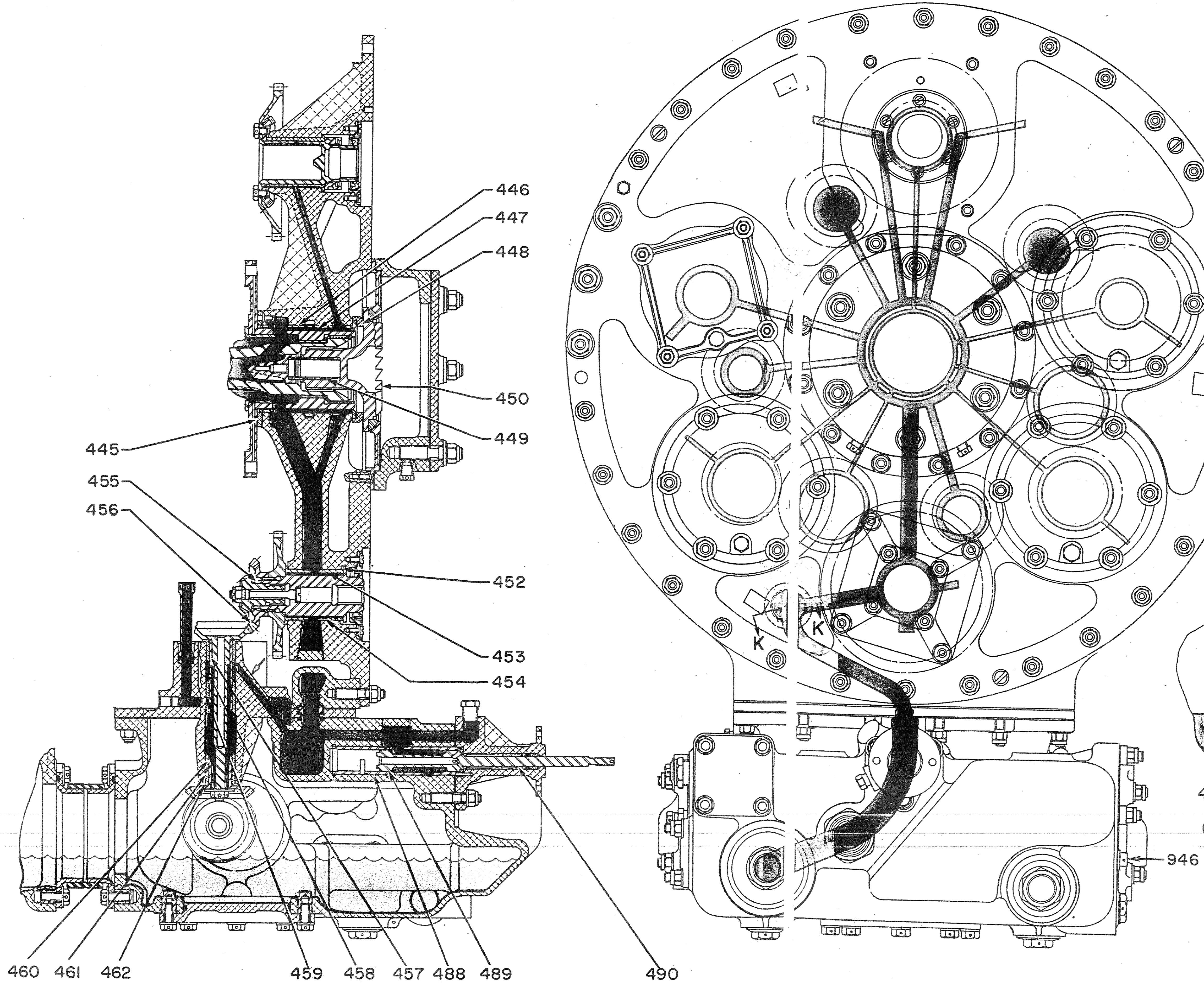


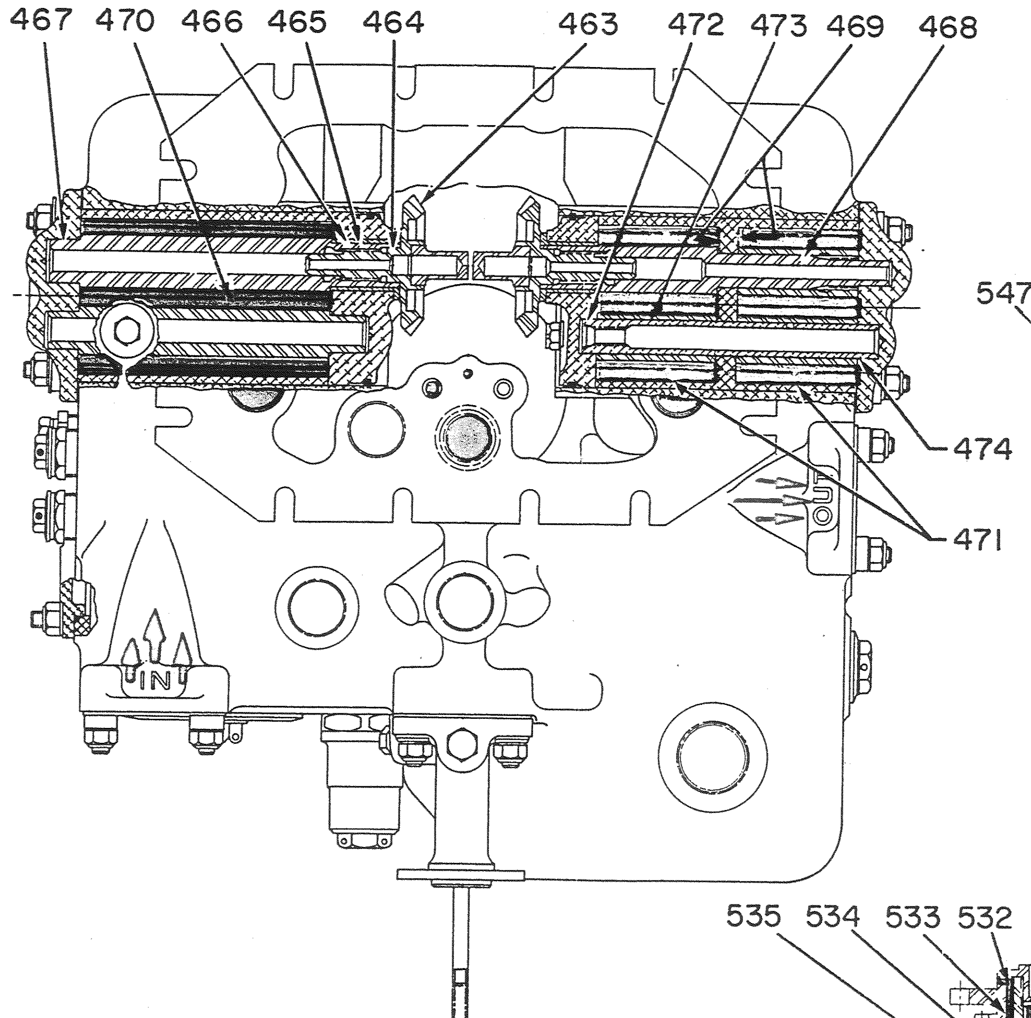
LIMITS AND LUBRICATION CHART FOR MODEL 981TC18EA1 & 988TC18EA1 ENGINES

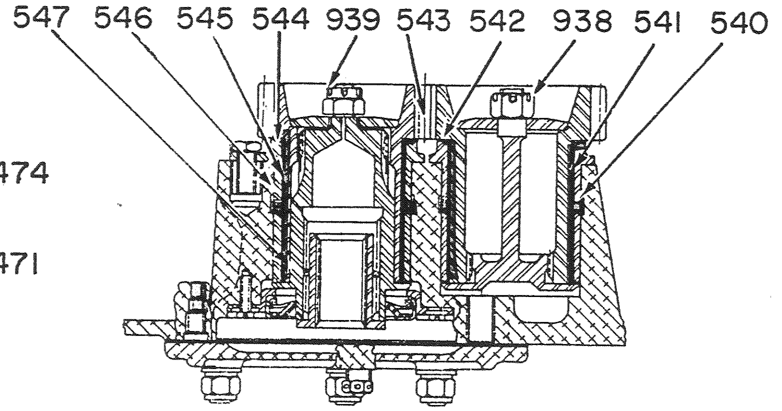
SUPERCHARGER REAR COVER REAR OIL PUMP AND SUMP

LEGEND

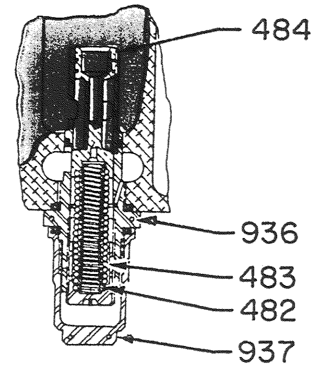
- ENGINE PRESSURE OIL
- DRAIN OIL



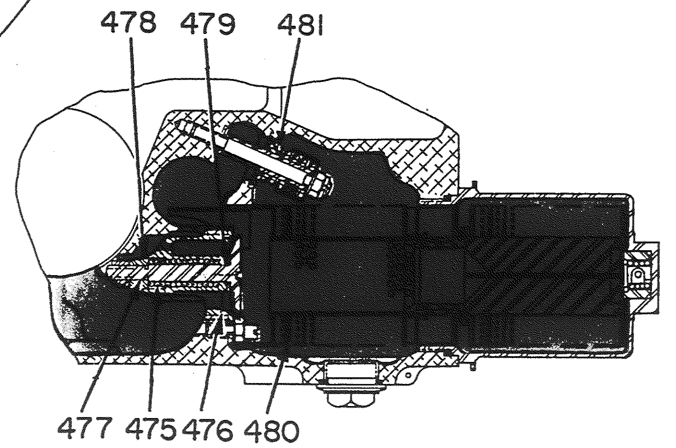




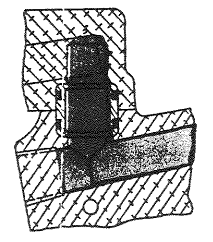
LEFT HAND GENERATOR DRIVE



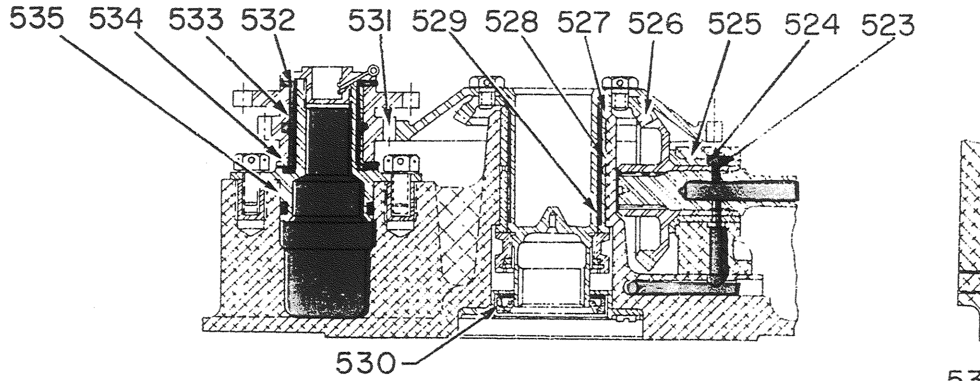
PRESSURE RELIEF VALVE REAR OIL PUMP



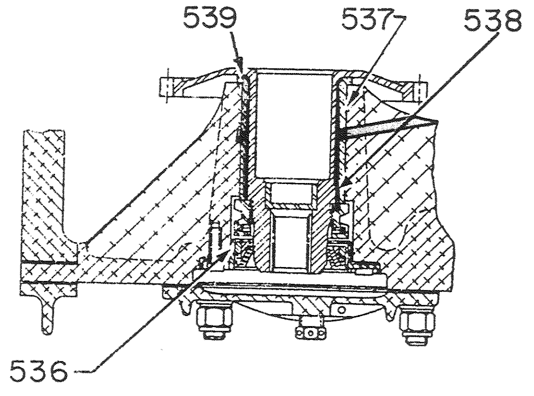
CHECK AND BY-PASS VALVES REAR OIL PUMP



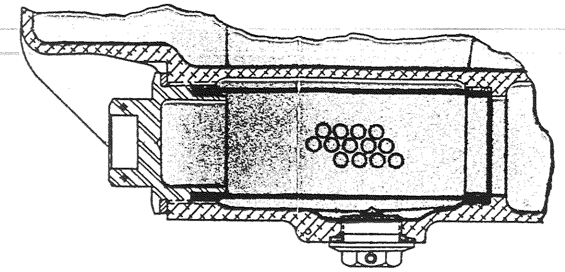
SECTION K-K



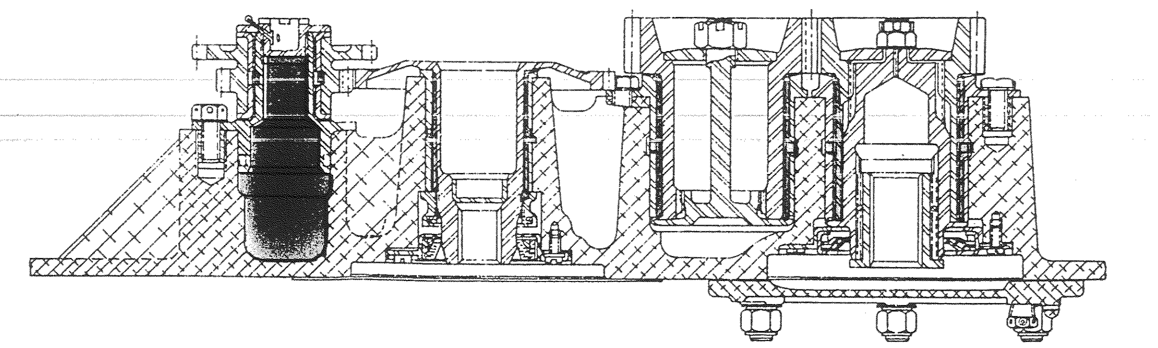
MAGNETO DRIVE AND FUEL INJECTION SHAFT DRIVE



LEFT HAND ACCESSORY DRIVE COUPLING



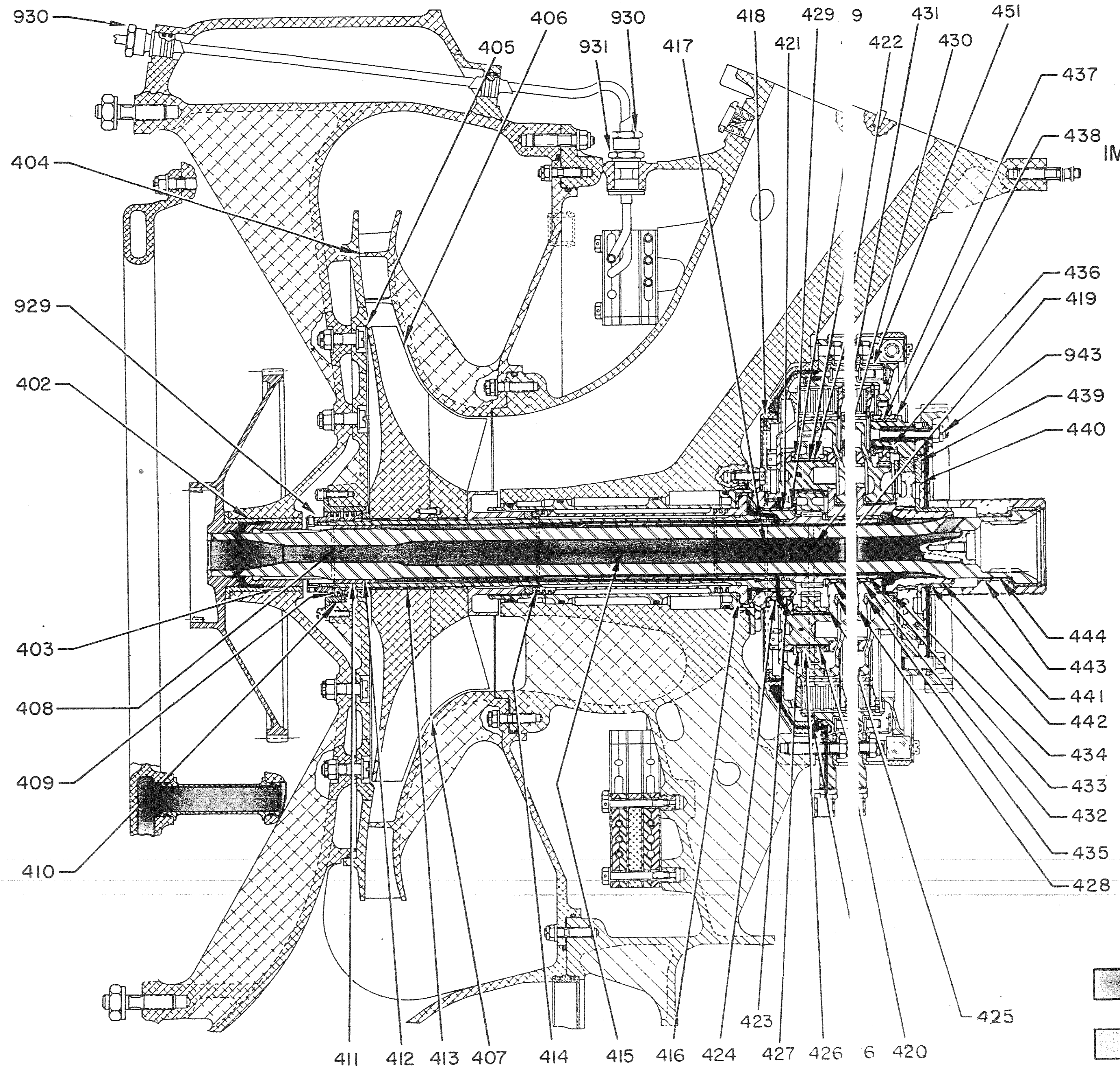
REAR OIL PUMP SCAVENGE STRAINER

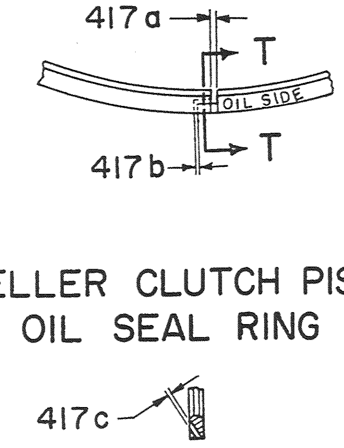


ACCESSORY DRIVE COUPLING AND RIGHT HAND GENERATOR DRIVE

SUPERCHARGER FRONT AND REAR HOUSING IMPELLER AND IMPELLER DRIVE

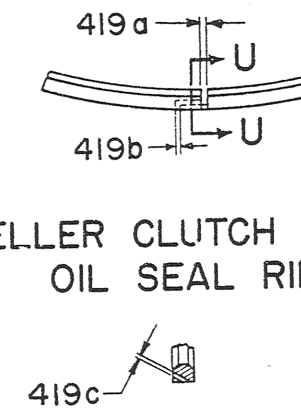
LIMITS AND LUBRICATION CHART FOR MODEL 981TC18EA1 & 988TC18EA1 ENGINES





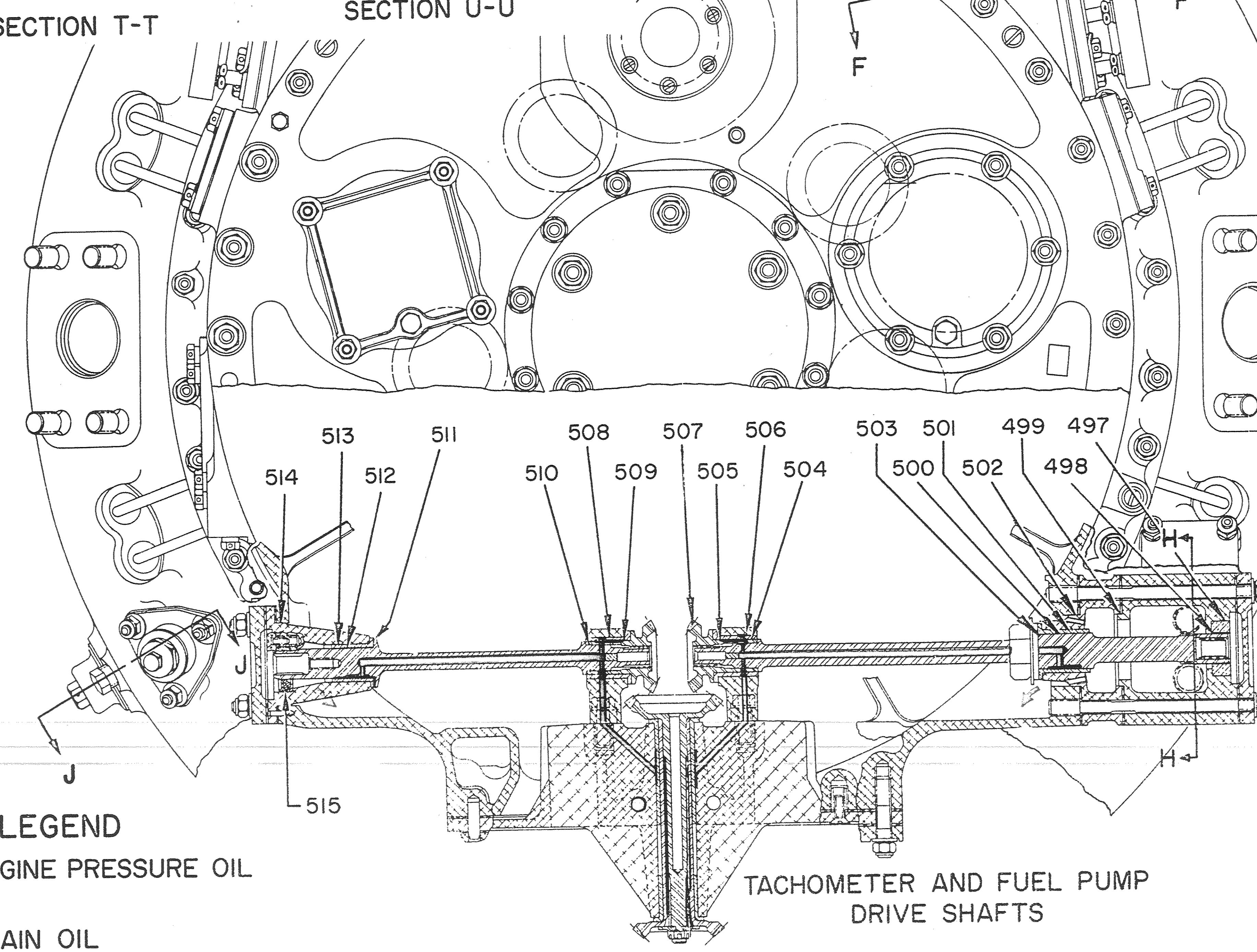
IMPELLER CLUTCH PISTON OIL SEAL RING

SECTION T-T

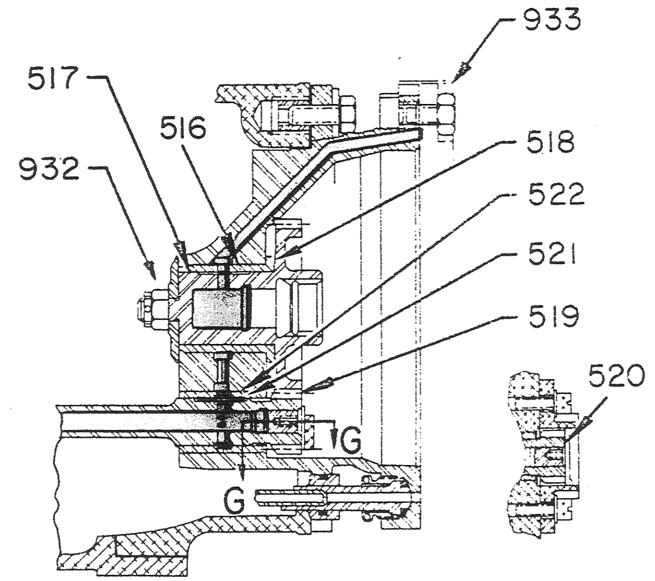


IMPELLER CLUTCH SUPPORT OIL SEAL RING

SECTION U-U

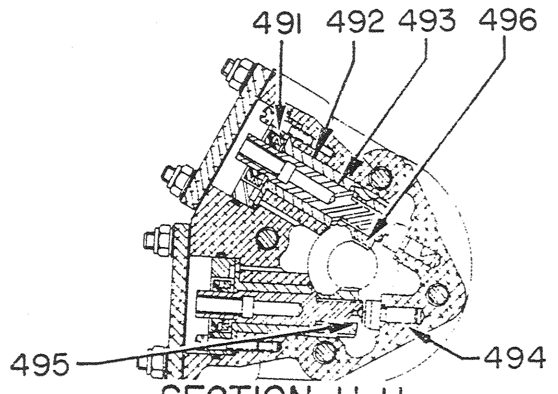


TACHOMETER AND FUEL PUMP DRIVE SHAFTS



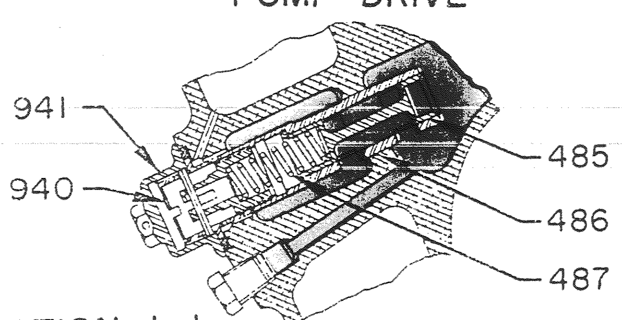
SECTION F-F SECTION G-G

FUEL INJECTION DRIVE



SECTION H-H

TACHOMETER AND FUEL PUMP DRIVE



SECTION J-J

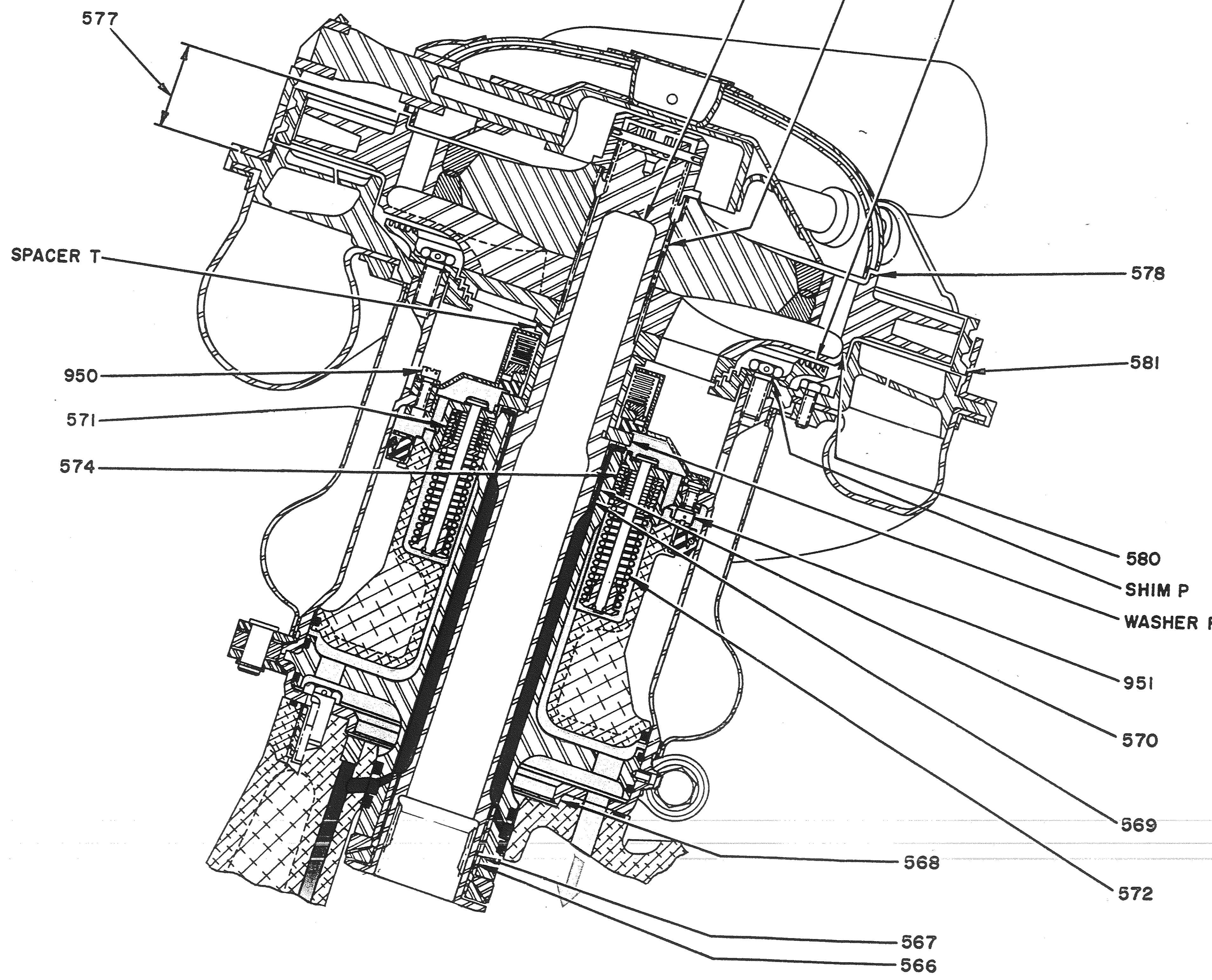
SUPERCHARGER OIL PRESSURE CONTROL VALVE

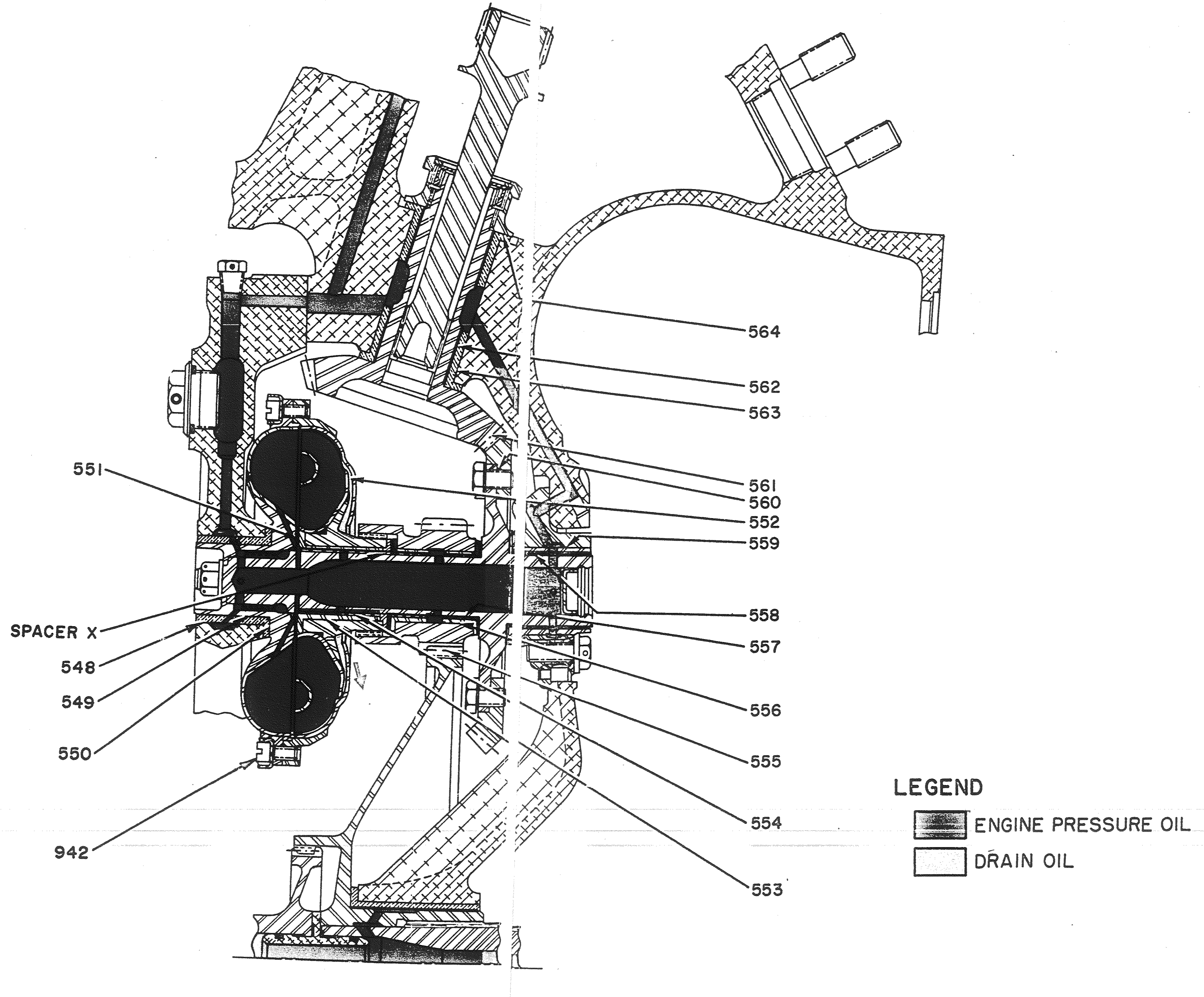
LEGEND

ENGINE PRESSURE OIL

DRAIN OIL

LIMITS AND LUBRICATION CHART FOR MODEL 981TC18EA1 & 988TC18EA1 ENGINES





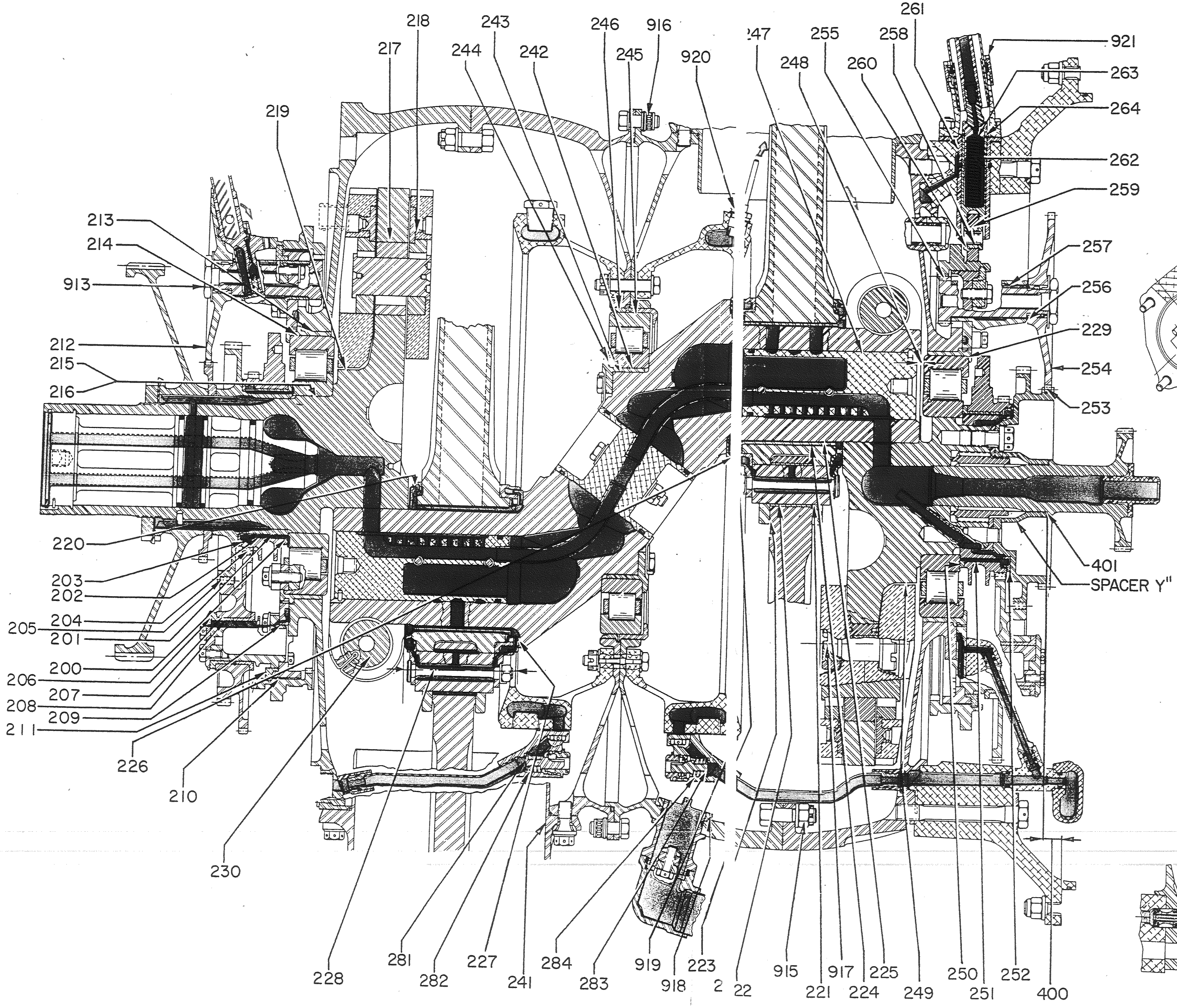
LIMITS AND LUBRICATION CHART FOR MODEL 981TC18EA1 & 988TC18EA1 ENGINES

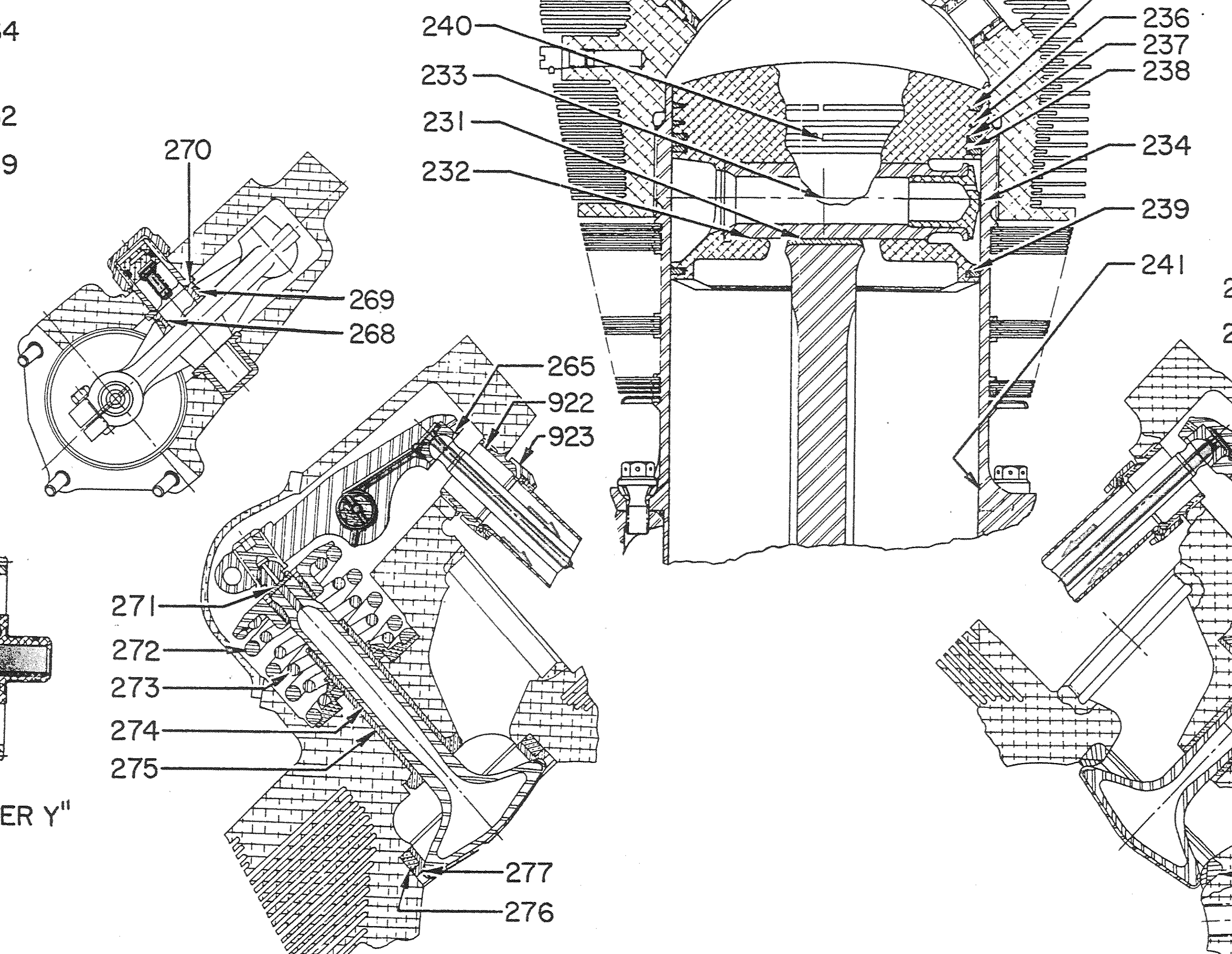
CHART 3 OF 7

POWER SECTION
CYLINDER AND PISTON
INTERNAL TORQUEMETER OIL TUBE

LEGEND

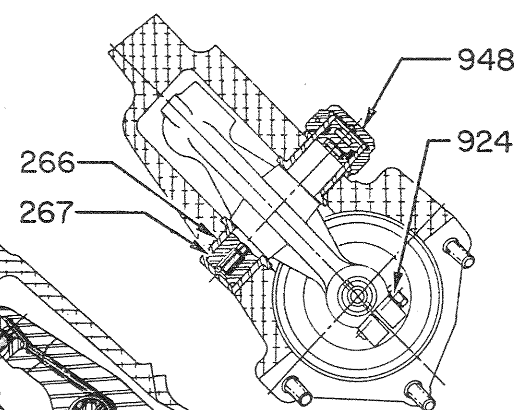
- ENGINE PRESSURE OIL
- TORQUEMETER GAGE OIL
- DRAIN OIL
- GOVERNOR DRAIN OIL

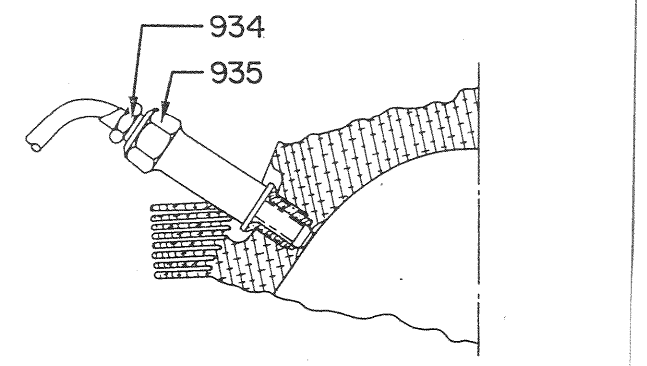




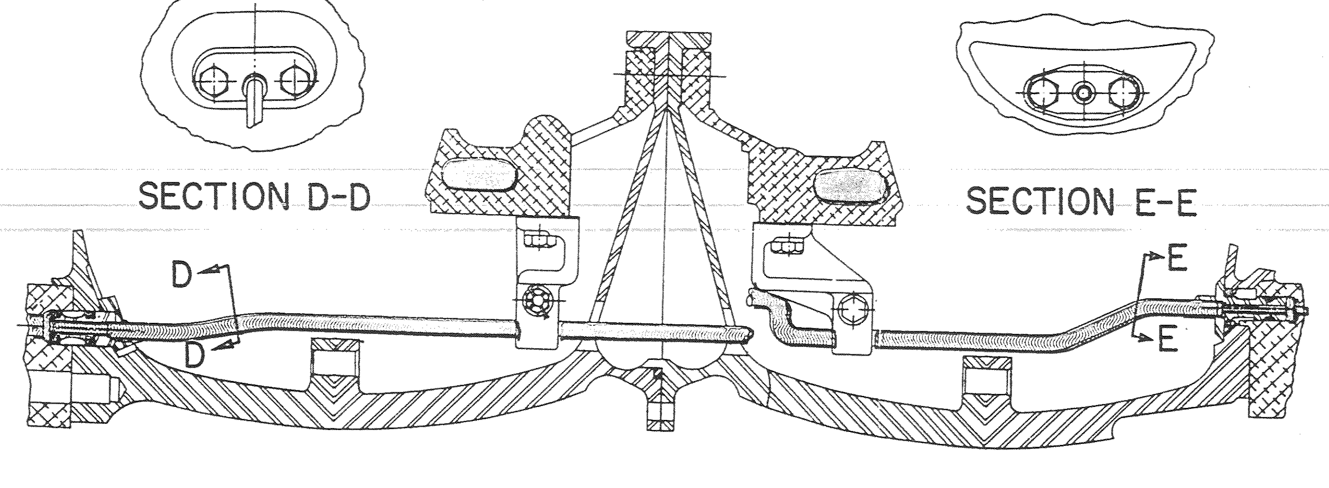
EXHAUST VALVE

INTAKE VALVE



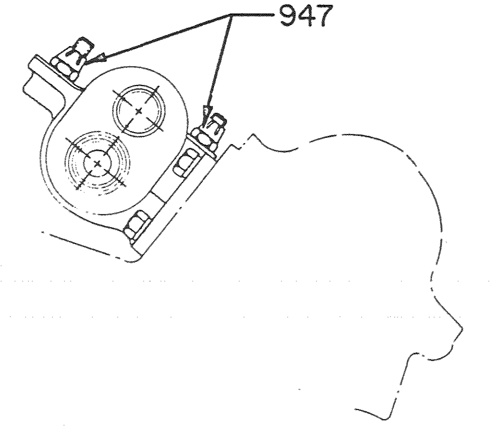


FUEL INJECTION NOZZLE



SECTION D-D

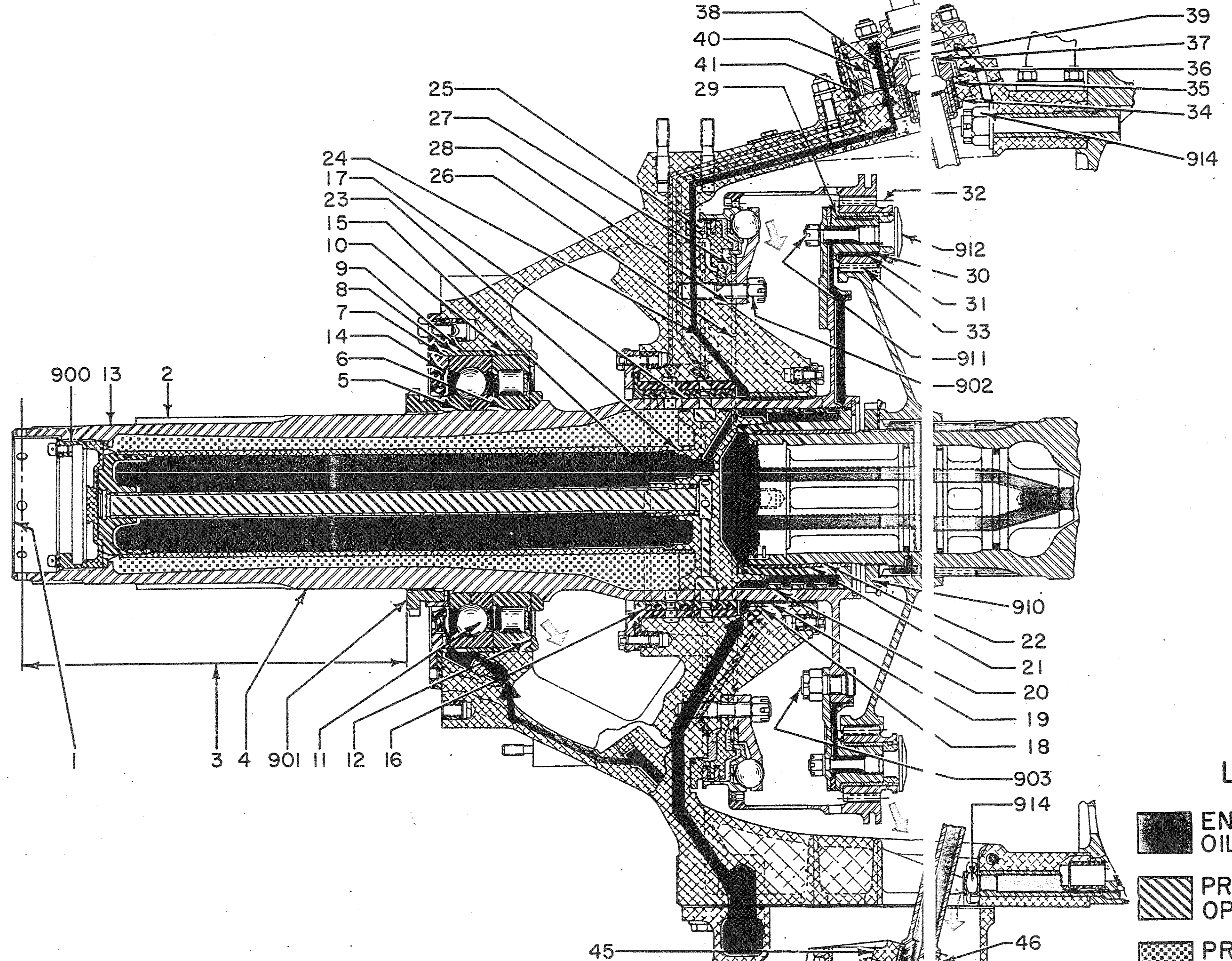
SECTION E-E

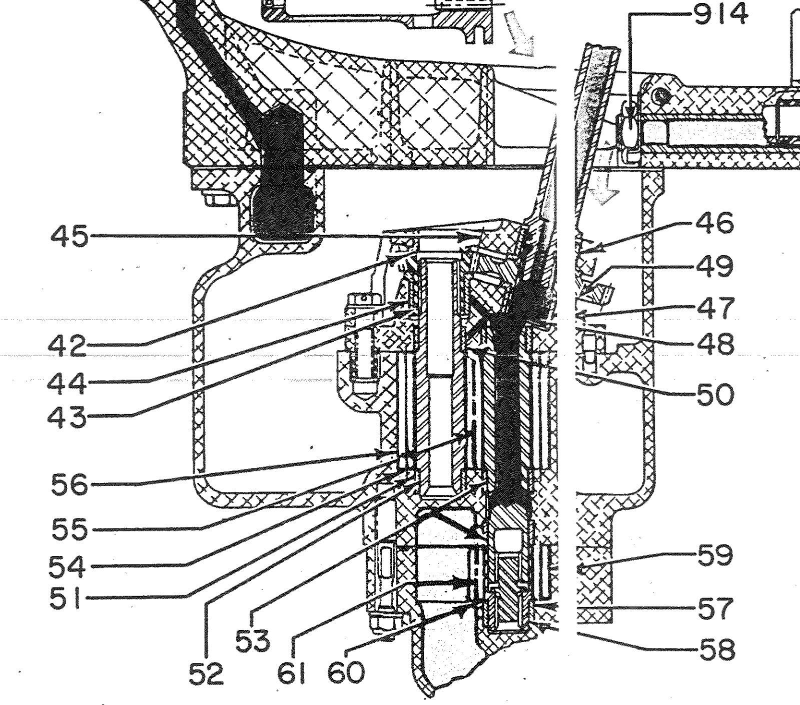


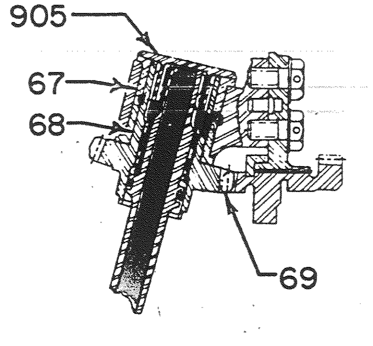
IGNITION COIL SADDLE AND STRAP

LIMITS AND LUBRICATION CHART FOR MODEL 981TC18EA1 & 988TC18EA1 ENGINES

CRANKCASE FRONT SECTION FRONT PUMP AND SUMP



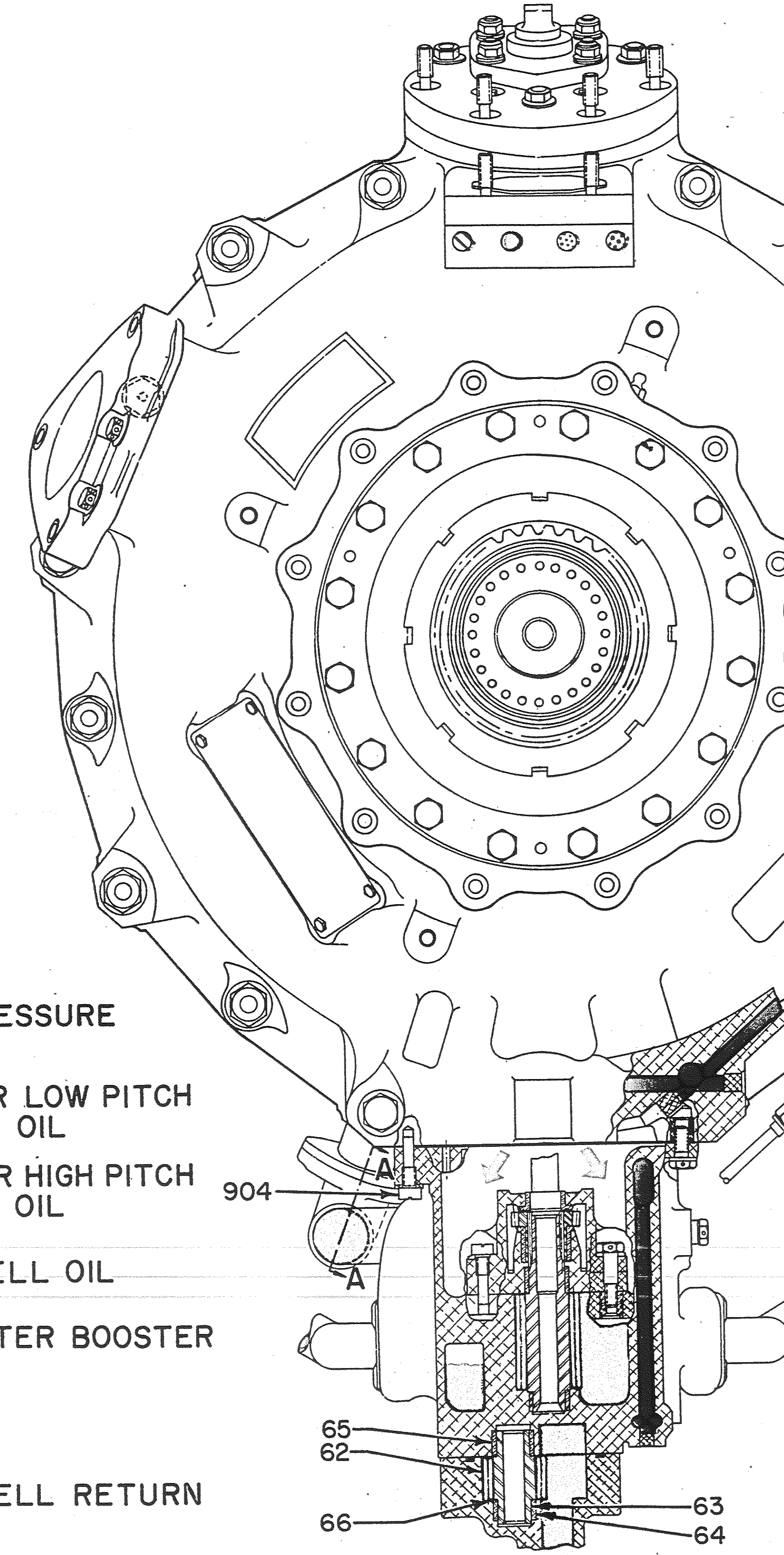


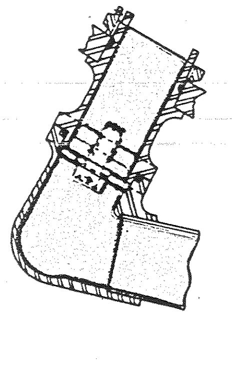


ACCESSORY DRIVE

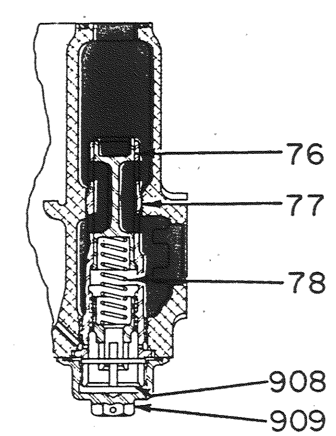
LEGEND

- ENGINE PRESSURE OIL
- PROPELLER LOW PITCH OPERATING OIL
- PROPELLER HIGH PITCH OPERATING OIL
- TORQUE CELL OIL
- TORQUEMETER BOOSTER PUMP OIL
- DRAIN OIL
- TORQUE CELL RETURN OIL

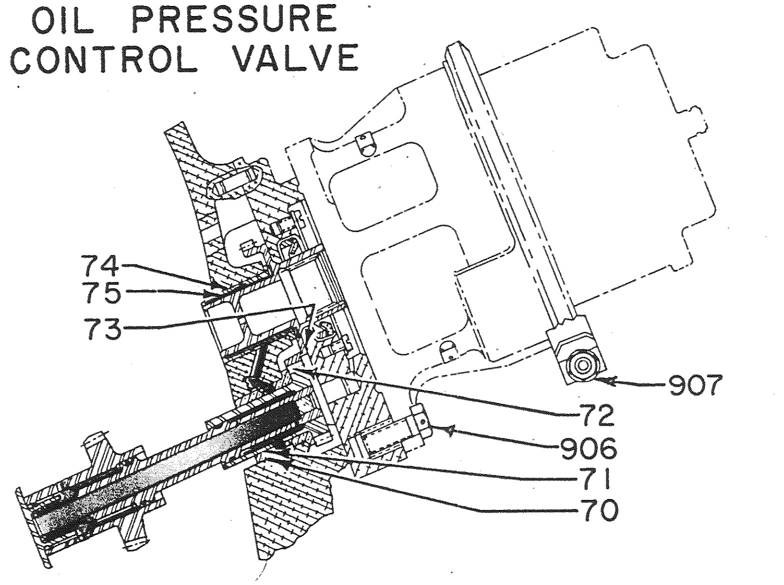




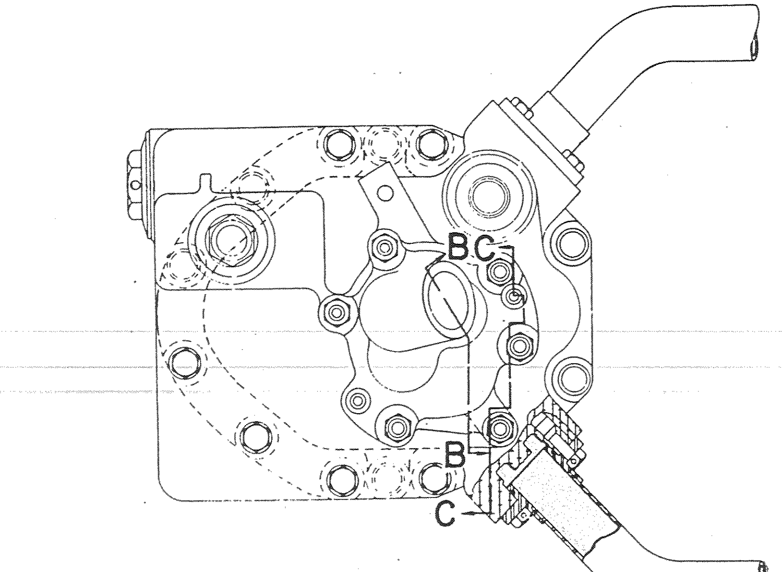
SECTION A-A



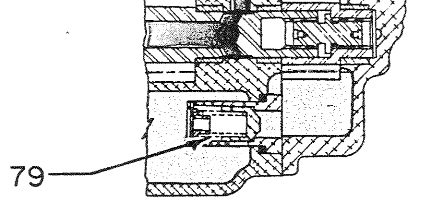
FRONT SECTION OIL PRESSURE CONTROL VALVE



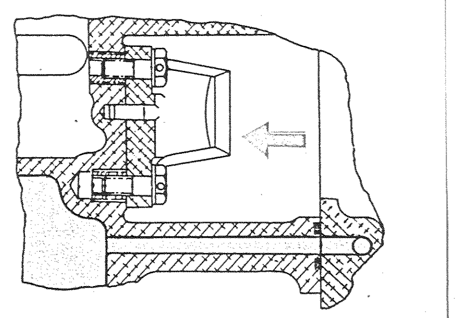
DISTRIBUTOR DRIVE AND DISTRIBUTOR CAP CLAMP



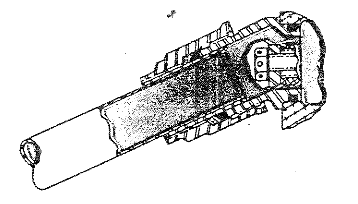
BOTTOM VIEW OF FRONT OIL PUMP AND SUMP



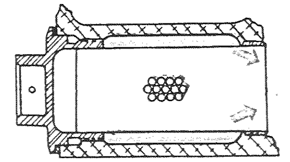
SECTION B-B



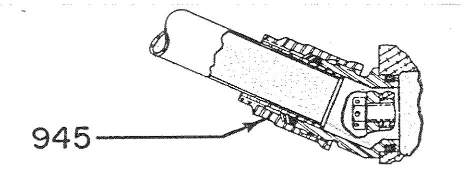
SECTION C-C



EXTERNAL OIL TUBE



FRONT OIL PUMP STRAINER



EXTERNAL OIL TUBE

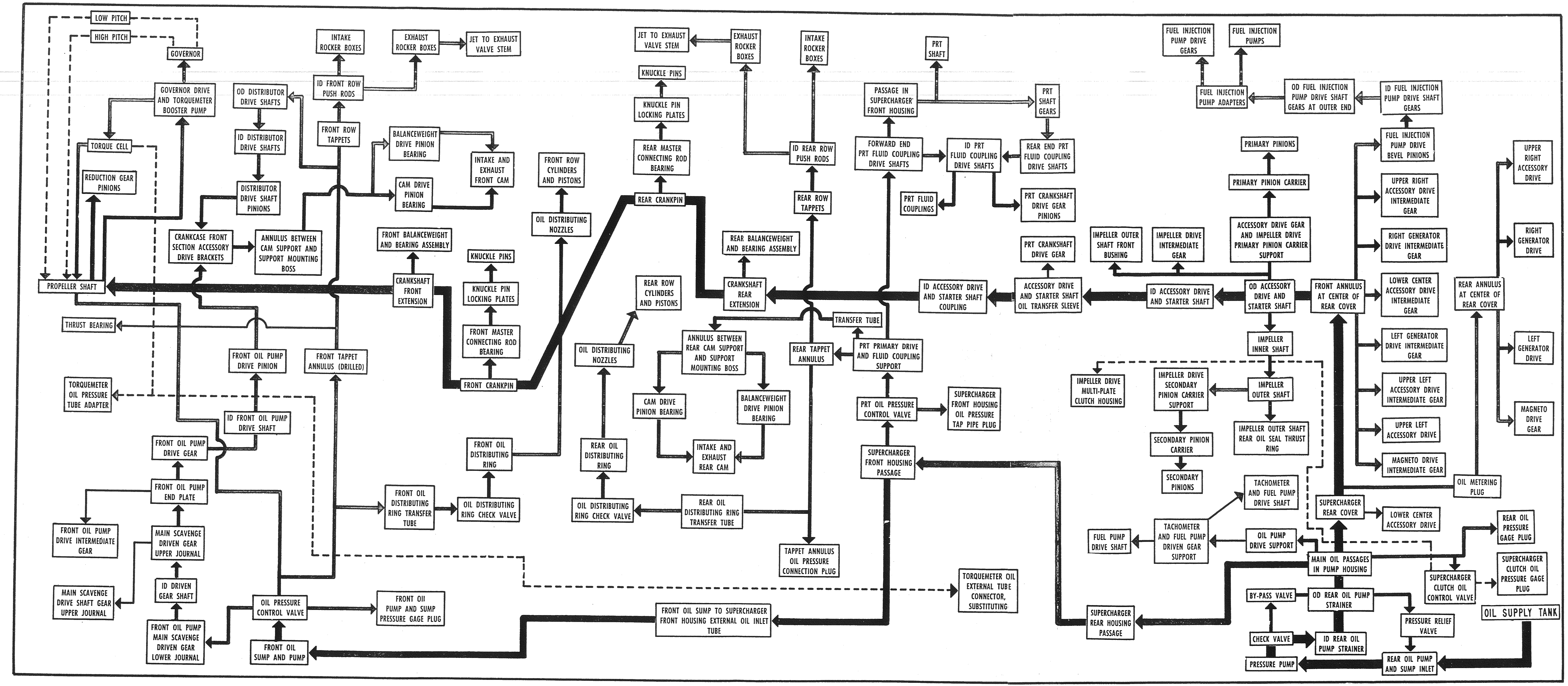


Figure 2-7. Diagram of Oil Pressure System

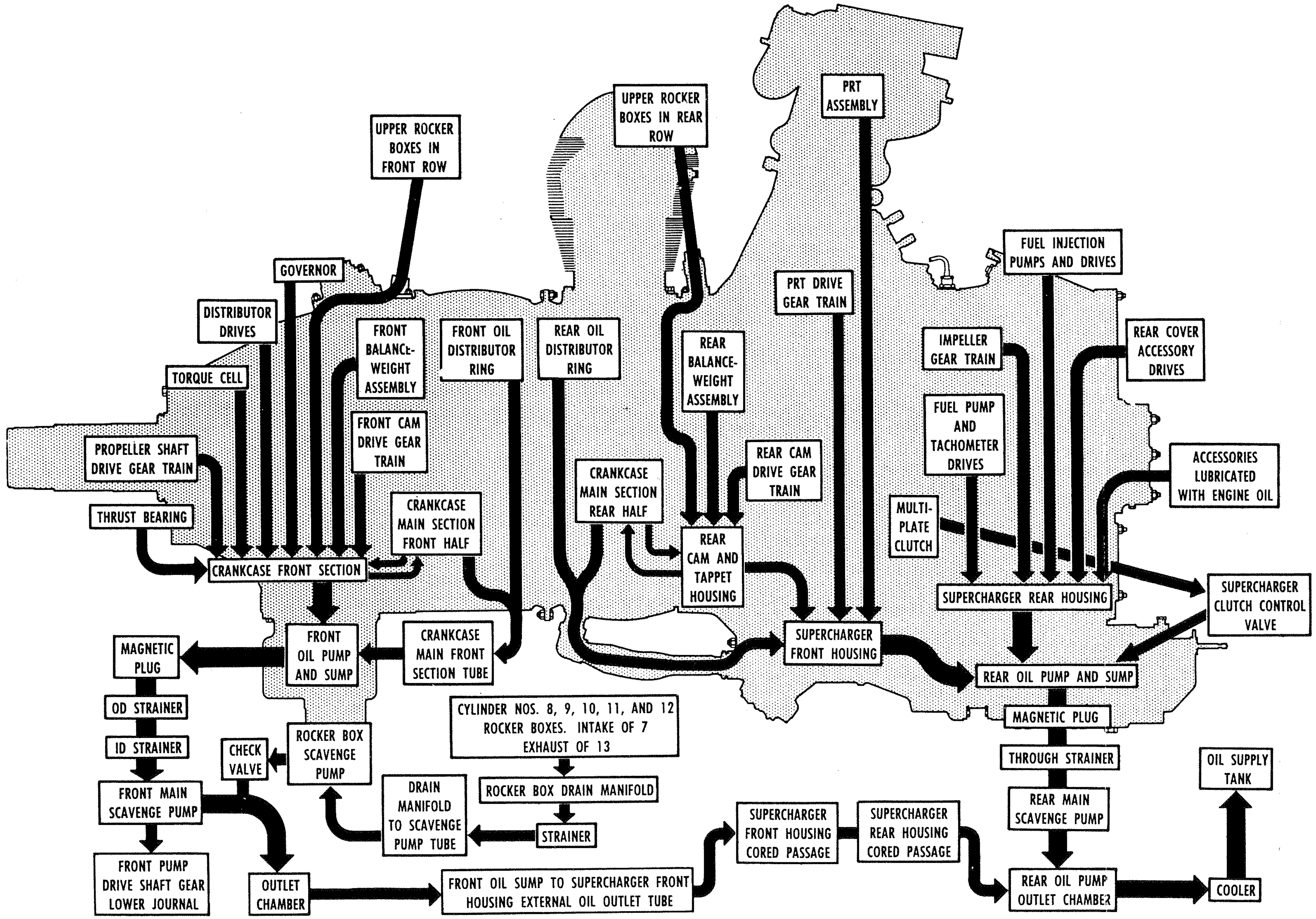


Figure 2-8. Diagram of Oil Scavenge System